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THE EARLY VISÉAN RUGOSE CORAL COMMUNITIES IN CHINA*

by

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(With 4 text-figures and 3 tables)

Abstract

Within China six Early Viséan rugose coral communities are recognized, they are: 1) the *Siphonophyllia* community, 2) the cool water *Gangamophyllum* community, 3) the *Thysanophyllum* community, 4) the *Bothrophyllum-Zaphrentites* community, 5) the island *Humboldtia* community and 6) the cold water *Hapsiphyllum-Rhopalolasma* community.

In northwest China, the *Siphonophyllia* community is distributed along the northern margin of the Tarim-Qaidam Oldland. The *Gangamophyllum* community was widespread north of the region occupied by the *Siphonophyllia* community, including north Tianshan, central Tianshan and east Junggar. In South China there were three rugose coral communities. The *Thysanophyllum* community occurs on the margin of the Upper Yangtze Oldland. The *Bothrophyllum-Zaphrentites* community was confined to the southern and western part of the region occupied by the *Thysanophyllum* community. These two communities merge into each other without a distinct boundary. The *Humboldtia* community is found only in the Baoshan area. The *Hapsiphyllum-Rhopalolasma* community is found in Xainza and Himalaya of Tibet.

The distribution of the six Early Viséan rugose coral communities was controlled by the palaeogeographical background. The *Gangamophyllum* community occurs along the southern margin of the Siberia Oldland, while the *Siphonophyllia* community is distributed along the northern margin of Tarim-Qaidam Oldland. The *Hapsiphyllum-Rhopalolasma* community is confined to the northern margin of the Gondwana Oldland. In the wide southern and western margin of Yangtze Oldland the distribution of the *Thysanophyllum* and the *Bothrophyllum-Zaphrentites* communities was controlled by the bathymetry. The *Humboldtia* community probably lived in island seas far from the Yangtze Oldland.

The concept of commmunity has been applied to the study of fossils for near 100 years. Although opinion is widely held on the definition of the community, many workers consider the community as a natural combination of various organisms, all living together in the same area and the same environment (Chen, 1984; Rong, 1986; Wu and Zhao, 1989).

Boucot (1975) established six benthic assemblages on the basis of the five Silurian marine brachiopod communities recognized by Ziegler (1965) between the shoreline and the pelagic facies in Wales and the Welsh Borderland. The study of Palaeozoic benthic communities shows that Boucot's benthic assemblages are very useful in showing the distribution of level-bottom benthic community in a open marine where the distribution of communities are mainly controlled by depth of sea

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water. It has to be pointed out that beside water depth, a lot of other factors, including temperature, sediments, tectonic as well as organic revolution, can affect the distribution of benthic community, and similar communities may occur in different environment. For instance, the community composed of small, solitary, nondissepimented corals, which was common in Palaeozoic period, may represent at least five different environments: 1. the lower part of continental slope in normal, warm open marine, which is represented by deep water forms described by Sando (1980); 2. deep water of faulted basins formed within the continental margin, this can be demonstrated by the forms known from the Middle Devonian Nandan type deposits of South China; 3: cold, shallow water, so far reported in Early Permian rugose corals from southern Tibet are all small solitary forms without dissepiments (Wu, 1975; Wu et al., 1982; Lin, 1983); 4. shallow water with abundant clastic sediments; and 5: normal shallow water on declining stage, exemplified by the Famennian corals in the Holy Cross Mountain of Poland (Rozkowska, 1969). Moreover, coral communities of same depth may occur in the form of reef, non-reef or only small solitary nondissepimented corals depending on the variations of the temperature. In addition, barrier seas were also present, and the massifs between adjacent continents were common during geologic history. On islands there were certain communities, which sometime look like those developed on the continental margin of the open marine. These represent a special type of environment. Therefore in the course of studying palaeoecology, palaeogeography, palaeobiogeography, tectono-palaeogeography, palaeoclimatology and others affecting the distribution of organism, should receive more attention.

All ecologists and palaeontologists agree that communities should be named, but there are divergent views on how to name a community. Environment, locality, stratigraphic unit and geologic time have been used to name communities. Recently most authors tend to name a community according to organic classification units, although no agreement exists on the level of classification units. We prefer to select dominant genera with high diversity and choose characteristic genera to designate the name of a community, which may best characterize environments in which they lived.

Pedder and McLean (1982), Liao (1984) and Wu and Zhao (1989) all accepted Boucot's (1975) benthic assemblage in rugose coral paleoecology. According to Pedder and McLean (1982), almost all Devonian, open marine, coral-bearing, level-bottom communities fall within the range of 3 through 5 in Boucot benthic assemblage scale, and some of the so-called *Cyathaxonia* facies community may include benthic assemblage 6 in this scale.

The Lower Viséan, widespread in China, is rich in rugose corals (Table 1) and provides an ideal basis for the study of rugose coral communities. So far within China, only two Early Viséan communities, the *Empachyphyllum-Clisiophyllum* community and the *Pugilis-Michelinia* community, have been recognized from western Guizhou (Wu and Zhao, 1989). In the present paper, the Early Viséan rugose corals, namely those forms occurring within the range between the *Pseudouralinia*

Table 1 The distribution of Early Viséan rugose coral genera in different parts of China (see below)

	1*	2	3	4	5	6	7	8	9	10	11
Amplexiidae											
Amplexus	×		×								
Laccophyllidae											
Amplexicarinia								×			
Barrandeophyllum	×			×							
Cyathaxoniidae											
Cyathaxonia	×							×			
Hapsiphyllidae											
Amplexizaphrentis											×
Hapsiphyllum				×	×	×					
Longiclava						×					
Zaphrentites	×	×				×		×			×
Zaphrentoididae											
Cumminsia						×					
Zaphrentoides	×										
Bradyphyllidae											
Bradyphyllum	×		×		×						
Fasciculophyllum	×										
Rotiphyllum	×										×
Plerophyllidae											
Plerophyllum						×					
Endothecium					×						
Rhopalolasma					×	×					
Lophophyllidae											
Lophophyllidium	×										
Lophophyllum	×		×				×		×		×
Caniniidae											
Caninia	×	×	×	×			×		×	×	×
Bothrophyllidae											
Bothrophyllum							×	×			×
Calmiussiphyllum								×			
Caninophyllum	×						×		×		×
Characophyllum								×			
Enygmophyllum	×							×	×		
Heterocaninia	×							×	×	×	×
Kueichouphyllum	×	×		×			×	×	×	×	×
Kusbassophyllum							×				×
Parazaphriphyllum								×			
Uralinidae											
Humboldtia	×						×				
Keyserlingophyllum							×		×		
Siphonophyllia	×	×	×	×			×	×			
Palaeosmiliidae											
Faberophyllum				×							
Palaeosmilia	×	×	×	×			×				×
Qinghaiphyllum	×										
Koninckophyllidae											
Arachnolasma	×		×	×			×		×	×	×
Eostrotion								×			
Koninckophyllum				×							
Amygdalophyllidae											
Amygdalophyllum	×										

	1*	2	3	4	5	6	7	8	9	10	11
Arachnolasmella							×				
Curruthersella	×							×	×		
Cravenia								×	×	×	
Ekvasophyllum	×										
Rylstonia	×							×			
Zaphriphyllum	×						×				
Clisiophyllidae											
Clisiophyllum	×			×			×	×	×	×	
Cyathoclisia	×						×				
Cysticyathoclisia	×										
Hunanoclisia									×	×	
Neoclisiophyllum	×			×				×	×	×	×
Dibunophyllidae											
Corwenia								×		×	×
Dibunophyllum							×	×	×	×	×
Aulophyllidae											
Auloclisia			×	×			×	×			×
Dizonophyllum								×			
Empachyphyllum								×			
Lithostrotionidae											
Diphyphyllum			×	×				×		×	×
Donophyllum							×	×	×	×	
Kwangsiphyllum										×	×
Lithostrotion	×	×	×	×					×	×	×
Orionastraea	×										
Siphonodendron	×						×				×
Auliniidae											
Aulina	×										×
Thysanophyllidae											
Dorlodotia	×										
Thysanophyllum								×	×	×	×
Stylastraea											×
Stelechophyllum											×
Petalaxidae											
Petalaxis	×								×	×	
Axophyllidae											
Axophyllum	×										
Gangamophyllum		×	×								
Lonsdaleia			×								
Paragangamophyllum								×			
Geyerophyllidae											
Kionophyllum											×

* localities:
1. the north part of the Qaidam Basin (Luo & Zhao, 1962; Wang Z. J., 1986, 1987); 2. East Junggar (Regional Geological Survey Team, Bureau of Geology and Mineral Resourecs of Xinjiang Uygur Autonomous Region, 1982; Cai, 1988); 3. North Tianshan (Reginal Geological Team, Geological Bureau of Xinjiang, 1982; Cai, 1988); 4. Central Tianshan (Regional Geological Survey Team, Bureau of Geology and Mineral Resourecs of Xinjiang Uygur Autonomous Region, 1982; Cai, 1988); 5. Xainza (Yang & Fan, 1982; Fan, 1985, 1988); 6. Himalaya (Fan 1985, 1988); 7. Baoshan-Shidian (Song, 1982; Duan, 1985); 8. the western Guizhou and the eastern Yunnnan (Wang H. D., 1978; Wu & Zhao, 1989); 9. the southern Guizhou (Wang, H. D., 1978); 10. Guangxi (Bureau of Geology and Mineral Resources of Guangxi Zhuang Autonomous Region, 1985); 11. Hunan and Guangdong (Jia et al., 1977; Jiang, 1982; Regional Geological Survey Team, Bureau of Geology and Mineral Resourecs of Hunan Province, 1987).

Table 2 The matching coefficients of Early Viséan rugose coral faunas in different parts of China

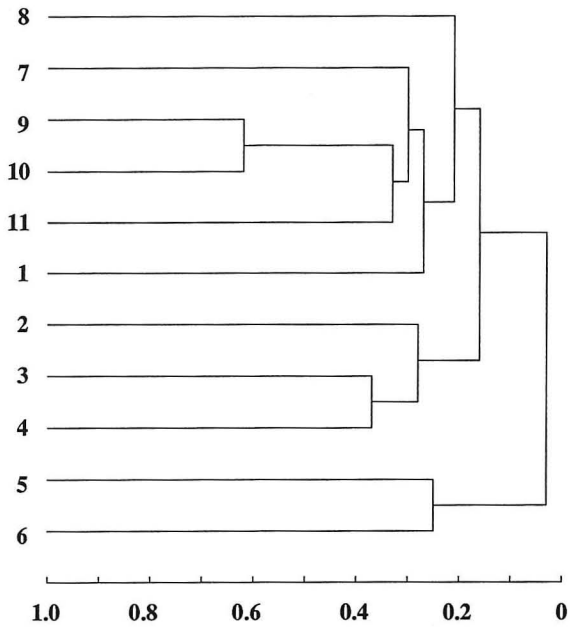
		36* 1**	7 2	12 3	14 4	4 5	6 6	19 7	26 8	18 9	16 10	25 11
36	1		6*** .162	8 .200	9 .220	1 .026	1 .024	12 .279	10 .192	12 .286	8 .182	13 .271
7	2			5 .257	5 .313	0 .000	1 .083	4 .182	3 .100	3 .136	3 .150	5 .185
12	3				7 .368	1 .067	0 .000	6 .240	3 .086	4 .154	4 .167	7 .233
14	4					1 .059	1 .053	7 .269	6 .176	6 .231	7 .304	8 .258
4	5						2 .250	0 .000	0 .000	0 .000	0 .000	0 .000
6	6							0 .000	1 .032	0 .000	0 .000	1 .033
19	7								7 .184	9 .321	6 .207	11 .333
26	8									10 .294	10 .313	10 .244
18	9										13 .619	10 .303
16	10											11 .367

* number of genera; ** localities same as in table 1: *** number of common genera in both localities, below which the matching coefficient; calculating formula of matching coefficient $Km=C/(A+B-C)$, Km: matching coefficient; A, B: number of genera occur respectively in compared both localities; C: number of common genera in both compared localities.

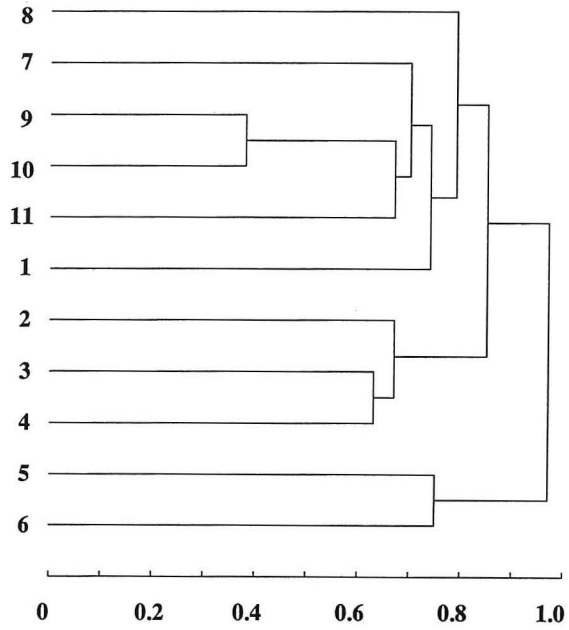
Table 3 Distance coefficients of Early Viséan rugose coral faunas in different parts of China

		36* 1**	7 2	12 3	14 4	4 5	6 6	19 7	26 8	18 9	16 10	25 11
36	1		6*** .838	8 .800	9 .781	1 .974	1 .976	12 .721	10 .808	12 .714	8 .818	13 .729
7	2			5 .643	5 .688	0 1.000	1 .917	4 .818	3 .900	3 .864	3 .850	5 .815
12	3				7 .632	1 .933	0 1.000	6 .760	3 .914	4 .846	4 .833	7 .767
14	4					1 .941	1 .947	7 .731	6 .824	6 .769	7 .696	8 .742
4	5						2 .750	0 1.00	0 1.00	0 1.00	0 1.00	0 1.00
6	6							0 1.00	1 .968	0 1.00	0 1.00	1 .967
19	7								7 .816	9 .679	6 .793	11 .667
26	8									10 .706	10 .688	10 .756
18	9										13 .381	10 .697
16	10											11 .633

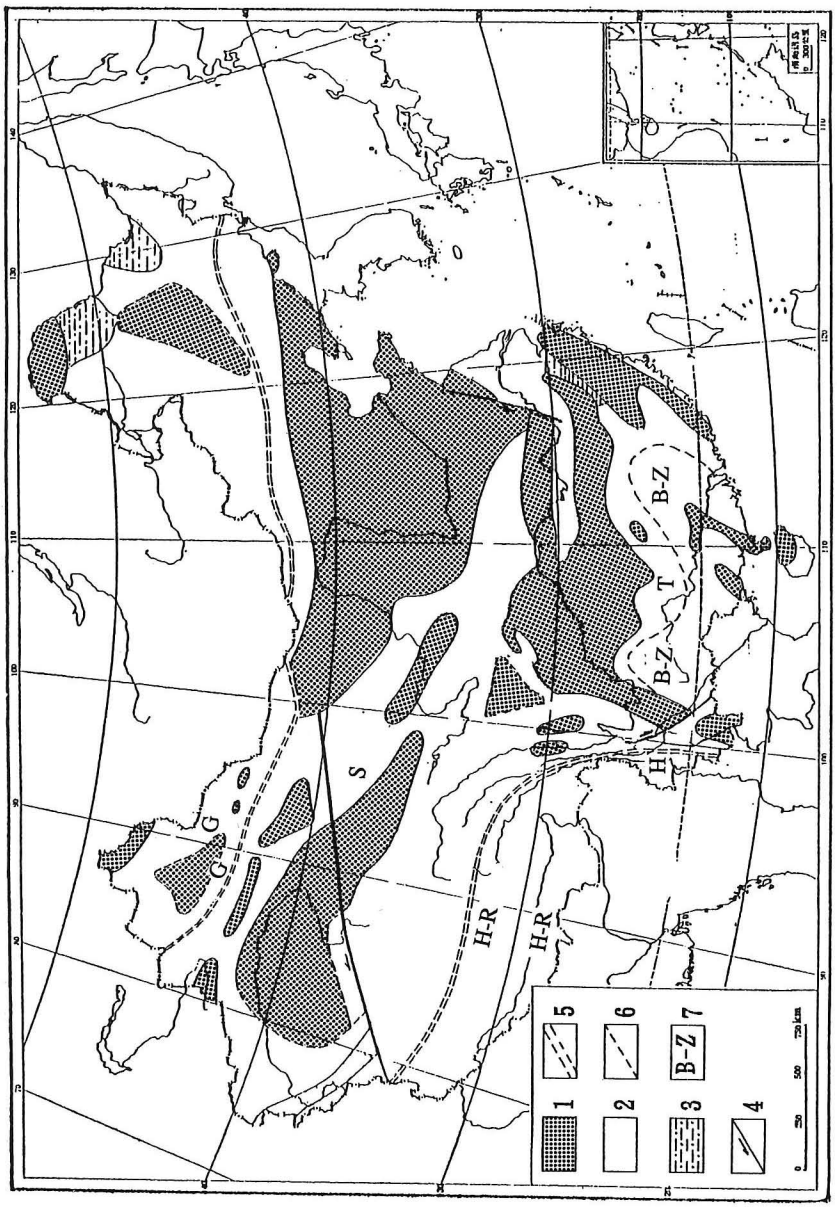
* number of genera; ** localities same as in table 1; *** number of common genera in both localities, below which is the distance coefficients; calculating formula of distance coefficient $Kd=(A+B-2C)/(A+B-C)$, Kd: distance coefficient, A, B: number of genera occurring respectively in both comparing localities; C: number of common genera in both comparing localities.



Text-fig. 1 Cluster dendrogram of the matching coefficients of Early Viséan rugose coral faunas in different parts of China
localities same as in table 1

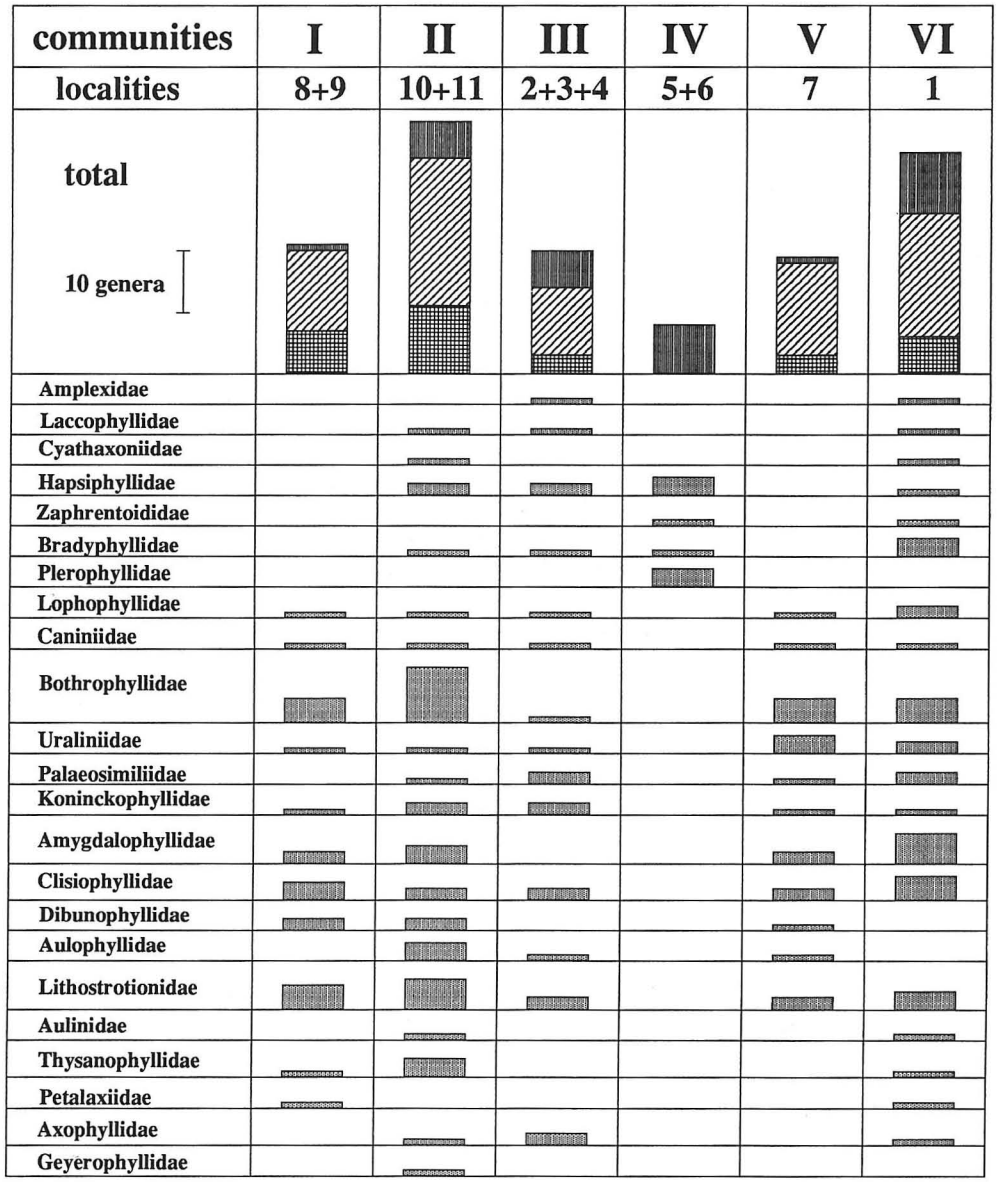


Text-fig. 2 Cluster dendrogram of the distance coefficients of Early Viséan coral faunas in different parts of China
localities same as in table 1



Text-fig. 3 The Distribution of the Early Viséan rugose coral communities in China

1. land ; 2. ocean ; 3. continental deposit ; 4. big fault ; 5. crustal convergence zone ; 6. inferred boundary between communities ; 7. community ; G. *Gangamophyllum* community ; S. *Siphonophyllia* community ; T. *Thysanophyllum* community ; B-Z. *Bothrophyllum-Zaphrentites* community ; H. *Humboldtia* community ; H-R. *Hapsiphyllum-Rhopalolasma* community.



Text-fig. 4 The components of the Early Viséan rugose coral communities in China
localities same as in table 1
Communities: I. *Thysanophyllum*; II. *Bothrophyllum-Zaphrentites*; III. *Gangamophyllum*;
IV. *Hapsiphyllum-Rhopalolasma*; V. *Humboldtia*; VI. *Siphonophyllia*.

zone and the *Yuanophyllum* zone, are statistically analysed on the basis of the Rugosa classification revised by Wang et al. (1989). According to the similarity coefficients of rugose coral faunas in various regions of China (Table 2, ; Text-figs. 1, 2) and lithofacies as well as tectono-palaeogeography, six different communities are recognized, they are: 1) the *Siphonophyllia* community, 2) the cool water *Gangamophyllum* community, 3) the *Thysanophyllum* community, 4) the *Bothrophyllum-Zaphrentites* community, 5) the island *Humboldtia* community and 6) the cold water *Hapsiphyllum-Rhopalolasma* community (Text-figs. 3, 4).

In northwest China there are two rugose coral communities. The *Siphonophyllia* community is distributed in thick-bedded limestone along the northern margin of the Tarim-Qaidam Oldland and represented by the rugose corals discovered in the northern margin of Qaidam Basin. It is high in diversity, 36 genera being found, of which 10 genera, about 28 percent of the total genera, are small nondissepimented solitary corals. Colonial rugose corals account for approximately 17 percent. Amygdalophyllidae, Clisiophyllidae and Bothrophyllidae are the most prominent. Bradyphyllidae and Lithostrotionidae are common. In this community the rugose corals are very abundant. They form bioclastic beds, of which 60 percent of individuals are *Siphonophyllia*. *Fasciculophyllum*, *Lophophyllidium*, *Qinghaiphyllum*, *Amygdalophyllum*, *Ekvasophyllum*, *Cysticyathoclisia*, *Orionastraea* and *Axophyllum* only known in this community at the period, may be regarded as the characteristic components. A few brachiopods and ostracods are associated with the rugose corals in this community. It is inferred that this community lived on the upper part of an open shelf, probably in the position of Boucot's BA4.

Another rugose coral community in north China is the *Gangamophyllum* community. This community was widespread north of the region occupied by the *Siphonophyllia* community, including north Tianshan, central Tianshan and east Junggar. Only 20 genera of rugose corals were found in clastic and tuffaceous sediments and interbedded limestone. Rugose coral individuals are also not abundant in this community. Thirty percent are small solitary corals without dissepiments; while colonial rugose corals are rare, only three genera being reported. A lot of families have their representatives, but no family is numerically abundant in the community. *Gangamophyllum*, *Lonsdaleia*, *Koninckophyllum* and *Faberophyllum* are the characteristic genera of the community. The fossils associating with the corals in this community include abundant brachiopods, lamellibranchs, rare gastropods and plants.

The study of palaeobiogeography and tectono-palaeogeography shows that this community and the *Siphonophyllia* community occurred on different continental margins and belonged to different palaeobiogeographic realms (Luo, 1985; Luo et al., 1989; Wang et al., 1989). The *Gangamophyllum* community, corresponding to Boucot's BA4, may have lived in a cool shallow water environment on the lower part of an inner-shelf which rapidly subsided.

In South China three rugose coral communities may be recognized, 1) the *Thysanophyllum* community, 2) the *Bothrophyllum-Zaphrentites* community and 3)

the *Humboldtia* community. The *Thysanophyllum* community occurs mainly in shale and marly limestones on the margin of the Upper Yangtze Oldland, represented by the rugose corals known from the southern Guizhou and Guangxi. It is not rich in individuals, and the diversity is also not high, with only 20 genera of rugose corals, of which only one genus of small solitary nondissepimented corals is present; But colonial rugose corals are common, about 35 percent in the number of genera. Bothrophyllidae and Lithostrotionidae are the most prominent families, and Clisiophyllidae is common. *Hunanoclisia* is the only characteristic genus of the community. The most striking characteristics of the rugose corals in the community is the rarity in small solitary corals without dissepiments and the abundance of colonial corals. A few brachiopods, lamellibranchs, bryozoans, gastropods, cephalopods and stems of crinoids are associated with corals in the community. The community may have lived in the innerpart of an open shelf and fall into the position of Boucot's BA3.

The *Bothrophyllum-Zaphrentites* community was confined to the southern and western part of the region occupied by the *Thysanophyllum* community. These two communities merge into each other without a distinct boundary. The *Bothrophyllum-Zaphrentites* community occurs in fine bioclastic limestone and marly limestone, is rich in rugose corals and high in diversity, containing 41genera, of which about 15 percent are small solitary corals without dissepiments; colonial corals account for approximately 27 percent. Bothrophyllidae is the most prominent family, in which 9 genera were discovered in the community. Lithostrotionidae are also very common, up to 5 genera. *Amplexocarina*, *Amplexizaphrentis*, *Charcophyllum*, *Parazaphriphyllum*, *Eostrotion*, *Dizonophyllum*, *Empachyphyllum* and *Paragangamophyllum* are known only in this community. The fossils associated with the corals in the *Bothrophyllum-Zaphrentites* community include brachiopods, tabulate corals, foraminifers and conodonts. In the western Guizhou the community corresponds to the *Empachyphyllum-Clisiophyllum* community and the *Pugilis-Michelinia* community proposed by Wu and Zhao (1989). According to the description given by Wu and Zhao (1989, p. 31), the *Pugilis-Michelinia* community is silimar to the *Empachyphyllum-Clisiophyllum* community in palaeontological components and lithological character, but differs in having *Pugilis*, *Delepinea* and *Megachonets* as characteristic genera rather than *Empachyphyllum* and *Clisiophyllum*. *Empachyphyllum* is a new genus established by Wu and Zhao in 1989. *Clisiophyllum* is also known in the *Thysanophyllum* community. *Bothrophyllum* and *Zaphrentites* only occur in the western Guizhou, Hunan and Guangdong, therefore both genera are selected as representatives of the community distributed in the regions mentioned above.

As noted above, the *Bothrophyllum-Zaphrentites* community and *Thysanophyllum* community merge without distinct boundaries. There are some common genera in both communities. This phenomenon is common in communities occurring in wide continental margins. The *Bothrophyllum-Zaphrentites* community and the *Thysanophyllum* community may be distinguished as follows: (1) The fossils of the *Thysanophyllum* community are commonly preserved in shale, but those of *Bothro-*

phyllum-Zaphrentites community occur in fine bioclastic limestones and marly limestones. (2) The *Thysanophyllum* community is not rich in rugose corals, is lower in diversity, almost no small solitary nondissepimented corals are present, and contains more colonial corals. The *Bothrophyllum-Zaphrentites* community contains numerous genera, and is very rich in individuals. About 15 percent of this community are small solitary corals without dissepiments; and the percentage of colonial corals is lower than that in the *Thysanophyllum* community. In accordance with the lithological characteristics and components of the *Bothrophyllum-Zaphrentites* community as well as palaeogeographical considerations, it is inferred that the community probably flourished in a shallow water environment on the outer shelf, corresponding to the upper part of Boucot's BA4 or lower part of BA3.

It should be pointed out that in both cluster dendrograms the rugose corals from the western Guizhou are different from those from the other regions within south China. This appearence results mainly because more new genera were described recently in the material from the western Guizhou; of the 26 genera of rugose corals recorded, 5 genera are new, yet the classificational system adopted here encompass more genera. Inconsistent units of classification of course affects the outcome of the cluster analysis.

The *Humboldtia* community is found only in the Baoshan area. It is very rich in individuals, but low in diversity. Only 19 genera have been discovered, of which small solitary nondissepimented corals are almost absent, and colonial corals are represented by only 3 genera. About 80 percent are solitary dissepimented corals. Amygdalophyllidae, Clisiophyllidae and Bothrophyllidae are the most prominent families in the community. This community occurs in limestones and bioclastic limestone, in which rugose corals are associated with brachiopods, ostracods, foraminfers, bryozoans and abundant stems of crinoid. During Late Palaeozeic time, the fauna in Baoshan was different from that in the Yangtze Oldland. Most typical components of the Yangtze Oldland, for example, Devonian corals *Temnophyllum*, *Endophyllum*, *Pseudozaphrentis*, brachiopods *Stringocephalus*, *Cyrtospirifer* and Carboniferous corals *Cystiphrentis*, *Pseudouralinia, Thysanophyllum*, *Yuanophyllum*, a brachiopod genus *Gigantoproductus* do not reach Baoshan. Moreover, in Middle and Late Devonian and Early Carboniferous time, the Baoshan area was rich in rugose corals, but the diversity was low. Maybe an abundant fauna with low diversity are characters peculiar to the fauna living on islands. The *Humboldtia* community in Baoshan probably lived on island seas off the the Yangtze Oldland, in water depth ranging from the upper part of Boucot's BA4 to the lower part of BA3.

The *Hapsiphyllum-Rhopalolasma* community is found in Xainza and Himalaya of Tibet. Only eight genera of rugose corals scarce in individuals, occur in bioclastic and clastic limestone. All of them are small solitary corals and no dissepimented solitary corals nor colonial corals are present. Cyathaxoniidae and Plerophyllidae are dominant, *Plerophyllum*, *Endothecium*, *Rhopalolasma, Longiclava* and *Cumminsia* are the characteristic genera of this community. In this community

rugose corals are associated with brachiopods, crinoid stems, lamellibranchs and gastropods. The study of palaeobiogeography and palaeotectonic (Fan, 1985; Wang et al. 1989) showed that the regions inhabited by the organisms of the *Hapsiphyllum-Rhopalolasma* community are the northern margin of the Gondwana Oldland. Therefore the *Hapsiphyllum-Rhopalolasma* communty may have lived in a nearshore shallow coldwater environment, which corresponds to Boucot's BA4.

The study of tectono-palaeogeography and palaeobiogeography shows that the distribution of the six Early Visẽan rugose coral communities was controlled by the palaeogeographical background. The *Gangamophyllum* community occurs along the southern margin of the Siberia Oldland, while the *Siphonophyllia* community is distributed along the northern margin of Tarim-Qaidam Oldland. The *Hapsiphyllum-Rhopalolasma* community is confined to the northern margin of the Gondwana Oldland. In the wide southern and western margin of Yangtze Oldland the distribution of the *Thysanophyllum* and the *Bothrophyllum-Zaphrentites* communities was controlled by the bathymetry. The *Humboldtia* community probably lived in island seas far from the Yangtze Oldland.

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