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CARBONIFEROUS CORALS: DISTRIBUTION AND SEQUENCE

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It has been stated that the whole Permo-Carboniferous coral evolution is covered by a single cycle of evolution which can be divided into three phases: the first phase contains strata between Strunian and Chokierian and most possibly also Alportian stages inclusively; the second phase extends up to the base of Orenburgian and the third one includes Orenburgian and Permian.

Provinciality of coral faunas has been reconstructed on a basis of plate tectonic data. Some provinces were probably determined not only by the sea/land configurations, but also by palaeocurrents. For some provinces and stages the main faunal regions and possible regions of speciation have been reconstructed.

K e y w o r d s: Carboniferous corals, palaeogeography, evolution.

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INTRODUCTION

Present knowledge of Palaeozoic corals, particularly their taxonomy, is still far from perfect, which detracts very much from their stratigraphic value. This paper is only an attempt to summarize the existing data and use them for general stratigraphic and palaeogeographic comparisons. Data on species are mainly not used because of extensive variation in the interpretation of the morphologic characters. Data on genera used here, are also not always certain because of wide homeomorphism and misinterpretations. The more controversial generic names are indicated by quotation or interrogation marks. Some of the information used has not yet been published and was sent to the author by working coral specialists.

Some names used here for particular regions and stages differ from those found in the literature. It may take place: 1) in a case the present author has been able to see the originals; 2) in a case he had at his dis-

posal new (so far unpublished) corrections from the working specialists; 3) whenever the available description and illustration of the type was good enough to allow the author to revise the names. Because the purpose of this paper was not to revise individual identifications, but to show possibly correct distribution of given genera, the old, reidentified names have not been mentioned. Inverted comas have been used for obviously incorrect original names in these cases when the reidentified names may have remained controversial.

The base maps (figs 1—5) for the coral geography have been taken from Scotese *et al.* (1979) as follows: their Early Carboniferous (Viséan) map has been adopted for Viséan and Tournaisian+Strunian. The Late Carboniferous (Westphalian C, D) map for Bashkirian, Moscovian and Kasimovian+Gshelian. Other maps of these authors or more adequate reconstructions have not been available at the time when this paper has been revised. Several data provided by corals are in a slight disagreement with individual parts of the paleogeography reconstructed by Scotese *et al.* (1979), what made the figures 1—5 published herein only tentative. The most important of the controversies are:

1. A presence of rich Viséan coral fauna in the mouth of the Lena River and reef formations in the Japanese Viséan (?) to Bashkirian. The former region has been reconstructured as located approximately 70°N. Position of the latter has not been indicated on the base maps, but judging from the position of Korea it was located approximately 55°—60°N. Development of shallow water corals and reefs so far north seems doubtful even considering a comparatively warm climate in the Carboniferous.
2. A lack of any marine connections between western part of America and pre-Tethys. Coral faunas of these regions are similar to each other and differ enough from that of the Ural and Arctic to postulate a presence of a direct connection between the areas discussed. This has been indicated by a slight modification of the Bashkirian and Moscovian palaeogeography.

Regions more important for the general orientation of maps, these the Recent position of which can be located with difficulty, and these deformed greatly due to the Mollweide projection of the maps have been marked by letters.

The land/sea relations on all the maps (figs. 1—5) were generalized. Individual provinces have been marked by numbers, but their boundaries have not been drawn as being interfingered in most cases.

The stratigraphic distribution of selected genera is presented (table 1) in connection with both recent and ancient geographical regions and in accordance with the accepted international and/or local stratigraphic nomenclature. In this context "W e s t e r n E u r o p e" appeared to be the most complex region. It extended eastward to Poland, southward to North Africa and westward to Nova Scotia in North America. Several areas

contributed in establishing the stratigraphy and coral faunas of individual parts of this complex section of the table. Its Strunian to Pendleian part is based on British and/or Belgian stratigraphy and coral faunas; for the Arnsbergian to Marsdenian (Lower Bashkirian) part the stratigraphy and coral fauna of North Africa and partly of Northern Spain were selected, while the Upper Bashkirian and the Moscovian is based on Spanish and the Kasimovian-Gshelian on the Carnic Alps and Yugoslavian corals. The Dinantian stratigraphy and coral faunas of this section was checked and discussed by Dr. M. Mitchell.

From the U S S R t e r r i t o r y the author selected only a few more interesting or better known regions, and this part of the text was checked by Dr. N. P. Vassiljuk. The Moscov basin section includes also corals from the Voronezh anticline. They became the base for the Bashkirian part of the section. Corals were not present at that period in the Moscow basin itself. The Strunian part of the Ural Mts and Novaya Zemlya section is based only on the corals from Novaya Zemlya. For the Middle Asia section the data of the Pamir, the Tien-Shan, southern and central Kazakhstan and adjacent areas were composed with the main ephasis being laid on the best known coral fauna from Kazakhstan. North-eastern Asia is one of the least known and, therefore, the most artificially composed sections of the table; majority of the fauna of this region is only listed and not described.

J a p a n. This section of the table in its Lower Carboniferous part is based mainly on the corals from the Kitakami Mts region and, in its Upper Carboniferous part, on corals from both the Kitakami Mts and the Akioshi regions. The section was checked and discussed by Dr. M. Kato.

N o r t h A m e r i c a. This section was separately checked and discussed by Drs. E. W. Bamer and W. J. Sando, who have also kindly sent me some of their unpublished data.

As far as the table is concerned there seem to be at least the following controversial points, which need explanation:

a) the Strunian Stage is described here as the forerunner of the Carboniferous because of the specific or Carboniferous type of the coral fauna. Also Flügel (1974) considered this fauna Carboniferous in character.

b) In the USSR the Kosva Horizon (= C_1^{γ} a in Donets and other equivalents) was traditionally left in the Viséan, although its coral fauna is Tournaisian in type. The reasons for this are given in the text.

c) Comparison of the Tournaisian/Viséan boundary in Europe and North America is most controversial. The author followed Austin *et al.* (1973) and Conil *et al.* (1977) for Europe and Sando *et al.* (1969, 1977) for North America, although these approaches are sometimes incompatible. The controversy cannot be solved from the coral evidence.

The following discussion, except for the Strunian and Pendleian to Alportian Stages was divided in accordance to individual series. Separation

of the mentioned stages was conditioned by a peculiarity of their coral faunas. In contrast, the coral faunas of Kosimovian and Gshelian Series were discussed jointly, because stratigraphical ranges and taxonomical characteristics of majority of coral genera of these series were inadequately or incorrectly established.

Acknowledgements. — I am deeply indebted to Dr. N. P. Vassiljuk (USSR) for her advices and help in completing data of the USSR Carboniferous and for her discussions on palaeogeography and coral distribution. Drs. E. W. Bamber (Canada), M. Kato (Japan), M. Mitchell (Gt. Britain), W. J. Sando (USA) and P. Semenoff-Tian-Chansky (France), who helped me so much by sending their unpublished data, emending individual parts of the table and the manuscript, are especially warmy tkanked for their friendly help. I am also cordially thankful to the late Professor M. Różkowska (Poland), Professor R. Conil (Belgium) and Drs. A. V. Dhondt and E. Poty (Belgium), A. Ferrari (Italy), G. E. de Groot (Holland), W. A. Oliver, Jr. (USA), and C. T. Scrutton (Gt. Britain) for their help in completing data and bibliography.

Abbreviations used in the Table 1

1. British stages:

Alp	Alportian	Kin	Kinderscoutian
Arns	Arnsbergian	L A?	Lower Autunian?
Asb	Asbian	LCM	Lower Coal Measures
Brig	Brigantian	Mar	Marsdenian
Chad	Chadian	MCM	Middle Coal Measures
Cho	Chokierian	Pend	Pendleian

2. The USSR standard Stages:

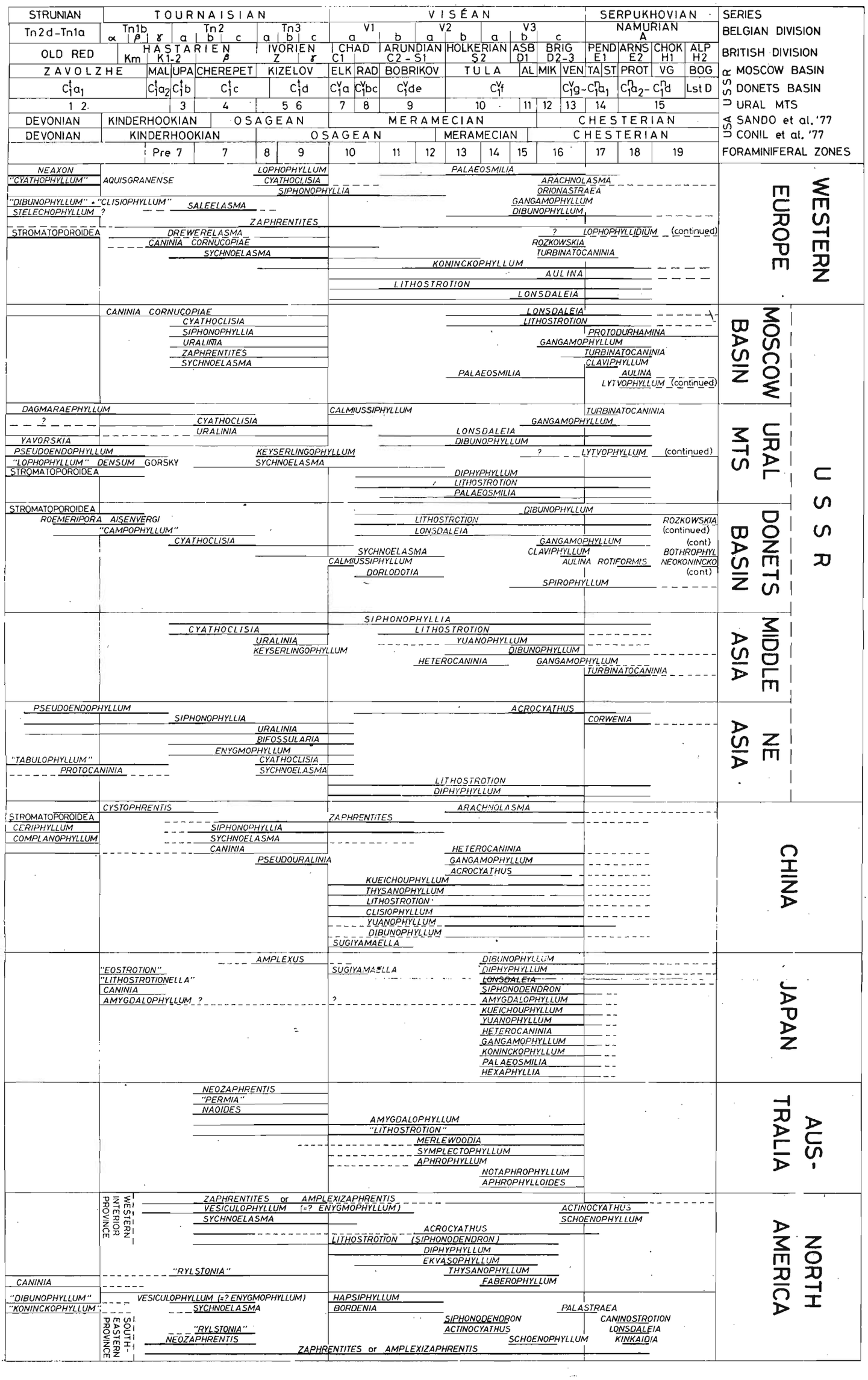
Amer	Amerevsk	Nog	Noginsk
Al	Aleksin	Oren	Orenburgian
Bog	Bogdanov	Pavlo	Pavloposadsk
Cherem	Cheremshan	Prik	Prikamsk
Dor	Dorogomirovsk	Prot	Protva
Elk	Elkov	Rad	Radeev
Jauz	Jauzsk	Pod	Podolsk
Kash	Kashira	Rus	Rusavkin
Kham	Khamovnitshan	Sev	Severokeltman
Kras	Krasnopoljan	St	Steshev
Krev	Krevjatin	Ta	Tarussa
Mal	Malevka	Ven	Venev
Mel	Melekv	Ver	Vereya
Mik	Mikhailov	V G	Verkhne-Gubakhin
Mjatsh	Mjatshkov		

3. Foraminiferal zones:

D s	*Daixina sokensis*	*Prot*	*Protriticites*
Jigul.	*Jigulites*	*Rauser*	*Rauserites*
Obsolet	*Obsoletes*	*Trit*	*Triticites*

Table 1

Stratigraphic range of some Carboniferous coral genera



	BASHKIRIAN			MOSCOVIAN				KASIMOVIAN				GSHELIAN				SERIES
	NAMURIAN B	NAMURIAN C	WEST PHALIAN A · B	WEST PHALIAN C	WEST PHALIAN D			STEPHANIAN A · B				STEPHANIAN C			D	BELGIAN DIVISION
	KIN R1 / MAR R2	YEADONIAN G1	LCM / MCM G2	UPPER COAL MEASURES											LA	BRITISH DIVISION
	KRAS	SEV	PRIK / CHEREM / MEL	VERE	KASH	PODO	MJATSHK	KREV	KHAM	DOR	JAUZ	RUS	AMER	PAVLO	NOG / OREN	USSR MOSCOW BASIN
	$C_1^n e_1$	$C_1^n e_2$	$C_2^b a$ – $C_2^b d$ / $C_2^b e$	$C_2^m a$	$C_2^m b$	$C_2^m c$	$C_2^m d$ / $C_2^m e$	$C_3 a_1$	$C_3 a_2$	$C_3 b$		$C_3 c$		$C_3 d$	$C_3 e$	USSR DONETS BASIN
	16	17	18 / 19	20	21	22	23	24	25	26		27 – 28			29	USSR URAL MTS
	MORROWAN		ATOKAN	DESMOINESIAN				MISSOURIAN				VIRGILIAN				USA SANDO et al. '77
	MILLERELLA 20 / 21		PROFUSULINELLA 22	FUSULINA - FUSULINELLA				OBSOLET PROTRIT / TRITICITES (TRIT)				TRIT (RAUSER) - JIGUL			Ds	USA CONIL et al. '77
																FORAMINIFERAL ZONES
WESTERN EUROPE	ARACHNOLASMA (continued)							colonial "PALAEOSMILA" HERITSH 1936								
								CARINTHIAPHYLLUM								
								KIONOPHYLLUM								
				AXOLITHOPHYLLUM												
	DIBUNOPHYLLUM (continued)			DONOPHYLLUM												
				PETALAXIS												
				LOPHOPHYLLIDIUM												
								AMANDOPHYLLUM								
								KONINCKOCARINIA								
	KONINCKOPHYLLUM (continued)				LONSDALEOIDES											
	AULINA (continued)				IVANOVIA											
MOSCOW BASIN	LONSDALEIA (continued)				IVANOVIA											
	LITHOSTROTION (continued)							KONINCKOCARINIA								
	PROTODURHAMINA (continued)			PSEUDOTIMANIA												
								BOTHROPHYLLUM								
			OPIPHYLLUM									TIMANIA				
			LONSDALEOIDES									GSHELIA				
	AULINA (continued)															
			LYTVOPHYLLUM													
			PETALAXIS													
URAL MTS				PSEUDOTIMANIA												
				FOMICHEVELLA												
				PROFISCHERINA												
				BOTHROPHYLLUM												
			LYTVOPHYLLUM									TIMANIA				
	?		PROTODURHAMINA ?									GSHELIA				
				PETALAXIS												
				NEOKONINCKOPHYLLUM												
				AMANDOPHYLLUM								NEOSYRINGOPORA				
DONETS BASIN	DIBUNOPHYLLUM (continued)															
	ROZKOWSKIA			SESTROPHYLLUM												
	solitary "LYTVOPHYLLUM"			LOPHOPHYLLIDIUM												
			LYTVOPHYLLUM	PETALAXIS												
				BOTHROPHYLLUM												
				NEOKONINCKOPHYLLUM												
				BARITICHISMA												
	SPIROPHYLLUM (cont)			ORYGMOPHYLLUM												
				AMANDOPHYLLUM												
								PALAEOPLISINA								
MIDDLE ASIA	PROTODURHAMINA			DARWASOPHYLLUM	BOTHROPHYLLUM											
	OPIPHYLLUM			DONOPHYLLUM												
	LYTVOPHYLLUM			YAKOVLEVELLA												
				ORYGMOPHYLLUM												
				PETALAXIS								GSHELIA				
				FOMICHEVELLA												
												BRADYPHYLLUM				
												SESTROPHYLLUM				
NE ASIA	? CORWENIA															
			BARITICHISMA													
	PETALAXIS															
CHINA				ARACHNOLASMA ?												
				PETALAXIS												
				FOMICHEVELLA												
				BOTHROPHYLLUM												
				AXOLITHOPHYLLUM - like genera												
				KIONOPHYLLUM												
				IVANOVIA												
				CHIELASMA								PARAWENTZELLOPHYLLUM				
				SKOLEKOPHYLLUM								AKAGOPHYLLUM				
				HUANGIA								KEPINGOPHYLLUM				
								SESTROPHYLLUM								
								LYTVOPHYLLUM								
								GSHELIA								
								TIMANIA								
JAPAN	DIBUNOPHYLLUM (continued)			IVANOVIA												
	DIPHYPHYLLUM (continued)			CARINTHIAPHYLLUM												
	LONSDALEIA (continued)			KONINCKOCARINIA												
	SCIOPHYLLUM							YABEIPHYLLUM								
	THYSANOPHYLLUM							FOMICHEVELLA								
			"LITHOSTROTIONELLA"					"CORWENIA"				?				
			AKIYOSHIPHYLLUM													
			NAGATOPHYLLUM													
			HIROSHIMAPHYLLUM													
			OMIPHYLLUM													
				TAISYAKUPHYLLUM												
				PSEUDOPAVONA												
AUS-TRALIA																
NORTH AMERICA	"AMPLEXIZAPHRENTIS" (? continued)															
			BARITICHISMA													
	STEREOCORYPHA															
	LOPHOTICHIUM															
								AMANDOPHYLLUM								
								LOPHOPHYLLIDIUM								
								PROFISCHERINA								
								SESTROPHYLLUM								
					PSEUDOTIMANIA											
								KIONOPHYLLUM								
													DURHAMINA			
													YABEIPHYLLUM			

Table 1 *continued*

THE RECOGNITION OF THE DEVONIAN/CARBONIFEROUS BOUNDARY

The 1935 Heerlen Congress suggested the base of the *Gattendorfia subinvoluta* Zone as the base of the Carboniferous System. This suggestion has been a subject of much controversy, because the subsequent correlations of this boundary resulted in the placement of the basal beds of the Tournaisian (Tn1a) in the Uppermost Devonian. Earlier studies of Conil *et al.* (1970, 1971) on foraminiferal and lithological sequences in Belgium and Austin's *et al.* (1973) conception of the discussed boundary were in disagreement with the mentioned Heerlen Congress suggestion. The recent redefinition of the base of the Tournaisian (Conil *et al.* 1977) acknowledged the base of the *Gattendorfia subinvoluta* Zone as the Famennian/Tournaisian (= Devonian/Carboniferous) boundary. Strunian Stage, defined by these authors as composed of the uppermost part of Fa2a, the whole Tn1a and the lower part of Tn1bα was left by them in the Upper Famennian (Devonian). Such an interpretation of the Tournaisian/Strunian boundary agrees not only with the lower limit of the *Gattendorfia subinvoluta* Zone (= Balvium) in Germany but also with the lower limit of Carboniferous System in Britain and the lower limit of Kinderhookian in the USA. The redefined base of the Tournaisian Series and the two Belgian Tournaisian stages Hastarien and Yvorien were recently recognized and accepted in Britain by Ramsbottom and Mitchell (1980). Because there is no internationally accepted conception as to the lower limit of Carboniferous System, and because the Conil *et al.* (1977) conception is based on the type sections and areas, it is adopted herein. It must be admitted, however, that ancestral Carboniferous rugose corals fauna was found in Strunian, what makes a discussion of this Stage necessary.

More comprehensive discussion concerning Devonian/Carboniferous boundary as shown by Coelenterata records is given recently by Vassiljuk (1978). Unfortunately many unrevised generic names used by her without interrogation marks (e.g. *Cyathophyllum, Lophophyllum, Clisiophyllum, Dibunophyllum*, etc.) suggest stratigraphic ranges of these genera much wider than really stated. Also some simplifications of stratigraphic limitations of individual genera were made: e.g. all genera described by myself from Dalnia (Fedorowski 1973) were listed by Vassiljuk (1978) as representatives of the *Wocklumeria* Zone although they are either of that or of the *Gattendorfia* Zone; *Palaeosmilia membiensis*, listed by Vassiljuk as occurring in the *Wocklumeria* Zone was described by Minato and Ogata (1977) as Lower Tournaisian.

Stromatoporoids were mentioned several times herein, although their cyanophycean nature has been recently suggested (Kaźmierczak 1976). These references were made without any taxonomical implications, still controversial, but only in the context of their environmental, geographical and stratigraphical importance for the Strunian Stage.

STRUNIAN STAGE

Western and central Europe. — Coral-bearing marine sediments have been found mostly along the belt expanding from the Franco-Belgian basins, Westfalen and Thuringia into Pomerania, the Sudetes and Cracow region in Poland. Terrigenous and interbedded limy-shaly sediments prevail in this belt. Reef facies containing Stromatoporoidea have been described or recorded in NE France (e.g. Etroeungt, St. Hilaire, Avesnelles), Belgium (e.g. Comblain, Dolhain), F.R.G. (e.g. Kornelimünster, Cromford) and SE Poland (near Krzeszowice). Rugosa and Tabulata are known to

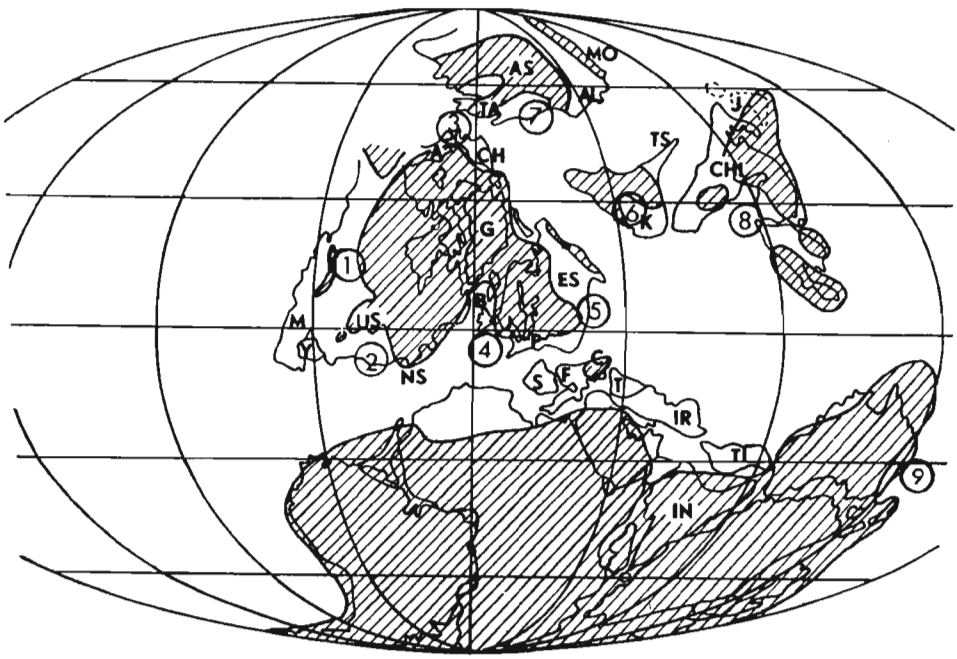


Fig. 1. The Tournaisian and Strunian palaeogeography and coral distribution. *Regions* (explanations of figs 1—5): *A* Alaska, *AL* Altay, *AS* North-Asiatic part of the USSR, *AU* Australia, *B* Britain, *C* Czechoslovakia, *CH* Chukotka, *CHI* China, *ES* European part of the USSR, *F* France, *G* Greenland, *IN* India, *IR* Iraq, *J* Japan, *K* Kazakhstan, *M* Mexico, *MO* Mongolia, *P* Poland, *A* Spain, *T* Turkey, *TA* Taymyr, *TI* Tibet, *TS* Tien-Shan, *US* United States of America, *Y* Yukatan. *Provinces*: *1* Western Interior, *2* South-eastern, *3* Chukotka-Alaskan, *4* Western European, *5* Eastern European, *6* Central Kazakhstan, *7* Kuznetsk, *8* Chinese, *9* Australian.

occur both in the reef and in the limy-shaly facies. The whole region, despite its differentiated facial development, can be considered as a single palaeozoogeographic province.

The stromatoporoid genera of this province, Devonian in character were represented by different species than occurred in the Devonian (Conil 1961). The main components of the fauna:

Actinostroma *Stromatopora*
Clathrodictyon *Stromatoporella*

Tabulata were not abundant. New species of *Michelinia* and *Pleurodictyum* appeared together with long-lived species of *Syringopora* but *Cleistopora* and the newly appeared genus *Vaughania* are the most important for the stratigraphy (Dehée 1929; Conil et Pirlet 1970; Weyer 1976).

Rugosa may be divided into the following groups:

1. Long-lived genera, Devonian in character (Różkowska 1969; Weyer 1971*a*, *b*, 1978):

Guerichiphyllum
Metriophyllum
Metrioplexus
Neaxon
Syringaxon
?Tabulophyllum

2. Long-lived genera, Carboniferous in character (Różkowska 1969; Fedorowski 1973):

"Amplexus"
Amplexocarinia
Bradyphyllum
Cyathaxonia
Gorizdronia
?Mesophyllum (*Cystiphylloides*)
?Saleelasma
Siphonophyllia
Soshkineophyllum
Ufimia
Heterocorallia:
Heterophyllia

3. Genera and species expanding into younger horizons and being considered as ancestors of younger taxa, e.g. *"Endophyllum" transitorium* Gröber, *Caninia* cf. *cornucopiae* Michelin, *"C." patula* Michelin (Gröber 1910; Dehée 1929; Salée 1910).

4. Genera and species of rather Devonian or very specialized morphology, often endemic, characteristic for this stage only (Różkowska 1969; Weyer 1971*b*):

Czarnockia
Famaxonia
Friedbergia
Hillaxon
Petraiella
Thecaxon
Heterocorallia:
Oligophylloides

5. Genera and species Carboniferous in morphology, characteristic for this stage only (Frech 1885, Salée 1910, Vaughan 1915, Dehée 1929):

"Clisiophyllum" kayseri Frech, 1885
"Clisiophyllum" omaliusi Haime, 1855
"Dibunophyllum" praecursor Frech, 1885
"Cyathophyllum" aquisgranense Frech, 1855

All of these species are characterized by structures typical of Viséan genera.

Mixture of Devonian and Carboniferous morphology, complex and simple structures, long- and short-ranging genera and the comparatively large number of the latter is the most characteristic feature of the coral fauna discussed above. Their distribution, often restricted to small separated areas, seems to be a function of the outcrops pattern rather than of isolation of individual places and areas, although a certain degree of the latter should not be excluded.

The USSR. — Zavolgie and its equivalents are commonly considered as coeval with the Strunian deposits of western Europe. This meaning was slightly modified by Conil *et al.* (1977) who correlated upper part of the Zavolgie with Tn1bβ and the upper part of Tn1bα in Belgium. This opinion, based mainly on foraminifera, is here tentatively accepted.

The following three provinces have been recognized by Vassiljuk (1970, 1978): Novaya Zemlya-Donets Province (including the Ural Mts., the Moscow basin and the Voronezh anticline), Kazakhstan-Altay Province and Kuznets Province. The latter was small and endemic in character. The reconstructed positions of continents (fig. 1) indicate that the Altay region could not be composed with Kazakhstan into a single province as proposed by Vassiljuk (*l.c.*). A very poor knowledge of the fauna of the former region made any consideration upon its relation impossible.

Novaya Zemlya-Donets Province. — The coral fauna of Novaya Zemlya has been most completely described (Gorsky 1935, 1938, 1951). The Stromatoporoidea were Devonian in character. Vesicular genera, such as *Rosenella, Stromatocerium* prevailed and those of compact structures such as *Actinostroma* and *Stromatopora* were less common.

Long-ranging *Syringopora, Michelinia, Tetraporinus* made up most of the tabulate corals fauna. *Yavorskia* was the only new genus to appear.

Rugosa:

Caninia
"Caninia" s.l.
Cyathoclisia
Dagmaraephyllum
Uralinia
Pseudoendophyllum

All the listed genera appeared for the first time but are known to occur also in the Lower Tournaisian part of the sequence. *"Lophophyllum" densum* Gorsky, the species similar to *"Cyathophyllum" aquisgranense* Frech, is restricted to the Strunian.

A fauna that is similar but impoverished (except for abundant Stromatoporoidea) was described from the Donets basin (Vassiljuk 1960, 1966, 1970, 1975). The contemporaneous coral fauna in the Urals is also similar to that of Novaya Zemlya, but it is poor and not adequately described (Vassiljuk 1970, Degtjarev 1973 a, c). In contrast Kachanov (1975) listed over 10 genera of Rugosa and 4 genera of Tabulata as present in the Lytva Stage:

Rugosa:

"Amplexus"
Aulacophyllum
Campophyllum
Caninia
Cyathaxonia
Cyathoclisia
Pterorrhiza
Siphonophyllia
Tabellaephyllum
Tabulophyllum
Zaphrentites

Tabulata:

Gorskyites
Michelinia
Syringopora
Yavorskia

Since no illustrated descriptions of these mixed, Devonian and Carboniferous genera are given, their identification could not be checked and are treated herein as tentative.

It seems possible that the fauna from the transitional Devonian-Carboniferous Elergetkhyn Series of the Omolon Massif (Chukotka) belongs to this province. The following genera have recently been described and are listed herein without any remarks on their taxonomy.

Rugosa (Onoprienko, 1979*a*):
Protocaninia
Tabulophyllum

Tabulata (Smirnova, 1979*a*):
Michelinia
Ortholites
Roemeripora
Syringopora
Yavorskia

Stromatoporoidea (Smirnova, 1979*b*):
Atelodictyon
Anostylostroma
Stictostroma
Rosenella
Trupetostroma

The Transcaucasus region was separated by Vassiljuk (1978) as the Mediterranean Subprovince. The recently recorded rich *Cystophrentis* fauna of this region (Papojan 1977) indicates a close connection between that region and China and a possible beginning of the development of the future Mediterranean Province. This makes Vassiljuk's (1978) conception more likely.

Kuznets Province. — A completely new fauna came into the Kuznets basin. It is characterized by: a) the lack of Stromatoporoidea, b) the appearance of the Viséan-like corals such as "*Arachnolasma*" and "*Yuanophyllum*", and c) the appearance of genera which were widely distributed and/or continued in their development such as *Dagmaraephyllum* and "*Lophophyllum*" *densum* Gorsky. Long-ranging Tabulata: *Michelinia*, *Thecostegites* and *Syringopora* were also present (Tolmachoff 1924, 1931; Fomichev 1931; Dobroljubova, Kabakovich and Sayutina 1966).

Kazakhstan Province. — The Devonian facies and the small Devonian-type, mainly "*Cyathaxonia*"-fauna persisted in this region (Gorsky 1932; Volkova 1938, 1941; Keller 1959; Bykova 1966):

Rugosa:
Barrandeophyllum?
Cystophrentis
"*Meniscophyllum*"
Neaxon
"*Stereolasma*"
"*Zaphrentis*"

Stromatoporoidea:
Actrinostroma
Atelodictyon
Stromatopora

China. — Deposits and faunas which can possibly be correlated with the European Strunian Stage were distinguished only in Southern China in Guangxi (lower Shihtzehsu Fm.), Guizhou (lower Kolaoho Fm.), Hunan (lower Shaodung Fm.) and other provinces. Many stromatoporoids such as *Pseudolabechia*, *Stromatocerium*, *Pennastroma* occurred in these formations. Wu and Zhao (1979) distinguished two coral assemblages: the

lower *Ceriphyllum elegantum* assemblage with "*Zaphrentoides*" *delanouei*, "*Z.*" *konincki*, *Complanophyllum compressum* and *Caninia shaodongensis*, and the upper *Caninia dorlodoti* assemblage with "*Caninia*" *patula*, "*Diphyphyllum*" *antiquatum* and "*Dematophyllum*" *minor*. Although found together with Strunian brachiopods, the discussed coral assemblages differ greatly from those of Europe and, judging from the names, are rather Tournaisian in character. Unfortunately, the lack of detailed descriptions and illustrations made all the above identifications uncertain. The not abundant Tabulata are represented mainly by *Tetraporinus*, *Michelinia* and *Syringopora* (Yü 1933; Chu 1933).

Australia. — A coral-bearing Strunian has not been identified in Australia. A few Famennian tetracorals have been described by Hill (1936, 1954) from Western Australia. "*Palaeosmilia*" *contexta* Hill and "*Caninia*" *rudis* Hill are most interesting because of their Carboniferous character.

North America. — Williams (1943) described a small coral fauna from the Louisiana Limestone in Missouri. Paproth (1969) considered that formation to be an "Etroeungt" equivalent and followed American conodont specialists in placing it in the Devonian. Conil *et al.* (1977) is of a similar opinion. The other coral fauna of similar age was found in widely separated areas and remains undescribed. The faunal list given by Sando, Bamber and Armstrong (1977) and the present author's personal observations suggest a strongly Carboniferous character for these corals. This makes possible their comparison with some groups of western European and Novaya Zemlya Strunian corals.

Conclusions

1. The international stratigraphic correlation of regions other than western Europe are only approximate and so are the conclusions.

2. Stromatoporoid genera in the Strunian were long-lived and of Devonian type. They possibly did not occur higher than in the *Cymaclymenia euryomphala* horizon.

3. Tabulata, except for *Cleistopora*, *Vaughania* and *Yavorskia*, are not of stratigraphic importance on the generic level.

4. Rugosa form the richest and the most diversified group of coelenterates. Although found in widely separated areas, they show similar general characteristics: a) a mixture of Devonian and Carboniferous-like faunal elements; b) a large number of very short-ranging taxa (species and genera) often endemic and restricted only to this stage; c) an appearance of morphological features (axial structures of *Dibunophyllum* type, biseptal or complex pseudocolumella) characteristic for the Upper Tournaisian or even Upper Viséan genera; d) an appearance of ancestral forms for some Carboniferous lineages. The above characteristics could be considered as typical for the intermediate Devonian/Carboniferous phase of tetra-

coral evolution. Although Devonian elements are still abundant, Rugosa entered the new, Carboniferous period of their evolution not later than in Tn1a zone. Kachanov (1975) is of a similar opinion.

5. Two centres of faunal distribution were most important: a) A belt of outcrops between northern France, Belgium, GDR, FRG and Poland. Although generally connected as indicated by common genera and species, the province was subordinately divided into smaller regions inhabited by endemic or slightly different faunas (e.g. an absence of "*Dibunophyllum*", "*Clisiophyllum*" and "*Caninia*" *patula* in Poland *versus* much less abundant "*Cyathaxonia*"-fauna in western regions of the province). There are no criteria as yet to establish directions of migrations of the coral fauna within and outside the province. Poland seems to have been located close to the eastern boundary of the province. The presence of western European types of stromatoporoids in central Kazakhstan (Vassiljuk 1978) may hardly justify the existence of additional (southern-more) ways of communication between these two provinces. It seems rather incidental and probably reflects only the independent, homeomorphic development of western European and Kazakhstanian taxa. b) Novaya Zemlya. The fauna of this centre expanded as far east as China (if the identifications are correct) and as far west as Poland, where *Pseudoendophyllum* has been found (Fedorowski, unpubl.) together with Belgian-type Stromatoporoidea (Gürich 1903). The very early appearance of some genera (e.g. *Caninia, Cyathoclisia*) in Novaya Zemlya indicate that they possibly migrated from this centre to western Europe. Such important genera as *Uralinia, Enygmophyllum, Dagmaraephyllum* and the eastern type of stromatoporoids have never been found in central and western Europe.

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Western European Province. — The Tn1b horizon of Belgium may be considered as the natural continuation of sedimentation and coral fauna of the underlying stage. This is understandable when the cyclic conception of sedimentation and faunal development is used. Ramsbottom (1973) assigned the whole Tournaisian in Britain to his First Major Cycle (= Courceyan of George *et al.* 1976) whereas Conil et Pirlet (1970) and Conil *et al.* (1971) divided Tournaisian deposits in Belgium into three Major Sequences. The horizon Tn1b was correlated with the upper part of the first Major Sequence. This meaning was slightly modified by Conil *et al.* (1977) who started the Tournaisian with the transgressive sequence in the middle of Tn1bα and recognized regressive phase of Tn1bβ and the transgressive sequence again in Tn1bγ. This part of the Belgian sequence is coeval with the former Km and K_1 Zones (= the lowermost Courceyan = lower part of Hastarian) in Britain and *Gattendorfia* Zone in FRG.

The coral fauna of this age is very rare and poorly known. In Britain *Vaughania* is present and *Zaphrentites delanouei* is the only rugosan species known (Dr. M. Mitchell). Weyer (1973) described a new genus *Drewerelasma* from the *Gattendorfia* Zone of FRG. This genus is also abundant in the not yet described part of the fauna from Dalnia (Holy Cross Mts, Poland). Several species of other genera described from that locality by Fedorowski (1973) may also be of the *Gattendorfia* age. Colonial rugosan genera and Aulophyllidae are not known to occur in Lower Tournaisian deposits of the province. Among Cyathopsidae *Caninia cornucopiae* Michelin is recorded in the uppermost Tn1b of Belgium (Conil et Pirlet 1970). "*Allotropiophyllum*", *Pentaphyllum, Caninia* (species other than *C. cornucopiae* Michelin), "*Caninia*" *patula*-like, *Siphonophyllia, Heptaphyllum, Michelinia, Palaeacis, Syringopora, Vaughania* and other genera have also been described (Koninck, de 1872; Salée 1910, 1913*a*, *b*, 1920; Vaughan 1915; Hill 1938—1941; and others), but the stratigraphic positions of these genera have not been confirmed. Some of them have recently been recorded from younger deposits. Several need revision and redescription.

The Middle Tournaisian — Tn2 (= Second Major Sequence of Conil *et al.* 1971 and Conil *et al.* 1977). The correlation of these deposits with either those in Britain or in FRG is only approximate. The uppermost part of the former K_2 Zone and the lower part of the Black Rock Limestone (= former β and lower part of Z Zones) in Britain and lower part of *Siphonodella crenulata* Zone in FRG are possible equivalent of that part of the Belgian sequence. The name Hastarien was introduced by Conil *et al.* (1977) for the Lower and Middle Tournaisian in Belgium. The most characteristic taxa for Tn2 in Belgium (Salée 1913*a*, *b*; Conil et Pirlet 1970; Weyer 1970):

Rugosa:
Caninia cornucopiae
"*Caninia*" *patula*
Cyathaxonia cornu
Saleelasma delepini
Siphonophyllia cylindrica
Sychnoelasma konincki

Tabulata:
Michelinopora
Syringopora

In Britain the lower part of the "Lower Fauna" recorded by Mitchell and Green (1965) from Burrington Combe may be an equivalent of the upper part of this sequence.

The Upper Tournaisian — Tn3 (= Third Major Sequence of Conil *et al.* 1971 = Ivorien of Conil *et al.* 1977 = upper Z Zone to the middle upper part of C_1 Zone, i.e. up to the top of Courceyan = Ivorien in Britain). *Lophophyllum, Koninckophyllum, Cyathoclisia* and *Fasciculophyllum* appeared most probably only as early as this divison in the Franco-Belgian basins, and the genera which occurred earlier are still known to occur.

At Burrington Combe in Britain three faunas were distinguished in the Black Rock Limestone (Mitchell and Green 1965) and these have been

given formal assemblage biozone names (Ramsbottom and Mitchell 1980). The *Zaphrentites delanouei* Assemblage Biozone (= Lower Fauna = β and Z Zones):

Rugosa:	Tabulata:
Fasciculophyllum omaliusi	*Michelinia favosa*
Sychnoelasma konincki	*Syringopora vaughani*
Zaphrentites delanouei	

The *Caninophyllum patulum* Assemblage Biozone (= Middle Fauna = = Horizon γ):

"Allotropiophyllum" sp.	*"Caninia" patula*
Amplexus sp.	*Cyathaxonia cornu*
Cravenia sp.	*Cyathoclisia tabernaculum*
Caninia cornucopiae	*Sychnoelasma konincki*

The *Siphonophyllia cylindrica* Assemblage Biozone (= Upper Fauna = = C_1 Zone, part) contains *S. cylindrica* in addition to many of the species from the *C. patulum* Biozone, but on the evidence of the conodont faunas is of Viséan age (Dr. M. Mitchell's written comm).

Other genera were also described or mentioned from the Tournaisian of the British and Franco-Belgian basins (Koninck, de 1872; Garwood 1912, 1916; Vaughan 1905, 1915; Salée 1910, 1913*a*, *b*; Hill 1938—1941; and others), but are not mentioned because of uncertain stratigraphic positions.

Comparison of British and Belgian corals may indicate that during the Middle and Upper Tournaisian Belgium remained the main centre of faunal origin. Most of the genera and species which came into British territory in upper Hastarien and in Ivorien were known to occur earlier in Belgium. The records may be unreliable, however.

Outside the British-Belgian area, Weyer (1975) recorded or described from islands Rügen and Hiddensee:

Rugosa:	*Ufimia*
Cyathaxonia	*Zaphrentites*
Drewerelasma	
Lophophyllum	Tabulata:
Pentaphyllum	*Cladochonus*
Rotiphyllum	*Palaeacis*
	Sutherlandia

The age of the above fauna is established by Weyer (*l.c.*) as Upper Tournaisian. Fedorowski (1975) listed from the Polish Pomerania:

Amplexocarinia	*Cyathaxonia*
Caninia	*Gorizdronia*
"Caninia" s.l.	*Sychnoelasma*
Claviphyllum	*Zaphrentites*

Very rich coral fauna was found in Poland in the neptunian dykes of the Holy Cross Mts. The Lower Tournaisian trilobites (Osmólska 1973) and mixed, Upper Famennian-Lower Tournaisian conodonts (Szulczewski 1973) restricted the upper limit of this fauna to the *Gattendorfia* Zone. From this fauna Stasińska (1973) described Tabulata and Fedorowski (1973) some of the very abundant Rugosa.

Rugosa:
Antikinkaidia
Bradyphyllum
Calophyllum
Commutia
Dalnia
Pentaphyllum
Plerophyllum
Soshkineophyllum

Tabulata:
Acaciapora
Emmonsia
Kueichowpora
Michelinia

Fedorowski (unpubl.) identified the following genera from the rich Tournaisian coral fauna of SW Poland (the Dębnik area near Cracow):

Caninia
Cyathoclisia
Fasciculophyllum
Keyserlingophyllum
Siphonophyllia
Sychnoelasma
Zaphrentites

Small and scattered Tournaisian coral faunas described from Spain, Turkey and Sahara are mainly of a deep water "*Cyathaxonia Fauna*" kind, cosmopolitan in character. The connection of it to any individual province is uncertain. Kullmann (1968) recorded "*Metriophyllum*" and *Neaxon* in Cantabria (Spain). *Caninia*, "*Zaphrentis*" and *Palaeacis* have been listed from Turkey (Frech 1916; Unsalaner-Kiragli 1958; Kato 1979). *Cyathaxonia* and "*Zaphrentis*" have been described from the Sahara (Menchikoff and Hsu 1935).

The USSR. — The Stromatoporoidea did not continue their development in Tn1b equivalents. Reef facies is not known, and the number of colonial Rugosa is very limited.

Eastern-European Province. — Novaya Zemlya lost ist importance as faunistic centre. Only some Tn1a genera and species continued to live there in Tn1b equivalent (Gorsky 1935, 1938, 1951). Very little is known about the Moscow basin, where rare *Caninia* has been recorded (Soshkina 1960). In the Donets basin primitive clisiophyllids occur and "*Campophyllum*" *caninoides* Vassiljuk 1960 (non Sibly 1906) was abundant in the Malevka and Upa Stages. Corals, mainly *Cyathoclisia* and *Sychnoelasma*, were more common in the Cherepet Stage. In the uppermost Tournaisian *Calmiussiphyllum* dominated (Vassiljuk 1960, 1966, 1975).

The Lower Tournaisian (Kynov) coral fauna of the Ural Mts. was mostly composed of genera and species known from the previous Stage (*Caninia*, *Siphonophyllia*, *Enygmophyllum*, *Cyathoclisia*, *Yavorskia*), but new elements such as *Dagmaraephyllum* also appeared. Beginning with the Kizel Stage the Ural Mts. region became one of the main centres for faunal distribution. Something like 13 rugose corals genera and several Tabulata entered the fauna (Vojnovsky-Krieger 1934, 1956; Sokolov 1955; Kachanov 1971, 1975; Degtjarev 1973*a*, *b*; Sayutina 1973 and others).

Rugosa:
"*Caninophyllum*"
?*Clisiophyllum*
Cystophrentis
Enygmophyllum
"*Stereolasma*"
Sychnoelasma
Uralinia
Zaphrentites

	Tabulata:
Keyserlingophyllum	*?Emmonsia*
"Meniscophyllum"	*Gorskyites*
Neomicroplasma	*Kueichowpora*
?Pseudouralinia	*Michelinia*
Rotiphyllum	*Tetraporinus*
Rylstonia	*Yavorskia*

Degtjarew (1973*a*) proposed to lower the Kosva Stage and to treat it as an Upper Tournaisian member and so did Kachanov (1975). This seems correct when only corals are concerned. The majority of typically Tournaisian genera such as *Enygmophyllum*, *Uralinia* and *Yavorskia* still existed and *Dibunophyllum*, *Lithostrotion*, *Lonsdaleia* or other Viséan genera are not known to occur. Another fauna, however (Conil, Lipina and Rejtlinger 1970) indicated lowermost Viséan age for Kosva Stage, which is tentatively used in the present paper.

A scattered coral fauna has been described from the northern part of the Siberian Platform (Koksharskaja 1965; Iwanowski 1967; Vassiljuk *et al.* 1970):

?Amplexus	*Keyserlingophyllum*
Amplexocarinia	*Lophophyllidium*
"Hapsiphyllum"	*Pseudouralinia*
"Campophyllum"	*Siphonophyllia*
Cyathoclisia	*Sychnoelasma*
Cystophrentis	*Uralinia*

Relation of this fauna is uncertain. The earliest known true *Lophophyllidium* may indicate its affinity to American Upper Carboniferous faunas, but the presence of Chinese genera and *Keyserlingophyllum* advocate rather for the Chinese and eastern-European connections. The present knowledge of this fauna does not allow any final decision as to its attachment to any province.

The Chukotka-Alaskan Province. — A very rich rugose fauna has recently been described and listed from Chukotka (Onoprienko 1973, 1976, 1977, 1979*a*, *b*). Several generic names of this fauna are new. Their real taxonomic value is uncertain however, because of inadequate illustrations and lack of information concerning ontogeny and fine structure. All of them are treated herein as tentative.

The Lower Tournaisian:	
Caninia	*Protocaninia*
"Caninia" s.l.	*Pseudoendophyllum*
"Caninophyllum"	*Tabulophyllum*
Malonophyllum	*Uralinia*
Neokeyserlingophyllum	
The Middle Tournaisian:	
Bifossularia	*Keyserlingophyllum*
"Caninia" s.l.	*Siphonophyllia*
Enygmophyllum	

The Upper Tournaisian:

?Amplexus	*Kolymaphyllum*
?Amygdalophyllum	*Koninckophyllum*
?Arachnolasma	*Liardiphyllum*
Bothrophyllum	*"Lophophyllum"*
"Campophyllum"	*Neomicroplasma*
Clisiophyllum	*Palaeosmilia*
Cravenia	*Sychnoelasma*
Cyathoclisia	*Zaphrentites*

All the Middle and some Lower Tournaisian genera continued to occur in the Upper Tournaisian (not listed). The main aspect of this fauna, i.e. its great diversity and early appearance of many genera in comparison to other regions (if the correlation and identifications are precise) makes it one of the most important Tournaisian faunas of the world. In this context the Chukotka region should be treated as one of main centres for the Lower Carboniferous coral faunas evolution and distribution. Appearance of *Kolymaphyllum*, a most probable ancestor of Upper Viséan/Lower Bashkirian Rozkowskiidae Fedorowski 1970, forms one of examples. The Alaskan Province, erected by Sando *et al.* (1977) seems to has been only a part of larger province, of which Chukotka composed the main part. Such a province, called herein the Chukotka-Alaskan Province, had comparatively good links of connections with both American and Euro-Asiatic provinces being separated from them only by wide open sea areas (fig. 1). This was reflected in a large number of Euro-Asiatic and American genera found there. An absence of *Lithostrotion* (*Siphonodendron*) and *Lithostrotionella*, common American Osagean genera and their early appearance in America may indicate the last region as their place of origin. This may also mean that westward direction was the main way of the coral fauna migration.

The Central Kazakhstan Province is characterized by a comparatively rich, but mostly endemic rugose fauna (Gorsky 1932; Volkova 1938, 1941; Iljina 1939; Keller 1959; Bykova 1966):

"Amplexus"	*"Lophophyllum"*
"Caninia" s.l.	*Rylstonia*
Cyathaxonia	*Siphonophyllia*
Cyathoclisia	*"Stereolasma"*
"Meniscophyllum"	*Zaphrentites*
"Laccophyllum"	

None of the genera *Dibunophyllum*, *Clisiophyllum*, *Lytvophyllum* (Keller 1959) and *Lithostrotion* (Iljina 1939) were present in the Tournaisian of this Province. A real taxonomic position of them and of a majority of the other has to be reestablished.

The Kuznets Province. — After isolation during the time of the Abyshev Stage, the corals of this province were included in general circulation of the Tournaisian coral fauna. This is confirmed by an appearance

of Western-European genera mixed with the endemic ones (Tolmachoff 1924, 1931; Fomichev 1931; Dobroljubova, Kabakovich and Sayutina 1966):

Rugosa:
Amplexizaphrentis
Bifossularia
Caninia
Cyathoclisia
Fasciculophyllum
Gangamophyllum
Kuzbassophyllum
Palaeosmilia
Siphonophyllia
Stelechophyllum
Sychnoelasma
Tachyphyllum
Zaphrentites

Tabulata:
Michelinia
Roemeripora
Syringopora
Yavorskia

The small Tournaisian fauna of Altay consists of *Bradyphyllum*, "*Hapsiphyllum*", "*Stereolasma*" and "*Rotiphyllum*". Both, the content of this fauna and inadequate descriptions and illustrations (Spassky and Kachanov 1971) made its closer affinity uncertain.

Transcaucasia. — Tchudinova (1970; 1974) and Papojan (1970, 1974, 1977) reported:

Lower Tournaisian Rugosa:
Cyathoclisia
Cystophrentis
Sychnoelasma
Urciphyllum
Zaphrentites

Upper Tournaisian:
Rugosa:
Cyathoclisia
Keyserlingophyllum
Kueichouphyllum
Pseudouralinia
Siphonophyllia

Tabulata:
Kueichowpora
Multithecopora
Pleurosiphonella
Syringopora

The fauna of this region showed a closer connection with that of China than any other of the USSR territory and may in fact have belonged to the same zoogeographical province. The seaway between those two regions must have been open (fig. 1).

China. — The lithological development and the coral faunas of Carboniferous deposits of individual parts of China differ greatly, making possible the distinction of the following natural regions: 1) The southern region covering major part of the Chinese Carboniferous deposits is characterized by rather complete series of deposits and very rich coral fauna slightly endemic in character. The endemism of coral fauna of this region is to some extent seen already in the Shaodung Formation equivalents what makes possible the distinction of the Chinese Province.

2) The northwestern region. Both Lower and Upper Carboniferous strata and coral faunas occur there but the knowledge of distribution and development of corals is less advanced.

3) The northern region; this will be discussed later on because of only the Upper Carboniferous deposits being developed there.

Tournaisian coral faunas of the northwestern region are uncertain.

These of the Limestone Member (= *Siphonophyllia opressa* assemblage) of the Chilienshan Mts., considered by Lo and Zhao (1962) as Upper Tournaisian are Viséan in character. According to Dr. C.M. Yu (personal comm. 1979) the discussed deposits and faunas are now correlated with the Viséan. The so called *Meniscophyllum xinjiangense* assemblage of Wu and Zhao (1979) may eventually be Tournaisian in age. This assemblage contains also *Neozaphrentis* and *Crassiphyllum*, the genera which seem to need new identification.

Chinese Province. — The lowermost coral assemblages distinguished by Wu and Zhao (1979) have already been discussed in the Strunian section of this paper in spite of their rather Tournaisian character. The *Cystophrentis kolaohensis* and *Pseudouralinia gigantea* assemblages identified by Wu and Zhao (1979) as Tournaisian contain also *Zaphrentites*, *Sychnoelasma*, *Siphonophyllia*, *Caninia*, *Michelinia* and *Syringopora* (Yü 1931, 1933; Wu 1964; Yang and Wu 1964) and may well be correlated with the European Tournaisian.

The Carboniferous Lexicon of Japan (1978) made clear the stratigraphic situation of the Japanese region of the Chinese Province. Corals are very rare and scattered. Minato and Kato (1978) cited *Amplexus*, *Caninia* and *Amygdalophyllum* as existing in the Hikoroichi Series and *Amplexus* in the Arisu Series.

Australian Province. — The oldest Carboniferous coral faunas were found in equivalents of Cu IIα (= Upper Tournaisian) in New South Wales. "*Neozaphrentis*" and "Permia" (probably new genera), *Naoides*, *Amygdalophyllum*, "*Lithostrotion*", *Michelinia*, and *Syringopora* have been described by Pickett (1966). ?*Yavorskia*, *Cladochonus* and *Bibucia* have also been recorded by Hill (1973). *Merlewoodia* appeared close to the Viséan boundary. Endemism of this fauna is discussed below together with the Viséan fauna.

North America. — Despite the use of extensive data on foraminifera and conodonts, differences in opinions regarding correlation of the Osagean-Meramecian boundary in the North American Mississippian with respect to the Tournaisian-Viséan boundary in the Lower Carboniferous of Europe make analysis of the Mississippian coral faunas difficult to bring into the context of European stratigraphy. Weller *et al.* (1948), Sando *et al.* (1969, 1977) regarded the Osagean as Middle and Upper Tournaisian, whereas Austin *et al.* (1973) and Ramsbottom (1973) placed almost all the Osagean in the Viséan. Conil *et al.* (1977) slightly revised these opinions by placing most of the Osagean (except for the Keokuk Limestone) in the Tournaisian. These differences largely reflected different opinions regarding the position of the Tournaisian-Viséan boundary in the European type sections. Because the position of the American authors conforms to long-standing agreement, the correlations of these authors are used in the following discussion of the North American Mississippian.

Two palaeozoogeographical provinces, recently renamed by Sando *et al.* (1977), are traditionally distinguished in the Lower Mississippian of North America: The Western Interior Province (from northern Canada southward to Sonora, Mexico) and the Southeastern Province (Midcontinent and southwestern U.S., Mississippi Valley and Appalachian region). These two provinces were connected in southern Arizona and in southern New Mexico. A third coral province in Nova Scotia distinguished by these authors, which was linked to western Europe, did not become evident until the Viséan. This province is recognized herein as a part of the Western European Province. The Alaskan Province recognized by Sando *et al.* (1977) was herein discussed as a part of the Chukotka-Alaskan Province. The mentioned paper of Sando *et al.* (1977) brings complete lists of American rugose and tabulate corals, as well as the most comprehensive data as to geography and development of the North American Mississippian coral faunas. All these data are fully accepted without repetition in this paper.

Conclusions

1. Lower Tournaisian coral faunas were poor, but the continuation of progressive Strunian genera was often observed.

2. Tabulata were rare and mostly unimportant stratigraphically on the generic level.

3. Rugosa were differentiated. The following, most important structures prevail: a) *Zaphrentites*-type arrangement of septa among small solitary corals; b) lonsdaleoid dissepimentarium (*Siphonophyllia*-type) and flat or concave tabularium.

4. The main centres for faunal distribution were: Franco-Belgian basins in western Europe, the Ural Mts in eastern Europe and in Asia, the Chukotka region in north-eastern Asia and Western Interior Province in North America. Central Kazakhstan, the Southeastern Province in North America and eastern Australia in particular were more or less isolated and endemic, although coral faunas of these provinces were rich and differentiated.

5. Communication between the North American provinces and those of Eurasia was possible, as indicated by the occurrence of *Syringopora* (common species of this genus have been recorded), *Cyathaxonia*, *Caninia*, *Zaphrentites*, *Sychnoelasma* and probably *Vesiculophyllum* and *Enygmophyllum* (if the last two are not synonyms). If the listed genera are not homeomorphic to those of Eurasia, they evidently came to North America from Asia, because the Eurasiatic species are geologically older.

6. Expansion of the coral fauna in the Upper Tournaisian was not only associated with widespread transgression but perhaps more importantly

reflected the taxonomic and quantitative development of this fauna, as well as its adaptation to new environments.

7. The following two aspects of the Tournaisian coral fauna should be taken into consideration: a) together with the beginning of this fauna (including some forerunners of the Strunian Stage), Permo-Carboniferous Cycle of Evolution began; b) Tournaisian fauna itself was the subject of adaptative evolution, it reached its culmination of development and died out in its larger part before the Viséan.

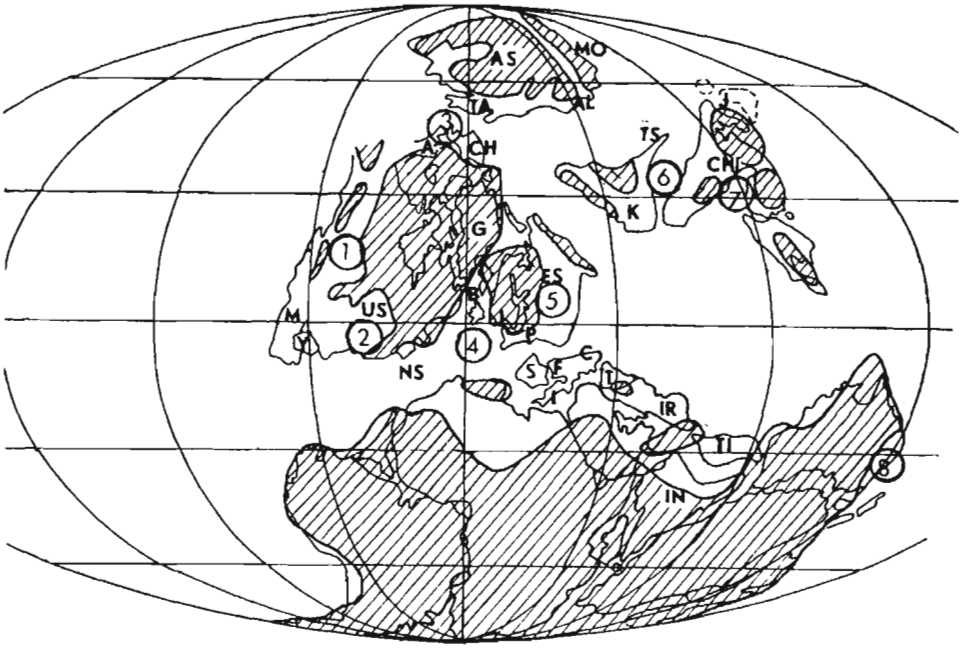

Fig. 2. The Viséan to Alportian palaeogeography and coral distribution. *Regions*: for explanations see fig. 1. *Provinces*: *1—5* as in fig. 1. *6* Middle Asiatic, *7* Chinese, *8* Australian. All provinces lost their importance or disappeared during Pendleian and Alportian or earlier (Australian Province).

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Western European Province (including North Africa and Nova Scotia in North America). — Viséan deposition in Britain started with the beginning of the Chadian Stage (George *et al.* 1976 = V1a of Belgium). The earliest Chadian faunas are found in the *Siphonophyllia cylindrica* Assemblage Biozone (= Upper Fauna of Mitchell and Green 1965) and are characterized by the presence of *S. cylindrica* together with species, including *Caninophyllum patulum* and *Cyathoclisia tabernaculum*, which range up from the Upper Tournaisian. The late Chadian faunas are marked in Britain by the entry of the following Rugosa:

"Caninia" caninoides
Lithostrotion (Siphonodendron) martini
Palaeosmilia murchisoni

The other corals present include (Vaughan 1905, 1915; Garwood 1912, 1916; Hill 1938—1941; Mitchell and Green 1965; Mitchell 1972; George *et al.* 1976; emended by Mitchell *in litt.*):

Rugosa:
Axophyllum simplex
Carruthersella compacta
"Koninckophyllum" praecursor
Thysanophyllum pseudovermiculare

Tabulata:
Michelinia megastoma

According to Poty 1981 the Lower Viséan 1a strata of Belgium contain the following corals:

Amplexus coralloides
Axophyllum mendipense
A. aff. *simplex* (Garwod)
"Caninophyllum" patulum
Carruthersella aff. *compacta* Garw.
Cyathaxonia modavense
Keyserlingophyllum avesnensis
Palaeosmilia murchisoni
Siphonophyllia cylindrica
S. garwoodi
Synchoelasma urbanovichi
"Syringaxon" berninensis

The Arundian Stage (= V1b—V2a of Belgium) is marked by the entry of many new species, especially among lithostrotionids, and some new genera. In Britain:

Clisiophyllum
Cravenia
Diphyphyllum
Ufimia
Haplolasma subibbicina
Palaeosmilia murchisoni
Siphonophyllia garwoodi

In Belgium only *Siphonophyllia garwoodi* was recorded in VIb (Poty 1981). In V2 entered (Conil et Pirlet 1971:, E. Poty 1981);

Carruthersella garwoodi
Corphalia mosae
Dorlodotia briarti
Lithostrotion (Siphonodendron) martini

Heterocorallia:
Heterophyllia ornata
Hexaphyllia mirabilis

The Holkerian (= V2b—V3a of Belgium) rugose fauna in Britain includes:

Axophyllum vaughani
Clisiophyllum — some new species
Lithostrotion (Lithostrotion) aranea
Lithostrotion (Lithostrotion) minus
Lithostrotion (Siphonodendron) — some new species

In Belgium some species recorded from earlier beds continued to exist and for the first time early *Dibunophyllum* probably appeared. Poty (1975b, 1977, 1981) recorded abundant tetracoral and heterocoral faunas in V2. Poty *in*: Kimpe *et al.* (1978) listed from V3 of the Brabant Massive:

Rugosa:
?Amygdalophyllum
Axophyllum
Carruthersella
Clisiophyllum
Cyathaxonia
Lithostrotion (Siphonodendron)
Palaeosmilia

Heterocorallia:
Heterophyllia

The Asbian (= lower and middle parts of V3b of Belgium) has a rich coral fauna in Britain with a typical assemblage from this stage consisting of:

Axophyllum vaughani
Dibunophyllum bourbonense
Koninckophyllum vaughani
Lithostrotion (Lithostrotion) arachnoideum
Lithostrotion (Siphonodendron) junceum
Lithostrotion (Siphonodendron) pauciradiale

Genera appearing for the first time include:

Rugosa:
Aulina (except for *A. horsfieldi*)
Auloclisia
Aulophyllum
Lonsdaleia (except for *L. praenuntia*)

Heterocorallia:
Heterophyllia
Hexaphyllia

In the Brabant Massive the fauna is as listed above but is often represented by more diversified species and enriched by as *Rotiphyllum, Lonsdaleia* and *Diphyphyllum* (Poty *in*: Kimpe *et al.* 1978). Corals of other regions of Belgium are rare, *Cyathaxonia cornu* and *Siphonophyllia samsonensis* were recorded for certain (Poty 1981).

The Brigantian (= upper part of V3b and V3c of Belgium) was marked in Britain by several new species of:

Clisiophyllum
Dibunophyllum
Lonsdaleia (Lonsdaleia)
Lonsdaleia (Actinocyathus)
Aulophyllum pachyendothecum
Corwenia rugosa
Diphyphyllum lateseptatum
Palastraea regia

The genera *Orionastraea* and *Nemistium* appeared only at this level. In Belgium Lithostrotionidae and Aulophyllidae occur in great number. The Brigantian contains the richest coral faunas in Britain and the corals recorded by Hill (1938—1941) from the D_2 Zone (= Coral Zones 2 and 3, excluding the Great Limestone which is of Namurian age) belong here. In the Brabant Massive the number of taxa is drastically impoverished in V3c. Poty (*in*: Kimpe *et al.* 1978) listed only:

Lithostrotion (Siphonodendron) junceum
Lithostrotion (Siphonodendron) sociale
Lonsdaleia (Actinocyathus) floriformis
Palaeosmilia murchisoni

In the Namur-Dinant basin and in the region of Visé the situation is similar (Poty, 1981).

Viséan Tabulata were not abundant in the British-Belgian region. The following genera have been described by authors:

Cladochonus
Emmonsia
Michelinia
Palaeacis
"Salpingium"
"Stratiphyllum"
Syringopora
Vaughania

Proper stratigraphical positions of some of these genera were mentioned earlier. Some of these genera need revision in respect of both taxonomy and stratigraphic position.

The reconstructed positions of Spain, most part of France (except for the southern Ardennes), Yugoslavia, Italy and Czechoslovakia (fig. 2)

indicate a possible similarity of coral faunas of these regions to the faunas of Transcaucasia, Turkey and Iran and a possible connection of them to the Mediterranean rather than Western European province. A cosmopolitan character of most genera listed below and a fragmentary knowledge of Turkish and Iranian faunas leaves the question open. A lack of *Kueichouphyllum* and *Heterocaninia* in the former group of countries can be interpreted either as an evidence of incorrectness of reconstruction of their positions or as an argument for the conception of creation of these genera in the latter regions and their migration eastwards due to the direction of main warm currents. The second possibility is tentatively accepted in the following discussion.

From Cantabria (Spain) Kullmann (1968) recorded:

Claviphyllum
Cyathaxonia
Fasciculophyllum
"Metriophyllum"
"Trochophyllum"
Ufimia
"Zaphrentoides"

from the *Pericyclus* Zone; *"Zaphrentoides"* from the Goα—β Subzones, and *Ufimia* from the Goγ Subzone. From the Pyrenees Perret and Semenoff-Tian-Chansky (1971) described from V1: *Palaeosmilia* (appeared in the Tournaisian), *Dibunophyllum* and *Diphyphyllum*; from V2: the continuation of earlier genera and the first appearance of *Axophyllum* and *Hexaphyllia*; from V3: in the lower part *Lithostrotion*, *Melanophyllum*, *Gangamophyllum*, *Lonsdaleia* and *Boswellia* and in the middle and upper parts *Koninckophyllum* and *Aulina* appeared.

A rich rugose coral fauna occurred in Yugoslavia (Kostić-Podgorska 1957, 1958, 1964):

Lower part of the series:
Cyathaxonia (*Cyathaxonia*)
Cyathaxonia (*Cyathocarinia*)
Carruthersella
Palaeosmilia
Upper part of the series:
Amygdalophyllum
Auloclisia
Aulophyllum
Axophyllum
Bothrophyllum
"Caninia" s.l.
Clisiophyllum
Dibunophyllum
Gangamophyllum
Koninckophyllum
Lithostrotion

Zukalová (1961, 1965) described the following genera from Moravia (Czechoslovakia):

Rugosa:
Axophyllum
"Caninia" s.l.
Cyathoclisia
Dibunophyllum
Diphyphyllum
Gangamophyllum
Koninckophyllum
Lithostrotion (*Siphonodendron*)
?Lonsdaleia
Palaeosmilia

Tabulata:
Syringopora
Heterocorallia:
Heterophyllia

An Upper Tournaisian age is suggested for some of these corals, although the presence of *Dibunophyllum*, *Lithostrotion* (*Siphonodendron*) and especially *Heterophyllia*, known everywhere in Europe only from the Viséan, makes this doubtful.

The Viséan coral fauna of Poland is only partly described (Kunth 1869; Schindewolf 1941; 1942; Fedorowski 1968, 1970, 1971, 1975; Nowiński 1976; Khoa 1977). Very little is known about the Lower and Middle Viséan. Nowiński (1976) described seven species of *Syringopora* and Fedorowski (unpubl.) tentatively identified the following genera of Rugosa from the Cracow region:

"Caninia" s.l.
Koninckophyllum
Lithostrotion
Palaeosmilia
Sychnoelasma
Ufimia
Zaphrentites

A very rich coral fauna was present in the Upper Viséan, especially in Brigantian:

Rugosa:
"Allotropiophyllum"
?Amplexizaphrentis
Amplexocarinia
Arachnolasma
Aulophyllum
Axophyllum
Biphyllum
Bothrophyllum
Bradyphyllum
Calophyllum
"Caninia" s.l.
Carruthersella
Claviphyllum
Clisiophyllum
Corwenia
Cyathaxonia
Dibunophyllum
Diphyphyllum
?Fasciculophyllum
Gangamophyllum
Haplolasma
Koninckinaotum
Koninckophyllum
Lithostrotion (Lithostrotion)
Lithostrotion (Siphonodendron)
Lonsdaleia (Actinocyathus)
Lublinophyllum
Melanophyllum
Mirka
"Neokoninckophyllum"
Nervophyllum
Orionastraea
Palaeastraea
Palaeosmilia
Pentaphyllum
Rotiphyllum
Rozkowskia
Rylstonia
Slimoniphyllum
Spirophyllum
Turbinatocaninia
Ufimia
Zakovia
Zaphrentites

Heterocorallia:
Heterophyllia
Hexaphyllia

Tabulata:
Cladochonus
Emmonsia
Michelinia
Multithecopora
Palaeacis
Syringopora
Syringoporella
Sinopora
Squameofavosites

Chaetetida:
Chaetetella
Chaetetipora
Cyclochaetetes

A very rich rugose coral fauna is known to occur in North Africa. From the lower part of the Viséan Semenoff-Tian-Chansky (1974) described:

Amygdalophyllum
Auloclisia
Axoclisia
Axophyllum
Rylstonia

The Upper Viséan/Lower Namurian coral fauna is much more diversified and consists of:

Amygdalophyllum
Arachnolasma
Aulina
Aulophyllum
Axophyllum
Bothrophyllum
Caninia
Carruthersella
Clisiophyllum
Dibunophyllum
Gangamophyllum
Haplolasma
Koninckophyllum
Palaeosmilia
Pareynia
"Pseudozaphrentoides"
Rylstonia
Siphonophyllia

Many colonial corals, as well as elements of "*Cyathaxonia*"-fauna have been found together with these listed above, but have not yet been described (P. Semenoff-Tian-Chansky *in litt.*). From the last two faunas, Daguin (1929) and Menchikoff and Hsu (1935) described *Zaphrentis* (= *Amplexizaphrentis* in part and *Soshkineophyllum* in part), *Lithostrotion* (*Siphonodendron*), and *Lonsdaleia* (*Lonsdaleia*).

In Nova Scotia, *Zaphrentis* (= *Amplexizaphrentis*), "*Caninia*" *s.l.*, *Pseudocaninia* (= *Bothrophyllum*), *Koninckophyllum*, *Dibunophyllum* and *Lonsdaleia* (*Lonsdaleia*) have been described from the uppermost Viséan and "Namurian A" (Bell 1929; Lewis 1935).

The USSR. — The Tournaisian-Viséan boundary in the main faunal regions remains doubtful. In the Ural Mts, the Viséan age of Kosva Stage has been questioned by Degtjarev (1973*a*) and Kachanov (1975). In the Donets basin, Vassiljuk (personal comm.) lowered the C a Zone into the Tournaisian. The same should be done with Podjakov Stage in the Kuznetsk basin if its correlation with Kosva Stage is correct. According to Degtjarev (1973*a*) a faunistic break can be seen in the coral fauna of the Ural Mts where the Kosva fauna was rich and did not differ greatly from that of the Kizelov Stage, while the Zapadnouralsk Stage fauna was very poor and corals were represented by new genera. Kachanov (1975) is of a slightly different opinion, indicating roots of 11 genera (two heterocoral genera in this number) already in the upper part of the Zapadnouralsk Stage.

There are also controversies as to the coral genera occurrence in particular horizons of the Ural Mts. *Thysanophyllum* and *Diphyphyllum* listed by Degtjarev (1973*a*) as Lower Tournaisian were considered by Kachanov (1975) as Lower Viséan. The absence of modern, illustrated descriptions makes impossible to comment on these identifications.

The Tournaisian-Viséan break of the coral fauna development is not so obvious between $C_1^{\gamma}a$ and $C_1^{\gamma}b$ Zones in the Donets basin. Perhaps this is because the described fauna was not so rich, but *Lonsdaleia* did not occur in this area before $C_1^{\gamma}b$. In the Kuznetsk basin, on the contrary, the fauna in the beginning of the Podjakov Stage changed significantly. Tournaisian genera such as *Enygmophyllum*, *Stelechophyllum*, *Uralinia* and *Yavorskia* no longer occurred, and *Lithostrotion* (*Siphonodendron*) entered together with "*Faberophyllum*", "*Lophophyllum*" and *Rylstonia*. However, such tabulate genera as *Michelinia*, *Syringopora* and rugose corals *Amplexizaphrentis*, *Bifossularia*, *Caninia* and *Fasciculophyllum* were still represented mostly by the same species as seen in the previous stage. No other corals, except one badly preserved *Syringopora*, have been found in the Kuznetsk basin above the Podjakov Stage.

Vassiljuk *et al.* (1970) divided the USSR territory into four palaeozoogeographical provinces: Eastern-European Province (including Moscow basin, the Ural Mts and Novaya Zemlya), Central Kazakhstan Province, Donets-Middle Asia Province, and Eastern Siberia Province (including Kuznetsk basin, Taymyr and Far North-east Siberia). This division is only in part supported by the reconstructed positions of the continents (fig. 2). The poorly known coral faunas of the Middle Asiatic and the northern Asiatic areas (except for the Omolon Massif) leaves the question of the two latter palaeozoographical provinces open. The author believes that:

a) Eastern-European Province should be restricted eastward to the western slope of the Ural Mts.

b) Donets basin seems to be the region of intersection of a few main and secondary directions of migrations of the coral faunas. This made that region especially interesting, but it should not be separated as a distinct palaeozoogeographical province. The analysis of the appearance of individual genera indicates that it was also not a fauna-creative region.

c) The middle Asiatic areas (southern and eastern Kazakhstan, Tien-Shan, Pamir) and the eastern slope of the Ural Mts belong probably to a separate province or subprovince, distinguished herein as Middle Asiatic Province(?). It is related to the northern Chinese and Japanese regions on one side and to the Eastern-European Province on the other. The migration of coral faunas was probably possible in both directions. The problem of Altay Mts is different. Its position advocates for the Kuznets affinity rather than the middle-Asiatic one and so does its inadequately known fauna.

d) Chukotka was a part of the Chukotka-Alaskan Province and the rest of the northern Siberia should have some connections with North American corals but the knowledge of the coral fauna of these northern regions is not adequate for any final discussion.

Eastern-European Province. — The problem regarding the Kosva Stage was discussed above. The Zapadnouralsk Stage of the Ural Mts is poor as

far as corals are concerned. They have been found only in five places (Degtjarev 1973*a*). However, the listed variety of genera (Degtjarev 1973*a*, *b*; Kachanov 1975) is large and contains:

Rugosa:
"Amplexus"
Aulina
Bifossularia
"Campophyllum"
"Caninia" s.l.
Clisiophyllum
?Corwenia
Cravenia
Cyathaxonia
Dibunophyllum
Diphyphyllum
"Eolithostrotionella"
"Hapsiphyllum"
Heterocaninia
Koninckophyllum
Lithostrotion
Lonsdaleia
"Lophophyllum"
Melanophyllum
Palaeosmilia
Rylstonia
Sychnoelasma
Thysanophyllum

Tabulata:
Multithecopora
Syringopora

Heterocorallia:
Heterophyllia
Hexaphyllia

Much of this fauna has not been studied in detail and the above identifications are treated herein as tentative. The equivalent stage of Novaya Zemlya is not identified with certainty, but the coral fauna in the lower part of the Viséan is even poorer there. No corals have been recorded from the Radeev and Bobrikov Stages in the Moscow basin.

The Tula Stage (= V2) and its equivalents contain a comparatively rich and widely distributed coral fauna only in the Ural Mts. (Degtjarev 1973*a*, *b*; Sayutina 1973; Kachanov 1975) and perhaps also in Novaya Zemlya (Gorsky 1938, 1951). This fauna is chiefly composed of the previously existing genera, however. The only newcomers are:

Amplexizaphrentis
Auloclisia
Aulophyllum
Axophyllum
Gangamophyllum
Palastraea

Many new species and the following genera enriched the fauna in equivalents of the Oka Stage (Dagtjarev 1973*a*; Sayutina 1973; Kachanov 1975):

Amygdalophyllum
Arachnolasma
Auloclisia
Carruthersella
Kazachiphyllum
Lytvophyllum
Nemistium
Nervophyllum
Paralithostrotion
Spirophyllum

Reliability of identifications of the above genera is much greater than that of the older ones, mainly due to the work of *Sayutina* (*l.c.*). Only *Faberophyllum* described by her does not belong to that American genus.

The Viséan Coelenterata fauna first penetrated the Moscow basin in the Tula Stage. The main characters of that fauna were:

a) Abundance of colonial Rugosa such as *Lonsdaleia* (both subgenera), *Lithostrotion* (both subgenera), *Diphyphyllum* and *Orionastraea*. Solitary corals (except for *Palaeosmilia*), e.g. *Dibunophyllum*, *Gangamophyllum*,

Ufimia as well as colonial *Tschernowiphyllum* (= *Paralithostrotion*) appeared in the Oka Stage only (Dobroljubova 1952*a*, *b*, 1958, 1970; Kabakovich 1952*a*, *b*).

b) Striking ecological and faunistic differences between western and southeastern parts of the basin. The southeastern part was connected through the Voronezh anticline with the Donets basin and the migration of the southeastern fauna occurred through that seaway. In the western part of the basin western European influences are clearest. The seaway allowing the migration of the coral fauna to or from western Europe most probably crossed Poland.

The Donets basin collected faunal elements of different provinces, but tended most closely to the Eastern European province. Differences between Zones $C_1^{\gamma}a$ and $C_1^{\gamma}b$ were discussed above. The latter and the following Zones $C_1^{\gamma}c, d$ contained a comparatively rich rugose coral fauna (Vassiljuk 1960, 1964) composed mainly of Viséan genera. This fauna forms the so called complex III of Vassiljuk (1975). The most important genera are:

"Amplexus"
"Caninia" s.l.
Clisiophyllum
Dibunophyllum
Diphyphyllum
Dorlodotia
Lithostrotion (both subgenera)
Lonsdaleia (*Actinocyathus*)
?Protolonsdaleia
Sychnoelasma

A break in the development of the coral fauna in Zone $C_1^{\gamma}e$ is observed, but a very rich fauna appeared again in Zone $C_1^{\gamma}f$ to form the complex IV of Vassiljuk (1975). Corals continued to be common into the "Namurian". In addition to majority of the genera listed above, the following ones occur in the $C_1^{\gamma}f$—$C_1^{\gamma}g$ Zones (Vassiljuk 1960, 1964):

Rugosa:
"Allotropiophyllum"
Amplexizaphrentis
Arachnolasma
Aulina
Aulophyllum
Claviphyllum
Cyathaxonia
Gangamophyllum
"Koninckophyllum"
Nervophyllum
Orionastraea
Palaeosmilia
Paralithostrotion
"Permia"
Pseudoclaviphyllum
Rylstonia
Spirophyllum
Ufimia

Tabulata:
Aulopora
Michelinia
Syringopora

Heterocorallia:
Heterophyllia
Hexaphyllia

Chaetetida:
Boswellia
Chaetetella
Chaetetes
Chaetetipora
Fistulimurina

The Middle Asiatic Province. — The Viséan coral fauna of Pamir and Tien-Shen is poor and insufficiently studied, whereas in southern Kazakhstan the following rugosan genera occur (Bykova 1966):

"Caninia" s.l.	*Lithostrotion*
Diphyphyllum	*Siphonophyllia*
Heterocaninia	

The Upper Viséan coral faunas of the discussed regions were mixed and genera of Mediterranean (*Heterocaninia, Kueichouphyllum, Kueichowpora*), as well as European or Uralian (*Gangamophyllum, Melanophyllum, Paralithostrotion*) origin have been found together. Many genera and species were common with those of the central Kazakhstan (Gröber 1908, Pyzhjanov 1965, Bykova 1966, Kropacheva 1966*a*, *b*, Vassiljuk *et al.* 1970). In contrast to Vassiljuk *et al.* (1970) the latter region is not considered herein as a separated province.

In the eastern Kazakhstan the following rugosan genera occur in the Middle and Upper Viséan (Bykova 1974):

?Amygdalophyllum	*Lithostrotion*
Aulina	*"Rotiphyllum"*
"Clinophyllum"	*Soshkineophyllum*
Cyathaxonia	*"Stereolasma"*
Gangamophyllum	*Zaphrentites*

Faberophyllum described by Bykova (1974) from the same sequence does not belong to that American genus and might well be the ancestor of the Bashkirian *Faberolasma* Bykova, 1974.

The coral fauna of the Ishim Stage of central Kazakhstan is poor and is represented mainly by long-ranging genera (Gorsky 1932; Bykova 1966):

Rugosa:	Tabulata:
"Amplexus"	*Michelinia*
Caninia	*Syringopora*
"Caninia" s.l.	
Fasciculophyllum	
Siphonophyllia	

In the middle and upper parts of the Viséan (Yagovkin and Dalnen Stages), this region was much less isolated than before, although some species and genera were endemic. Several genera, especially these listed below in inverted comas need reidentification. Majority of them are new and possibly endemic for the Middle Asia or for the discussed region only. Gorsky (1932), Volkova (1938, 1941) and Bykova (1966) described and listed:

Rugosa:	*"Carruthersella"*
?Amplexocarinia	*?Corwenia*
"Amplexus"	*?Cyathoclisia*
Amygdalophyllum	*Dibunophyllum*
Arachnolasma	*Diphyphyllum*
"Arachnolasma"	*?Fasciculophyllum*
?Arachnolasmia	*Gangamophyllum*
Aulina	*"Hapsiphyllum"*
Auloclisia	*Kazachiphyllum*
Axophyllum	*"Koninckophyllum"*
Bothrophyllum	*Kueichouphyllum*
"Caninia" s.l.	*Lithostrotion* (both subgenera)

"Lophophyllum"
Palastraea
Palaeosmilia
Paralithostrotion
Pentaphyllum
Rylstonia
Siphonophyllia
Spirophyllum
"Stereolasma"
?Yaunophyllum
Ufimia
Zaphrentites

Tabulata:
Michelinia
Syringopora

Transcaucasia. — This region certainly belonged to the Mediterranean Province and its Viséan coral fauna resembled that of China. Papojan (1969, 1970, 1974) recorded primitive kueichouphylla from the Lower Viséan what may indicate that this very characteristic "Chinese" genus originated in Transcaucasia and than migrated to China. Papojan (1977: 200) listed some other genera as present in the Viséan deposits of Transcaucasia and came independently to a similar conclusion.

The Chukotka-Alaskan Province. — A very interesting and rich coral fauna has been recorded from Chukotka by Onoprienko (1973, 1976, 1977). Three faunal assemblages can be distinguished: The Lower Viséan assemblage consists of:

Amplexizaphrentis
"Caninophyllum"
Dibunophyllum
Koninckophyllum
Lithostrotion (Siphonodendron)
Palaeosmilia
Zaphrentites

Only species of *Lithostrotion* (*Siphonodendron*) and *Diphyphyllum* form the Middle Viséan assemblage. The Upper Viséan coral fauna is dominated by the cerioid *Lithostrotion* (a very distinctive feature compared with the Western Interior Province of North America), accompanied by:

Ekvasophyllum
Enygmophyllum
Faberophyllum
"Lithostrotionella"
Rozkowskia
?Thysanophyllum

The rarity of Aulophyllidae is especially worth attention because of similar situation in North America.

Armstrong (1975) published a preliminary report of the Carboniferous corals from Alaska. The following genera have been listed from the Middle-Upper Meramecian/Lower Chesterian:

Rugosa:
Acrocyathus
Amplexizaphrentis
Diphyphyllum
Ekvasophyllum
Faberophyllum
Lithostrotion (Siphonodendron)
Sciophyllum
Thysanophyllum

Tabulata:
Syringopora

The north-eastern Siberia belongs at least in part to the discussed province, what may eventually caused a redefinition of the whole area. Corals are known to occur only in its northern region. Sokolov (1947) and Vassiljuk *et al.* (1970) described or recorded from the eastern Taymyr:

Rugosa:	Tabulata:
Canadiphyllum	*Kueichowpora*
Faberophyllum	*Multithecopora*
Liardiphyllum	*Syringopora*
Lithostrotion	*Tetraporinus*

From the Middle and Upper Viséan at the mouth of the Lena River Iwanowski (1967) reported:

Amygdalophyllum	*"Symplectophyllum"*
Lithostrotion	*Thysanophyllum*

China. — The Viséan deposits of southern China (Chinese Province) have been divided (Wu 1964) into two Zones: the *Thysanophyllum-Kueichouphyllum sinense* Zone, which may be an approximate equivalent of Arundian Stage in Britain and the *Yuanophyllum* Zone. The latter has been subdivided by her into three subzones. Later on Wu and Zhao (1979) reduced this subdivision into two subzones: the lower, *Arachnolasma sinense — Heterocaninia tholusitabulata* Subzone and the upper, *Neoclisiophyllum yengtzeense — Koninckophyllum stellatum* Subzone. The upper subzone is correlated by these authors with D_2 (= Brigantian) and E (= Pendleian) Stage of western Europe, what seems to be acceptable. The northern region shows more "European" character in the coral fauna, but differences are mostly on the specific level what makes one able to consider it as a part of the Chinese Province. The lower, *Orionastraea huaitoutalaensis* — assemblage and the upper, *Yuanophyllum kansuense* assemblage distinguished there by Wu and Zhao (1979) are possible equivalents of the upper two assemblages (subzones) of the Viséan of southern region. The first appearance of *Thysanophyllum*, *Lithostrotion*, *Kueichouphyllum* and *"Caninia"* (= *Haplolasma*) *subibicina* marked the lower boundary of the Viséan in the southern region (Wu and Zhao 1979). In northwestern region (Chiliensh an) this boundary is marked by *Siphonophyllia*, *Sugiyamaella*, *Amygdalophyllum* and *Lithostrotion* from the Chenchangou Series (Lo and Zhao 1962; Kato 1968; Wu and Zhao 1979).

The *Yuanophyllum* Zone was well marked by the abundance of Aulophyllidae, accompanied by many genera of other families (Reed 1927; Yü 1931, 1933, 1934, 1937; Yu 1964; Chi, 1933; Lin B. J. 1958, 1963; Lin and Fan 1959; Yoh 1961; Lo and Zhao 1962; Wu 1964; Lin J. D. 1966; Wu and Zhao 1979 and others). The following list of genera is very incomplete for two reasons: a) All genera introduced in the newly published Atlases are lacking because the present author had no direct access to that edition; b) Several genera introduced lately by the Chinese authors are omitted here because of inadequate descriptions and illustrations. *Caninostrotion* and *Faberophyllum* recorded from China by Wu (1964) were misidentified and are not related to American type species. The more important and/or better examined genera are:

Rugosa:
Acrocyathus
Amplexizaphrentis
Arachnastraea
Arachnolasma
Aulina
Bothrophyllum
Clisiophyllum
Cyathaxonia
Dibunophyllum
Diphyphyllum
Gangamophyllum
Heterocaninia
Koninckophyllum
Kueichouphyllum
Lithostrotion (both subgenera)
Lonsdaleia (both subgenera)
Rotiphyllum
Zaphrentites

Heterocorallia:
Heterophyllia
Hexaphyllia

Tabulata:
Aulocystella
Aulopora
Chia
?Cystodendropora
Fuchungopora
Kueichowpora
Neomultithecopora
Pseudofavosites
Remesia

Several genera, such as *Amygdalophyllidium*, *Hiroshimaphyllum*, *Ozakiphyllum*, *Ramiphyllum* and *Batangophyllum* described by Wu and Zhang (1979) from Xuchika Formation (= ?Pendleian) indicate strong connection with the inner Zone of Japan.

The coral fauna became markedly poorer in the uppermost part of the *Yuanophyllum Zone* (Wu 1964) what is in agreement with the world-wide tendency of this age (Pendleian).

The Carboniferous deposits in Japan are divided into inner and outer zones. In the outer zone *Sugiyamaella* has been described from the Lower (?) Viséan Ohdaira Series (Minato 1955; Minato and Kato 1978). A new coral fauna listed below appeared as early as the Onimaru Series (Upper Viséan) (Minato 1955; Minato and Kato 1957, 1978; Kato 1959; Minato and Minoura 1976 and others):

Rugosa:
Adamanophyllum
Amygdalophyllum
Aulina
Axophyllum
"Caninia" s.l.
Dibunophyllum
Dorlodotia
Gangamophyllum
Heterocaninia
Kueichouphyllum
Lithostrotion (*Siphonodendron*)
Lonsdaleia (*Actinocyathus*)
?Neokoninckophyllum
Palaeosmilia
Sciophyllum
Yuanophyllum

Tabulata:
Kueichowpora
Syringopora

That fauna, according to Minato an Kato (1978) may range slightly across the boundary of V3 and is readily comparable with that of northern China and the European provinces. The fauna of the inner zone is different, if represented in this Stage, and will be discussed below. Kato (1979*a*) summarized the up-to-date knowledge of the coral distribution in Japanese Carboniferous. He also presented complete lists of coral genera in accordance to the strata and main regions of their occurrence. He pointed

out a scantiness of the Tournaisian corals and their abundance in the Viséan Onimaru Series.

The Chinese Province expanded into Viet-Nam, Laos and as far south as to northwestern Australia (Hill 1973). In Viet-Nam and Laos, the following genera have been described (Mansuy 1913; Fontaine 1955, 1961, 1964):

Rugosa:
Arachnolasma
Bothrophyllum
Clisiophyllum
Cyathaxonia
"Hapsiphyllum"
Kueichouphyllum
?Rotiphyllum

Tabulata:
Hayasakaia
Michelinia
Syringopora

Heterocorallia:
Heterophyllia
Hexaphyllia

A small fauna probably of Viséan age has been described by Smith (1948) from Kuantan. It consists of *Amygdalophyllum*, *Siphonophyllia* and *Diphyphyllum*. From north-western Australia, Hill (1973) recorded *Kueichouphyllum*, *?Palaeosmilia*, *Michelinia* and *Palaeacis*.

The Viséan coral faunas of the pre-Tethys region outside the USSR and China have received only limited attention. Schindewolf (1932) and Flügel (1966) described from Tibet:

Rugosa:
"Amplexus"
"Caninophyllum"
Carruthersella
Lithostrotion (Siphonodendron)
Siphonophyllia

Tabulata:
Aulopora
Michelinia

From northwestern Afghanistan Schuppé (1970) described the following small fauna that may belong partly to the Tournaisian:

Amygdalophyllum
"Caninophyllum"
Fasciculophyllum
Zaphrentites

From Iran, Douglas (1950) and Flügel (1963) described:

Bothrophyllum
Keyserlingophyllum
Kueichouphyllum
Siphonophyllia
Zaphrentites

The richest fauna of the pre-Tethys outside the USSR and China is that of Asia Minor (Frech 1916; Charles 1933; Heritsch 1941*a*; Flügel and Kiaatliogliu 1956; Unsalaner-Kiragli 1958; Kato 1979):

Rugosa:
Aulophyllum
Axophyllum
"Caninia" s.l.
Clisiophyllum
Dibunophyllum
Diphyphyllum
Dorlodotia
Koninckophyllum
Kueichouphyllum
Lithostrotion (Siphonodendron)
Lonsdaleia (Actinocyathus)
Palaeosmilia

Tabulata:
Kueichowpora
Michelinia
Syringopora

The listed fauna consists mainly of the European immigrated genera. Only

Kueichouphyllum and maybe *Kueichowpora* came to this area from the nearby Transcaucasia.

North America. — The Tournaisian provinces are still recognizable and the Pacific Coast Province was distinguished by Sando *et al.* (1977).

In the Southeastern Province *Hapsiphyllum* and *Bordenia* appeared in Lower Meramecian and *Cyathaxonia* was still present (foraminiferal zones 10—12). The first appearance of *Lithostrotion* (*Siphonodendron*) and *Acrocyathus* was characteristic for the St. Louis Limestone. *Schoenophyllum* probably first occurred in the uppermost Meramecian and was still present in the lower Chesterian, where *Lithodrumus* has also been recorded (Grove 1935; Easton 1943, 1944, 1951; emended by Sando *in litt.*).

In the Western Interior Province the majority of the Osagean genera ranged across the upper boundary of that stage and occurred in the lower Meramecian. Among these genera *Zaphriphyllum* and *Canadiphyllum* were typical of lower Meramecian for western Canada (Assemblage 1 of Macqueen and Bamber 1968). *Ankhelasma* and probably *Ekvasophyllum* and *Diphyphyllum* appeared in the lower Meramecian. Bamber (*in litt.*) pointed out, however, that phaceloid lithostrotionids with a very poorly developed columella occur in Osagean rocks of western Canada. *Thysanophyllum*, *Sciophyllum*, *Faberophyllum* and one species of *Lithostrotion* (*Lithostrotion*) have been recorded from the middle part of this stage. *Lithostrotion* (*Siphonodendron*), *Acrocyathus* were very abundant in the Upper Meramecian. The middle part of forminiferal Subzone 16i is the upper limit for *Lithostrotion* (*Siphonodendron*), *Diphyphyllum*, *Sciophyllum*, and *Thysanophyllum*, but *Schoenophyllum* first appeared at that level and continued into Upper Chesterian. *Lonsdaleia* and probably *Aulina* first appeared in Zone 16a and continued similarly like *Schoenophyllum* (Kelly 1942; Parks 1951; Easton 1958, 1962, Sutherland 1958; Nelson 1960, 1962; Langenheim and Tischler 1960; Armstrong 1962, 1970*a*, *b*, 1972*a*, *b*, 1973; Bamber 1966; Sando 1960, 1963, 1965, 1969 and others; emended by Sando and Bamber *in litt.*). According to Sando (*in litt.*) rare *Dibunophyllum* and *Hexaphyllia* also occurred in the Viséan. The complete list of 42 Meramecian genera with comments concerning distribution, provinciality and interrelations of individual faunas of that age has recently been published by Sando *et al.* (1977).

Australian Province. — The Viséan corals of eastern Australia have recently been discussed in detail by Hill (1973). The occurrence of the following genera has been recorded (Hill 1934, 1973; Campbell 1957; Campbell and Mc Kellar 1969; Cvancara 1958; Pickett 1966; Jull 1969, 1974*a*, *b*):

Rugosa:
"Allotropiophyllum"
Amygdalophyllum
Aphrophylloides
Aphrophyllum
"Aulina"
"Carcinophyllum"
Coenaphrodia

Cyathaxonia
?Cyathoclisia
"Lithostrotion"
Merlewoodia
Notaphrophyllum
"Orionastraea"
Symplectophyllum

Tabulata:
?Michelinia
Palaeacis
Syringopora
?Vaughanites

Heterocorallia:
Heterophyllia

The endemic nature of this fauna has been discussed for several times (lately by Vassiljuk *et al.* 1970 and by Hill 1973), the present author, however, wishes to emphasize it more strongly. Australian corals referred to *Lithostrotion* at their first appearance were quite different (minor septa, dissepiments) from the Eurasiatic and North American genus. They tend to develop lonsdaleoid dissepiments, aphrophylloid or naosoid peripheral structures and a *Cionodendron*-like columella during evolution. These trends were different from those observed among the typically developed lithostrotionids of Eurasia and North America. Australian *"Orionastraea"* was not comparable either to the type species or to any other species of this genus, but showed affinities to *"Lithostrotion" parvicolumnare* Pickett (Pickett 1966). The species of *Cyathoclisia* was so modified that in can hardly be assigned to this genus. Australian *"Aulina"* was not colonial. The Australian species of *Michelinia* had a much more vesicular tabularium than any other species of this genus. I believe that all the Australian genera discussed above were homeomorphs of Eurasiatic and American genera. All the Aphrophyllidae might be related to the peculiar coral fauna of the inner zone of Japan. *Amygdalophyllum* seems to be the only Australian genus, which has been found outside the Australian Province, but even this genus was probably restricted to eastern Asia, because majority of other records are doubtful. The cosmopolitan genera *Cyathaxonia, Syringopora* and *Heterophyllia* belonged to a very narrow group of immigrants, which were able to penetrate that isolated area. These genera may indicate some connections of the Australian Province with the world seas, but the connections were probably very limited.

PENDLEIAN TO ALPORTIAN STAGES

The existing controversies concerning the placing of the Lower/Upper Carboniferous boundary and the peculiarity of the coral fauna of this part of the Carboniferous System makes its separate discussion most practical.

Western European Province. — The existence of Namurian is commonly accepted by European stratigraphers, as the Series was introduced for

western Europe. The coral faunas in Britain remained the best known. Hill (1938—1941) recorded from the Pendleian:

Axophyllum
Aulina
Clisiophyllum
Dibunophyllum
Diphyphyllum
Koninckophyllum
Lithostrotion (*Siphonodendron*)
Lonsdaleia (both subgenera)
Zaphrentites

This fauna became very poor in the so called Coral Zone 4 and died out before the end of Arnsbergian. *Zaphrentites* and *Lithostrotion* (*Lithostrotion*) are the only genera reported from this stage with certainty (Hill 1938—1941; Johnson, Nudds and Robinson 1980).

No reliable data are known from Belgium and northern France. From the possible equivalents to Pendleian and (?) Arnsbergian of the Pyrenees Perret and Semenoff-Tian-Chansky (1971) described:

Rugosa:
Aulina
Dibunophyllum
Koninckophyllum
Lonsdaleia (*Lonsdaleia*)
"Pseudozaphrentoides"
Heterocorallia:
Hexaphyllia

Kullman (1966, 1968) described *Plerophyllum* and *Ufimia* of the same age from Cantabria in Spain.

A small coral fauna, Pendleian-Arnsbergian in age, was described from the Polish Upper Silesian Coal Basin by Schindewolf (1952) and revised by Weyer (1977). It contains:

?Claviphyllum
Rotiphyllum
Ufimia
Zaphrentites

A different type of rugose coral fauna existed also in the lowermost "Namurian" of eastern Poland (the Lublin Coal Measures). All this fauna seems to be not younger than Pendleian. Khoa (1977) described:

"Caninia" s.l.
?Bothrophyllum
Lithostrotion (*Siphonodendron*)
Mirka
?Neokoninckophyllum
Turbinatocaninia

The rugose coral fauna of North Africa, although comparatively abundant, was enriched only by a single genus *Diaschophyllum*, while seven Upper Viséan genera died out (Semenoff-Tian-Chansky 1974). The great majority of the remaining genera did not cross the upper limit of Djenien Formation (= ?Arnsbergian). Semenoff-Tian-Chansky (*l.c.*) described:

Arachnolasma
Aulina
Aulophyllum
Axophyllum
Bothrophyllum
Carruthersella
Clisiophyllum
Dibunophyllum
Gangamophyllum
Koninckophyllum
Palaeosmilia
"Pseudozaphrentoides"

The USSR. — The Carboniferous Commission of the Geological Union of the USSR (Leningrad 1974) decided to use the name Serpukhovian Series for equivalents of the Pendleian to Alportian Stages of western Europe and accepted the lower boundary of the Krasnopoljan Stage (= the

bottom of the Kinderscoutian Stage) as the beginning of the Bashkirian (Stratigraficheskiy Slovar SSSR. Karbon, Perm. 1977). Einor *et al.* (1973*b*) described a complete marine section in the Ural Mts where the Chokerian to Marsdenian equivalent deposits succeeded each other. Those authors were also able to indicate the boundaries between series and stages. Kachanov (1973) describing corals of this sequence noted *Plerophyllum* in the Serpukhov Series. The problem of the Lower/Middle Carboniferous boundary is discussed also by Einor *et al.* 1973, 1975, 1978.

Two palaeozoogeographical provinces were recognized by Vassiljuk *et al.* (1970): The Eastern European — Siberian Province and the Mediterranean Province. This generalization probably resulted from the deterioration of the fauna and its rather inadequate investigation. It seems possible, however, to recognize the Chukotka-Alaskan Province also in the equivalents of the Upper Chesterian Stage (= Upper Serpukhovian).

In the Eastern European — Siberian Province the rugose coral fauna was impoverished in most places (e.g. Novaya Zemlya, Ural Mts, Moscow basin), but did not loose it Viséan character. The following and other Upper Viséan genera continued to occur in Ust-Sarbay Stage, but quickly declined in importance later on (Gorsky 1938, 1951; Dobroljubova 1952*a*, *b*, 1958, 1970; Kachanov 1965, 1975, 1979; Degtjarev 1973*a*, *b*; Sayutina 1973):

Amplexizaphrentis
Arachnolasma
Aulina
?Auloclisia
Aulophyllum
Bothrophyllum
Clisiophyllum
Cyathaxonia
Dibunophyllum
Gangamophyllum
Koninckophyllum
Lithostrotion (*Siphonodendron*)
Lonsdaleia (*Actinocyathus*)
Melanophyllum
Palaeosmilia
Rylstonia

The Voronezh anticline region was characterized by an open sea and a continuous coral fauna related to both the Moscow and the Donets basin faunas. Especially common were colonial corals, but solitary genera were also abundant. The following genera are most important:

Arachnolasma
Aulina
"*Koninckophyllum*"
Lithostrotion (*Siphonodendron*)
Lonsdaleia (both subgenera)
Palaeosmilia
Protodurhamina

Some species of these genera were "Asiatic" and indicate a close connection with the Mediterranean Province. Kozyreva (1978) analyzing the development and sequence of the Voronezh anticline coral fauna found its maximum development in the Upper Viséan, a great abundance in the Tarusa-Steshev Stages (= Pendleian Stage) and a rapid extinction at the end of the Protva Stage (= Arnsbergian). It could be predicted by comparison with other schemes that the Chokerian Stage was the extinction period also in the Voronezh anticline sea.

The Mediterranean Province. — The Donets basin belonged to this

province, but it was also closest to the Voronezh anticline sea and open communication can be observed between those two areas. Most of the Viséan genera and a few Viséan species were present in the $C_1^n a$—$C_1^n d$ Zones (= Pendleian — Arnsbergian Stages). Vassiljuk (1960, 1964) described:

Rugosa:
Adamanophyllum
"Amplexus"
Arachnolasma
Aulina
Axophyllum
"Caninia" s.l.
?Clisiophyllum
Bothrophyllum
Dibunophyllum
Diphyphyllum
Gangamophyllum
Lithostrotion (both subgenera)
Lonsdaleia (Actinocyathus)
Lytvophyllum
Nervophyllum
Palaeosmilia
Ufimia
Zaphrentites

Tabulata:
Michelinia
Syringopora

In a more recent paper Vassiljuk (1975) erected several faunal complexes, the fifth of which ($C_1^n a$—$C_1^n d$, up to the D_7 group of limestones exclusively) can be probably correlated with the Pendleian — Arnsbergian Stages of western Europe. Colonial *Lithostrotion* (both subgenera) and *Aulina*, although represented by four species only, form the quantitative majority of the fauna. The sixth faunal complex of Vassiljuk (1975) contains both the Chokerian — Alportian (limestones of the D_7 group) and the Kinderscoutian (limestones E_1—E_9) coral fauna. This fauna is currently being studied in detail. It differs greatly from the former one not only in a severe reduction in number and variety but first of all in appearance of very small (less than 1 cm in across) dissepimentate specimens representing ancestor forms of the Upper Carboniferous genera. The last representatives of the Viséan genera *Dibunophyllum*, *Spirophyllum* and *Rozkowskia* survived as far as this zone, and *Bathrophyllum* is present.

A rich rugose coral fauna, possibly of Pendleian — Arsnbergian age was present in Middle Asia and in Central Kazakhstan. These regions were also areas of expanded transgressions. The following genera have been reported (Pyzhjanov 1965; Bykova 1966; Vassiljuk *et al.* 1970; Shchukina 1973):

Arachnolasma
Aulina
Clisiophyllum
Diphyphyllum
Gangamophyllum
"Koninckophyllum"
Lithostrotion
Palastraea
Palaeosmilia

The Chukotka — Alaskan Province. — Armstrong (1975) recorded a presence of *Acrocyathus* in the foraminiferal zones 17—18 (Upper Chesterian) of Alaska. *Lithostrotion* was the most characteristic coral genus for the possibly Pendleian deposits of Taymyr. Quite a rich fauna has been listed from the same age of Chukotka (Onoprienko 1973, 1977):

Acrocyathus
Axophyllum
Bothrophyllum
"Campophyllum"
"Caninia" s.l.
?Corwenia
Dibunophyllum
Gangamophyllum
Koninckophyllum
Paralithostrotion
Protodurhamina

The Mediterranean Province outside the USSR. — The Pendleian coral fauna in China is similar to that of the Upper Viséan. Wu *et al.* (1974) listed *Aulina*, *Dibunophyllum*, *Lithostrotion*, *Palaeosmilia* and *Palastraea*. In Japan the fauna of the Nagaiwa Series (Minato and Kato 1974) may be partly equivalent of Arnsbergian. The fauna of the inner zone of Japan, discussed below as Bashkirian, is probably represented also in the Pendleian — Arnsbergian equivalents and may even include the uppermost Viséan (Kato *in litt.*). The problem of the Lower/Upper Carboniferous boundary in Japan remains open. Minato and Kato (1978: 44) are in favour of placing it "somewhere around the basal part of the massive limestones of the Akioshi, Atetsu and Omi". Table 3 of the same authors makes also clear differences in interpretation of the lower boundary of the Nagaiwa Series and its relation to the Onimaru Series.

No "Namurian" corals have been described from Australia.

In North America, the Upper Chesterian foraminiferal zones 17—18 were compared with the Pendleian-Arnsbergian Stages and the post-18 zone with Chokerian to Marsdenian Stages of western Europe. In the more recent paper Sando *et al.* (1977) correlated the lower boundary of Chesterian with V3b of Belgium, but restricted the upper limit of Chesterian to the Alportian only. This idea makes correlative at least the lower boundary of Baskirian, Pennsylvanian and the Kinderscoutian. No corals have been found in zone 19 (or zone post-18) in the Southeastern Province. In foraminiferal zones 17—18 (= Pendleian-Arnsbergian Stages) the following rugosan genera have been described (Easton 1943*a*, *b*, 1945*a*, *b*, 1951):

Amplexizaphrentis
"Amplexus"
Caninostrotion
Kinkaidia
Lonsdaleia (Actinocyathus)
Palastraea
Zaphrentites

In the Western Interior Province the following genera are known to occur in foraminiferal zones 17—18 (= Pendleian — Arnsbergian Stages) (Easton 1945*a*, 1951, 1962; Armstrong 1962, 1970*a*, *b*, 1973; Sando 1963, 1965, 1969; Bamber 1966; Bamber and Waterhouse 1971; and others):

Rugosa:
Acrocyathus
Aulina
Lonsdaleia (Actinocyathus)
Schoenophyllum
"Siphonophyllia"
Zaphrentites

Tabulata:
Duncanopora
Michelinia
?Multithecopora
Syringopora

No corals except perhaps for *Barytichisma*, have been found in foraminiferal zone 19.

The complete list of North American Chesterian genera is compiled by Sando *et al.* (1977: 182).

Conclusions

1. Upper Tournaisian and Lower Viséan coral faunas can be distinguished, but the boundary between them is not sharp either in particular geographic regions or when the world-wide ranges of genera are considered. The poverty of Lower Viséan faunas in comparison with those of the Upper Tournaisian emphasizes the boundary of subphase of coral evolution.

2. The widespread nature of coral faunas during the Viséan caused much mixing and, in fact, it is difficult to distinguish any well defined palaeozoogeographical provinces in the Upper Viséan, except for the Australian Province.

3. Upper Viséan with its most diversified and most abundant fauna can be indicated as the culminating point of the Lower Carboniferous phase and, maybe, also the culminating point of the Permo-Carboniferous cycle of coral evolution.

4. Viséan and Pendleian — Lower Arnsbergian coral faunas were very similar; they belonged to the same subphase of coral evolution and were separated in this paper only because of the uncertain situation in placing the Lower/Upper Carboniferous boundary and because of the fast worldwide deterioration of the coral fauna during the latter series.

5. A major break in the worldwide development of the coral fauna started in the uppermost Viséan; it was strongly accentuated in the Upper Arnsbergian — Chokerian Stages and was probably caused by orogenic movements, reduction of shelf seas and to a lesser extent by climatic changes. The same coral fauna followed pulsations of the sea and returned during Pendleian and to a lesser extent during Lower Arnsbergian whenever normal marine conditions returned.

6. During upper Arnsbergian and Chokerian the coral fauna became very poor and restricted geographically. Where normal marine conditions persisted in the Alportian Stage one can observe the appearance of new forms — the ancestors of Bashkirian genera.

BASHKIRIAN SERIES

Coral bearing deposits became limited. They are restricted to the following palaeozoogeographical provinces: the Mediterranean Province, the Eastern European-Siberian Province, the North American Province

and the inner zone of Japanese Carboniferous, which should be treated as a separate province.

Starting from this part of the paper, the stage and series names introduced in the USSR will be used as the standard names for the following discussion.

The Mediterranean Province. — This was the only one in which the maritime conditions were widespread. Spain, North Africa, Yugoslavia, the Donets basin, Middle Asia, China and the outer zone of Japanese Carboniferous are included in this province. The reconstructed positions of individual continents (fig. 3) indicate that it should be subdivided into at least two subprovinces: the southern and the north-eastern subprovince. The coral faunas of both subprovinces are apparently similar to each other in the basic content. This may have resulted from the inadequate knowledge rather than from reality, however.

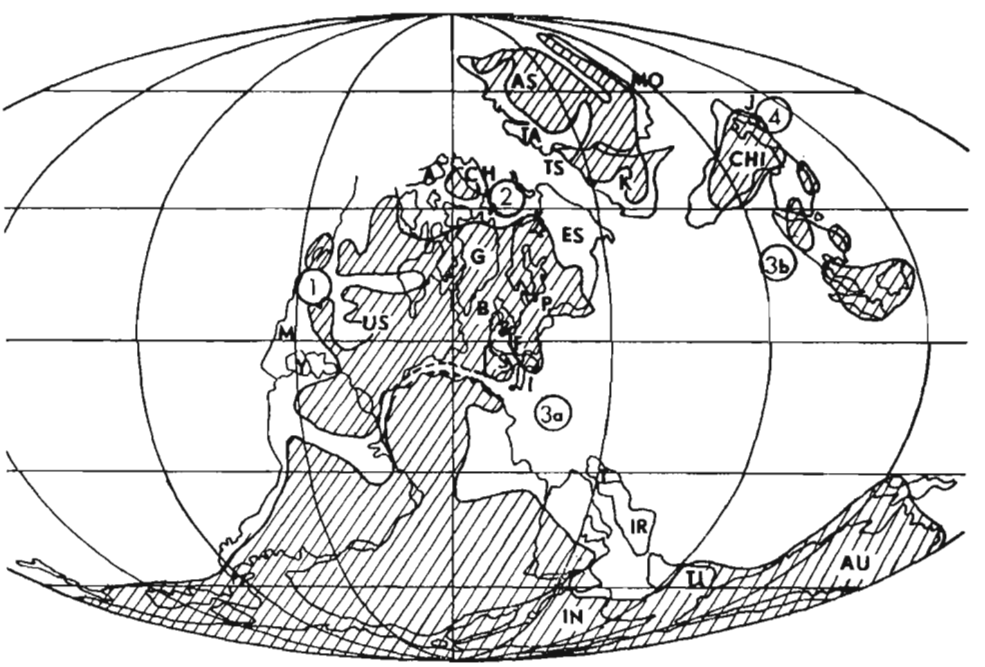

Fig. 3. The Baskirian palaeogeography and coral distribution. *Regions*: for explanations see fig. 1. *Provinces*: *1* North American, *2* Eastern European-Siberian, *3* Mediterranean with subprovinces a) southern, b) north-eastern, *4* Japanese.

The southern subprovince. — The Donets basin is the best developed region of the southern subprovince, because the sequence is complete and mostly marine. (Aizenverg *et al.* 1978). It has been studied in detail and the coral fauna is comparatively well known. Krasnopoljan (= Kinderscoutian — Marsdenian Stages) and Severokaltmensk (= the lower part of the Yeadonian Stage) were extremely poor in corals as compared with

lower and upper parts of the sequence. This break in the development of the coral fauna was accentuated by the fact that only a very limited number of the previously occurring genera are still known to occur in the Krasnopoljan and Severokaltmansk Stages (= limestones "E" in Donets basin). They are: *Michelinia*, *Dibunophyllum* and *Rozkowskia*. The rest of the fauna consisted of small (approximately 1 cm in diameter) solitary corals with dissepiments. Solitary "*Lytvophyllum*" of Vassiljuk (1960), probably a new genus, also belongs to this group. The only colonial coral was *Lytvophyllum dobroljubovae* Vassiljuk. Small zaphrentoid corals such as "*Actinophrentis*" or "*Stereophrentis*", possessing a slightly more extended counter septum, *Amplexocarinia*, *Baritichisma* and rare *Boswellia* were found there (Vassiljuk 1960 and her tentative identifications 1975; collection seen by the present author).

The coral fauna of the Prikamsk Stage (= Limestone "F" in the Donets basin = faunal complex VII of Vassiljuk 1975 = upper Yeadonian) was poor. The following genera were described or listed (Fomichev 1953; Vassiljuk 1975):

Rugosa:
Amplexocarinia
Axolithophyllum
Barytichisma
Bothrophyllum
?*Cyathaxonia*
Lophophyllidium
"*Lophophyllum*"
"*Stereophrentis*"

Tabulata:
Cladochonus
Michelinia
Sutherlandia

A more abundant and better differentiated rugose coral fauna appeared in the upper Cheremshan and Malekesk Stages (= Limestones "H" to "K_3" in the Donets basin). Fomichev (1953) described:

"*Campophyllum*"
"*Clinophyllum*"
Cyathaxonia
"*Cystophora*"
Bradyphyllum
Lophophyllidium
"*Monophyllum*"
Neokoninckophyllum
Orygmophyllum
Sestrophyllum
"*Stereophrentis*"
Yuanophylloides

To the west of the Donets basin Heritsch (1935) described from Czechoslovakia:

Bothrophyllum
Bradyphyllum
"*Dibunophyllum*"
Donophyllum
"*Koninckophyllum*"
?*Spirophyllum*

This fauna needs revision and may well be Moscovian in age. Kostič-Podgorska (1960, 1967, 1972) described "*Amplexus*" and *Multithecopora* from Yugoslavia.

The Santa Maria Limestone of Cantabria, Spain, containing *Profusulinella* and *Pseudostaffella* together with *Dibunophyllum* (= ? *Amandophyllum*) and *Lithostrotionella* (= *Petalaxis*) is probably Upper Bashkirian, whereas the lower part of the Perapertu Formation may be considered as uppermost Bashkirian or already Moscovian. The coral assemblage described by de Groot (1963) consists of:

"Carcinophyllum"	*Petalaxis*
"Clisiophyllum"	*"Pseudozaphrentoides"*
"Dibunophyllum"	*?Spirophyllum*
Koninckocarinia	

In the Leon Province of Spain, Winkler Prins (1971) recorded *Palaeofavosites* and *Cladochonus*, while de Groot (in appendix) described *Leonardophyllum.*

A very restricted fauna has been recorded from Southern Wales. Smith (1931) described *Zaphrentis* (= *?Ufimia*) from the *Gastrioceras cancellatum* Marine Band (= Severokaltmansk = Lower Yeadonian Stage). Semenoff-Tian-Chansky (1974) described *Dibunophyllum, Bothrophyllum, "Caninophyllum"* and *"Koninckophyllum"* from the Bassi Kerma Formation of the Sahara.

North-eastern subprovince. — Very little is know about middle Asiatic corals. *"Amygdalophylloides", "Corwenia"* (with carinate septa), *Cyathaxonia, Kionophyllum, Faberolasma* and *Chaetetes* and in the uppermost beds *Darwasophyllum* were recorded (Pyzhjanov 1964, 1965; Vassiljuk *et al.* 1970; Shchukina 1973; Bykova 1974).

The Weiningian Series with its Pseudostaffella — Profusulinella fusulinids and *Reticuloceras, Gastroceras, Brannoceras* goniatites can be considered as Bashkirian. Wu and Zhao (1979) established *Carinthiaphyllum exquisitum — Kionophyllum ovatum* coral assemblage of this age and listed *"Lithostrotion", "Corwenia", Ivanovia* and *Bothrophyllum.* Yu (1976) described *"Caninia", Fomichevella* and *Lithostrotionella* (= *Petalaxis*) from the Upper Baskirian Dianshan Formation.

The comparison of the Nagaiva Series in Japan with "Namurian" B and lower part of "Namurian" C (Minato and Kato 1978, Table 3) indicates that the coral fauna described by these authors in 1974 could well has extended up to the Bashkirian.

The Eastern European-Siberian Province. — The coral fauna of the Ural Mts and Novaya Zemlya was recorded mainly as having Viséan genera such as *Lithostrotion, Corwenia, Caninia, Koninckophyllum, Lophophyllum,* but these identifications are very doubtful (Degtjarev 1973*a*, *c*). Kachanov (1971, 1973) and Dektjarev (1979) described:

"Amplexus"	*Lytvophyllum*
"Caninia" s.l.	*Petalaxis*
Cyathaxonia	*Pentaphyllum*
"Darvasophyllum"	*Profischerina*
Fomichevella	*Protodurhamina*
Koninckocarinia	*Zaphrentites*

Part of a large coral fauna, described by Gorsky (1978) as Middle Carboniferous may be Bashkirian in age (compare the stratigraphic Table 3 of Shcherbakov *in* Gorsky, *l.c.*). Solitary corals present include:

?Arctophyllum	*"Caninia" s.l.*
"Campophyllum"	*Bothrophyllum*

"Lophophyllum"	*Pseudotimania*
Neokoninckophyllum	*Sychnoelasma*
Orygmophyllum	*Yakovleviella*

Colonial corals include:

Fomichevella	*Profischerina*
Lytvophyllum	*Protodurhamina*
Petalaxis	

The majority of the genera mentioned range up into the Moscovian. All of them should be restudied and renamed in accordance to the modern systematics. The possible alternative names are indicated here only tentatively. Degtjarev (1975) analyzed Bashkirian and Moscovian coral faunas from the Ural Mts taking into consideration not only the earlier published papers, but also Gorsky's (1978) paper, not yet published at that time, what makes his Table 1 and some remarks slightly confusing. Nevertheless he established a clear distinction between Bashkirian and Moscovian coral faunas on the specific level and suggested starting the Baskirian within the Sjuran (= Krasnopoljan) Stage and ending it with Uklukain Stage. This is in accordance with the generally accepted scheme (Einor *et al.* 1978; Stratigraficheskiy Slovar SSSR 1977) and with the character of coral evolution. Pointing out the incorrectness of many generic names applied for Bashkirian and Moscovian corals Degtjarev (*l.c.*) did not propose any alternatives, however.

The coral fauna of the Voronezh anticline was lately studied by Kozyreva (1973, 1976, 1978*a*, *b*; collections seen by the present author). She recorded the following faunas:

The Krasnopolyan Stage:

Rugosa:	Tabulata:
Aulina	*Michelinia*
Donophyllum	*Syringopora*
Lytvophyllum	
Petalaxis	
Thysanophyllum	

The Severokeltman Stage:

Lonsdaleoides	*Petalaxis*
Lytvophyllum	*Protodurhamina*

The Prikamsk Stage:

?Lonsdaleia	*Petalaxis*
Lonsdaleoides	*Protodurhamina*
Opiphyllum	

The Cheremshan Stage:

?Lonsdaleia	*Petalaxis*
Lytvophyllum	*"Pseudodorlodotia"*
Opiphyllum	*"Thysanophyllum"*

In the Malekes Stage the coral fauna became poor. *Petalaxis* did not occur but was replaced by *Bothrophyllum*.

No Bashkirian corals have been recorded from the Moscow basin and those indicated here in the Table 1 belong to the Voronezh anticline area.

Japanese Province. — The first establishment of this province may have been as early as in the Upper Viséan and it was possibly not later than the Pendleian when many new peculiar genera comparable only with the Australian Upper Viséan coral fauna appeared in the Japanese inner zone:

Akioshipphyllum
"Clisaxophyllum"
Echigophyllum
"Lonsdaleoides"
Omiphyllum
Nogatophyllum
Pseudopavona
Taisyakuphyllum

Similar trends toward development of naosoid structures and compact axial zones are observed in both the faunas. Pickett (1966) speculated that the Australian coral fauna had been pushed north by glaciation, and he compared it with the Japanese Viséan fauna. In the present author's opinion this is true only when the Japanese "Namurian" coral fauna of the inner zone is considered. Ota (1968) discovered an atoll form with *Chaetetes* as a framework in the Akioshi Limestone (Central Honshu), the best developed region of the Japanese Province. This may mean that similar atoll forms should be expected in Australia and the fauna was a reef coral fauna *sensu stricto*, while the other faunas might only have been associated with reefs. Eurasiatic and American genera were very limited in this province. The most important were long-ranging *Acrocyathus*, which may be *Petalaxis* in part, *Amygdalophylloides* and *Neokoninckophyllum* (Ozawa 1925; Minato 1955, 1975; Yokoyama 1957; Yamagiwa 1961; Kato 1967; Kato and Minato 1975; Ota 1968; Rowett and Minato 1968; and others). Kato (1979) divided the Upper Carboniferous coral fauna into Nagaiwa Fauna of boreal connections and Akiyoshi Fauna of a more endemic character. The latter one is here considered as belonging to the separate Japanese Province. The complete list of genera is published by Kato (*l.c.*) and will not be repeated.

North American Province. — Only one province is recognized in North America in the Pennsylvanian, although Sando (*in litt.*) believes that a few subprovinces may be distinguished there. The Morrowan fauna (an equivalent of lower Bashkirian) is known mostly from the midwestern States. The following genera have been described (Barbour 1911; Jeffords 1942, 1947; Moore and Jeffords 1945; Rowett and Sutherland 1964; Sutherland 1977):

Rugosa:
?Amandophyllum
"Amplexizaphrentis"
Amplexocarinia
Baritichisma
"Craterophyllum"
"Dibunophyllum"
"Koninckophyllum"
Leonardophyllum
Lophophyllidium
Lophotichium
Petalaxis
Soshkineophyllum (*Empodesma*)

Tabulata:
Acaciapora
Aulopora
Michelinia
Multithecopora
Palaeacis
Striatopora
Syringopora

The coral fauna of the Atokan Series, which is an equivalent of upper Bashkirian and Lower Moscovian(?), was rather sparse and/or poorly described. Lophophyllidiidae were most abundant and *Barytichisma*, *"Caninia" s.l.*, *Cumminsia*, *Syringopora* and *Multithecopora* have been described (More and Jeffords 1945; Wilson 1963; Sando 1965). *"Corwenia" jagoensis* Armstrong, 1973 in Alaska might be one of the oldest *Profischerina* in North America. Bamber (*in litt.*) reported the occurrence of this genus in foraminiferal zone 21 of Yukon Territory (Canada), Rowett (1969) and Rowett and Timmer (1973) described *"Cryptophyllum"*, *Lophophyllidium*, *Soshkineophyllum*, *"Zaphrentoides"*, *"Neozaphrentis"* and *Cladochonus* from post-Morrowan deposits in Alaska. A peculiar Atocan coral fauna (probably early Moscovian in age), containing mostly new genera, has been found in the Canadian Arctic Archipelago. Bamber (in litt.) tentatively recorded *Amplexocarinia* sp., cf. *Calophyllum* sp., *Cyathaxonia* sp. and *Pseudofavosites* sp. Rowett and Timmer (1973) believed this northern faunas to be provincial, although their work suggests the possibility of a connection between North America and Asia through Alaska and Siberia.

Conclusions

1. The lower boundary of the Bashkirian, as concerns the coral fauna, may well be lowered into the base of the Chokierian Stage, at which level a number of new taxa first appeared.
2. The Bashkirian rugose coral fauna started a new phase of evolution of the Rugosa. In the regions marine conditions changed very little (Voronezh anticline, Donets basin, parts of the Ural Mts) some Lower Carboniferous genera persisted, but even in these regions the appearance of new structures on a general scale can be observed.
3. The north-western seaway from the Ural Mts into the Canadian Arctic Archipelago seems to have been almost closed to the corals, although the marine deposits have been recorded from Arctic.
4. The main faunistic centres were scattered but none was situated in northern regions. They were connected with the Mediterranean seaways in Eurasia and were located in the midwestern States of North America. This may indicate the most favourable conditions for corals in those regions.
5. The most characteristic morphological structures of Bashkirian corals were the same as those for the geologically younger ones. They were: a) elongated counter (rarely cardinal) septum, which became the origin of the axial structure, b) flat or concave tabularium, c) "caninoid" stage of mature specimens of dissepimentate solitary corals; this stage was reached by corals belonging to different phylogenetic lines.

MOSCOVIAN SERIES

The Mediterranean Province. — As during the Bashkirian period, this province should be subdivided into the southern and north-eastern subprovinces.

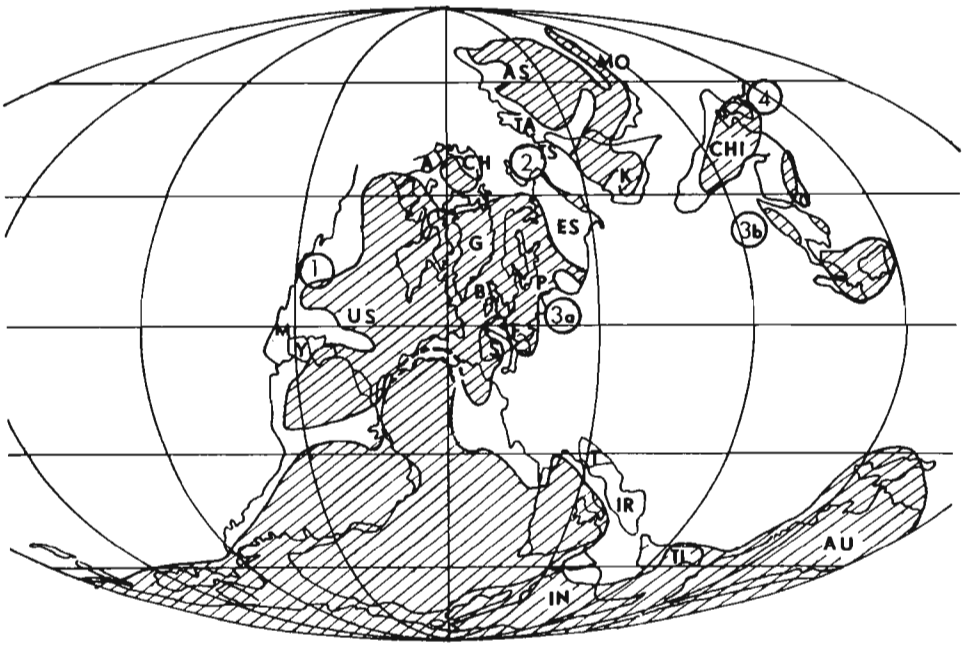

Fig. 4. The Moscovian palaeogeography and coral distribution. *Regions*: for explanations see fig. 1. *Provinces*: *1*, *3*, *4* as in fig 3. Province *2* Uralian-Arctic.

The southern subprovince. — Northern Spain was one of the richest regions of this subprovince. In the lower Moscovian (upper Perapertu Formation) de Groot (1963) described:

Amandophyllum
"Carcinophyllum"
"Clisiophyllum"
"Dibunophyllum"
Donophyllum
?Duplophyllum
Koninckocarinia
"Koninckophyllum"
Petalaxis
"Pseudozaphrentoides"
?Spirophyllum
?Thysanophyllum

In the Cotarroso Limestone and Sierra Corisa Limestone, the equivalents of the upper Moscovian, most of the above listed rugosan genera are known to occur as well as:

Amandophyllum
Amplexocarinia
?Amygdalophyllum
Arachnestraea
Axolithophyllum
Bothrophyllum
Bradyphyllum
Calophyllum
"Corwenia"
Lophophyllidum
Petalaxis
"Rotiphyllum"
Soshkineophyllum
Ufimia
"Zaphrentites"

The fauna closely resembled that of the Moscow and Donets Basins of the USSR (de Groot, *l.c.*).

A new fauna appeared in Yugoslavia as early as the Vereja Stage, but corals were abundant only starting with the Mjachkov Stage. The following genera have been recorded from there (Heritsch 1940, 1941*b*; Kostić-Podgorska 1954, 1955, 1956, 1957, 1962, 1964, 1967):

Allotropiophyllum
Amandophyllum
Bothrophyllum
Bradyphyllum
"Caninia" s.l.
Donophyllum
"Hapsiphyllum"
Kionophyllum
"Lopholasma"
Lophophyllidium
"Meniscophyllum"
Neokoninckophyllum
Petalaxis
?Thysanophyllum

The coral fauna of the Mjachkov Stage in the Carnic Alps region (= Fauna I of Heritsch 1936) consisted of *"Caninia" s.l.* and *Amplexocarinia* (Heritsch 1936).

A small coral fauna appeared in Westphalian C of South Wales. *Zaphrentis postuma* (a composite species, containing probably a few distinct genera), *Cyathaxonia* cf. *rushiana* Vaughan and *?Caninia cornucopiae* Michelin have been described (Smith 1931). All these species need careful revision. *Zaphrentis* aff. *postuma* Smith (= *Bradyphyllum*) was described in Belgium from the same age (Demanet 1943).

The Donets basin was again one of the main faunistic centres, although calcareous and shaly facies, as well as terrestrial deposits were interbedded there. Fomichev (1953) and Vassiljuk (1975) recorded:

"Actinophrentis"
Axolithophyllum
Baritichisma
Bothrophyllum
Bradyphyllum
"Campophyllum" (solitary)
"Caninia" s.l.
Cyathaxonia
"Cystolonsdaleia"
Donophyllum
Ivanovia
Lophophyllidium
Neokoninckophyllum
Orygmophyllum
Petalaxis
"Stereophrentis"

The north-eastern subprovince. — According to Pyzhjanov (1964, 1965), the *Caninia-Clisiophyllum* Fauna prevailed in the Pamir region, and colonial corals were relatively rare. *Darwasophyllum* was the only coral genus from this region that was not present in the Donets basin. The lack of illustrated descriptions of majority of the genera listed from that area made this opinion not fully documented.

Corals of the Chinese region and probably the outer zone of Japan also, were rather distinct from the rest of the fauna of that province and have been correctly treated as subprovince by Vassiljuk *et al.* (1970). Chaetetidae were numerous but similarly monotonous like the Tabulata, which were represented mainly by *Michelinia*, *Multithecopora* and *Syringopora*. Rugosa were more differentiated (Reed 1927; Chu 1928; Chi 1931, 1935; Minato 1955, 1975; Minato and Kato 1965*a*, *b*, 1970, 1975, 1977; Wu 1962;

Yu 1976), but their identifications need revision. The substitute names used herein are tentative.

?Arachnolasma
Axolithophyllum
Bothrophyllum
"Caninia" s.l.
"Dibunophyllum"
Huangia
Ivanovia
Kionophyllum
"Koninckophyllum"
"Lithostrotionella"
?Profischerina
"Siphonodendron"

The small Moscovian coral fauna described recently from southern Jiangsu by Yu (1976) consists of:

"Clisiophyllum"
"Cystolonsdaleia"
Huanglongophyllum
Kionophyllum
Skolekophyllum

Moscovian is the series of the first appearance of the Upper Carboniferous corals in the northern region of China. Wu and Zhao (1979) recorded *Bradyphyllum, Soshkineophyllum* and *"Hapsiphyllum"* and grouped these corals into the *Bradyphyllum obscurum* assemblage. This assemblage is accompanied by *Fusulina* and *Fusulinella* what makes its stratigraphic position well documented.

Wu and Zhao (1979) making a summary of the Chinese Carboniferous coral distribution left the discussed part of the system unclear. Their *Nephelophyllum hexagonum — Pseudotimania delicata* assemblage of the lower Maping Formation is associated by fusulinids of the *Triticites* Zone, i.e. Kasimovian — Gshelian equivalents. Because the *Pseudostaffella — Profusulinella* Zone was established for the preceding assemblage one can presume that either there is a gap in stratigraphy corresponding with the Moscovian or that the existing data are incomplete. None of these suppositions can be worked out herein, thus the Wu and Zhao's (*l.c.*) coral assemblages for southern and north-western China are not adopted in this paper.

Japanese Province. — Most of the genera recorded in the Bashkirian probably continued to exist also in the Moscovian *Fusulina-Fusulinella* Zone. The exact stratigraphic position is not always certain because of the continuation of similar light-coloured calcareous deposits, containing similar coral fauna. In addition to numerous Chaetetida and very limited Tabulata the following Rugosa have been described so far (Ozawa 1925; Minato 1955, 1975; Yokoyama 1957; Igo 1958; Yamagiwa 1961; Yamagiva and Ota 1963; Kato 1967, 1979*a*; Ota 1968; Rowett and Minato 1968, and others):

"Amygdalophyllum"
"Clisaxophyllum"
Carinthiaphyllum
Echigophyllum
?Ivanovia
Koninckocarinia
"Koninckocarinia" (colonial)
"Lophophyllidium"
"Lophophylloides"
Omiphyllum
?Petalaxis
Pseudopavona
Taisyakuphyllum

Uralian-Arctic Province. — Vassiljuk *et al.* (1970) proposed this name for Gshelian and Permian faunas, but in the present author's opinion this province was also present in the Moscovian. It consists of the Moscow basin, the Ural Mts, Novaya Zemlya, Spitsbergen, the Canadian Arctic Archipelago and possibly eastern Alaska as well.

The coral fauna reappeared in the Moscow basin only in the Vereja Stage and was mainly represented by *Bothrophyllum* and *Pseudotimania*. A very rich fauna appeared there in the Mjachkov and Podolsk Stages (Dobroljubova 1935, 1937, 1940, 1948; Kabakovich 1937):

Amandophyllum
Arachnastraea
Axolithophyllum
Bothrophyllum
Cyathaxonia
Fomichevella
Ivanovia
Koninckocarinia
"Meniscophyllum"
Petalaxis
Pseudotimania

The coral faunas of the Ural Mts and Novaya Zemlya were similar (Dobroljubova 1936*a*, *b*; Gorsky 1938, 1951, 1978; Degtjarev 1973*a*, *c*, 1975, 1979):

Rugosa:
?Allotropiophyllum
Amandophyllum
"Amplexus"
?Arctophyllum
Bothrophyllum
Bradyphyllum
"Caninia" s.l.
Cyathaxonia
"Campophyllum" (solitary)
Fomichevella
"Hapsiphyllum"
Lophophyllidium
Lytvophyllum
"Monophyllum"
Neokoninckophyllum
Orygmophyllum
Petalaxis
Profischerina
Pseudotimania
Skolekophyllum
Yakovleviella

Tabulata:
Multithecopora
Syringopora

From the lower Moscovian of north-eastern Pribalkashye Iwanowski (1976) described:

Amandophyllum
Lophophyllidium
"Neokoninckophyllum"
Orygmophyllum
Petalaxis
?Ufimia

The coral fauna Spitsbergen is known only in the Upper Moscovian. Most of the listed (Forbes *et al.* 1958) or described (Tidten 1972) genera extended up to Kasimovian:

Rugosa:
"Caninia" s.l.
Cyathaxonia
Bothrophyllum
Fomichevella
Koninckocarinia
Profischerina
Pseudotimania
?Timania

Tabulata:
Cladochonus
Syringopora

In the Canadian Arctic Archipelago the following genera have been

tentatively identified by Bamber (*in litt.*) (collection seen by the present author):

"Caninia" s.l.	*Petalaxis*
Bothrophyllum	*?Profischerina*
Fomichevella	*Pseudotimania*
?Hornsundia	

No cerioid, aphroid or plocoid colonial rugose corals have been found in the northern Ural Mts, Spitsbergen or in the Canadian Arctic Archipelago.

North American Province. — The Desmoinesian coral fauna described so far did not differ greatly from that of the Atokan and has been very incompletely studied. *Lophophyllidium* was again the most common genus and *"Lophamplexus"*, *Dibunophyllum* (= *Amandophyllum*) and *"Neokoninckophyllum"* are known to occur (Moore and Jeffords 1945; Jeffords 1947; Ross and Ross 1962, 1963). *Dibunophyllum* sp. Ross and Ross (1963) may be the oldest American *Sestrophyllum.* Among the Tabulata *Multithecopora*, *Syringopora* and *Palaeacis* were probably most common.

Conclusions

1. The Mediterranean and adjacent regions were most probably the main creative regions of coral faunas. The taxonomic differentiation, abundance of genera and comparatively large percentage of colonial forms indicate favourable living conditions.
2. Moscovian was the time during which northwest seaway was opened for corals from the Mediterranean through the Ural Mts and Arctic into North America.
3. The absence of the most commonly recorded American genera, especially *Lophophyllidium* in the Chinese and Japan regions indicates that there was no direct connection between the far eastern part of Asia and North America.

KASIMOVIAN AND GSHELIAN SERIES

The current knowledge of the coral fauna does not permit these two series to be clearly distinguished. Even the appearance of *Durhamina* and *Yabeiphyllum* noted on the Table 1 as Virgilian (Gshelian) may in fact be earlier. Most of the provinces previously discussed are still recognizable, although in some areas the coral fauna withdrew due to orogenic movements of the Leonian phase.

The Mediterranean Province. Southern subprovince. — Yugoslavia and the Carnic Alps may be treated as a single part of this province. A careful re-study of the taxa introduced so far (Heritsch 1936, 1941b; Felser 1937; Kostić-Podgorska 1955, 1964) is needed prior to any more precise relation of the fauna listed below is established:

?Allotropiophyllum
Amandophyllum
Amplexocarinia
"Bradyphyllum"
"Caninia" s.l.
Carinthiaphyllum
?Carniaphyllum
Kionophyllum
"Lopholasma"
Lophophyllidium
"Lophophyllidium"
"Lophophylloides"
"Palaeosmilia"
"Thysanophyllum"

An impoverished fauna: *"Caninia" s.l.*, *"Zaphrentis"* and *Cladochonus* has been described from Hungary (Rakusz 1932).

The Donets basin remains one of the main faunal centres although Rugosa became much less abundant and differentiated than in the Moscovian (Fomichev 1953; Vassiljuk 1975; Vassiljuk *et al.* 1970). The uppermost beds of Gshelian do not contain corals.

Rugosa:
"Actinophrentis"
"Amplexus"
Axolithophyllum
Bothrophyllum
"Caninia" s.l.
Cyathaxonia
Ivanovia
Lophophyllidium
Neokoninckophyllum
Orygmophyllum
Sestrophyllum
Tachylasma

Tabulata:
Aulopora
Michelinia
Sinopora

Chaetetida:
Chaetetes
Chaetetiporella

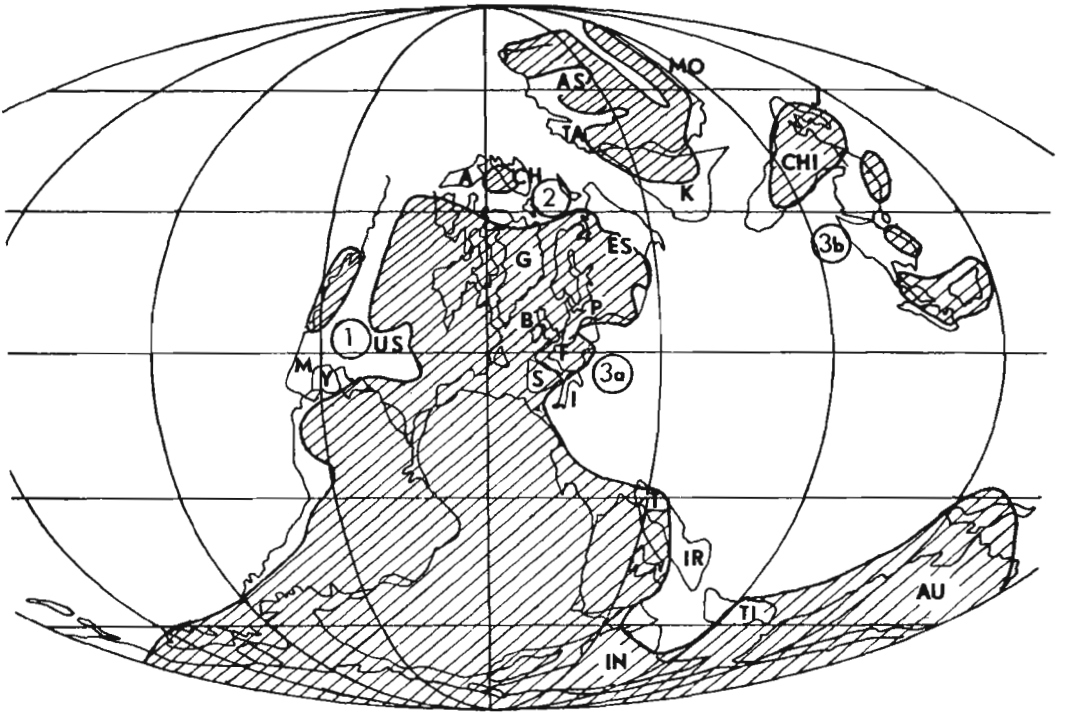

Fig. 5. Kasimovian-Gshelian palaeogeography and coral distribution. Regions and provinces as in figs 1 and 2 except for the Japanese Province that disappeared.

North-eastern subprovince. — The coral fauna of Pamir resembled that of the Donets basin but is far less rich. Quite a few large *"Caninia" s.l., Bothrophyllum, Gshelia* and *Orygmophyllum* have been listed (Pyzhjanov 1965). No colonial rugosans are known. An absence of illustrated description of these genera restricted greatly the usefulness of the existing data.

No corals of this unit have been described from Japan.

The uncertain stratigraphic position of the Maping Formation and its equivalents in southern China has been discussed in the preceding chapter. The *Lophocarinophyllum scanthiseptum* assemblage distinguished by Wu and Zhao (1979) in the northern region of China may in part be of the Upper Carboniferous and in part of Sakmarian age.

Yu (1977) distinguished two zones in the Upper Carboniferous Chungshan Formation. From the lower Zone he listed:

Amandophyllum
Amplexocarinia
"Bothroclisia"
Bothrophyllum
"Caninophyllum"
"Caninia" s.l.
Chuangshanophyllum
"Cystolonsdaleia"
Gshelia
Ivanovia
Jingtingophyllum
Kionophyllum
Koninckocarinia
"Koninckophyllum"
Lytvophyllum
"Melanophyllum"
Neokoninckophyllum
?Paralithostrotion
Protoivanovia
"Pseudocarniaphyllum"
Pseudotimania
"Pseudozaphrentoides"
Sestrophyllum
?Tschussovskenia

To the upper Zone the following genera belong:

Akagophyllum
"Bothroclisia"
Ivanovia
Kepingophyllum
Koninckocarinia
Neokoninckophyllum
Parawentzellophyllum
Protoivanovia
"Pseudozaphrentoides"

Brief descriptions (in Chinese) and illustrations restricted to the newly introduced taxa makes any discussion upon this fauna impossible. Several of the names used are commonly considered as synonyms. It also seems probable that *Jingtingophyllum* is a junior synonym of *Lonsdaleoides* while *Chuangshanophyllum* can be a synonym of *Carniaphyllum.*

The Uralian-Arctic Province. — In the Moscow basin Dobroljubova (1940, 1948) described:

Arctophyllum
Cyathaxonia
Fomichevella
Gshelia
Koninckocarinia
Paracaninia
Pseudotimania

No massive colonial rugosans are known to occur in the Moscow basin, in the Ural Mts or in Novaya Zemlya (Dr. M. A. Simakova, personal communication). In the last two regions the genera listed above, as well as true Timania and *Neosyringopora, Multithecopora, Sinopora* and some

other tabulata corals have been described (Dobroljubova 1936*a*, *b*; Gorsky 1938, 1951; Degtjarev 1973*a*, *c*).

The Kasimovian and Gshelian coral fauna of Vestspitsbergen is very similar to that of the Upper Moscovian. It has been enriched by (Heritsch 1939; Forbes, Harland and Hughes 1958; Tidten 1972):

Rugosa:
Amplexocarinia
Gshelia
Arctophyllum
Siedleckia

Tabulata:
Roemeripora

From the "Ambigua Limestone" of Bear Island, Fedorowski (1975*a*) described:

Rugosa:
Arctophyllum
Bothrophyllum
"Caninia" s.l.
Fomichevella
Kionophyllum
Orygmophyllum
Pseudotimania
Siedleckia

Tabulata:
Kueichowpora

Chaetetida:
Boswellia

Corals are almost unknown in post-Moscovian rocks of the Canadian Arctic Archipelago, but those found are similar to the corals occurring in the Moscovian (Bamber *in litt.*). This fauna is currently being studied.

North American Province. — The Missourian and Virgilian coral fauna is much richer than actually reported (Jeffords 1942, 1947; Ross and Ross 1962, 1963; Cocke 1969, 1970; Cocke and Cocke 1968, 1969; Cocke and Haynes 1973; Cocke and Molinary 1973). From the so far recorded genera the first appearance of *Durhamina* and *Yabeiphyllina* in the Virgilian and the presence of the following genera during the whole period discussed is worth to be noted:

Rugosa:
Axolithophyllum
Amandophyllum
"Amplexizaphrentis"
Bradyphyllum
"Dibunophyllum"
Lophophyllidium
Kionophyllum
"Neokoninckophyllum"
Sestrophyllum

Tabulata:
Aulopora
Michelinia
Multithecopora
Stratiopora
Syringopora

Conclusions

1. The Kasimovian and Gshelian Series cannot be subdivided on the basis of the coral fauna described so far.

2. The coral fauna of this age may be treated as an impoverished Moscovian coral fauna and at the presents level of knowledge it is of a little value for detailed stratigraphic studies. The lack of massive colonial corals in the middle and upper part of this period of time distinguish it from the Lower Permian coral fauna. The lower boundary of Kasimovian may be in places distinguished by the first appearance of

Gshelia and *Timania*. Neither the lower nor the upper boundary of these two series is sharp and no faunal break is indicated by the corals.

3. Large "*Caninia*" *s.l.* seems to be the most characteristic group of corals in the Mediterranean and Uralian-Arctic Provinces and after careful revision it may provide the basis for biostratigraphic subdivision. The revised Geyerophyllidae and *Amandophyllum*-like corals may play the same role in the Mediterranean Province and North American Province.

4. Both the richness of the Arctic coral fauna, as well as the early appearance of many species suggest that the Arctic was the main creative region for coral faunas of the Uralian-Arctic Province.

5. The reconstructed tendency of south and north American continents to unite (Scotese *et al.* 1979: Carboniferous and Permian maps) and absence of marine deposits in their contacting parts let the author to revise his earlier concept as to the direct communication between North America and Mediterranean provinces (Fedorowski 1977). For the total separation of these two provinces during the Kasimovian-Gshelian and possibly Upper Moscovian advocates an appearance of new and endemic (?) genera in North America (Fedorowski, in preparation). Against it advocate abundance of geyerophyllids and presence of sestrophyllids. It seems possible to hypothesize, however, that these two and some other common families had developed from the common ancestors during the Bashkirian time, when the communication must have been open. Further study is needed to confirm or cease this hypothesis.

GENERAL CONCLUSIONS

A. The development of the Permo-Carboniferous coral fauna is covered by a single cycle of evolution, but may be divided into three phases:

1. The first phase ranged from the Strunian until the Arnsbergian inclusively. This phase may be subdivided into three subphases: Strunian, Tournaisian and Viséan (including Pendleian and Arnsbergian stages). The boundaries between subphases are not sharp (possibly except for the Strunian). The Strunian introductory subphase is characterized by the appearance of a new type of the fauna mixed with the persisting Devonian one and by very short-ranging genera possessing morphology similar to that of some representatives of the Viséan subphase. It seems possible that some groups of genera in the Tournaisian and Viséan subphases died out or appeared slightly earlier or later in different areas. Such an appearance and exchange of the faunas made the boundary between these subphases variable a little. There is no evidence to support the separation of Namurian Series or Serpukhovian Series as an independent subphase in coral evolution.

2. The second phase. In the Chokierian as well as in the Krasnopoljan to Prikamsk (= Kinderscoutian to Yeadonian) Stages several new genera and new morphological structures appeared. Some of these new genera

were probably short-ranging and characteristic only for this intermediate step of evolution, whereas the others began the Upper Carboniferous and Permian phylogenetic lines. Bashkirian was the Series when almost all the characteristic structures of the Upper Carboniferous and Permian rugosans appeared.

3. The boundary between the third, Permian phase of Rugosa evolution and the preceding one is not very sharp and the existence of this phase has been questioned (Fedorowski 1977). The new, mostly unpublished data of North American, Arctic and the USSR Permian made possible to revise that opinion. Similarly, like in the Lower Carboniferous phase, the roots of the Permian phase are to be found in the preceding unit. The uppermost part of Gshelian (Orenburgian) can be treated as an introductory subphase (?) of the Permian. The Permian phase can be hardly divided into the Lower Permian subphase (Sakmarian and Artinskian equivalents) characterized by the abundance of the coral fauna with comparatively numerous new genera and the Upper Permian subphase characterized by impoverished and endemic faunas.

As far as the phases and subphases of evolution of the coral fauna are concerned, the Permo-Carboniferous can be divided into three periods: 1. Lower Carboniferous (including Strunian at the bottom and Arnsbergian at the top), 2. Upper Carboniferous (starting from the Chokierian and ending at the bottom of Orenburgian), 3. Permian (starting from the Orenburgian). The Lower Carboniferous can be readily subdivided into Strunian, Tournaisian and Viséan (including indistinguishable Pendleian-Arnsbergian faunas). Upper Carboniferous can hardly be subdivided into Bashkirian, Moscovian and Kasimovian-Gshelian. This may change when the fauna and especially the very abundant large "*Caninia*" *s.l.* are better known. Smaller subdivisions of Permian are not yet fully documented by coral studies, but at least lower and upper faunas can be distinguished.

B. Abundance of the coral fauna is not connected with environmental conditions in a simple way. At the beginning of a phase or subphase of evolution the fauna was very sparse, although widespread transgressions and conditions profitable for corals were recorded. This suggests a periodicity of coral evolution during the Carboniferous. It may also mean, however, that only a fully developed fauna, like that of Pendleian was able to migrate by means of the pulsations of the seas. The new coral faunas needed some period of time to develop and spread into a new area.

C. The reconstructed positions of continents, the land-sea relations and the established appearances of the coral genera in individual regions may indicate some main ways of migrations of these coral faunas. The author believes that warm currents were one of the main factors making the migration of the coral faunas possible, whereas the absence of such currents or the presence of cool currents effectively isolated particular faunas or regions. The larval stage was the only period of life when any

tabulate or rugose coral genus was able to migrate, but the larva was not a very active swimmer and must has been carried by the current. Other reasons of isolation of the coral faunas are obvious and as such need not be discussed here.

In the Lower Carboniferous the following main directions of migration of the coral faunas may have existed:

a) The circum-mediterranean, directed eastward in southern part of the pre-Tethys and westward in its northern part. It may or may not have passed through the straits between North and South America.

b) Along the Ural geosyncline. There were most probably a few directions and branches during particular periods and even the simultaneous opposite directions in individual parts of the area were possible.

c) Along the Cordilleras, most probably in a southward direction. This supposition is supported by earlier appearance of some coral genera in the Western Interior Province. Local migration in the opposite direction should not be excluded.

There must also have been many local directions of migration of coral faunas such as around the American midcontinent gulf, along the land of eastern Asia, in Europe, etc.

In the Upper Carboniferous there were three main faunistic regions: Mediterranean, American and Uralian-Arctic regions. The relationships between these regions changed because of the gradual isolation of the Uralian-Arctic region and separation of the North American and Mediterranean provinces. This isolation was most obvious in the Kasimovian and Gshelian. The main directions of the migrations of coral faunas changed a little in individual periods. Generally, they probably were as follows:

a) Northward along the Ural geosyncline and then westward along the shore of the North Atlantic Land mass.

b) Southward along the Cordilleras.

c) Communication between North American and Mediterranean provinces through the straits between North and South America must have been open at least during the Bashkirian time. The direction of migration of the fauna is uncertain, however. It might have taken place both ways in different time.

d) Eastward along the norther shore of the Gondwana Land.

As in the Lower Carboniferous, there existed many local directions of migration of coral faunas. Some of them may even have been opposite to the main directions.

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Д. Е., БРАЖНИКОВА, Н. Е., ВАСИЛЮК, Н. П., ВДОВЕНКО, М. В., ГОРАК, С. В., ДУНАЕВА, Н. Н., ЗЕРНЕТСКАЯ, Н. В., ПОЛЕТАЕВ, В. Я., ПОТЕВСКАЯ, П. Д., РОТАЙ, А. П. СЕРГЕЕВА, М. Т. 1978. Разрез карбона Донбасса как эталонный разрез каменноугольной системы. — (Carboniferous sequence of the Donets basin as the standard section of the Carboniferous). — *Huitième Congr. Inter. Strat. Geol. Carbon., Compte Rendu* **3**, 158—169, Moscov.

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ROZWÓJ I ROZPRZESTRZENIENIE GEOGRAFICZNE KORALOWCÓW W KARBONIE

Streszczenie

Współczesny stan badań koralowców karbońskich umożliwia dokonanie wstępnej rekonstrukcji rozwoju i rozprzestrzenienia geograficznego na szczeblu rodzaju. Bardziej szczegółowa analiza korelacji stratygraficznych na poziomie gatunkowym jest możliwa tylko w niektórych regionach świata i w stosunkowo niewielkich przedziałach stratygraficznych, np. w dolnym karbonie Europy Zachodniej.

Badania tektoniki kier kontynentalnych oraz rekonstrukcje konfiguracji tych kier w poszczególnych okresach geologicznych pozwoliły na wyjaśnienie zagadkowych dotychczas podobieństw faun obecnie odległych od siebie, lub odwrotnie — dużych różnic dzielących fauny obecnie terytorialnie bliskie, np. wschodniego i zachodniego Uralu. W niektórych przypadkach bliskie pokrewieństwo faun koralowych, rzekomo oddzielonych od siebie wielkimi obszarami kontynentalnymi, umożliwia poddanie w wątpliwość proponowanych aktualnie rekonstrukcji położenia kier kontynentalnych, opartego na badaniach paleomagnetycznych i paleoklimatycznych (np. obszar śródziemnomorski i północno-amerykański w piętrze baszkirskim).

Kompleksowa analiza fauny pozwoliła stwierdzić, że rozwinęła się ona w wyniku jednego cyklu ewolucyjnego, obejmującego okres od strunu do najwyższego permu włącznie. Cykl ten można podzielić na trzy fazy ewolucyjne: 1. Faza dolno-karbońska, obejmująca okres od strunu do arnsbergu (zony amonitowe od *Wocklumeria* do *Eumorphoceras*) włącznie; 2. Faza górno-karbońska, od czokeru (chokerian) (zona amonitowa *Homoceras*) do piętra gżelskiego włącznie; 3. Faza permska, od orenburgu (najwyższy karbon) do końca permu.

Każda z faz ewolucji korali karbońskich charakteryzuje się dominującym typem struktur morfologicznych oraz może być określona krzywą liczebności światowego rozprzestrzenienia rodzajów. Każdą z tych faz można z kolei podzielić na podfazy lub okresy, określone własnymi krzywymi liczebności i rozprzestrzenienia geograficznego rodzajów. Niejasne granice okresów w górnym karbonie i w permie wynikają zapewne z braku dostatecznej ilości danych. Należy jednak podkreślić, że granice okresów nie są ostre, co może wynikać z nierównoczesnego pojawiania się rodzajów przewodnich w poszczególnych regionach w początkowych stadiach okresu.

Obserwuje się ubóstwo taksonomiczne i ilościowe oraz separację geograficzną faun inicjujących poszczególne fazy, a niekiedy również okresy rozwoju ewolucyjnego koralowców. Dzieje się tak pomimo szerokiego zasięgu i łatwej dostępności siedlisk ekologicznie odpowiednich, dokumentowanych osadami bez fauny lub z bardzo ubogą fauną koralowców (np. dolny turnej i dolny baszkir). Odwrotne zjawisko obserwuje się w końcowych etapach fazy, a niekiedy również okresu. Bogate fauny koralowe migrowały wówczas wraz z bardzo krótkimi pulsacjami morza, tworząc zespoły bogate

ilościowo, chociaż monotonne taksonomicznie. Pierwsze z wymienionych zjawisk wynika z niewielkiej liczebności, słabego zróżnicowania i przystosowania faun stojących u progu swojego rozwoju, wymagających czasu, nawet w skali geologicznej, dla pełnej adaptacji i migracji. W drugim przypadku fauna doskonale zespolona ze środowiskiem wędruje wraz z ingresjami morskimi, nie zmieniając w istocie tego środowiska (np. fauny wkładek morskich dolnego namuru Europy Zachodniej i Środkowej).

W skali globu można wydzielić następujące fazy i okresy ewolucyjnego rozwoju koralowców w karbonie i permie:

Fazy	Podfazy (okresy)
Permska	b. górno-permska a. orenbursko-dolnopermska
Górno-karbońska	c. kazimowsko-gżelska b. moskiewska a. baszkirska
Dolno-karbońska	c. wizeńska (do arnsbergu włącznie) b. turnejska a. struńska

Bardziej szczegółowy podział nie jest przy dzisiejszym stanie zaawansowania badań możliwy.

Każdy okres inicjujący daną fazę rozwoju cechuje się przemieszaniem form archaicznych, dożywających, form progresywnych, wyjściowych dla najszerzej rozprzestrzenionych i najważniejszych rodzajów danej fazy oraz rodzajów krótkotrwałych, typowych tylko dla danej podfazy (okresu), często endemicznych. Szczególnie dobrym przykładem tego typu okresu jest strun, zaliczany według innych kryteriów do dewonu, należący jednak niewątpliwie do permo-karbońskiego cyklu rozwoju koralowców. Okres inicjujący fazę górno-karbońską cechuje się podobnymi właściwościami, pogłębionymi jeszcze przez niezwykłe ubóstwo fauny, znanej z niewielkich, izolowanych regionów świata i w niezwykle ograniczonej liczbie egzemplarzy.

Okres rozpoczynający permską fazę rozwojową jest mniej wyraźnie scharakteryzowany; faza ta nie była wydzielana przez autora we wstępnej, skróconej wersji pracy (Fedorowski 1977). Nowe dane uzyskane z prowadzonych obecnie, nieopublikowanych badań permo-karbońskich faun Teksasu, ZSRR i Arktyki pozwalają na wydzielenie tej fazy. Przejście z fazy górno-karbońskiej do permskiej jest również bardzo słabo poznane i niedokładnie udokumentowane.

Różnego rodzaju czynniki izolujące poszczególne obszary mórz doprowadziły do powstania pewnej liczby prowincji zoogeograficznych, różnie kształtujących się w różnych piętrach permokarbonu (fig. 1—5). Oprócz bardzo rozległych barier lądowych zimne prądy morskie były czynnikiem w decydujący sposób kształtującym układ i powstanie tych prowincji. Koralowce, jako organizmy rozprzestrzeniające się tylko w stadium słabo pływającej larwy, mogły być izolowane takimi prądami równie

skutecznie jak lądem. Przykładem tego typu izolacji dwu blisko sąsiadujących, połączonych morzem prowincji był obszar Japonii w piętrze baszkirskim i moskiewskim. Bliskie pokrewieństwo faun tego samego okresu w prowincji północno-amerykańskiej i śródziemnomorskiej wskazuje na konieczność istnienia w tym okresie przynajmniej wąskich przesmyków pomiędzy Gondwaną a Lądem Północno-Atlantyckim (fig. 3). Poszczególne prowincje, a w prowincjach pewne regiony, odgrywały wyraźną rolę w procesie powstawania faun. Takimi centrami ewolucji były np. Zachodnia Europa i Nowa Ziemia w strunie, Czukotka i Ural w turneju, obszar śródziemnomorski i środkowo-zachodnie stany USA w piętrach baszkirskim i moskiewskim, prowincja arktyczna w piętrze kazimowskim i w dolnym permie. Drugim takim obszarem były w tym czasie południowo-zachodnie stany USA. Centrum ewolucji w górnym permie były południowo-zachodnie stany USA i pra-Tetyda.

Bezpośrednia komunikacja pomiędzy większością prowincji była otwarta bezpośrednio lub poprzez przyległe obszary, wskutek czego liczne grupy fauny, rodziny, a często i rodzaje miały zasięg światowy (Tabela 1). W ciągu całego permo-karbonu można w zasadzie wyróżnić zaledwie dwie niemal zupełnie izolowane prowincje: australijską w dolnym karbonie i japońską w piętrach baszkirskim i moskiewskim. Najswobodniejsza komunikacja istniała w górnym wizenie, gdy, z wyjątkiem prowincji australijskiej, obserwuje się ogólnoświatową wymianę faun koralowych. Piętro to jest również okresem, w którym koralowce są najbardziej zróżnicowane taksonomicznie i najliczniejsze. Słusznym wydaje się zatem uznanie wizenu za kulminacyjny okres całego permo-karbońskiego cyklu ewolucyjnego koralowców.