

FIG. 19. Small calcareous problematica considered by VOLOGDIN (1931, 1932) to be larval and young stages of Archaeocyatha; A, "sphaerion"; B, "fistula"; C-G, "dolium"; all  $\times 13$ .

The few studies of ontogeny based on longitudinal or serial transverse sections of individual archaeocyathan cups suggest that postlarval development began with the formation of an aporose curved sheet that became the tip of the cup as the archaeocyathan grew. The edge of this calcareous sheet grew upward and outward to form the outer wall of the conical cup (Fig. 20).

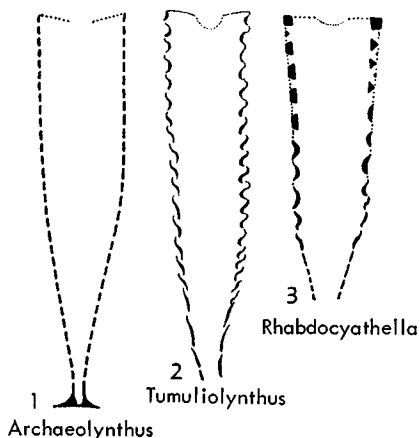


FIG. 20. Ontogenetic stages of development in one-walled cups (Zhuravleva, 1963b).—1. *Archaeolyntus*, showing wall with simple pores throughout.—2. *Tumuliolyntus*, showing adult wall with tumuli.—3. "*Rhabdocyathella*," showing adult wall thick with external microporous sheath.

### EVOLUTION

#### ONTOPHYLETIC SPECULATION

It has been suggested that current classifi-

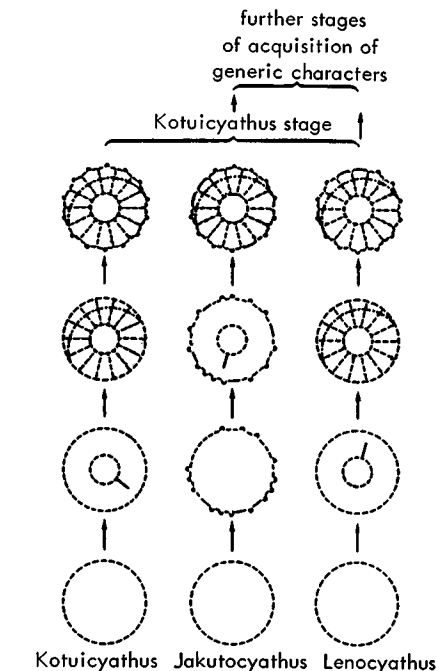


FIG. 21. Ontogenetic stages of development in genera of the family Lenocyathidae. Outer wall tumuli appear before inner wall, septa, and tabulae, in *Jakutyocyathus* (*Jakutyocyathus*) and after them in *Kotuicyathus* and *Lenocyathus*, demonstrating heterochronous parallelism (after Rozanov, 1963).

At a cup diameter of 0.15 to 0.2 mm., simple pores appear. In Irregulares, dissepiments next appear, followed in two-walled forms by disoriented rods, and then by the inner wall, simply porous at least at first, and by some tabulae; in later stages the disoriented rods may be replaced by septa, or, in the *Syringocnemididae*, by hexagonal tubuli, and either or both walls may become complex. In two-walled Regulares a simply porous inner wall appears with or slightly earlier than the first intervallar structures, which in some are rods, in others are septa; tabulae may then appear, and both walls may become complex, and the complexity may increase; in some, complication of the outer wall may begin before the appearance of the inner wall and septa (Fig. 21).

cation of the Archaeocyatha is a phyletic one, and that ontogenetic studies support this view. Thus, ZHURAVLEVA (1960b) con-

Cup Diam. mm.	Class Irregulares Long. Sec.	Class Regulares Long. Sec.
>1.8	G1	G2
1.7 to 1.1	F1	F2
1.0 to 0.8	E1	E2
0.7 to 0.5	D1	D2
0.45 to 0.22	C1	C2
0.20 to 0.13	B1	B2
0.12 to 0.05	A Metacyathus type	U Ajacicyathus type

FIG. 22. Ontogenetic stages in Archacocyatha. The cup diameters at which the different stages appear are shown in the left-hand column; in the middle column are representatives of the Irregulares. *A*, the embryonic, aperforate tip, is common to both classes; *B1-G1* are stages of development in representative Irregulares [*x*, form with tabulae; *y*, form with septa and tabulae; *z*, form with radial tubuli (Syringocnemidida)]; *B2-G2* are stages of development in representative Regulares [*a*, form with pectinate tabulae (Nochorocyathina); *β*, atabulate form (Ajacicyathina); *γ*, form with porous tabulae (Coscincyathina)] (after Zhuravleva, 1960b). [Explanation: *a*, outer wall; *b*, inner wall; *c*, radial rods in intervallum; *d*, septa; *e*, pectinate tabula; *f*, porous tabula; *g*, pore-canal of outer wall; *h*, composite tumulus of outer wall; *i*, rudimentary pore-tube of inner wall; *j*, pore-tube of inner wall; *k*, "hairs" at end of pore-tube of inner wall; *l*, rod in intervallum; *m*, dissepiments; *n*, taenia; *o*, taenial spines; *p*, convex tabula; *q*, hexagonal radial tubulus.]

sidered that the class characters (presence or absence of dissepiments before the inner wall appears) are established at a cup diameter of 0.13 to 0.2 mm.; that the inner wall appears between 0.5 and 0.7 mm. in two-walled Irregulares, and between 0.13 and 0.2 mm. in Regulares. She regards the regularian subordinal characters, mainly

type of tabulae, as established between 0.22 and 0.45 mm., whereas the subordinal characters of Irregulares do not appear until 0.5 to 0.7 mm. The family (outer wall) characters of Regulares develop between 0.5 and 0.7 mm., but in Irregulares not until 0.8 to 1.0 mm., at which diameters subfamily characters develop in Regulares. Generic

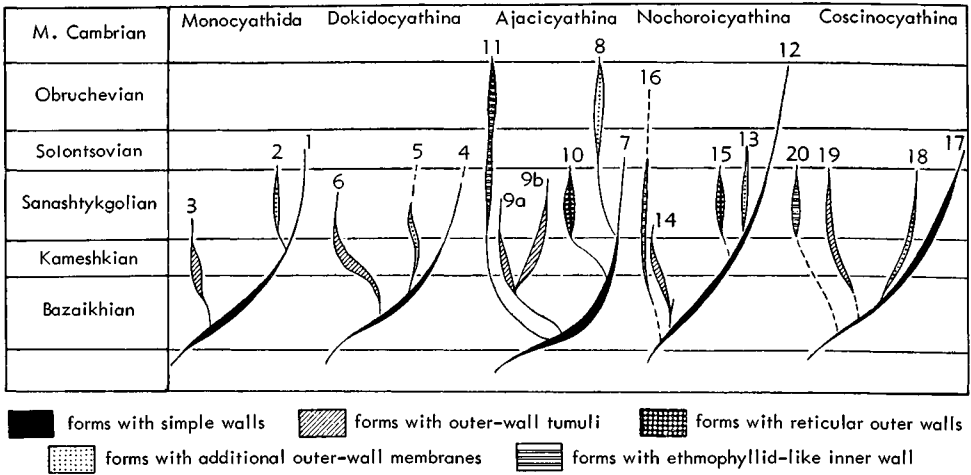


FIG. 23. Assumed phylogenetic relationships within the suborders of Regulares, according to ROZANOV (1963).—1. *Archaeolynthus*.—2. “*Rhabdocyathella*.”—3. *Tumuliolynthus*.—4. *Dokidocyathus* and *Vacuocyathus*.—5. *Kidryasocyathus* and *Uralocyathella*.—6. *Fransuasocyathus*.—7. Ajacicyathidae.—8. Erboicyathidae.—9. Tumulocyathidae (9a) and Annulocyathidae (9b).—10. Tercyathidae.—11. Ethmophyllidae.—12. Nochoroicyathidae.—13. Kordecyathidae.—14. Lenocyathidae.—15. Pamaacyathidae.—16. Formosocyathidae.—17. Coscinocyathidae.—18. Kasryicyathidae.—19. Alatacyathidae.—20. *Coscinocyathellus*.

characters appear in both classes between 1.1 and 1.7 mm. cup diameter and specific characters enter thereafter. Figure 22 shows ZHURAVLEVA’s hypothesis diagrammatically.

This generalization is very useful, though certainly oversimplified, as shown for instance by Figure 21. Figure 23 shows ROZANOV’s views of how the main families in suborders of the Regulares may have developed from an early and primitive stock for each suborder, by trends of development in complication of the outer walls.

**PARALLEL EVOLUTION**

Numerous trends in archaeocyathan development resulting in parallel, heterochronous, or convergent evolution, have been suggested. Most have been based in part on morphological comparison of bioseries in successive strata and in part on ontogenetic observation. The majority relate to complications in the wall structure (Fig. 21). The end result seems to be greater efficiency in straining currents of water through the wall pores; thus, the outer part of the outer wall is frequently more finely porous than the inner part of this wall, and wide variety in the construction of such double walls is

observed; pore-canals, pore-tubes, and tumuli of varied colony construction develop. Trends towards colony formation occur.

In addition there are trends in reduction, such as reduction in the number of longitudinal pore-rows to an intersept, reduction in the porosity of septa, and reduction in the number of pectinate tabulae (Fig. 24).

**INTRASPECIFIC VARIABILITY**

Dimensional differences noted between individuals of the same species have been correlated by ZHURAVLEVA (1960b) with differences in depth of floor, in character of bottom, and possibly in rate of flow of currents, in temperature, gas regime, and faunistic composition. Thus, outer wall tumuli may be larger in individuals from deeper seas.

Geographical variation has also been demonstrated by ZHURAVLEVA (1960b). Thus individuals of a species show in space as well as in time, variation in size of cup, range of numbers and size of wall pores and septal pores, frequency of septa, number of spines in the inner wall, and tendency to form colonies.

Growth form of a species may differ in

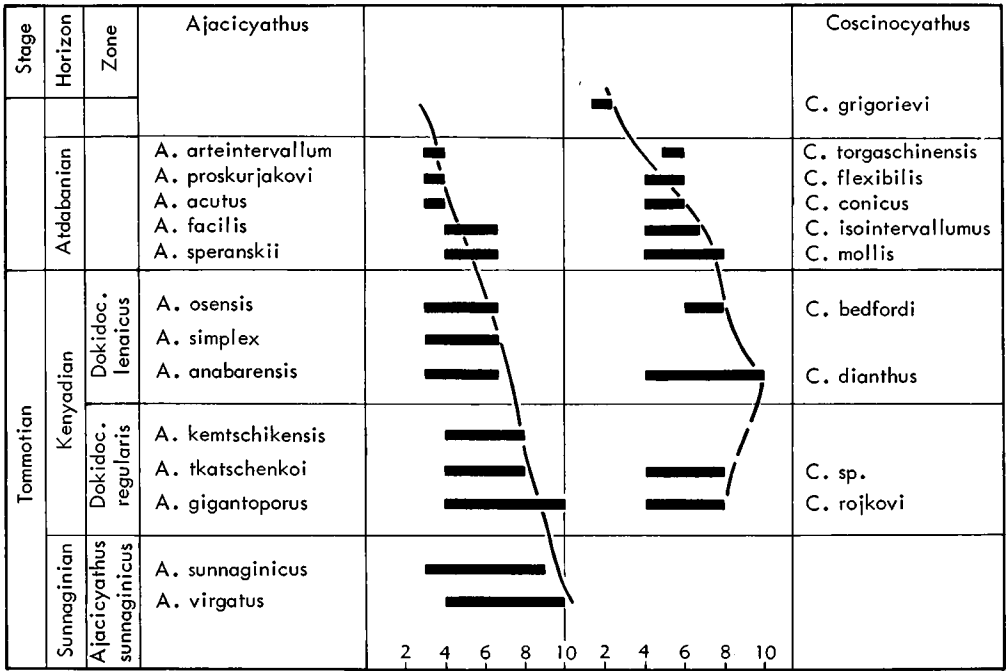


FIG. 24. Trend in reduction in number of longitudinal rows of pores to each intersept of outer wall in *Ajacicyathus* and in *Coscinocyathus* (Roazanov & Missarzhevskiy, 1966).

biohermal and interbiohermal facies (ZHURAVLEVA, 1960b). Thus, *Okulitchicyathus discoformis* (ZHURAVLEVA) may be discoid in the interbiohermal facies, presumably because it was there subject to frequent overturning, but is often of irregular conical form in the bioherms. Biohermal individuals of most species commonly have external adherent processes, interbiohermal individuals usually lack

them. Many species have smaller individuals in the bioherms. ROZANOV (1963) noted that latticed walls occur in representatives of two suborders in volcano-terrigenous facies, and considered that such a wall is an adaptive character.

Pectinate tabulae are so rare as to be hard to find in some individuals of one species but are very common in others (R. BEDFORD & J. BEDFORD, 1936, p. 25, 1939, p. 75).

### PALEOECOLOGY

The Archaeocyatha are marine, benthic, shallow-water organisms, mainly sessile with adherent outgrowths, but some were probably passively shifting in the bottom layers of the water, especially discoid forms whose shape is thought to be due to repeating overturning. All colonies are basally adherent, and solitary forms may adhere by various types of tubular processes or wide expansions from the base of the cup.

The predilection of the Archaeocyatha for the carbonate sedimentary facies has long been known. They have been con-

sidered the reef-builders of the Lower Cambrian, but it would seem that they were less important in this respect than algae. Algal-archaeocyathan bioherms and biostromes were constructed (Fig. 25) but archaeocyathans are also common in the interreef facies and in nonbiohermal limestones. Associated with them in interbiohermal strata are algae and the benthic gastropods, brachiopods, and trilobites, but hyolithids and coniconchs are also found. Where sponges are common, archaeocyathans tend to be rare.

## DEPTH

The most favorable depth, as indicated by the studies of ZHURAVLEVA and ZELENOV (1955), ZELENOV (1957), and ZHURAVLEVA (1960b) was from 20 to 30 m. and down to

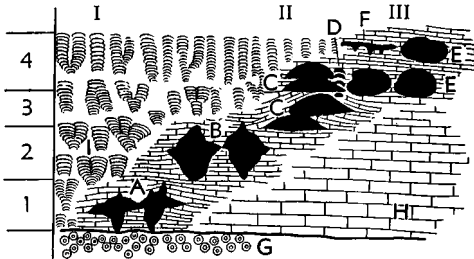


FIG. 25. Migration of archaeocyathan and algal-archaeocyathan bioherms in time and space in the Aldanian of the Siberian Platform, Rivers Lena and Aldan (Zhuravleva, 1966). [Explanation: *A*, littoral archaeocyathan dilophoid; *B*, fringing archaeocyathan dilophoid; *C*, archaeocyathan monolophoid; *D*, pseudostromatolitic algal-archaeocyathan biostrome; *E*, algal-archaeocyathan onkoidal dilophoid; *F*, bedded algal-archaeocyathan biostrome; *G*, onkolites; *H*, limestone without bioherms; *I*, stromatolites; *I*, shallow, littoral zone; *II*, depth over 10 meters; *III*, depth some tens of meters.]

50 m. (Fig. 26). The evidence on which this is based is the association with the blue-green alga *Renalcis*, the fragmentation of many skeletons, and the dimensions of the bioherms which, with the algae, they were able to construct. Above and below these optimum depths they were smaller and did not construct bioherms. From 50 to 100 m. they are commonly associated with the red alga *Epiphyton*, thin-walled with a narrow intervallum and not fragmented by wave action. They are not known in sediments presumed to have been deposited below 100 m.

## TEMPERATURE

VOLOGDIN (1932) and ZHURAVLEVA (1960b) assumed that the Archaeocyatha were organisms of the warm seas, on the grounds (not always reliable?) that bioherms are constructed always in warm-tropical or near-tropical seas. On the Siberian Platform they are abundant in the varicolored suite of brick-red to violet argillaceous dolomitic limestones which ZELENOV (1957) and others considered formed off land with a hot damp climate.

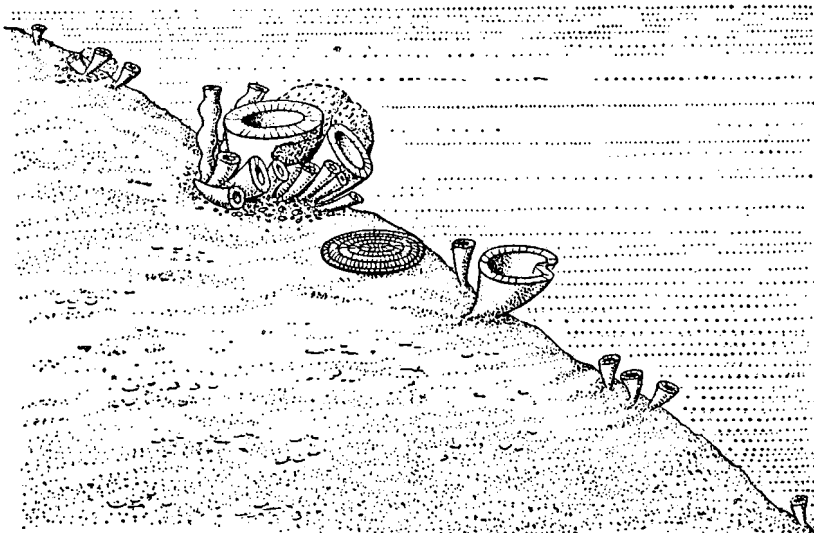


FIG. 26. Archaeocyathan growth-form in relation to depth (Zhuravleva, 1960b). [Explanation: *A*, a few small cups at depths up to 12 m.; *B*, small archaeocyathan bioherm at 20-30 m.; *C*, a few large discoid or conical cups between 30 and 50 m.; *D*, a few small cups between 50 and 60 m.; *E*, occasional cups to a depth of about 100 m.]

## SALINITY

The salinity tolerances of Archaeocyatha are thought to be related to the characters of the sediments in which they occur. ZHURAVLEVA (1960) found that they are commonest, and constructed bioherms, in rocks with 46 to 50 percent CaO (=78-91 percent CaCO<sub>3</sub>), but that they may be quite

rich in rocks with a CaO content of only 7 percent. Percentages of 5 to 8 percent MgO were endured by very few species, and with a still greater concentration of MgO, as in lagoonal deposits, the Archaeocyatha disappeared entirely. They were quite tolerant of terrigenous matter, and actually flourished best in sediments that contained 19 to 34 percent of insoluble residues.

## GEOGRAPHIC AND STRATIGRAPHIC DISTRIBUTION

Archaeocyatha have been described and illustrated from all continents except South America, from which, however, an occurrence has been reported recently by DEBRENNE (1964). They are characteristic of the calcareous facies of the Lower Cambrian (but not the Eocambrian), with a maximum in the Botomian Stage of the south Siberian fold belt. Whether they developed during Precambrian time is problematical. RADUGIN (1966) recently has described as primitive archaeocyathans a number of small calcareous problematica from the Late Proterozoic of Siberia, but these are not appended to this part of the *Treatise*. Only a few genera are known from the early Middle Cambrian *Paradoxides oelandicus* Zone in Australia (ÖPIK, 1956, 1961) and the Altay Mountains of Siberia (KHOMENTOVSKIY *et al.*, 1962), where they include, in the Katun anticline, *Tegerocyathus*, *Ethmophyllum*, and *Nochorocyathus*. However, VOLOGDIN (1957a) considered the Elanska faunal horizon at the top of the Lena Stage on the Siberian Platform to be Middle Cambrian, and ÖPIK (1956, 1961) suggested that the greater, upper, part of the Lena Stage is in the *P. oelandicus* Zone. If either of these contentions is correct, the number of genera ranging into the Middle Cambrian becomes quite large. An Upper Cambrian occurrence in Antarctica has recently been recorded (WEBERS, 1966), but all other occurrences later than early Middle Cambrian have been discounted (HILL, 1965, 1967). See map (Fig. 27) and Table 3.

### SUBDIVISION AND CORRELATION OF THE LOWER CAMBRIAN

Russian work on Cambrian biostratigra-

phy has been exceptionally vigorous over the last decade and some degree of unanimity has been achieved on the correlation of the various stratal sections on the Siberian Platform and in the Altay-Sayan fold belt, as well as between these two groups of sections. Ranges of archaeocyathan genera in the USSR can thus now be expressed in terms of the four stages into which the Russian Lower Cambrian is currently divided: Tommotian, Atdabanian, Botomian, and Lenian (ROZANOV, *et al.*, 1969; ZHURAVLEVA, KORZHUNOV, & ROZANOV, 1969; MESHKOVA, 1969; ZHURAVLEVA, 1970b).

Previously the Lower Cambrian of the Siberian Platform had been divided into two units, the Aldanian and the Lenian stages. These names are now being used as superstage names. The Tommotian and Atdabanian stages replace the earlier upper or Zhurian Substage of the old Aldanian and the lower or Tolbian Substage has been excised from the Lower Cambrian, named Vendian and transferred to the Precambrian. Also, the Tarynian horizon has been subtracted from the top of the old Aldanian and treated as the lower part of the new Botomian. The old Lenian has been divided into the thus augmented Botomian and the new or restricted Lenian Stages. The old Atdabanian Substage has had added to it the *Profallatopsis* Zone and the equivalent zone of *Retecoscinus zegebarti* (including the beds with bioherms of the second type of ZHURAVLEVA, 1960b) from the top of the old Kenyada horizon. The Tommotian therefore includes the Sunnaginian horizon and the thus restricted Kenyadian horizon. No trilobites are found anywhere in strata currently regarded as Tommotian. These nomenclatorial changes are shown in Table 1.

TABLE 1. Schemes of Subdivision of Lower Cambrian in the Stratotype Sections (middle Lena R. on Siberian Platform).

Conference, 1956, Leningrad				Conference, 1962, Yakutsk				Scheme of ZHURAVLEVA, KORSHUNOV & ROZANOV, 1969					
Lower Cambrian		Aldanian		Aldanian		Lentian		Aldanian		Lentian		Upper stage	
Tolbian		Zhurlian		Atdabanian		Lentian		Kenyadian		Ardabanian		Sub-stage	
Sunnaginian		Kenyadian		Atdabanian		Aldanian		Sunnaginian		Ardabanian		Stage	
Archaeocyathus polaris		Archaeocyathus anabarenensis		Judomia-Lenocyathus		Lentian		Kenyadian		Ardabanian		Stage	
Archaeocyathus polaris		Archaeocyathus anabarenensis		Judomia-Lenocyathus		Lentian		Kenyadian		Ardabanian		Stage	
Archaeocyathus polaris		Archaeocyathus anabarenensis		Judomia-Lenocyathus		Lentian		Kenyadian		Ardabanian		Stage	
Archaeocyathus polaris		Archaeocyathus anabarenensis		Judomia-Lenocyathus		Lentian		Kenyadian		Ardabanian		Stage	
Archaeocyathus polaris		Archaeocyathus anabarenensis		Judomia-Lenocyathus		Lentian		Kenyadian		Ardabanian		Stage	
Archaeocyathus polaris		Archaeocyathus anabarenensis		Judomia-Lenocyathus		Lentian		Kenyadian		Ardabanian		Stage	
Archaeocyathus polaris		Archaeocyathus anabarenensis		Judomia-Lenocyathus		Lentian		Kenyadian		Ardabanian		Stage	
<i>Archaeocyathus sunnaginicus</i>		<i>Archaeocyathus regularis</i>		<i>Dokidocyathus lenaicus</i>		<i>Leptosocyathus polyseptus-Reticocinus zegebari</i>		<i>Porocyathus pinus</i>		<i>Beds with Nochoroicyathus kokuimi</i>		Zones and beds with Archaeocyatha	
<i>Beds with Fansycyathus lermontovae</i>		<i>Botomocyathus zelenovi-Porocyathus squamosus</i>											
Upper Precambrian		Yudomian (Vendian) complex		Tommotian		Lower		Upper					
Upper Precambrian		Yudomian (Vendian) complex		Tommotian		Lower		Upper					
Upper Precambrian		Yudomian (Vendian) complex		Tommotian		Lower		Upper					
Upper Precambrian		Yudomian (Vendian) complex		Tommotian		Lower		Upper					

TABLE 2. Timestratigraphic and Biostratigraphic Correlation of Lower Cambrian Sequences of Siberian Platform (Zhuravleva, Korshunov, Rozanov, 1969; see also Meshkova, 1969) and of Altay-Sayan Fold Belt (Repina, Khomentovskiy, Zhuravleva, Rozanov, 1964; see also Zhuravleva and others, 1967; Zhuravleva, 1968a; Zhuravleva, 1970b).

Lower Cambrian		Lower Cambrian			
STAGES	HORIZONS OR SUBSTAGES, SIBERIAN PLATFORM	ZONES OF ARCHAEOCYATHA	HORIZONS, ALTAY-SAYAN REGION	STAGES	
Lenian	Elanskian horizon	<i>Erbocyathus heterovalium</i>	Obruchevian horizon	Lenian	
	Ketemian horizon	<i>Claurucyathus billingsi</i>	Solontsovian horizon		
Botomian	Sinsko-Kutorginian (Olekman) horizon	..... <i>Rozanovicyathus alexi</i>	Sanashtykgolian horizon	Botomian	
	Tarynian horizon	<i>Porocyathus squamosus-Botomocycyathus zelenovi</i>			
Atdabanian	Upper Atdabanian Substage	<i>Lencyathus lenaicus</i> <i>Nochoroicyathus kokoulini</i>	Kameshkiian horizon	Atdabanian	
	Lower Atdabanian Substage		<i>Porocyathus pinus</i>		
			<i>Retesciscinus zegebarti</i>		
Tommotian	Kenyadian horizon	<i>Dokidocyathus lenaicus</i>	Lower Bazaikhian horizon = Kundatian	Tommotian	
	Sunnaginian horizon	<i>Dokidocyathus regularis</i>			
Vendian	Yudomian	<i>Ajaciocyathus sunnaginicus</i>	Archaocyathia absent	Vendian	
		complex			



Whether the base of the Tommotian will prove acceptable internationally as the base of the Cambrian remains to be seen, but a good case has been argued for this by ROZANOV (1967). Whether the division between the Lower and Middle Cambrian should be drawn at the incoming of the *Paradoxides* fauna as advocated by R. RICHTER & E. RICHTER (1948) or at the extinction of the *Olenellus* fauna as advocated by ÖPIK (1967) also remains to be determined internationally. In the USSR the former boundary is generally adopted, and it is taken between the Elanskian faunal horizon at the top of the Lenian Stage and the *Oryctocephalops-Schistocephalus* Zone at the base of the Amgian Stage of the Siberian Platform. This boundary is here accepted. If ÖPIK's criteria were accepted, the division possibly would fall at the base of the Botomian (incoming of the *Protolenus* fauna).

Table 2 shows the current biostratigraphical correlation between the Lower Cambrian of the Siberian Platform and that of the Altay-Sayan Fold Belt, courteously supplied to me by Mme. I. T. ZHURAVLEVA.

Correlation of the North African, western European, Canadian, Australian, and Antarctic strata bearing Archaeocyatha with those of the USSR is still uncertain. It seems that the North African Amouslekiian, Timghitian, and Tasousektian stages range from the Atdabanian into the Botomian (DEBRENNE, 1964; ROZANOV, *et al.*, 1969). In Spain, France, and Sardinia the ranges appear to be within the Atdabanian and Botomian (DEBRENNE, 1964). In western Canada Archaeocyatha range from possibly the Atdabanian Stage into the Botomian; in western U.S.A. (Nevada) the range would seem to be Atdabanian. In South Australia, WALTER (1967) considered the range in the Hawker Group of the Wilkavillina Gorge region to be Kundatian (now upper Tommotian) to Sanashtykgolian (= Botomian). From the Northern Territory of Australia, ÖPIK (1956, p. 41) recorded *Archaeocyathus* from a chert with the trilobites *Xystridura*, *Oryctocephalus*, and *Peronopsis*, north-northeast of Alexandria, and from the Ranken limestone with *Peronopsis* and *Asaphiscus*; he considered these trilobites to be of early Middle Cambrian age. The South Australian fauna

from the Ajax Mine correlates best within the range of upper Atdabanian (Kameshki horizon) to lower Botomian (Taryn horizon). The Antarctic fauna similarly may range from the upper Atdabanian into the Botomian (HILL, 1964a,b; 1965).

## RANGES OF GENERA

The ranges of genera are given in Table 3.

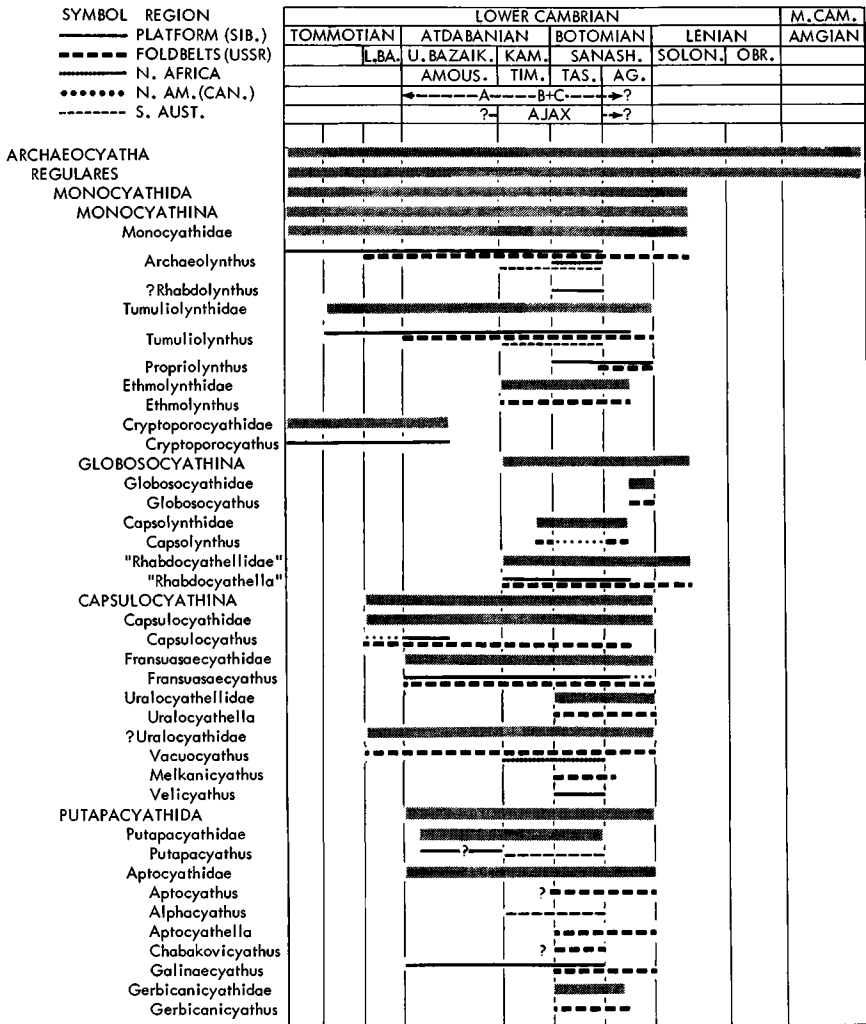
The Russian entries in the table represent two groups of sections; the first, the heavy unbroken line, represents the combined ranges in the various parts of the Siberian Platform. This includes the northwest (Igarka and Norilsk) region, the south (Angara-Lena watershed), the southeast (middle section of R. Lena and R. Aldan), the northeast (lower Lena R. and neighboring Kharaulakh Mts.), and the flanks of the Anabar massif. Data for this are taken mainly from ZHURAVLEVA, KORSHUNOV, & ROZANOV, 1969, from DATZENKO, ZHURAVLEVA, *et al.*, 1968, and from ROZANOV, *et al.*, 1969, but also from other papers. The second group, entered as heavy dashed lines, applies to Russian sections in the folded regions of the Southern Urals, Kazakhstan, the Altay-Sayan (including Tuva), the ranges beyond (east of) Lake Baykal, and the Far East. Data for these entries have been taken mainly from REPINA, KHOMENTOVSKIY, ZHURAVLEVA, & ROZANOV, 1964; ROZANOV & MISSARZHEVSKIY, 1966; ZHURAVLEVA, *et al.*, 1967; KHABAKOV, 1967; KONYUSHKOV, 1967; and YANKAUSKAS & ZHURAVLEVA, 1969.

Ranges for Australia (from BEDFORD & BEDFORD, 1934-39; HILL, 1965; WALTER, 1967; DEBRENNE, 1969) are shown in a medium broken line, those for North Africa (from DEBRENNE, 1964; DEBRENNE & DEBRENNE, 1965) in a fine broken line, and those of western North America (HANDFIELD, 1971) are indicated by a line of small circles.

## ZOOGEOGRAPHIC PROVINCES

In view of the tentativeness of intercontinental correlation, it may be too early to delineate paleozoogeographical provinces using archaeocyathan faunas, but ZHURAV-

TABLE 3. Stratigraphic distribution of archaeocyathan taxa plotted by region: Siberian Platform, Russian folded regions, North Africa, western North America, and Australia (Hill, n).



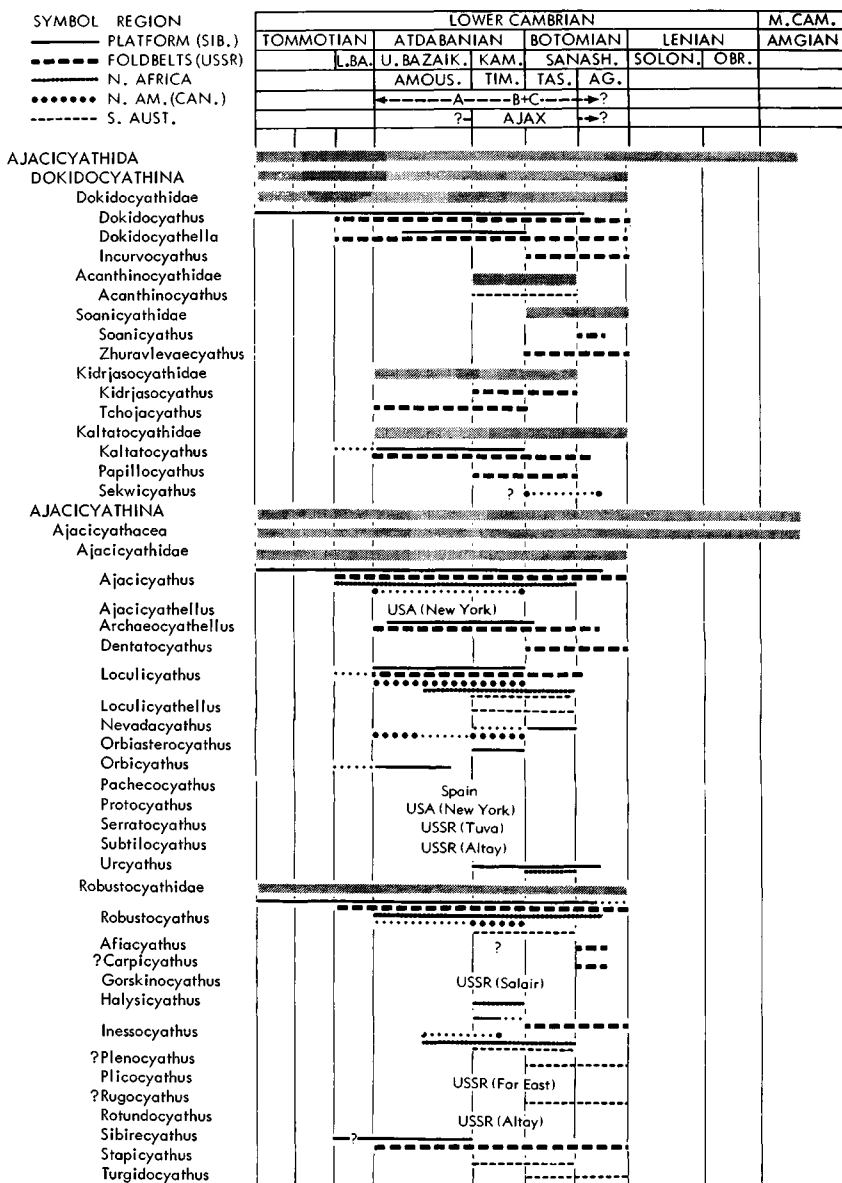
LEVA (1968a) has given a useful preliminary analysis.

Archaeocyatha of Tommotian age are well known only in the USSR; here ZHURAVLEVA has distinguished two sub-provinces, that of Yakutia (southeastern part of Siberian Platform), in which Archaeocyatha are relatively common, and that of the Altay-Sayan fold belts where they are sparser. The Tommotian fauna includes representatives of 15 families.

Eight of the more important of these, the Monocyathidae, Dokidocyathidae, Ajacicathidae, Nochorocyathidae, Coscinocyathidae, Dictyocyathidae, Metacyathidae, and Archaeosyconidae no doubt provided starting points for their respective suborders.

In Atdabanian time, Archaeocyatha greatly diversified, and became more widely distributed, being known from the Urals to the Far East of Asia, as well as in western Europe, North Africa, North America,

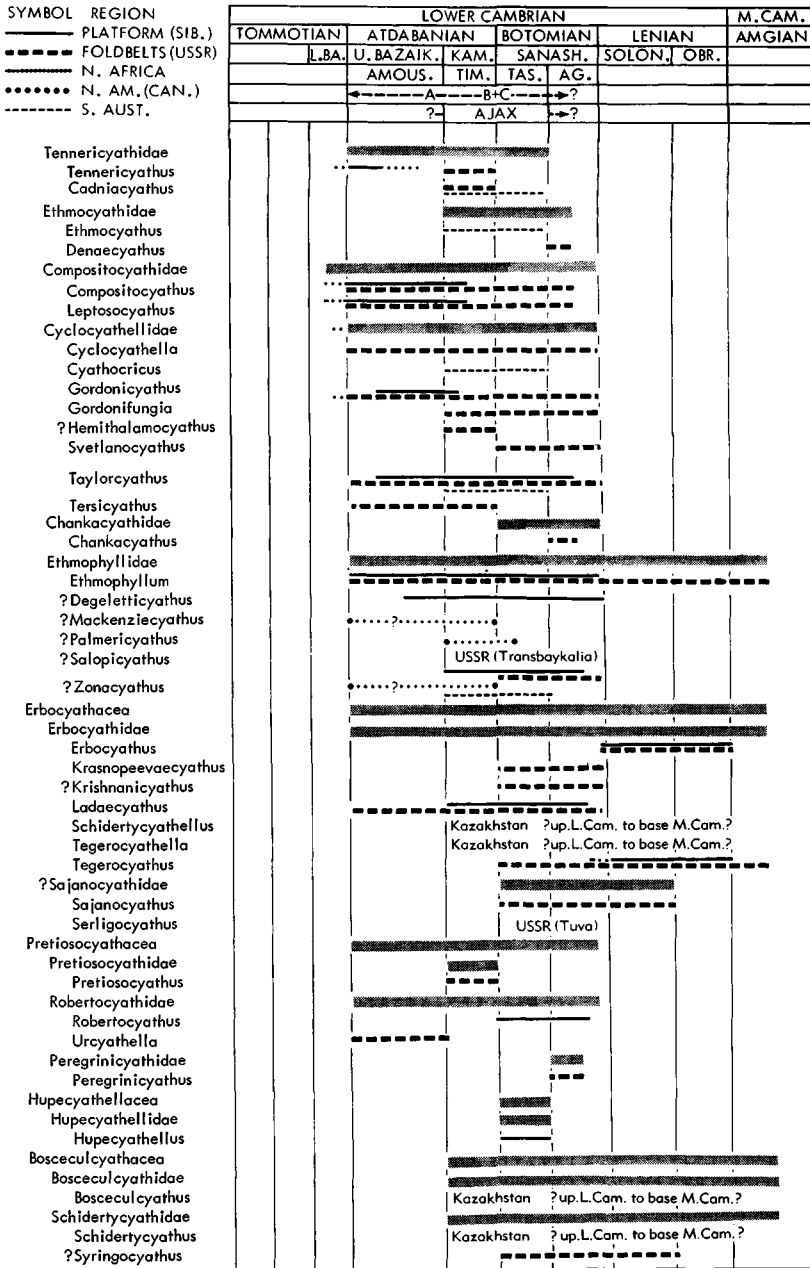
TABLE 3. (Continued.)



Australia, and possibly in Antarctica. At least 10 families attained a worldwide distribution. The number of genera present increased almost threefold. Perhaps the more important first occurrences are of the

Putapacyathida, Compositocyathidae, Ethmophyllidae, Cyclocyathellidae, and Erbo-cyathidae. Toward the end of the Atda-banian, it seems possible that three zoo-geographical regions were present, Afro-

TABLE 3. (Continued.)



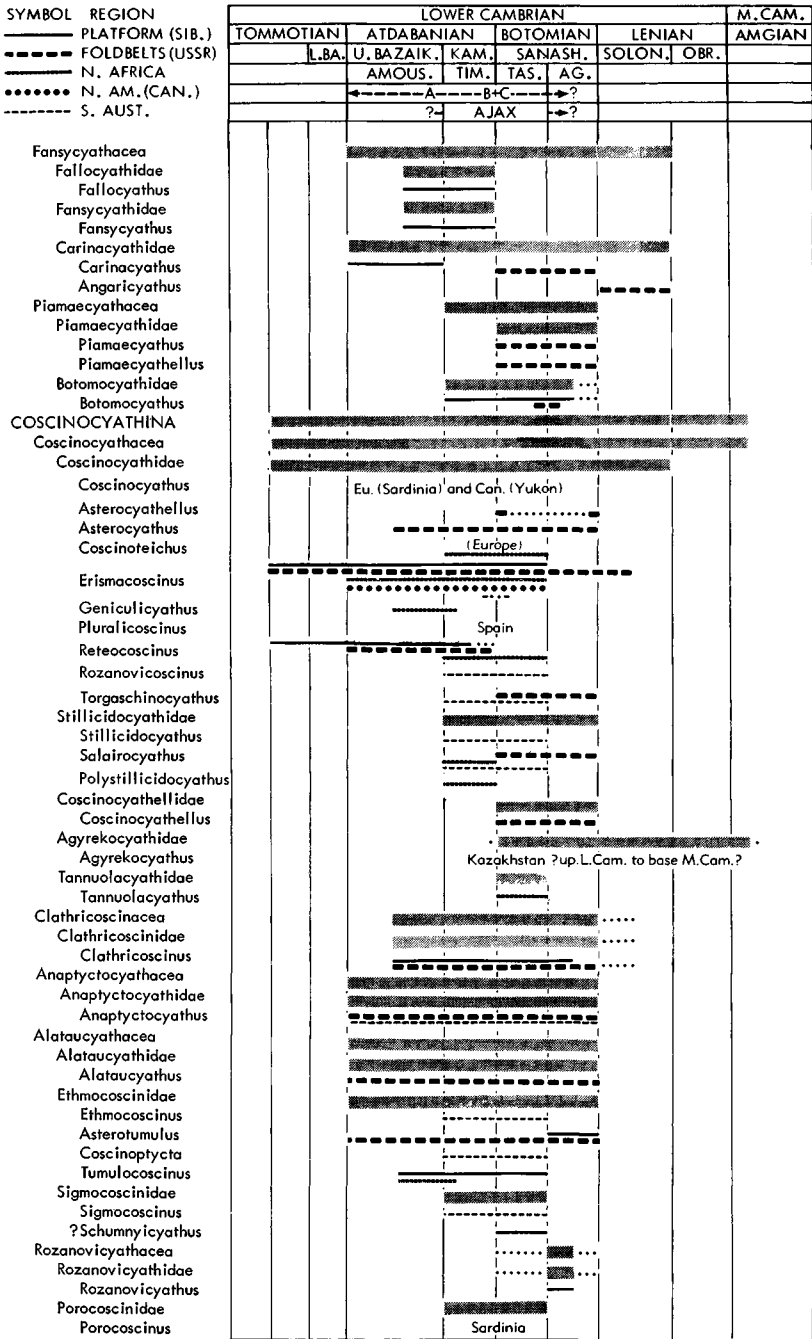
European, Siberian, and Australian. The Siberian region is divisible into two as before, the Yakutian and the Sayano-Altay, both widely extended in area.

In Botomian time the Archaeocyatha reached their acme, not only in distribution but also in diversity. ZHURAVLEVA (1968a) distinguished two centers of differentiation,

TABLE 3. (Continued.)

SYMBOL	REGION	LOWER CAMBRIAN					M. CAM.
		TOMMOTIAN	ATDABANIAN	BOTOMIAN	LENIAN	AMGIAN	
		L.BA.	U. BAZAIK.	KAM.	SANASH.	SOLON.	OBR.
		AMOUS.	TIM.	TAS.	AG.		
————	PLATFORM (SIB.)						
-----	FOLDBELTS (USSR)						
————	N. AFRICA						
.....	N. AM. (CAN.)						
-----	S. AUST.						
			A	B+C	→?		
			?	AJAX	→?		
	Tumulocyathacea						
	Tumulocyathidae						
	Tumulocyathus						
	Dailycyathus						
	Tumulocyathellus						
	Sanarkocyathidae						
	Sanarkocyathus						
	Vologdinocyathidae						
	Vologdinocyathus						
	Gagarincyathus						
	Annulocyathacea						
	Annulocyathidae						
	Annulocyathus						
	Annulofungia						
	Kijacyathidae						
	Kijacyathus						
	Gloriosocyathidae						
	Gloriosocyathus						
	Ringifungia						
	Rossocyathella						
	Russocyathus						
	?Tumulifungia						
	Porocyathidae						
	Porocyathus						
	?Cordilleracyathus						
	Squamosocyathus						
	?Yukonocyathus						
	Sigmocyathacea						
	Sigmocyathidae						
	Sigmocyathus						
	Tercyathacea						
	Tercyathidae						
	Tercyathus						
	Clathricyathus						
	NOCHOROICYATHINA						
	Nochoroicyathacea						
	Nochoroicyathidae						
	Nochoroicyathus						
	Pectenocyathus						
	Trininaeyathus						
	Bronchoyathidae						
	Thalamocyathus						
	Cricopectinus						
	Glaesnericyathus						
	Ethmopectinidae						
	Ethmopectinus						
	Formosocyathidae						
	Formosocyathus						
	Heckericyathus						
	Kordecyathacea						
	Kordecyathidae						
	Kordecyathus						
	Lenocyathacea						
	Lenocyathidae						
	Lenocyathus						
	Japhanicyathus						
	Geocyathidae						
	Geocyathus						
	Jakutocyathus						
	Jakutocarinus						
	Kotuyicyathus						

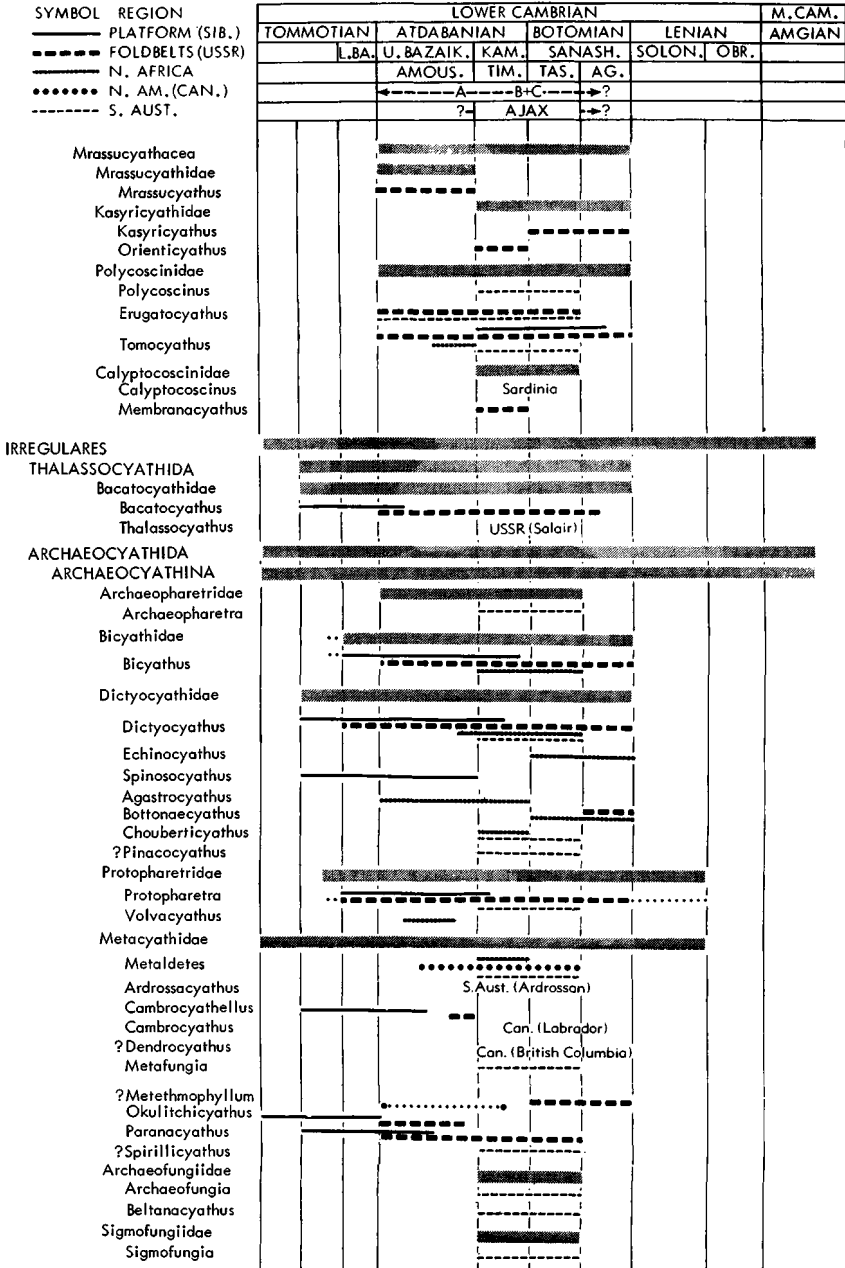
TABLE 3. (Continued.)



the Pacific-Atlantic and the Australo-Antarctic (Fig. 28). The first is subdivisible

into three subregions, North America, Afro-Europe, and Siberia. The Afro-European

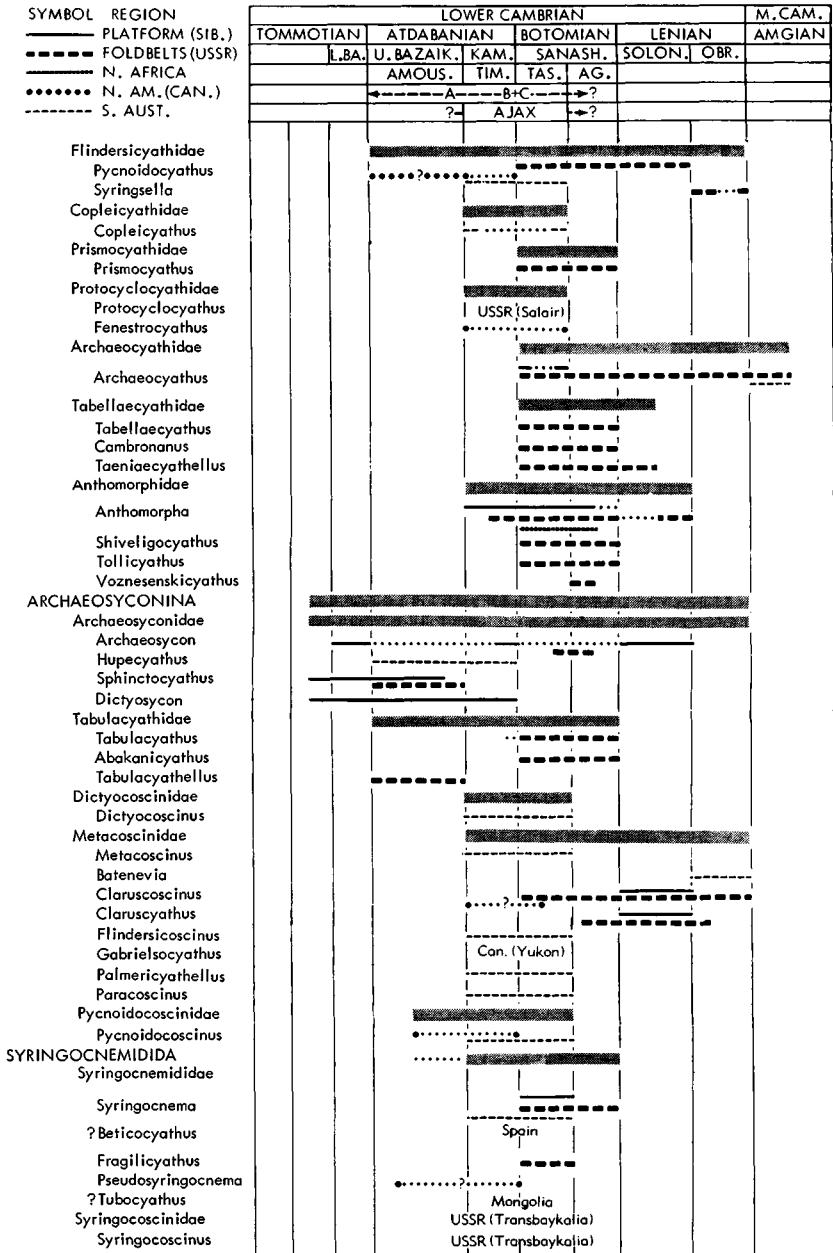
TABLE 3. (Continued.)



region is divisible into a northern and a southern, or North African, province which has many genera in common with the rich Siberian subregion. The Siberian subregion is again divisible into a Sayano-Altay

province extending from the Urals in the west to Baykalia and the Far East, with some differentiation between the eastern and western parts of this great belt, and a Yakutian province which shows differentia-

TABLE 3. (Continued.)



tion between its northern and southern parts.

In Lenian time the tempo of archaeocyathan evolution was greatly retarded, and *Archaeocyathus* is the most widespread

genus, but in Siberia the *Erbocyathidae* and ?*Ethmophyllidae* also occur, and no provincial differences are noted.

By Amgian time, at the beginning of the Siberian Middle Cambrian, only a few spe-



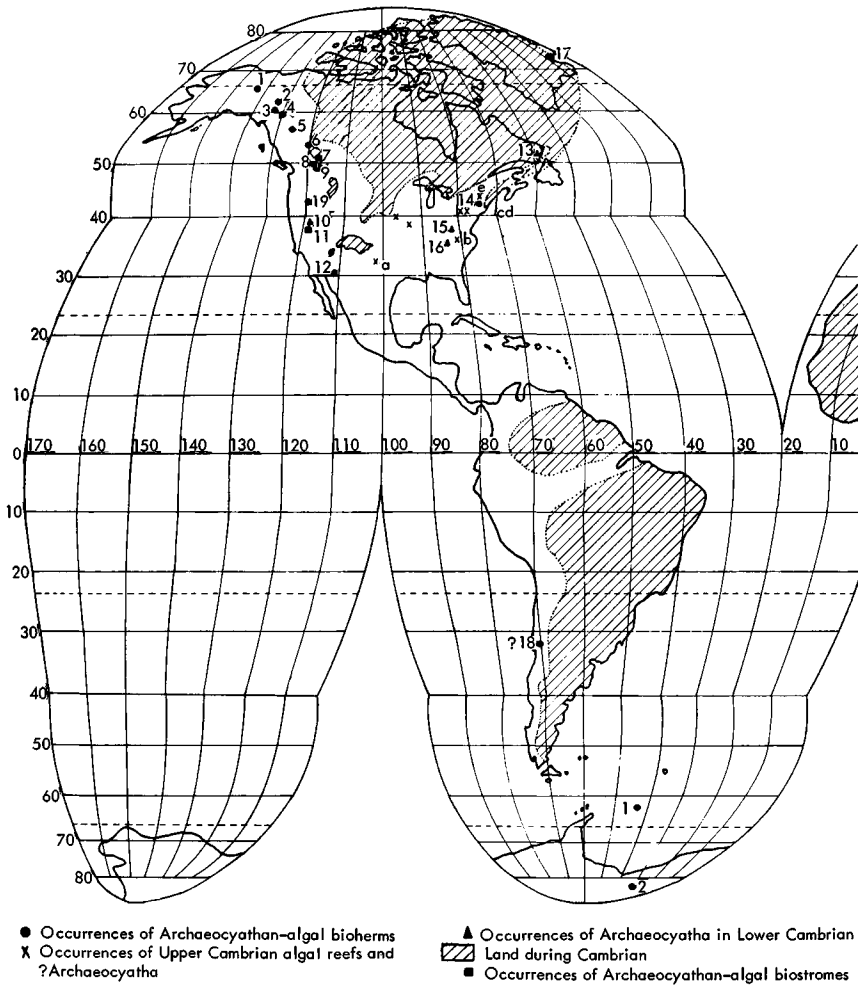


FIG. 27. Occurrences of Archaeocyatha and algal-archaeocyathan reefs in Lower Cambrian seas (Hill, n).

cies were still extant; and, except for a somewhat doubtful survivor in the Upper Cambrian of Antarctica, the phylum may be

considered to have become extinct in early Middle Cambrian time.

## GLOSSARY OF RECOMMENDED MORPHOLOGICAL TERMS

**annulus** (pl., **annuli**). Ring-shaped plate taking part in construction of wall.

**bar**. Elongate, thin skeletal element, rectangular in section.

**bract**. Scooplike extension from lower half of rim of pore of wall.

**central cavity**. Axial space enclosed by inner wall.  
**cup**. Archaeocyathan skeleton.

**dissepiment**. Aporose plate shaped like film of a bubble.

**framework**. Underlying, coarsely porous wall of a double wall.

**inner wall**. Wall enclosing central cavity in a two-walled cup.

**internal cavity**. Space enclosed in one-walled cup.

**intersept**. That portion of wall between edges of 2

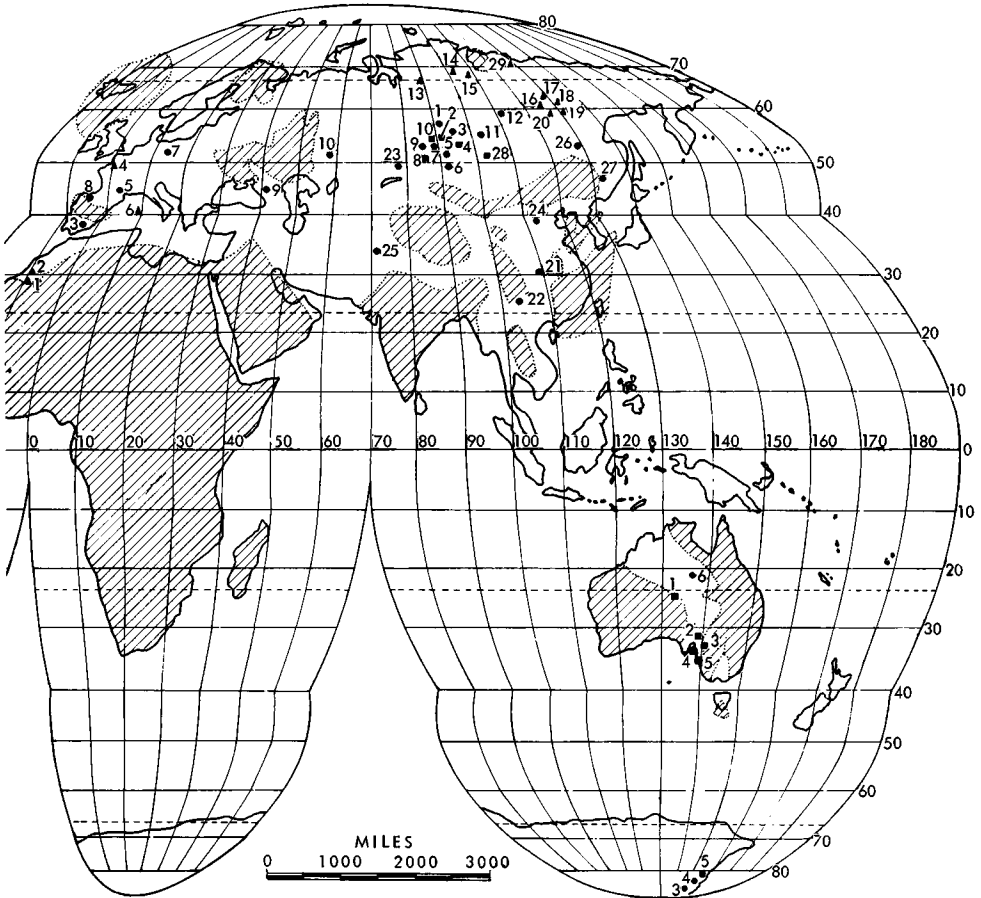


FIG. 27. (Continued from facing page.)

neighboring septa.

**intervallum.** Space between inner and outer walls.

**link.** Radial lath connecting the walls or vertical pillars of dictyocyathid cups.

**loculus** (pl., **loculi**). Space between two neighboring septa.

**louvre.** Wall plate, commonly oblique, developed between edges of 2 neighboring septa or longitudinal ribs.

**pariety.** Not recommended; replaced by more general term "septum."

**peak.** Extension shaped like peak of a cap-brim, from upper half of rim of pore of wall.

**pectinate tabula.** Tabula consisting of two rows of spines like teeth of combs each projecting toward the other from 2 neighboring septa.

**pellis.** Thin, commonly aporose sheet or sheath

outside cup.

**pelta.** Lidlike flap closing or partly closing internal cavity distally, porous or aporose.

**pore.** Hole in thin wall, septum or tabula, round, oval, slitlike, rectangular, hexagonal or polygonal or irregular.

**pore-canal.** Cylindrical or prismatic hole through thick wall; distance between pore-canals commonly greater than their diameter.

**pore-tube.** Cylindrical or polygonal thin-walled tube formed by horizontal or oblique or curved wall-plates, or by bracts or peaks or by a combination of these.

**rod.** Thin, elongate cylindrical or prismatic skeletal element.

**scale.** Flat or but slightly curved plate rising obliquely from the wall below a pore.

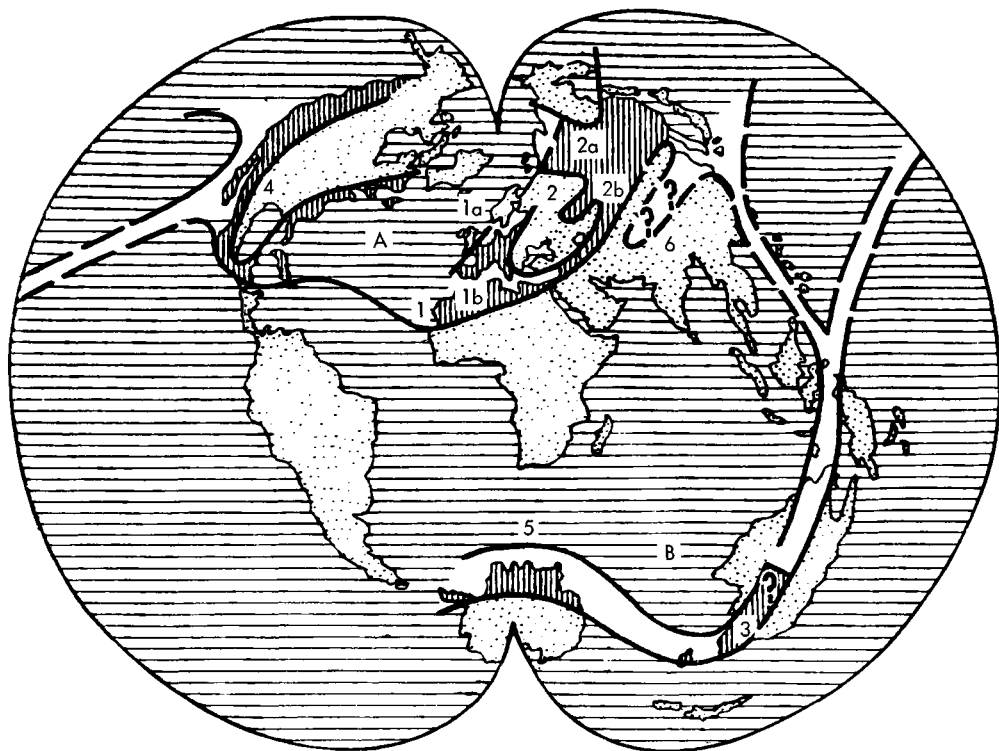


FIG. 28. Archaeocyathan zoogeographic provinces in Botomian time (Zhuravleva, 1968a). [Explanation: A, Pacific-Atlantic region (1,2,4); B, Australo-Antarctic region (3,5); 1, Afro-European subregion (1a, northern province; 1b, southern province); 2, Siberian subregion (2a, Yakutian province; 2b, Sayano-Altay province); 3, Australian province; 4, North American subregion; 5, Antarctic province; 6, Indian and Chinese occurrences.]

**septum.** Radial longitudinal plate connecting walls of a 2-walled cup, commonly flat, waved in some.

**sheath** (or sheet). Microporous covering to a wall.

**spitz.** Not recommended; replaced by English term "tip."

**synapticula** (pl., *synapticulae*). Transverse rod connecting 2 neighboring septa.

**tabula** (pl., *tabulae*). Transverse porous skeletal element connecting walls of a 2-walled cup.

**taenia.** Small curved segment of an irregularian septum; usage previously extended, but not sup-

ported herein, to mean the whole irregularian septum.

**tersioid outgrowth.** Holdfast of roughly cylindrical form, consisting of close, subparallel or curved plates connected by dissepiments.

**tip.** Inversely conical initial part of cup.

**tubulus** (pl., *tubuli*). Porous-walled, prismatic, radial tubules filling the intervallum of Syringocnemidida.

**tumulus** (pl., *tumuli*). Small bulge in wall, perforated by one or many pores.

## TECHNIQUES OF STUDY

Two different techniques are applicable in the laboratory study of archaeocyathans, differential solution and thin sectioning.

In some localities, such as at the Ajax Mine near Beltana in the Flinders Ranges of

South Australia, the calcareous skeletons have been replaced by silica. Silicification is commonly sufficiently delicate not to obscure the finer details of morphology, and the construction of the walls, the septa, and

the tabulae can be studied from exposed surfaces when the skeletons are dissolved out from the surrounding limestone by dilute hydrochloric acid.

However, in most specimens, where the skeletons remain calcareous in limestone, thin sections must be prepared. In order to complete the three-dimensional picture of the various structures, transverse, radial longitudinal, and tangential longitudinal sections are required and it is often necessary to take sections slightly obliquely to the structure being studied. Thus, to study a tabula, one needs a thin section within the tabula parallel to its upper and lower surfaces and two at right angles to the

upper and lower surfaces of the tabula, one radial to the cup and one tangential. To study a septum one needs three sections, similarly, and one also needs to observe changes in the construction of the septum during ontogeny. To study the walls, several sections are needed; perhaps most useful is a section tangential and slightly oblique to the wall, so that elements projecting inward and outward from the wall can be observed. Changes in the walls during ontogeny also must be noted, by taking sets of sections from the young, intermediate, and adult stages. Very small species must be reconstructed from many random sections.

## CLASSIFICATION OF ARCHAEOCYATHA

The systematic position of the Archaeocyatha has been much debated. The first archaeocyathan encountered by a scientist appears to have been a species from Labrador, Canada, that was referred to the coral genus *Cyathophyllum* by BAYFIELD (1845, p. 457). The next, from the variegated suite of the Lower Cambrian of the River Lena, Siberia, was originally determined as a Carboniferous plant, *Calamithes cannaeformis* (fide GEKKER, 1928). The first archaeocyathan described as such was *Archeocyathus atlanticus* BILLINGS (1861). BILLINGS at first thought that this fossil might be a coral or a sponge, but later he (1865) listed it under Protozoa. DAWSON (1865) and MEEK (1868) thought that the American archaeocyathans discovered up to that time were Foraminifera. The first representative to be found in Europe (Spain) was considered allied to the Receptaculitidae by ROEMER (1878). BORNEMANN (1884, 1886, 1891) thought the Sardinian archaeocyathans were best regarded as a special division of the Coelenterata. WALCOTT (1886) referred the family to the sponges, but HINDE (1889), after the most detailed microscopic examination and review made up until that time, considered that they were a special family of the stony corals. The first detailed description of Siberian archaeocyathans by VON TOLL (1899) referred them to the calcareous algae. Australian archaeocyathans first were described by ETHERIDGE (1890) and TAYLOR (1910), and TAYLOR concluded that they were a new class closest to cal-

careous sponges. TAYLOR's estimate received fairly general acceptance, and apart from the discovery and description of Antarctic Archaeocyatha (TAYLOR in DAVID & PRIESTLEY, 1914, p. 236; GORDON, 1920), little work was done on the group for twenty years.

In the decade 1930-40, work was vigorously pursued in Russia and Asia by VOLOGDIN, in Canada by OKULITCH, and in Australia by the BEDFORDS. Recognition of the systematic importance of ontogeny was a considerable step forward. SIMON (1939, 1941) indexed the species and genera described up to that time.<sup>1</sup> OKULITCH (1955) reviewed all earlier work and advocated a division of the Archaeocyatha into three classes: Monocyathea (one-walled), Archaeocyathea (two-walled, with porous septa), and Anthocyathea (two-walled, with aporose septa). These divisions have not proved acceptable and although VOLOGDIN (1962) in the Russian Treatise (*Osnovy Paleontologii*) accepted the Monocyathea for all one-walled cups, these are now divided between the Regulares and the Irregulares. Anthocyathea is now incorporated in Irregulares.

The great surge of Russian work since 1950, by VOLOGDIN and ZHURAVLEVA and their many colleagues, together with work on North African and Australian Archaeocyatha by DEBRENNE, and on Antarctic forms by HILL, has led to wide acceptance

<sup>1</sup> An index of North American Archaeocyatha has been provided by NITCKI (1967).

by paleontologists working on the group of the view that the taxon is an independent phylum, somewhere near the sponges in the animal kingdom. However, this is not acceptable to all zoologists. Thus ZIEGLER & RIETSCHER (1970) are not convinced that Archaeocyatha are not sponges. ZHURAVLEVA (1959b, 1970a) has given a detailed comparison with the Protozoa, the Porifera, and the Coelenterata. She regards the Archaeocyatha as a primitive phylum of multicellular animals, with a level of organization lying between that of the Protozoa and of the Porifera, and this view is adopted in the *Treatise*. KRASNOPEEVA (1960, 1969) and VOLOGDIN (1962b) seem to prefer a position nearer the Coelenterata.

Fundamentally, like this chapter, DEBRENE (1964), and HILL (1965), ZHURAVLEVA (1960b) divided the Archaeocyatha into the Regulares and Irregulares, following the pattern set by VOLOGDIN (1937) and others, but she interpolated the class Euarchoocyatha between the phylum Archaeocyatha and the Regulares and Irregulares, which she considered to be subclasses because the morphological distinctions between them are insignificant in comparison with those by which classes are distinguished in other groups of animals. This interpolated taxon is omitted herein.

Two small groups, the Silurian Aphrosalpingidae MYAGKOVA, 1955, and the Carboniferous to Cretaceous Sphinctozoa STEINMANN, 1882 (=Thalamida), which are homeomorphic with some families of Archaeocyatha, the first with the Syringocnemididae and the second with the Archaeosyconidae, are sometimes included (VOLOGDIN, 1957a, as classes Aphrosalpingoidea and Tabuloidea?) in the Archaeocyatha, or doubtfully compared (ZHURAVLEVA, 1960b), but they are here excluded by me. Aphrosalpingidae might possibly be algae, and Sphinctozoa seem best left in the Porifera as calcareous sponges as SEILACHER (1962) and REID (1968) have done. VOLOGDIN (1962d) included the Syringocnemidida in the Aphrosalpingoidea, but this course is not followed herein.

VOLOGDIN (1962c, 1964a) included in the Archaeocyatha a new class, the Cribricyathia, which comprises very small (approx. 1 mm. diam.), one or two-walled cylindrical, isometric, or conical cups in which at

least the outer wall is peripterate, i.e., of ribbonlike horizontal elements, or peripteratae, commonly applied to the outer edges of lathlike longitudinal elements so that a lattice is formed; these forms have neither septa nor tabulae, and no bilateral symmetry. VOLOGDIN considered them planktonic. Their characters seem to me to distinguish them from Archaeocyatha, and I prefer to consider them Problematica. However, since they were referred originally to the Archaeocyatha, and since YANKAUSKAS has left them doubtfully in this phylum, I have appended a summary treatment.

In the following the phylum Archaeocyatha is divided into two classes: 1) Regulares: this class comprises one-, or commonly two-walled, cups in which the radial elements and the inner wall of the skeleton appear in ontogeny earlier than the dissepiments (though this generalization is based on very few studies). The radial elements consist either of septa or of rods or bars, the septa having divergent longitudinal rows of pores. Regulares exhibit numerous types of wall construction. 2) Irregulares: in this class dissepiments appear in ontogeny earlier than radial skeletal elements or inner wall, ontogenetic changes are relatively slow. The radial skeletal elements consist of rods, or of straight or wavy septa in which the longitudinal rows of pores curve upward and outward from the inner wall, or the intervallum may be filled with radiating hexagonal tubuli. Porosity of walls and septa is less regular than in Regulares, and there are fewer and simpler types of wall construction.

The presence or absence of an inner wall and the presence or absence of septa or radial tubules serve to divide the classes into orders.

The orders are divided into suborders on the presence or absence of tabulae and on the type of tabulae. Tabulae are of considerable taxonomic interest. KRASNOPEEVA (1955) adopted a family classification in which the presence or absence of tabulae was regarded as of generic value only. But experience seems to show that tabulae are of subordinal value, although RAYMOND (1931) had suggested that their absence might mean they had been resolved by the protoplasm. An interesting problem of classification arises in the Archaeocyatha

with pectinate tabulae. The presence of pectinate tabulae in two-walled septate Regulares is considered diagnostic of the suborder Nochoroicyathina, but in some genera and species only 10 percent of individuals may show them. It is suspected that some of the two-walled septate forms without tabulae at present included in the Ajacicyathina may simply be atabulate individuals of nochoroicyathine species and genera, and more properly should be included in the Nochoroicyathina. It could also be argued that the presence or absence of pectinate tabulae is immaterial taxonomically, since it is not universal in a given species, and such a finding would lead to amalgamation into one suborder of the Nochoroicyathina and Ajacicyathina. However, in this volume the principle followed by ZHURAVLEVA and her colleagues is adopted, that when species of genera can be shown to have pectinate tabulae, albeit sporadically, the genera are included in the Nochoroicyathina.

The suborders, particularly in the Regulares, are divided into superfamilies mainly on the type of construction of the outer wall; and the superfamilies into families mainly on the construction of the inner wall. In the Regulares generic characters are commonly based on the subordinate features of wall construction such as forms of canals, forms of annuli, and corrugation of wall. Thus, the classification currently used, particularly of the Regulares, has the advantage of a morphological key. Its value is enhanced if, as many archaeocyathan workers suspect, ontogenetic differentiation of the walls from simply to complexly porous is consistent with phylogenetic differentiation, but far more ontogenetic studies are required to establish this happy conclusion.

In the Irregulares the general irregularity in pores and intervallar structures, combined with the apparently lesser complication of the walls, makes superfamilial, familial and generic classification more difficult, and the taxonomy of this class is at present much more tentative.

In her preliminary new classification of the Irregulares, DEBRENNE (1970b, p. 25) has given the same diagnostic weight to the characters of the intervallum, and to those of inner and outer walls, as in the

currently acceptable classification of the Regulares. She considers that the Regulares with two walls may be allotted to five new orders based on the types of their intervallar structures, though it seems to me that the analogous rank in Regulares is the suborder. Her new orders are:

- I. CHOUBERTICYATHIDA. Intervallum with rods radial and oblique.
- II. ARCHAEOPHARETRIDA. Intervallum with rods and "booklets" [platelets=*plaquettes* (F.)] vertical and oblique.
- III. METALDETIDA. Intervallum with "pseudo-septa" (defined as plates with wide pores to true radial plates with small, numerous pores, the area of which is less than that of the skeleton), without or with synapticalae, or with synapticalae and "pseudo-tabulae" (defined as synapticalae in horizontal planes reinforced by sieves).
- IV. PARANACYATHIDA. Intervallum with stout radial septa without synapticalae and tabulae.
- V. PARACOSCINIDA. Intervallum with septa and independent tabulae.

The Syringocnemidida of this *Treatise* is treated not as an order but as a family *incertae sedis* by DEBRENNE (1970b, p. 23), who states that radial, "honeycomb" tubes in some ways resemble the "tube-like structures" built by the wavy sides of septa and flat synapticalae of *Pycnoidocyathus* type; but in other characters, such as the constant diameter of pores and the regular honeycomb construction, *Syringocnema* resembles regular Archaeocyatha.

DEBRENNE (1970b, p. 27) has suggested that five groups each with a different type of outer wall may occur in each of her ordinal ranks, and that each of these five groups, by analogy with Regulares, should be regarded as superfamilies. But she did not give them superfamily names, because of the preliminary nature of her studies on this Class. She has considered, however, that six different types of inner wall could occur in each of the five groups, and each of these types she considers diagnostic of a family.

In what follows I have recognized the tentativeness of Mme. DEBRENNE's classification by placing the families she recognizes within the currently accepted ordinal clas-

sification of the Irregulares, and have for the time being included her five new orders in the synonymy of the currently accepted orders.

The ever-increasing precision in the observation of wall structure and of the characters of septa and tabulae requires frequent restudy of type specimens, to see whether previously acceptable definitions of genera are still valid. If, as seems likely, significant differences can be established between porocanals and pore-tubes, and between pore-tubes of different types, meanings attached to these terms in many of the older definitions must be reevaluated.

## OUTLINE OF CLASSIFICATION

The following outline of the Archaeocyatha summarizes taxonomic relationships, geologic occurrence, and numbers of recognized genera and subgenera in each suprageneric group from class to family. A single number refers to genera; where two numbers are given, the second indicates subgenera additional to nominotypical ones.

### *Main Divisions of Archaeocyatha*

- Archaeocyatha (*phylum*) (252;7). *L.Cam.-M.Cam.* (*base*), ?*U. Cam.*
- Regulares (*class*) (173;4). *L.Cam.-M.Cam.*
- Monocyathida (*order*) (14;1). *L.Cam.(low. Tommot.-low.Len.)*.
- Monocyathina (*suborder*) (5;1). *L.Cam.(low. Tommot.-low.Len.)*.
- Monocyathidae (2). *L.Cam.(low.Tommot.-low.Len.)*.
- Tumuliolythidae (1;1). *L.Cam.(up.Tommot.-Botom.)*.
- Ethmolythidae (1). *L.Cam.(up.Atdaban.-Botom.)*.
- Cryptoporocyathidae (1). *L.Cam.(low.Tommot.-low.Atdaban.)*.
- Globosocyathina (*suborder*) (3). *L.Cam.(up. Atdaban.-low.Len.)*.
- Globosocyathidae (1). *L.Cam.(Botom.)*.
- Capsolythidae (1). *L.Cam.(up.Atdaban.-Botom.)*.
- "Rhabdocyathellidae" (1). *L.Cam.(up. Atdaban.-low.Len.)*.
- Capsulocyathina (*suborder*) (6). *L.Cam.(up. Tommot.-Botom.)*.
- Capsulocyathidae (1). *L.Cam.(up.Tommot.-Botom.)*.

- Fransuaesyathidae (1). *L.Cam.(Atdaban.-Botom.)*.
- Uralocyathellidae (1). *L.Cam.(Botom.)*.
- ?Uralocyathidae (3). *L.Cam.(up.Tommot.-Botom.)*.
- Putapacyathida (*order*) (7). *L.Cam.(Atdaban.-Botom.)*.
- Putapacyathidae (1). *L.Cam.(up.Atdaban. or low.Botom.)*.
- Aptocyathidae (5). *L.Cam.(Atdaban.-Botom.)*.
- Gerbicanicyathidae (1). *L.Cam.(Botom.)*.
- Ajacyathida (*order*) (152;3). *L.Cam.-M.Cam.* (*base*).
- Dokidocyathina (*suborder*) (11). *L.Cam.(low. Tommot.-up.Botom.)*.
- Dokidocyathidae (3). *L.Cam.(Tommot.-Botom.)*.
- Acanthinocyathidae (1). *L.Cam.(up.Atdaban. or low.Botom.)*.
- Soanicyathidae (2). *L.Cam.(Botom.)*.
- Kidrijasocyathidae (2). *L.Cam.(Atdaban.-low.Botom.)*.
- Kaltatocyathidae (3). *L.Cam.(Atdaban.-Botom.)*.
- Ajacyathina (*suborder*) (85;1). *L.Cam.-base M.Cam.*
- Ajacyathacea (*superfamily*) (47;1). *L.Cam.-base M.Cam.*
- Ajacyathidae (13;1). *L.Cam.(low.Tommot.-Botom.)*.
- Robustocyathidae (13). *L.Cam.*
- Tennericyathidae (2). *L.Cam.(Atdaban.-Botom.)*.
- Ethmocyathidae (2). *L.Cam.(?up.Atdaban.-Botom.)*.
- Compositocyathidae (2). *L.Cam.(up.Tommot.-up.Botom.)*.
- Cyclocyathellidae (8). *L.Cam.(up.Tommot.-up.Botom.)*.
- Chankacyathidae (1). *L.Cam.(Botom.)*.
- Ethmophyllidae (6). *L.Cam.(Atdaban.-)M. Cam.(low.Amg.)*.
- Erbocyathacea (*superfamily*) (9). *L.Cam.* (*Atdaban.-Len.-)base M.Cam.*
- Erbocyathidae (7). *L.Cam.(Atdaban.-Len.-)base M.Cam.*
- ?Sajanocyathidae (2). *L.Cam.(Botom.-low. Len.)*.
- Pretiosocyathacea (*superfamily*) (4). *L.Cam.* (*Atdaban.-Botom.)*.
- Pretiosocyathidae (1). *L.Cam.(up.Atdaban.)*.
- Robertocyathidae (2). *L.Cam.(Atdaban.-Botom.)*.
- Peregrinicyathidae (1). *L.Cam.(Botom.)*.

- Hupecyathellacea (*superfamily*) (1). *L.Cam.*  
(*Botom.*).
- Hupecyathellidae (1). *L.Cam.*(*Botom.*).
- Bosceculyathacea (*superfamily*) (3). *L.Cam.*  
(*Botom.-Len.*)-?base *M.Cam.*
- Bosceculyathidae (1). *L.Cam.*(*Botom.* or  
?Len.) or ?base *M.Cam.*
- Schidertocyathidae (2). *L.Cam.*(*Botom.-*  
*Len.*) or ?base *M.Cam.*
- Tumulocyathacea (*superfamily*) (6). *L.Cam.*  
(*up.Tommot.-up.Len.*).
- Tumulocyathidae (3). *L.Cam.*(*up.Tommot.-*  
*Botom.*).
- Sanarkocyathidae (1). *L.Cam.*(*Botom.*).
- Vologdinocyathidae (2). *L.Cam.*(*Atdaban.-*  
*up.Len.*).
- Annulocyathacea (*superfamily*) (12). *L.Cam.*  
(*Atdaban.-Botom.*).
- Annulocyathidae (2). *L.Cam.*(*Botom.*).
- Kijacyathidae (1). *L.Cam.*(*Atdaban.-up.*  
*Botom.*).
- Gloriosocyathidae (5). *L.Cam.*(*Atdaban.-*  
*Botom.*).
- Porocyathidae (4). *L.Cam.*(*Atdaban.-Botom.*).
- Sigmocyathacea (*superfamily*) (1). *L.Cam.*  
(*up.Atdaban.* or *low.Botom.*).
- Sigmocyathidae (1). *L.Cam.*(*up.Atdaban.* or  
*low.Botom.*).
- Tercyathacea (*superfamily*) (2). *L.Cam.*  
(*Botom.-low.Len.*).
- Tercyathidae (2). *L.Cam.*(*Botom.-low.Len.*).
- Nochoroicyathina (*suborder*) (22;1). *L.Cam.*  
(*Tommot.-Botom.*, rare *Len.*), ?*M.Cam.*  
(*base Amg.*).
- Nochoroicyathacea (*superfamily*) (9). *L.Cam.*  
(*Tommot.-Botom.*, rare *Len.*), ?*M.Cam.*  
(*base Amg.*).
- Nochoroicyathidae (3). *L.Cam.*(*Tommot.-*  
*Botom.*, rare *Len.*), ?*M.Cam.*(*base Amg.*).
- Bronchocyathidae (3). *L.Cam.*(*Atdaban.-*  
*Botom.*).
- Ethmopectinidae (1). *L.Cam.*(*up.Atdaban.*  
or *low.Botom.*).
- Formosocyathidae (2). *L.Cam.*(*up.Tommot.-*  
*Botom.*).
- Kordecyathacea (*superfamily*) (1). *L.Cam.*  
(?up.*Atdaban.-Botom.*).
- Kordecyathidae (1). *L.Cam.*(?up.*Atdaban.-*  
*Botom.*).
- Lenocyathacea (*superfamily*) (5;1). *L.Cam.*  
(*mid.Tommot.-Botom.*).
- Lenocyathidae (2). *L.Cam.*(*Atdaban.*).
- Geocyathidae (3;1). *L.Cam.*(*mid.Tommot.-*  
*Botom.*).
- Fansycyathacea (*superfamily*) (4). *L.Cam.*  
(*Atdaban.-low.Len.*).
- Fallocyathidae (1). *L.Cam.*(*Atdaban.*).
- Fansycyathidae (1). *L.Cam.*(*Atdaban.*).
- Carinacyathidae (2). *L.Cam.*(*Atdaban.-low.*  
*Len.*).
- Piamaecyathacea (*superfamily*) (3). *L.Cam.*  
(*up.Atdaban.-Botom.*).
- Piamaecyathidae (2). *L.Cam.*(*Botom.*).
- Botomocyathidae (1). *L.Cam.*(*up.Atdaban.-*  
*Botom.*).
- Coscinocyathina (*suborder*) (34;1). *L.Cam.*  
(*mid.Tommot.-low.Len.*)-base *M.Cam.*
- Coscinocyathacea (*superfamily*) (15;1). *L.*  
*Cam.*(*mid.Tommot.-low.Len.*)-base ?*M.*  
*Cam.*
- Coscinocyathidae (10). *L.Cam.*(*mid.Tom-*  
*mot.-low.Len.*).
- Stillicidocyathidae (2;1). *L.Cam.*(?up.*At-*  
*daban.-Botom.*).
- Coscinocyathellidae (1). *L.Cam.*(*Botom.*).
- Agyrekocyathidae (1). *L.Cam.-base M.Cam.*
- Tannuolocyathidae (1). *L.Cam.*(*low.Bot-*  
*om.*).
- Clathricoscinacea (*superfamily*) (1). *L.Cam.*  
(*Atdaban.-low.Len.*).
- Clathricoscinidae (1). *L.Cam.*(*Atdaban.-*  
*low.Len.*).
- Anaptyctocyathacea (*superfamily*) (1). *L.Cam.*  
(*Atdaban.-Botom.*).
- Anaptyctocyathidae (1). *L.Cam.*(*Atdaban.-*  
*Botom.*).
- Alataucyathacea (*superfamily*) (7). *L.Cam.*  
(*Atdaban.-Botom.*).
- Alataucyathidae (1). *L.Cam.*(*Atdaban.-*  
*Botom.*).
- Ethmocosciniidae (4). *L.Cam.*(*Atdaban.-*  
*Botom.*).
- Sigmocosciniidae (2). *L.Cam.*(*up.Atdaban.*  
or *low.Botom.*).
- Rozanovicyathacea (*superfamily*) (2). *L.Cam.*  
(*Botom.*).
- Rozanovicyathidae (1). *L.Cam.*(*Botom.*).
- Porocosciniidae (1). *L.Cam.*(*up.Atdaban.* or  
*Botom.*).
- Mrassucyathacea (*superfamily*) (8). *L.Cam.*  
(*Atdaban.-Botom.*).
- Mrassucyathidae (1). *L.Cam.*(*Atdaban.*).
- Kasyricyathidae (2). *L.Cam.*(*Atdaban.-Bo-*  
*tom.*).
- Polycosciniidae (3). *L.Cam.*(*Atdaban.-Bo-*  
*tom.*).
- Calyptocosciniidae (2). *L.Cam.*(*Atdaban.-*  
?low.*Botom.*).
- Irregulares (*class*) (60;3). *L.Cam.-M.Cam.*



- Thalassocyathida (order) (2). *L.Cam.*(*Tommot.-Botom.*).
- Bacatocyathidae (2). *L.Cam.*(*Tommot.-Botom.*).
- Archaeocyathida (order) (52;3). *L.Cam.-M.Cam.*
- Archaeocyathina (suborder) (36;2). *L.Cam.-M.Cam.*
- Archaeopharetridae (1). *L.Cam.*(*Atdaban. or low.Botom.*).
- Bicyathidae (1). *L.Cam.*(*up.Tommot.-Botom.*).
- Dictyocyathidae (5;2). *L.Cam.*(*mid.Tommot.-Botom.*).
- Protopharetridae (2). *L.Cam.*(*mid.Tommot.-low.Len.*).
- Metacyathidae (10). *L.Cam.*(*Tommot.-low.Len.*).
- Archaeofungiidae (2). *L.Cam.*(*up.Atdaban. or low.Botom.*).
- Sigmofungiidae (1). *L.Cam.*(*up.Atdaban.-low.Botom.*).
- Flindersicyathidae (2). *L.Cam.*(?*Atdaban.-Len.*).
- Copleicyathidae (1). *L.Cam.*(*up.Atdaban. or low.Botom.*).
- Prismocyathidae (1). *L.Cam.*(*Botom.*).
- Protocyclocyathidae (2). *L.Cam.*
- Archaeocyathidae (1). *L.Cam.*(*Botom.*)-*M.Cam.*
- Tabellaeyathidae (3). *L.Cam.*(*Botom.-low.Len.*).
- Anthomorphidae (4). *L.Cam.*(*Atdaban.-low.Len.*).
- Archaeosyonina (suborder) (16;1). *L.Cam.*
- Archaeosyonidae (3;1). *L.Cam.*
- Tabulacyathidae (3). *L.Cam.*(*Atdaban.-Botom.*).
- Dictyoscocinidae (1). *L.Cam.*(*up.Atdaban. or low.Botom.*).
- Metascocinidae (8). *L.Cam.*(*up.Atdaban.-up.Len.*).
- Pycnoidoscocinidae (1). *L.Cam.*(*up.Atdaban. or low.Botom.*).
- Syringocnemidida (order) (6). *L.Cam.*
- Syringocnemididae (5). *L.Cam.*(?*up.Atdaban.-Botom.*).
- Syringoscocinidae (1). *L.Cam.*
- Class Uncertain (19). *L.Cam.-M.Cam.*
- Kazakhstanicyathida (order) (1). *Up.L.Cam.-?base M.Cam.*
- Kazakhstanicyathidae (1). *Up.L.Cam.-?base M.Cam.*
- Order Uncertain (18). *L.Cam.-M.Cam.*
- Acanthopyrgidae (1). *L.Cam.*
- Family Uncertain (extravallar outgrowths) (12). *L.Cam.-M.Cam.*
- Family Uncertain (supposed planktonic or larval Archaeocyatha) (5). *L.Cam.-M.Cam.*
- Phylum Uncertain (probably not Archaeocyatha) (45). *Precam.-U.Cam.*(*U.Sil.*), *M.Dev.*
- Aphrosalpingoida (class) (3). *U.Sil.*(*Ludlow*).
- Aphrosalpingida (order) (2). *U.Sil.*(*Ludlow*).
- Aphrosalpingidae (1). *U.Sil.*(*Ludlow*).
- Nematosalpingidae (1). *U.Sil.*(*Ludlow*).
- Palaeoschadida (order) (1). *U.Sil.*(*Ludlow*).
- Palaeoschadidae (1). *U.Sil.*(*Ludlow*).
- Cribricyatha (class) (problematical microfossils) (29). *L.Cam.*
- Conoidocyathida (order) (3). *L.Cam.*
- Conoidocyathidae (3). *L.Cam.*
- Cribricyathida (order) (13). *L.Cam.*
- Cribricyathidae (6). *L.Cam.*(*Botom.-Solontsov*).
- Pyxidocyathidae (6). *L.Cam.*(*Botom.-Solontsov*).
- Capillicyathidae (1). *L.Cam.*(*Botom.*).
- Vologdinophyllida (order) (13). *L.Cam.*(*Aldan.*).
- Vologdinophyllacea (superfamily) (7). *L.Cam.*(*Aldan.*).
- Leibaellidae (3). *L.Cam.*(*Aldan.*).
- Vologdinophyllidae (4). *L.Cam.*(*Aldan.*).
- Akademiophyllacea (superfamily) (6). *L.Cam.*(*Aldan.*).
- Akademiophyllidae (4). *L.Cam.*(*Aldan.*).
- Achorocyathidae (2). *L.Cam.*(*Aldan.*).
- Class Uncertain (3). *L.Cam.*(*Aldan.-low.Botom.*).
- Archaeophyllida (order) (2). ?*L.Cam.*(*low.Botom.*).
- Archaeophyllidae (2). ?*L.Cam.*(*low.Botom.*).
- Order Uncertain (1). *L.Cam.*(*Aldan.*).
- Manacyathidae (1). *L.Cam.*(*Aldan.*).
- Radiocyatha (class) (1). *L.Cam.*(*up.Atdaban.-low.Botom.*).
- Hetairacyathida (order) (1). *L.Cam.*(*up.Atdaban.-low.Botom.*).
- Hetairacyathidae (1). *L.Cam.*(*up.Atdaban.-low.Botom.*).
- Class Uncertain (probably not Archaeocyatha) (9). *Precam.-U.Cam.*, *M.Dev.*
- Order Uncertain (9). *Precam.-U.Cam.*, *M.Dev.*
- Matthewcyathidae (1). *M.Cam.*
- Korovinellidae (1). *L.Cam.*(*up.Botom.*).
- Family Uncertain (7). *Precam.-U.Cam.*, *M.Dev.*