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Significance of radiolarian cherts from the Chert-Spilite Formation, Telupid, Sabah

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Abstract: Chert in Telupid area is found associated with basalt, serpentinite and peridotite. This rock association may represent a part of the ophiolite sequence. The chert occurs as thinly bedded chert interbeds with siliceous shale. The chert is red to reddish brown in colour. The chert contains abundant skeletons of radiolaria. The radiolaria were retrieved, from their siliceous matrix by leaching with hydrofluoric acid. Several species of radiolaria were identified and their age was determined. Geochemical analysis of bedded radiolarian chert exhibits very high percentage of silica (more than 75%). Most of the chert consists of biogenic silica., The low content of Al_2O_3 and CaO suggests that the chert was deposited very far away from sources of terigenous detritus and below the calcite compensation depth.

Abstrak: Rijang di kawasan Telupid didapati berasosiasi dengan basalt, serpentinit dan peridotit. Asosiasi batuan ini mewakili sebahagian jujukan ofiolit. Rijang ini wujud sebagai lapisan nipis yang berselang lapis dengan syal bersilika. Rijang ini berwarna merah hingga merah-perang. Rijang mengandungi kelimpahan rangka radiolaria. Radiolaria dikeluarkan daripada matrik silika dengan melarutkan dalam asid hidrofluorik. Beberapa spesies radiolaria dikenalpasti dan usia telah ditentukan. Analisis geokimia lapisan rijang berradiolaria menunjukkan peratusan silika yang tinggi (lebih 75%), kebanyakannya terdiri daripada silika biogen. Kandungan Al_2O_3 dan CaO yang rendah mencadangkan rijang ini diendapkan jauh daripada punca gersik terigen dan diendapkan di bawah kedalaman pampasan kalsit.

INTRODUCTION

The Chert-Spilite Formation was introduced by Fitch (1955) for a sequence of rocks consisting of chert, red and gray shale, sandstone, calcareous siltstone, limestone, marl, porcelanite and conglomerate associated with volcanic rocks comprising pillow lava, basalt, spilite and diabase. The term Chert-Spilite Formation is misleading and should be reviewed. The word "Formation" is mainly used for sedimentary rocks, low grade metamorphic rocks, interbedded volcanic rocks and stratified volcanic rocks. The Chert-Spilite Formation consists of two classes of rocks viz. sedimentary and mafic and ultramafic igneous rocks. The word "complex" is more appropriate (Article 37. North American Commission on Stratigraphic Nomenclature, 1983). I would like to propose the term "Telupid complex" (informal name) for the rock association which consists of peridotite, serpentinized peridotite, serpentinite, basalt (spilite) and chert in the Telupid area.

The rocks in Telupid area were classified into at least four formations viz. the Chert-Spilite Formation, ultramafic rocks (mainly of serpentinite and peridotite),

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Kulapis Formation and Garinono Formation (Fitch, 1955; Wilson, 1963; Leong, 1974; Walls and Johnston, 1975). The Chert in Telupid area, comprises interbedded of radiolarian chert and siliceous shale which overlies the pillow lava, basalt, spilite, serpentinite and peridotite. The chert is commonly thinly bedded and interbeds with siliceous shale. The thickness of the chert beds ranges from 2cm to 10 cm thick. This sequence is known as radiolarite (Folk and McBride, 1978). Most of the bedded chert is folded and fractured. The colour of the chert varies from dark brown to red.

Several chert samples were collected from the Ruku-Ruku valley in the Telupid area for petrological, geochemical and micropaleontological studies. The geochemical composition and mineralogy of the chert were determined by using X-ray analisis (X-ray fluorescence and X-ray diffraction methods). Radiolaria in the chert are quite well preserved. They were retrieved by using hydroflouric acid. Some of them are still in their original shapes. The aims of this paper are to study the biogenic and geochemical composition of the chert and siliceous shale, and their significance for determining environment of deposition, and their age.

GEOLOGICAL SETTING

The Telupid area is composed of three types of rocks, viz. ultramafic and mafic rocks, chert sequence, and olistostrome. The ultramafic and mafic rocks consist mainly of peridotite, serpentinite, basalt, spilite and pillow lava. These rocks are widely distributed in this area and their boundaries are not very clear. This rock association represents the initial oceanic crust prior to deposition of the chert sequence. Kirk (1968) considers that the mafic and ultramafic rocks of this area as an ophiolitic association which were emplaced during the Late Cretaceous and Tertiary.

The chert sequence is exposed only in the Ruku-Ruku valley (Fig.1). The valley is surrounded by serpentinite and peridotite hills. This chert sequence is underlain by basalt, pillow lava, spilite, serpentinite, serpentinised peridotite and peridotite. The chert sequence is composed of rhythmic alternations of thinly interbedded of red chert and strongly weathered siliceous shale, otherwise known as ribbon chert. The boundaries between chert and siliceous shale are sharp. These rocks were folded and the total thickness of the bed was not known. The state of preservation of radiolaria reveals that the chert was not affected by metamorphism, but it shows some diagenetic changes.

At locality 2 (see figure 1) the chert sequence and the spilitic lava are separated by a highly weathered red mudstone. The lower part of the mudstone contains some pebbles and granules of spilitic lava. The top part contains numerous poorly preserved radiolaria. The ultramafic rocks such as peridotite, serpentinised peridotite and peridotite are slightly weathered. Pelagic limestone is not found in this area.

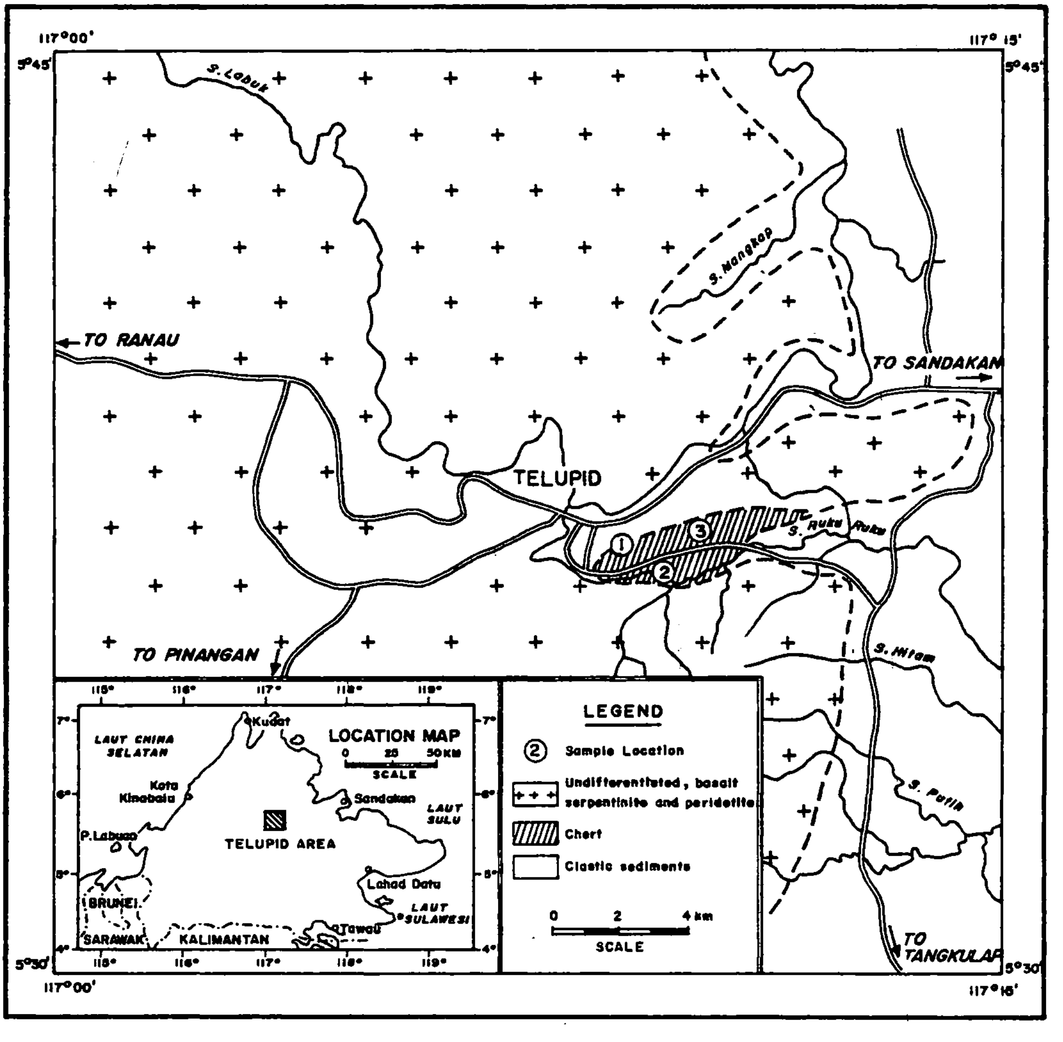

Figure 1: Geological map of Telupid area showing fossil localities.

The olistostrome was previously mapped as Kulapis and Garinono Formations by Walls and Johnston (1975). Many exposures of the olistostrome were recently exposed along the road-cut at the east of Telupid town. The olistostrome consists of various sizes olistoliths which ranges from mega-boulders to granules. All the olistoliths are embedded in highly sheared black mudstone matrix. The occurrence of some Middle Eocene larger foraminifera such as *Nummulites* sp. and *Pellatispira* sp. in a limestone boulder suggests that the age of the olistostrome is younger than Middle Eocene (probably Late Eocene-Oligocene).

A detailed observation at the distribution of the chert sequence, the mafic and ultramafic rocks and their relationship reveals that this rock association is actually a part of dismembered ophiolite sequence which represents a top part of oceanic crust. Basalt, pillow-lava, spilite, serpentinite and peridotite formed the initial oceanic crust as a result of sea floor spreading or rifting, then followed later by deposition of interbedded radiolarian chert and siliceous shale. This ophiolite sequence was obducted or thrusted prior to the deposition of Tertiary sediments (Rangin *et al.*, 1990).

MATERIAL AND METHOD

Several chert samples were collected from two abandoned earth quarries and a road-cut. Two samples (R1 and R2) were collected from a quarry at locality 1 (see figure 1). Sample R1 was taken at the topmost of the chert sequence. Samples R2 was taken at the bottom of the chert sequence. Sample R3 and R4 were taken from a chert layer and a siliceous shale bed respectively at the road-cut locality 2. At this locality, the chert sequence overlies the basaltic pillow lava. Samples R5 and R6 were collected from a quarry at locality 3. Sample R5 represents a chert bed and R6 represents siliceous shale bed.

The samples were cut into several thin-sections for microscopic studies. Some parts of the samples were processed for X-ray analysis. The remaining parts were treated with hydrofluoric acid to extract the radiolaria.

PETROGRAPHY AND GEOCHEMISTRY OF THE CHERT SEQUENCE

The chert consists of abundant skeletons of radiolaria which were preserved as cryptocrystalline quartz crystals in siliceous matrix. Some chert contain variable amount of clay (2%-15%) and hematite (1%-17%). In the thin section, the radiolaria appear as grains of various shapes from spherical spumellariids to conical nassellarids (figure 2). They are embedded in siliceous clay matrix mixed with hematite. The original opal tests of radiolaria are now composed of microcrystalline quartz 5-20 μm. The central capsules of radiolaria are filled by chalcedony. Most of radiolaria are still in their original shapes. Various sizes and shapes of radiolaria were deposited together in a layer of the chert. This indicates that they were not transported by current. Some bedded radiolarian cherts exhibit gradded bedding with an upward decreases in size .

The siliceous shale is composed of up to 20 percent of microcrystalline quartz of poorly preserved radiolarian tests (radiolarian ghosts) and the rest are silica, clay minerals and limonite (figure 3). The siliceous shale is highly weathered. A large number of radiolaria were retrieved from the shale but the state of preservation is very poor compared to those of the radiolarian chert.

Major elements analysis of a few selected chert and siliceous shale was carried out by using X-ray fluorescence method. The radiolarian chert samples contain more than 75% of silica, less than 6% of Al_2O_3 ,less than 8% of iron oxide and other elements are traced (table 1). This indicates that the radiolarian chert contains very high percentage of silica and very low percentage of clay and iron oxide. Iron oxide in the chert occurs as hematite which gives the red-brown colour.

The selected siliceous shale samples contain lower percentage of silica compared to those of radiolarian chert (table 1, samples R4 and R6). The samples have higher percentage of Al_2O_3 and iron oxide. This indicates that the siliceous shale contains high percentage of clay and iron oxide. Two types of clay minerals were identified by using X-ray diffraction method, they are mainly illite and kaolinite. Iron oxide in the shale occurs as limonite.

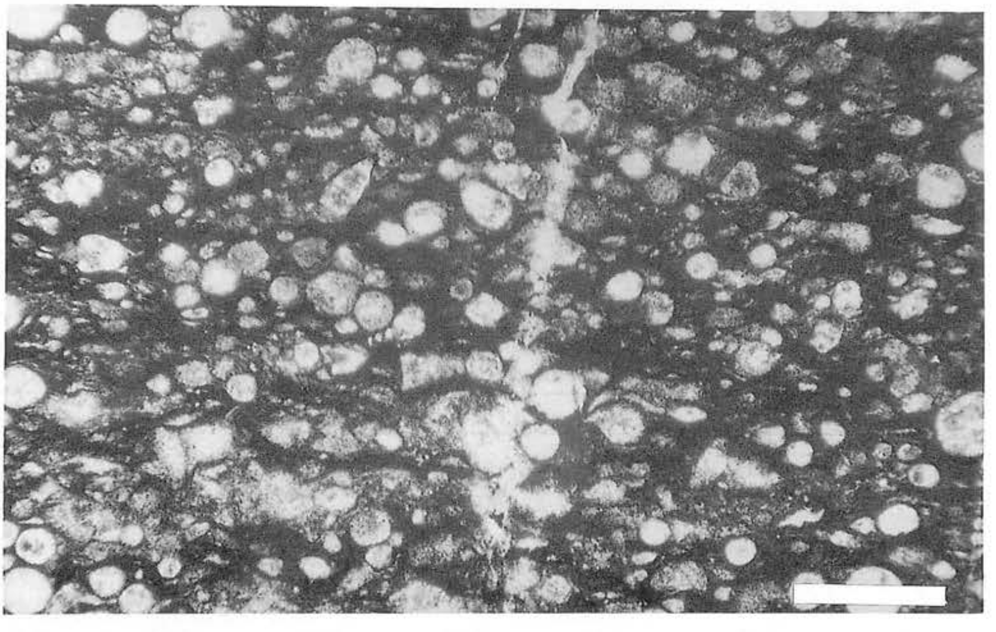

Figure 2: Photomicrograph of radiolarian chert showing various sizes and shapes of radiolaria. Scale bar is 0.5mm.

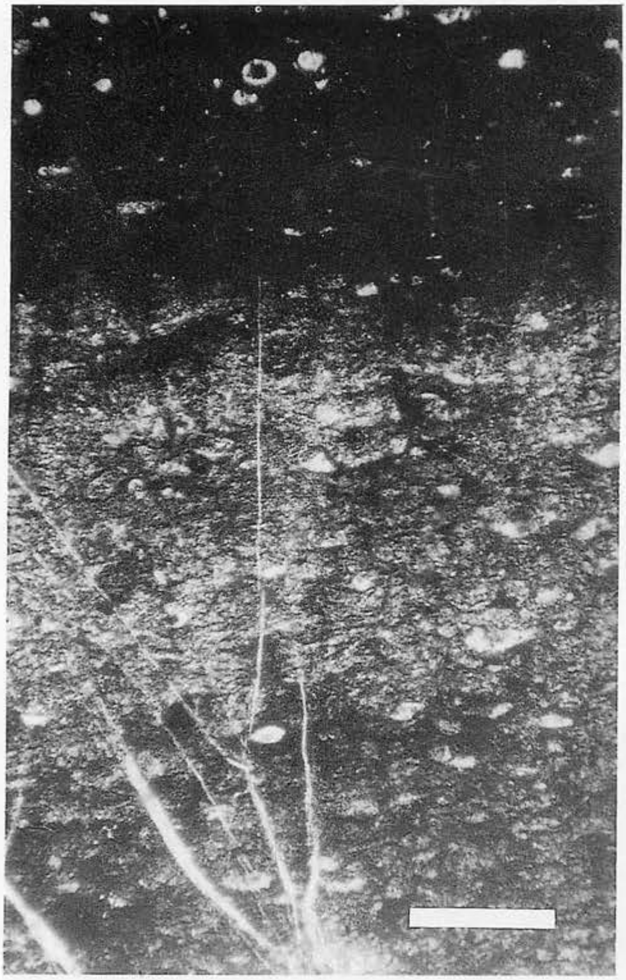

Figure 3: Photomicrograph of siliceous shale. Scale bar is 0.5mm.

Table 1. Geochemical composition of some selected chert and siliceous shale samples.

Oxides	Sample No. and Percentage of oxides					
	R1	R2	R3	R4	R5	R6
SiO_2	90.97	86.71	91.04	52.79	77.52	67.36
Al_2O_3	2.69	3.41	2.45	15.39	5.58	14.08
Fe_2O_3	2.48	1.73	3.12	17.42	7.78	7.53
MgO	0.76	1.26	0.52	0.83	1.81	1.19
CaO	0.16	0.65	0.06	0.01	0.05	0.04
Na_2O	0.06	0.60	0.05	0.38	0.08	0.58
K_2O	0.39	0.43	0.09	0.09	1.83	0.21
TiO_2	0.01	0.16	0.06	0.51	0.26	0.80
P_4O_5	0.01	0.11	0.07	0.07	0.08	0.08
MnO	0.16	0.11	0.02	0.11	0.07	0.14
LOI	2.29	5.05	2.43	12.42	4.94	7.98
	99.98	100.22	100.00	100.02	100.00	99.99

ENVIRONMENT OF DEPOSITION

The main source of the bedded chert was biogenic silica from radiolaria only. There was no skeletons of diatoms or sponge spicules present. According to Jones and Murchey (1986), a large number radiolaria are dissolved in the water column before they are deposited on the ocean floor. Some of them are usually destroyed due to diagenetic process. Rapid production of radiolaria is considered to be a requirement for the formation of bedded chert. In the present ocean, a high productivity of radiolaria is found in an upwelling area.

This bedded radiolarian chert was probably accumulated in the upwelling belts where the productivity of radiolaria was high. The depositional environment in which radiolarian-rich siliceous sediments accumulated must have been away from sources of terrigenous material. The absence of pelagic limestone and a very low percentage of calcium present in the chert indicate that the chert was deposited below the calcite compensation depth, (the depth at which calcite dissolves in ocean). The calcite compensation depth is variable. It is elevated in the regions of upwelling. This bedded chert was probably deposited below the calcite compensation depth in an upwelling belt of the equatorial ocean.

In contrast, the siliceous shale which interbeds with radiolarian chert contains higher percentage of Al_2O_3, the element which is commonly found in the terrigenous clastic sediments especially mud. The mud was probably transported either by weak bottom current or deposition from the water column.

The rhythmic beddings of chert sequence may be explained by four hypotheses (McBride and Folk, 1979); (1), diagenetic segregation of silica from initially sub-homogenous siliceous mud; (2) episodes of rapid and slow production of radiolaria in surface waters during the constant rate of mud deposition; (3) episodes of current deposition of radiolarian silt during constant mud deposition; (4) episodes of current deposition of mud during constant radiolaria sedimentation. In the present study, the development of the rhythmic beddings of the chert sequence may be related to more than a single process.

The radiolarian chert sequence was probably deposited on a sea floor during the early period of seafloor spreading or rifting. It seems that the chert was accumulated in a graben very far away from the source of terrigenous clastics. It was deposited below the calcite compensation depth near the upwelling zone. This environment was probably influenced by episodic bottom currents which supplied the mud particles.

AGE OF RADIOLARIAN CHERT

Several chert samples were collected from the Ruku-Ruku valley, only six samples yielded quite well preserved radiolaria. Radiolaria in the chert are better preserved compared to those of siliceous shale. A total of 28 species radiolaria were identified (table 2). The most common species are *Conosphaera tuberosa*

Table 2. Occurrence and distribution of radiolaria. The number of individuals are represented by letter symbols (C) common and (R) rare.

	Location	1		2		3	
	Sample Number	R_1	R_2	R_3	R_4	R_5	R_6
1.	*Acaeniotyle diaphorogona*			R			
2.	*Acaeniotyle umbilicata*			R	R		
3.	*Conosphaera tuberosa*	C	C	C	C	C	
4.	*Staurosphaera septemporata*			R			
5.	*Hagiastrum* sp.		R	C		C	
6.	*Higumastra* sp.			R	R	R	
7.	*Paronaella* sp.	C	C	C		C	
8.	*Alievium* sp.		R	R	R		
9.	*Spongodiscus* sp.			R	R	R	
10.	*Orbiculiforma* sp.			R	R	R	
11.	*Archaeodictyomitra brouweri*	R		R	R		
12.	*Archaeodictyomitra pseudoscalaris*	R	R	C	R	R	R
13.	*Archaeodictyomitra vulgaris*	R		C	R	R	
14.	*Archaeodictyomitra* sp.	R		C	R	C	R
15.	*Eucyrtis micropora*			R		R	
16.	*Lithomitra pseudopinguis*			R	R	R	
17.	*Pseudodictyomitra* sp.	R		C	R	C	
18.	*Pseudodictyomitra carpatica*	R	R	C	R	C	
19.	*Pseudodictyomitra lilyae*			C	R	R	
20.	*Sethocapsa cribrata*			R	R	R	
21.	*Stichomitra asymbatos*	R	R	C	C	C	
22.	*Thanarla conica*	C	C	C	C	C	C
23.	*Thanarla pulchra*	C	C	C	C	C	C
24.	*Ultranapora* sp.			R		R	
25.	*Xitus alievi*			C	R	C	
26.	*Xitus spicularius*	R	R	R	C	C	
27.	*Siphocampium davidi*		R	C	R		
28.	*Hemicryptocapsa pseudopilula*	C	C	C	C	C	C

Tan Sin Hok, *Archaeodictyomitra pseudoscalaris* (Tan Sin Hok), *Archaeodictyomitra vulgaris* (Pessagno), *Pseudodictyomitra carpatica* (Lozynyak), *Stichomitra asymbatos* Foreman, *Thanarla conica* (Aliev), *Thanarla pulchra* (Squinabol), *Xitus spicularius* (Aliev), *Hemicryptocapsa pseudopilula* Tan Sin Hok, and *Archaeodictyomitra* sp.

The less common species are *Lithomitra pseudopinguis* Tan Sin Hok, *Pseudodictyomitra lilyae* Tan Sin Hok, *Sithocapsa cribrata* Hinde, *Xitus alievi* (Foreman), *Siphocampium davidi* Schaaf, *Archaeodictyomitra brouweri* Tan Sin Hok, *Hagiastrum* sp., *Higumastra* sp. *Paronaella* sp., *Alievium* sp., *Spongodiscus* sp., *Orbiculiforma* sp., and *Pseudodictyomitra* sp..

The rare species are *Acaeniotyle umbilicata* (Rust), *Acaeniotyle diaphorogona* Foreman, *Staurosphaera septemporata* Parona, *Eucyrtis micropora* (Squinabol), and *Ultranapora* sp..

Stratigraphical distribution of radiolaria from the six selected samples exhibits no significant difference in age of the chert. The different assemblages among the samples were probably due to the state of preservation rather than the change in true population of the fauna. Since the samples were not systematically collected, a detailed biostratigraphic zonation cannot be established. The radiolarian assemblage indicates that the age of the chert sequence is Early Cretaceous. Based on stratigraphic distribution of some selected radiolarian species (figure 4), the radiolarian assemblage of the present material indicates that the most probable age of the chert ranges from the *Staurosphaera septemporata* Zone to the *Crolanium pythiae* Zone (late Valanginian to Barremian), the same age as established by Leong (1977).

The younger chert was not found in this area. The studies of radiolarian chert from the Chert-Spilite Formation in central and northern Sabah particularly at Kudat Peninsula (Basir Jasin and Sanudin Tahir, 1988) and Taratipan area (Basir Jasin and Sanatulsalwa Hasan in preparation) indicate that the age of the chert is restricted to Early Cretaceous only. The basaltic rocks, serpentinite and peridotite which formed below the chert were older than the chert. These rocks were probably emplaced during the Late Jurassic or very Early Cretaceous and not in the Late Cretaceous and Early Tertiary as suggested by Kirks (1968). The chert is stratigraphically separated from the olistostrome by a hiatus which ranges from the Late Cretaceous to Eocene. This period of non-deposition or erosion could be related to the intensive tectonic activities prior to the deposition of the olistostrome.

CONCLUSION

The Chert-Spilite Formation and the ultramafic rocks which were previously separated, are now group together as Telupid complex which represents a part of dismembered ophiolite sequence. It is now suggested that the age of the ultramafic igneous rocks were older than the Early Cretaceous and most probably Late

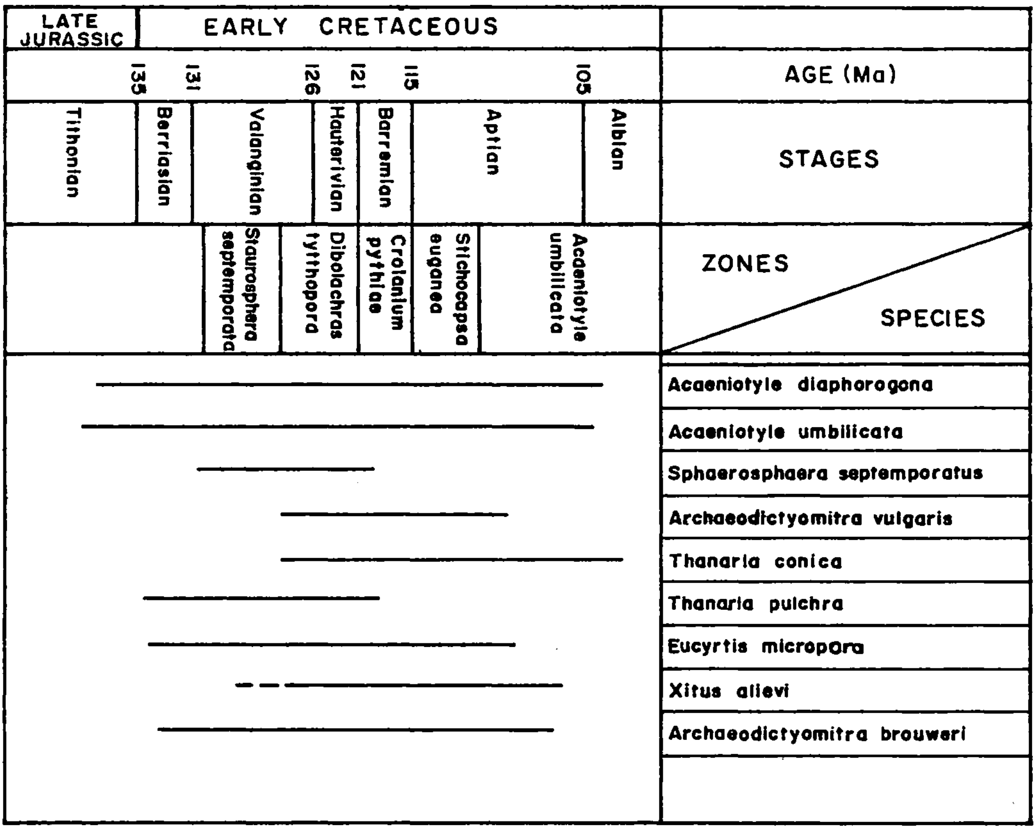

Figure 4: Stratigraphical distribution of some selected species of radiolaria (based on Sanfilippo and Riedel, 1985)

Jurassic. The radiolarian assemblage indicates that the age of the chert sequence of the Telupid complex is Early Cretaceous (fig.5). The dismembered ophiolite sequence was exposed by obduction or thrusted during the Late Cretaceous-Early Paleogene, prior to the deposition of Tertiary clastic sediments.

The seafloor spreading during the Late Jurassic or early Early Cretaceous, produced initial layers of seafloor aphiolite sequence which comprises basalt, serpentinite and peridotite. This event was followed by deposition of chert and siliceous shale beds during the Early Cretaceous. The deposition of these rocks were probably occurred in a graben which was episodically influenced by weak bottom currents. I conclude that the rocks were deposited in a relatively deep water environment below the calcite compensation depth.

This dismembered ophiolite sequence is stratigraphically separated from the younger clastic sediments by a hiatus which ranges from the Late Cretaceous to Paleocene. This stratigraphic gap probably represents a period of intensive tectonic activities.

OUTLINE OF CLASSIFICATION

All the specimens are illustrated on plate 1, 2, and 3. A detailed systematic classification of the species will be described elsewhere.

Subclass: RADIOLARIA Muller
Superorder: POLYCYSTINA Ehrenberg
Order: SPUMELLARIA Ehrenberg
Family: ACTINOMMIDAE Haeckel

Acaeniotyle diaphorogona Foreman
Acaeniotyle umbilicata (Rust)
Conosphaera tuberosa Tan Sin Hok
Stourosphaera septemporata Parona

Family: HAGIASTERIDAE Riedel

Hagiastrum sp.
Higumastra sp.

Family: PATULIBRACCHIIDAE Pessagno

Paronaella sp.

Family: PSEUDOAULOPHACIDAE Riedel

Alievium sp.

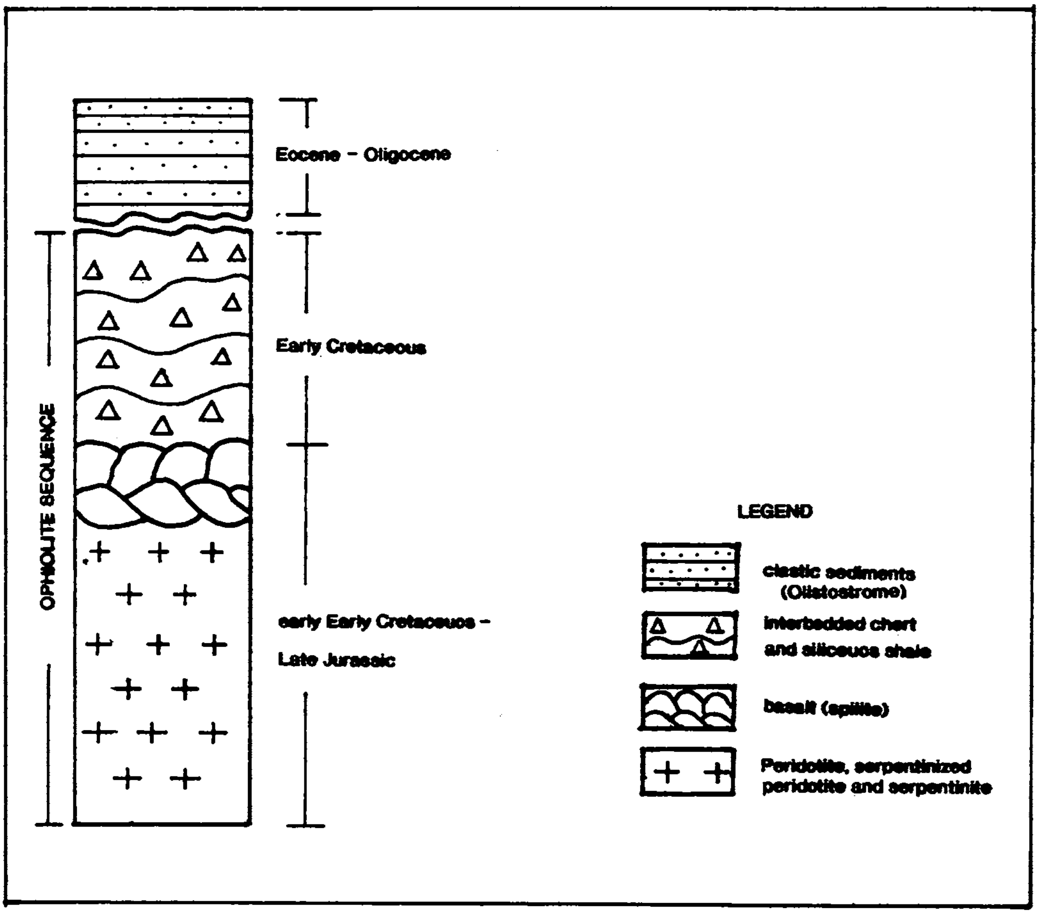

Figure 5: Stratigraphic relationship of various rocks in the Telupid Area (figure not to the scale).

Family: SPONGODISCIDAE Haeckel

Spongodiscus sp.
Orbiculiforma sp.

Order: NASSELLARIA Haeckel
Suborder: CYRTIDA Haeckel
Family: ARCHAEODICTYOMITRIDAE Pessagno

Archaeodictyomitra brouweri var. a (Tan Sin Hok)
Archaeodictyomitra pseudoscalaris (Tan Sin Hok)
Archaeodictyomitra vulgaris Pessagno
Archaeodictyomitra sp.
Thanarla conica (Aliev)
Thanarla pulchra (Squinabol)

Family: EUCYRTIDAE

Eucyrtis microphora (Squinabol)

Family: PSEUDODICTYOMITRIDAE Pessagno

Pseudodictyomitra lilyae (Tan Sin Hok)
Pseudodictyomitra carpatica (Lozynyak)
Pseudodictyomitra sp.

Family: SYRINGOCAPSIDAE Foreman

Sethocapsa cribrata Hinde

Family: THEOPERIDAE Haeckel

Lithomitra (?) *pseudopinguis* Tan Sin Hok
Stichomitra asymbatos Foreman

Family: ULTRANAPORIDAE Pessagno

Ultranapora sp.

Family: XITIDAE Pessagno

Xitus alievi (Foreman)
Xitus spicularius (Aliev)

Family: AMPHIPYNDACIDAE Riedel

Siphocampium davidi Schaaf

Family: WILLIRIEDELLIDAE Dumitrica

Hemicryptocapsa pseudopilula Tan Sin Hok.

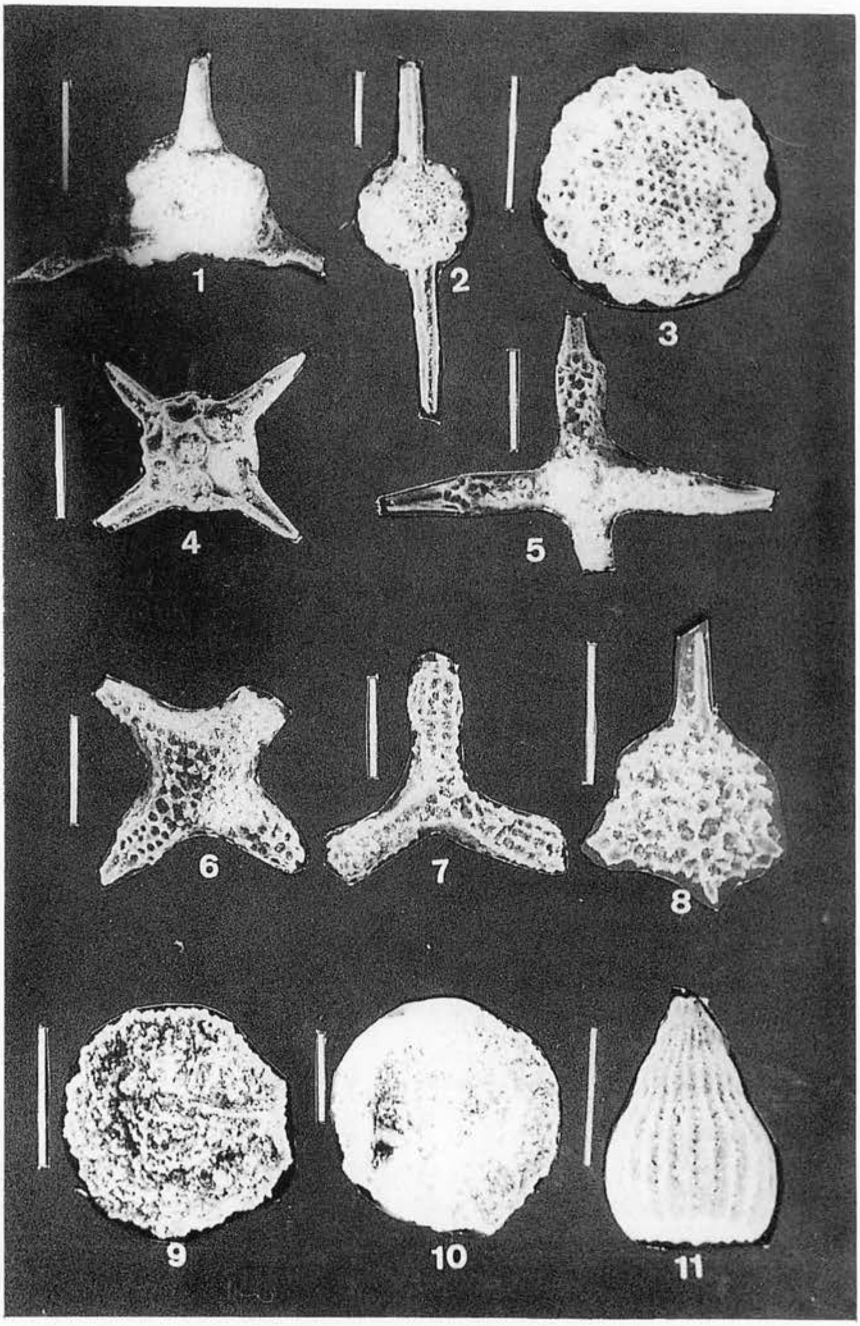

Plate 1. (Scale bar = 0.1mm)

1. *Acaeniotyle diaphorogona* Foreman.
2. *Acaeniotyle umbilicata* (Rust)
3. *Conosphaera tuberosa* Tan Sin Hok
4. *Staurosphaera septemporata* Parona
5. *Hagiastrum* sp.
6. *Higumastra* sp.
7. *Paronaella* sp.
8. *Alievium* sp.
9. *Spongodiscus* sp.
10. *Orbiculiforma* sp.
11. *Archaeodictyomitra brouweri* (Tan Sin Hok)

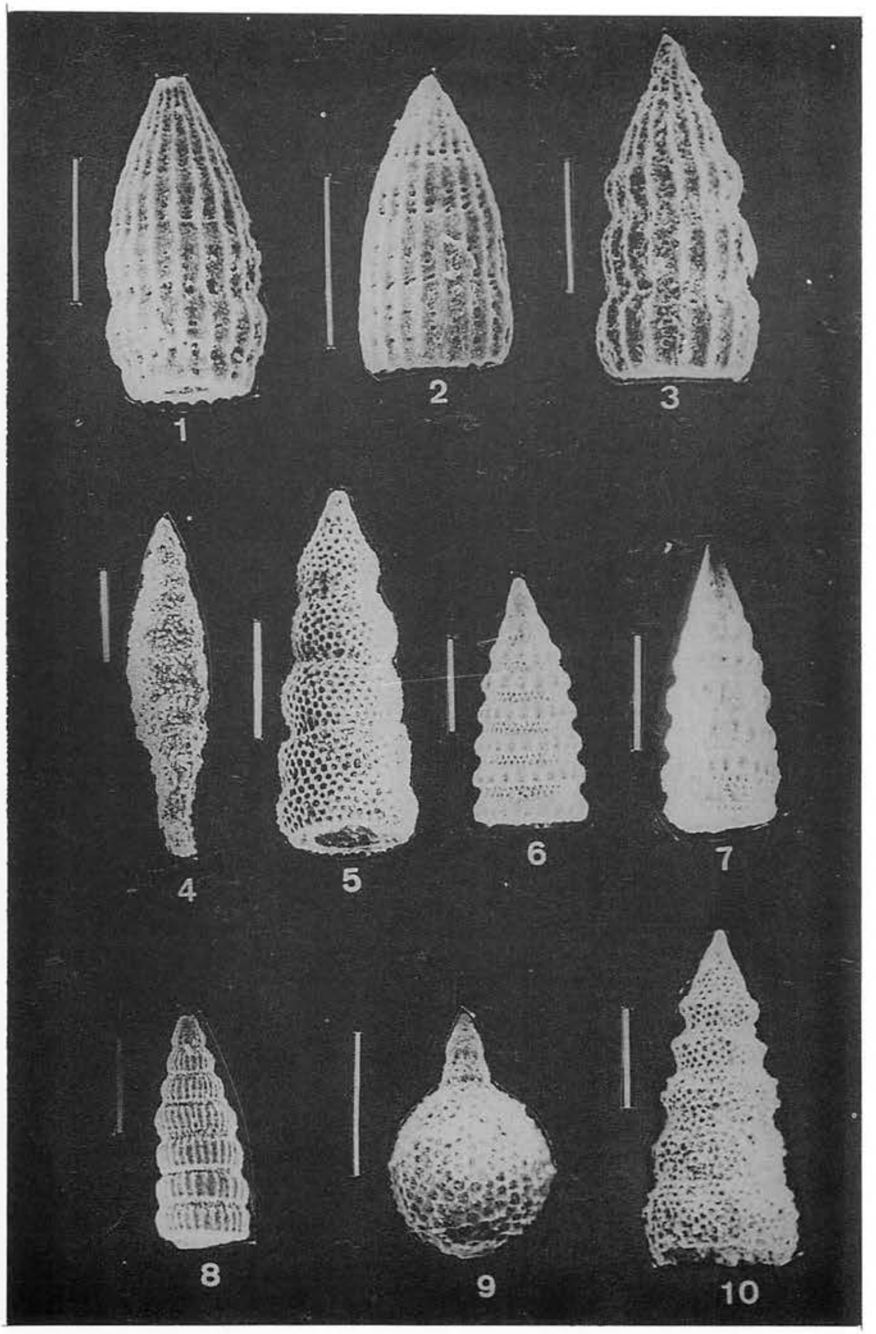

Plate 2. (Scale bar = 0.1mm)

1. *Archaeodictyomitra pseudoscalaris* (Tan Sin Hok)
2. *Archaeodictyomitra vulgaris* Pessagno
3. *Archaeodictyomitra* sp.
4. *Eucyrtis micropora* (Squinabol)
5. *Lithomitra pseudopinguis* Tan Sin Hok
6. *Pseudodictyomitra carpatica* (Lozynyak)
7. *Pseudodictyomitra lilyae* (Tan Sin Hok)
8. *Pseudodictyomitra* sp.
9. *Sethocapsa cribrata* (Hinde)
10. *Stichomitra asymbatos* Foreman

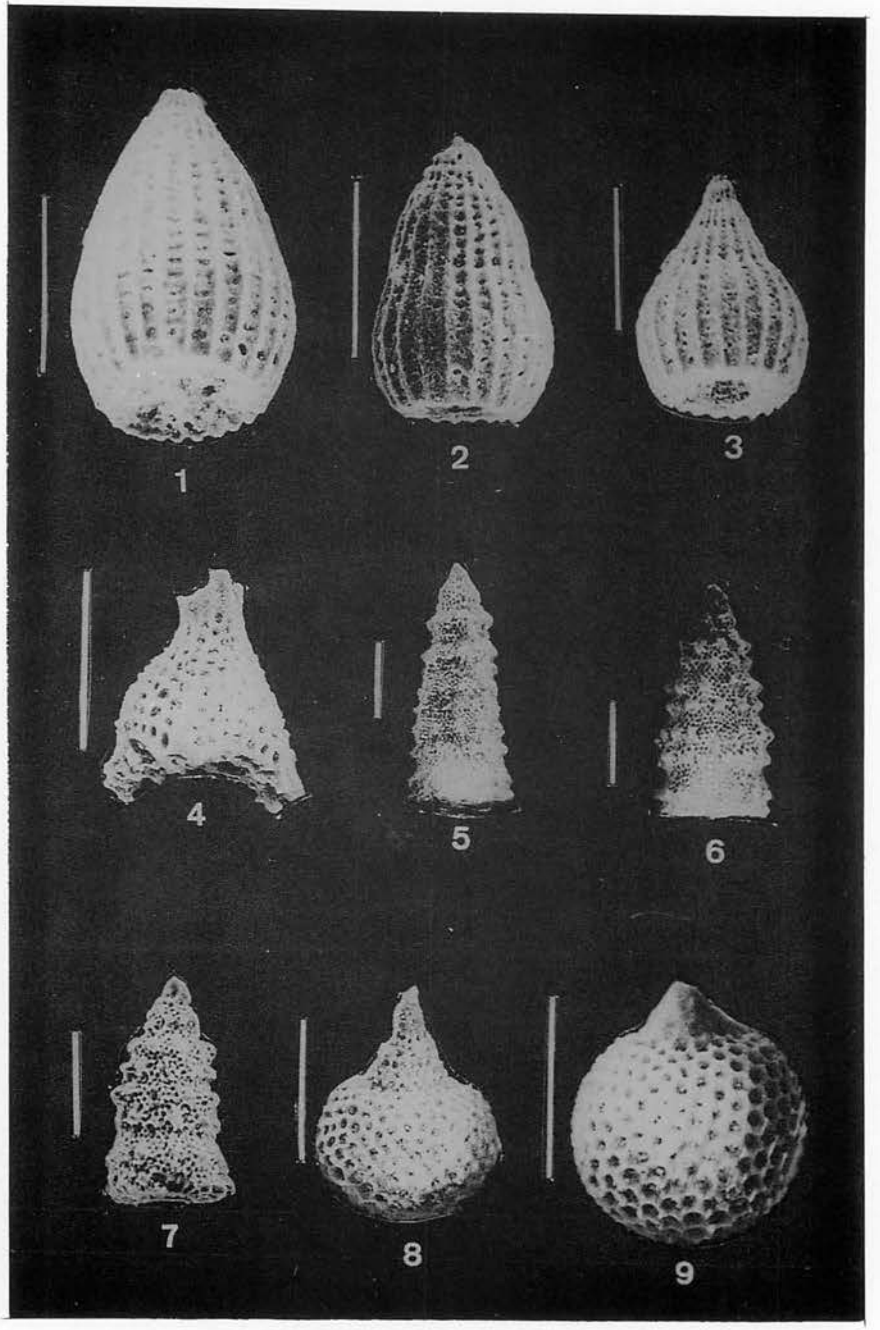

Plate 3. (Scale bar = 0.1mm)

1. *Thanarla conica* (Aliev)
2. *Thanarla conica* (Aliev)
3. *Thanarla pulchra* (Squinabol)
4. *Ultranapora* sp.
5. *Xitus alievi* (Foreman)
6. *Xitus spicularius* (Aliev)
7. *Xitus spicularius* (Aliev)
8. *Siphocampium davidi* Schaaf
9. *Hemicryptocapsa pseudopilula* Tan Sin Hok.

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