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Aptian to Turonian Radiolarians from Chert Blocks in the Kuamut Melange, Sabah, Malaysia

(Aptian hingga Turonian Radiolaria daripada Blok Rijang dalam Melange Kuamut, Sabah, Malaysia)

JUNAIDI ASIS* & BASIR JASIN

ABSTRACT

The Kuamut Melange is located in the Kunak district, south east Sabah. The mélange consists of clasts and blocks of broken Paleogene formations and dismembered ophiolite blocks embedded in shale matrix. Fourteen samples were collected from sections S1 and S2 of the Kuamut Melange. A total of 45 species of radiolarians have been identified and only 36 selected species are used for age determination. Three assemblages (I-III) were identified. Assemblage I consists of Dictyomitra excellence, Crucella bossoensis, Hiscocapsa asseni, Hexapyramis precedis, Thanarla brouweri, Acanthocircus levis, Obeliscoites vinassai, Stichomitra communis, Staurosphaeretta longispina, Xitus spicularius, Triactoma cellulosa, *and* Dactyliosphaera maxima. *This assemblage is marked by the occurrence of Crucella gavalai indicative of Aptian to Albian in age. Assemblage II was characterized by zonal maker* Xitus mclaughlini. *Other species in this assemblage are* Xitus spinosus, Stichomitra tosaensis, Dictyomitra gracilis, Dictyomitra montisserei, Pseudodictyomitra pseudomacrocephala, Pessagnobrachia fabianii, Crucella messinae, Tuguriella pagoda, Dictyomitra obesa, Triactoma paronai, Rhopalosyringium euganeum, Acanthocircus venetus, Acaeniotyle rebelis, Dictyomitra formosa, Pseudodictyomitra tiara *and* Patellula helios. *This assemblage ranges from Albian to Cenomanian. Assemblages III is represented by zonal maker* Crucella cachensis *and others species in this assemblage are* Hemicryptocapsa polyhedra, Eostichomitra bonum, Pseudotheocampe tina, Ultranapora cretacea *and* Alievium superbum. *Assemblage III is Turonian in age. The radiolarian assemblages suggest that the age of chert blocks ranges from Aptian to Turonian, Cretaceous. The cherts were originally deposited on an oceanic crust of a marginal basin during Cretaceous and were tectonically deformed to form melange in Miocene time.*

Keywords: Aptian; Kuamut; Melange; radiolarians; Turonian

ABSTRAK

Melange Kuamut terletak di daerah Kunak, tenggara Sabah. Melange Kuamut terdiri daripada klasta dan blok batuan sedimen formasi Paleogen yang terpecah dan blok ofiolit yang terpisah, yang tertanam dalam matriks syal. Empat belas sampel diambil daripada singkapan S1 dan S2 dalam Melange Kuamut. Sebanyak 45 spesies telah dikenal pasti dan hanya 36 spesies pilihan digunakan untuk penentuan usia. Tiga himpunan (I-III) telah dikenal pasti. Himpunan I terdiri daripada Dictyomitra excellence, Crucella bossoensis, Hiscocapsa asseni, Hexapyramis precedis, Thanarla brouweri, Acanthocircus levis, Obeliscoites vinassai, Stichomitra communis, Staurosphaeretta longispina, Xitus spicularius, Triactoma cellulosa *dan* Dactyliosphaera maxima. *Himpunan ini ditandai oleh kehadiran Crucella gavalai yang menunjukkan usia Aptian hingga Albian. Himpunan II dicirikan oleh penanda zon Xitus mclaughlini. Spesies lain dalam himpunan ini adalah* Xitus spinosus, Stichomitra tosaensis, Dictyomitra gracilis, Dictyomitra montisserei, Pseudodictyomitra pseudomacrocephala, Pessagnobrachia fabianii, Crucella messinae, Tuguriella pagoda, Dictyomitra obesa, Triactoma paronai, Rhopalosyringium euganeum, Acanthocircus venetus, Acaeniotyle rebelis, Dictyomitra formosa, Pseudodictyomitra tiara *dan* Patelulla helios *yang menunjukkan usia Albian hingga Cenomanian. Himpunan III diwakili oleh penanda zon Crucella cachensis dan spesies lain dalam himpunan ini ialah* Hemicryptocapsa polyhedra, Eostichomitra bonum, Pseudotheocampe tina, Ultranapora cretacea *dan* Alievium superbum. *Himpunan III ini berusia Turonian. Himpunan radiolarian ini membuktikan bahawa usia rijang ialah Aptian hingga Turonian, Kapur. Rijang diendapkan di kerak lautan iaitu di lembangan pingiran semasa Aptian-Turonian, seterusnya mengalami defomasi tektonik yang membentuk melange pada usia Miosen.*

Kata kunci: Aptian; Kuamut; Melange; radiolaria; Turonian

INTRODUCTION

The chaotic deposit namely the Kuamut Melange is exposed in the Kunak district area, south east of Sabah, Malaysia (Figure 1). The Melange is made up of a mixture of clasts and blocks of broken Paleogene formations and dismembered ophiolite block embedded in shale matrix. This chaotic deposit formerly known as the Kuamut Formation introduced by Collenette (1965), then revised and given a new term called melange by Clennell (1991, 1992). The Kuamut Melange is included in the Sabah

Melange and others melange such as the Ayer Melange in Lahad Datu, the Wariu Mélange in Kudat and the Garinono Melange in Sandakan area (Clennell 1991, 1992). The occurrence of chert blocks in the Kuamut Melange has been reported by Leong (1974). No specific radiolarian research has been carried out on the chert blocks from the Kuamut Melange. Only the chert blocks from the Wariu and Ayer Melanges have been studied. The radiolarians assemblages from the Wariu Melange are indicative of Albian age (Basir et al. 1989; Basir 2000a, 2000b). Aitchison (1994) recorded some of pre-Albian radiolarians from cherts blocks in the Ayer Melange.

The radiolarian cherts are also found in the Sabah Complex or formerly known as the Chert-Spilite Formation (Basir 1992). The Sabah Complex is composed of ophiolitic rock association which represents remnant of supra-oceanic crust. This complex is found as isolated outcrops mainly in Kudat, Tandek, Telupid, Segama Valley, Darvel Bay Valley, Timbun Mata Island and Banggi Island. The radiolarians from the Sabah Complex have been studied by Leong (1974, 1977), Basir and Sanudin (1988), Basir (1992, 2000a, 2000b), Basir and Sanatulsalwa (1992) and Basir and Tongkul (2000). The age of the cherts was thought to range from Valanginian to Cenomanian. The aims of this paper were to determine the age of chert blocks in the Kuamut Melange and their depositional environment.

GEOLOGICAL SETTING

The Kuamut Melange is a chaotic mixture of clasts and blocks of broken Paleogene formations and dismembered ophiolite blocks embedded in shale matrix (Clennell 1991; Sanudin & Baba 2007). The Kuamut Melange comprises of basalt, pillow basalt, serpentinite, chert, sandstone, mudstone, tuffaceous sandstone and shale. Leong (1974) recorded the Kuamut Melange overlying the ophiolitic rocks, notably in the Tingkayu and the Upper Segama Areas. The Kuamut Melange probably unconformably overlies the Darvel Bay Ophiolite Complex. The Darvel Bay Ophiolite Complex is a part of the Sabah Complex (Basir 1991). The Kuamut Melange is overlain by the Lower to Middle Miocene Tanjong Formation (Collenette 1965). Leong (1974) observed the contact between undisturbed Tanjong Formation overlying the Kuamut Melange in the Melua Valleys, Kuamut and Malabuk area. The Kuamut Melange was considered as Miocene in age by Liechti et al. (1960). Collenette (1965) stated that the age of the Kuamut Melange is Oligocene to Miocene and then Leong (1974) revised the age and assigned it to Miocene. Basir et al. (1995) reported some late Early Miocene planktonic foraminifera from the mudstone matrix of the Garinono Melange at the Bidu-Bidu Hill, Sandakan area. The geological characteristic of the Garinono Melange is similar to the Kuamut Melange. We conclude that the age of the melange is Early Miocene.

Mc Manus and Tate (1986) suggested that these chaotic deposits were considered to form from diapiric origin. Clennell (1991, 1992) has considered that the rock assemblages as melange and has been confirm by other researchers (Aitchison 1994; Basir 2000; Rangin et al. 1990). Clennell (1991, 1992) concluded that the melanges were mostly produced by submarine slope failures triggered by tectonic rearrangement of the Central Sabah Basin at the end of the Lower Miocene. Parts of the melanges are of olistostrome origin, associated with slump structures. These melanges are interpreted as having been deformed during the thrusting and faulting during Middle Miocene time (Clennell 1991, 1992; Hutchison 2005; Rangin et al. 1990).

THE OCCURENCE OF CHERT BLOCK

Field survey shows that the blocks are of various sizes and highly fractured and faulted. The radiolarian cherts in the Kuamut Mélange commonly exist as blocks or clasts. The chert blocks are exposed at two localities S1 and S2

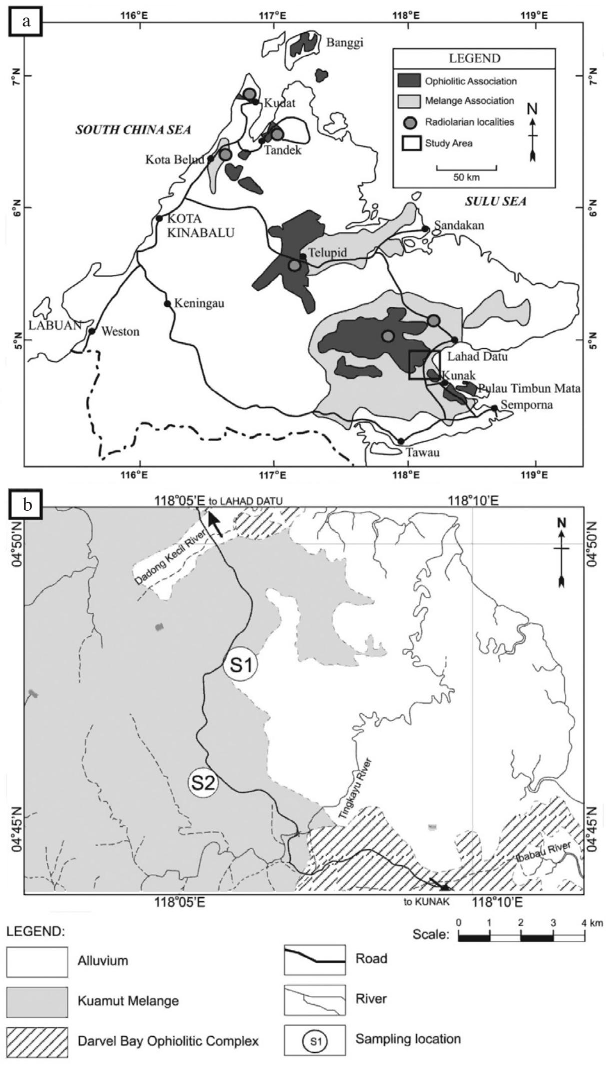

FIGURE 1. Map of the study area. a. Distribution of ophiolitic and melange associations (after Leong 1974 and Basir 2003) and b. Geological map of the study area showing sample localities

at road-cuts from Lahad Datu-Kunak road (Figure 1). Section S1 is exposed at a road-cut south of Dadong Kecil River (N4°47′53.9″, 118°05′56.6″E), about 34 km from Kunak Town. Section S2 is located about 3 km north of Tingkayu River (N4°46′26.8″, 118°05′26.4″E). The chert sequence is folded and faulted. The thickness of the chert layers range from 1 cm to 10 cm and strongly deformed. Both sections of Dadong Kecil River section (Section S1) and Tingkayu River section (Section S2) exhibit the same physical characteristics. The bedded chert is reddish-brown in colour and interbedded with thin siliceous shale. These chert blocks are associated with basalt, serpentinite and block of Paleogene formation embedded in shale matrix.

A total of fourteen samples of cherts were collected from the two localities; three samples from section S1 and 11 samples from section S2. The bedded chert sequence and sampling horizons of section S1 and S2 is portrayed in Figure 2.

Materials and Methods

All samples were crushed into small fragments (1 cm to 2 cm) and then all fragments were soaked in dilute hydrofluoric acid for about 24 h (Pessagno & Newport 1972). After that all samples were rinsed and dried. The residues were examined under binocular microscope. Well-preserved specimens have been photographed by scanning electron microscope (SEM) for further examination.

Results and Discussion

The identification of the species in this study is based on that of O'Dogherty (1994) and O'Dogherty et al. (2009). The radiolarian biostratigraphy is mainly based on the middle Cretaceous zonation of O' Dogherty (1994). This zonation has been established using the unitary association method (Guex 1991).

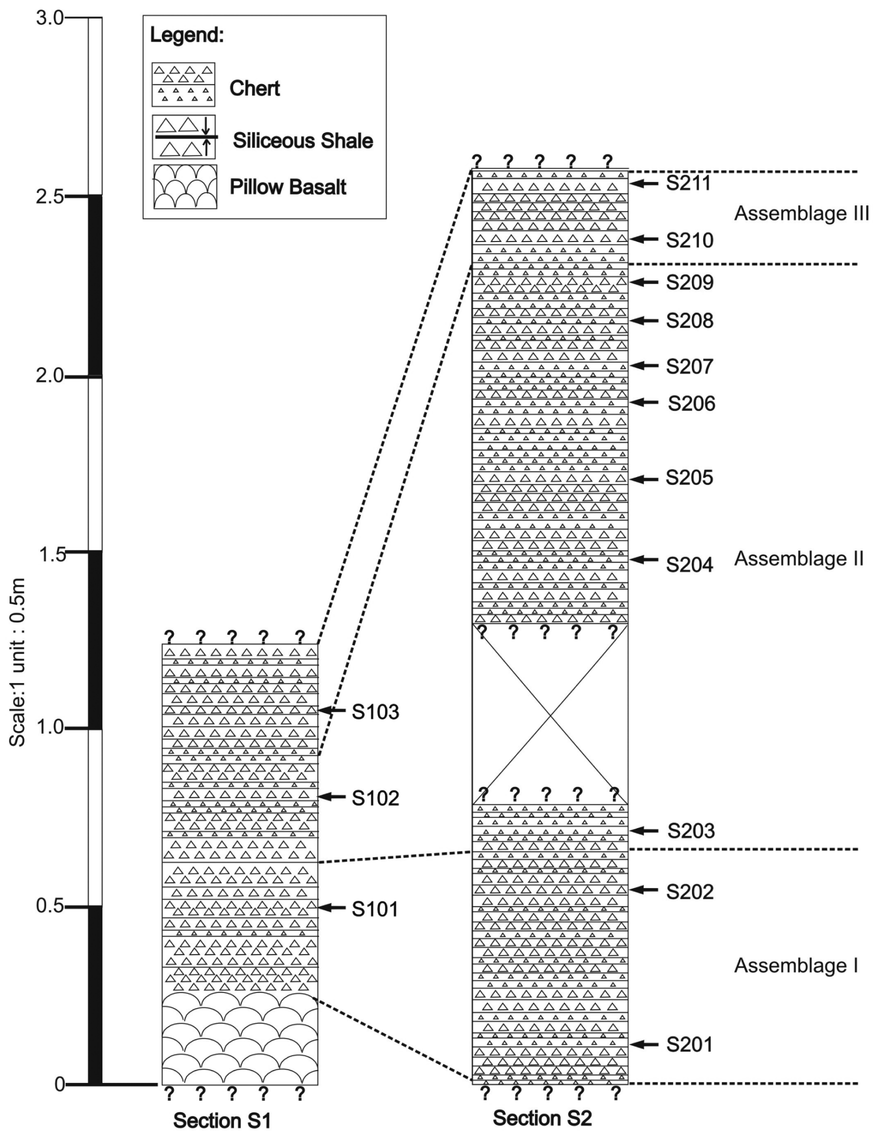

FIGURE 2. Lithologic log the chert sequence and sampling horizons of sections S1 and S2

Generally all samples yielded poorly preserved specimens, however some of them are still identifiable. A total of 44 species have been identified from 14 samples of section S1 (S101-S103) and section S2 (S201-S211). The distribution of radiolarians species and assemblages are shown in Table 1. Both sections consist mainly of nassellarians, with a few spumellarians. Only 36 selected species are used to determine the age of the radiolarian chert (Figure 3). We discovered three radiolarians assemblages from two outcrops located at the Dadong Kecil River (Section S1) and Tingkayu River (Section S2).

TABLE 1. Distribution of each species in samples of sections S1 and S2

	Assemblage I	Assemblage II	Assemblage III	Assemblage I		Assemblage II							Assemblage III	
	Section S1			Section S2										
RADIOLARIAN SPECIES	S101	S102	S103	S201	S202	S203	S204	S205	S206	S207	S208	S209	S210	S211
Dictyomitra excellens (Tan)	■													
Hexapyramis precedis Jud	■													
Crucella bossoensis Jud	■													
Crucella gavalai O'Dogherty	■			■										
Obeliscoites vinassai (Squinabol)				■										
Staurosphaeretta longispina (Squinabol)	■	■	■	■	■									
Acanthocircus levis (Donofrio & Mostler)	■	■		■		■								
Thanarla brouweri (Tan)	■	■		■	■	■	■							
Hiscocapsa asseni (Tan)				■	■	■	■							
Dactyliosphaera maxima (Pessagno)				■	■		■							
Stichomitra communis Squinabol	■	■	■	■	■	■	■	■	■	■		■	■	
Holocryptocarnium barbui Dumitrica		■	■	■	■	■	■	■	■	■		■	■	
Triactoma cellulosa Foreman	■	■	■	■		■		■	■	■	■		■	
Xitus spicularius (Aliev)	■	■	■	■		■	■	■	■	■	■	■		■
Cryptamphorella conara Foreman	■			■	■	■	■	■	■	■				■
Praeconocaryomma universa Pessagno	■	■	■		■	■	■					■	■	■
Foremanina schona Empson-Morin						■								
Xitus mclaughlini Pessagno		■				■	■		■			■		
Stichomitra tosaensis Nakaseko & Nishimura		■												
Triactoma paronai Squinabol		■												
Dictyomitra obesa (Squinabol)						■		■	■					
Tuguriella pagoda (Squinabol)						■			■					
Pseudodictyomitra pseudomacrocephala (Squinabol)		■	■			■	■		■	■				
Dictyomitra gracilis (Squinabol)		■				■	■	■			■	■		
Pseudodictyomitra tiara (Holmes)		■				■		■	■	■	■	■	■	
Dictyomitra montisserei (Squinabol)							■							
Xitus spinosus (Squinabol)	■						■							
Alievium superbum (Squinabol)	■	■					■	■				■	■	
Pessagnobrachia fabianii (Squinabol)		■	■				■						■	
Dictyomitra formosa Squinabol		■	■				■	■		■	■	■	■	■
Amphypindax pseudoconulus (Pessagno)								■						
Rhopalosyringium euganeum (Squinabol)								■						
Acaeniotyle rebellis O'Dogherty		■	■					■				■		■
Lithocampe manifesta (Foreman)										■	■			
Crucella messinae Pessagno		■									■	■	■	
Stichomitra parapedhia Bragina & Bragin												■		
Hemicryptocapsa polyhedra Dumitrica		■	■									■	■	■
Pseudoaulophacus pargueraensis Pessagno													■	
Patellula helios (Squinabol)		■	■											
Acanthocircus venetus (Squinabol)		■	■											
Ultranapora cretacea (Squinabol)		■	■										■	■
Eostichomitra bonum (Kozlova)			■											■
Pseudotheocampe tina (Foreman)														■
Crucella cachensis Pessagno			■											■

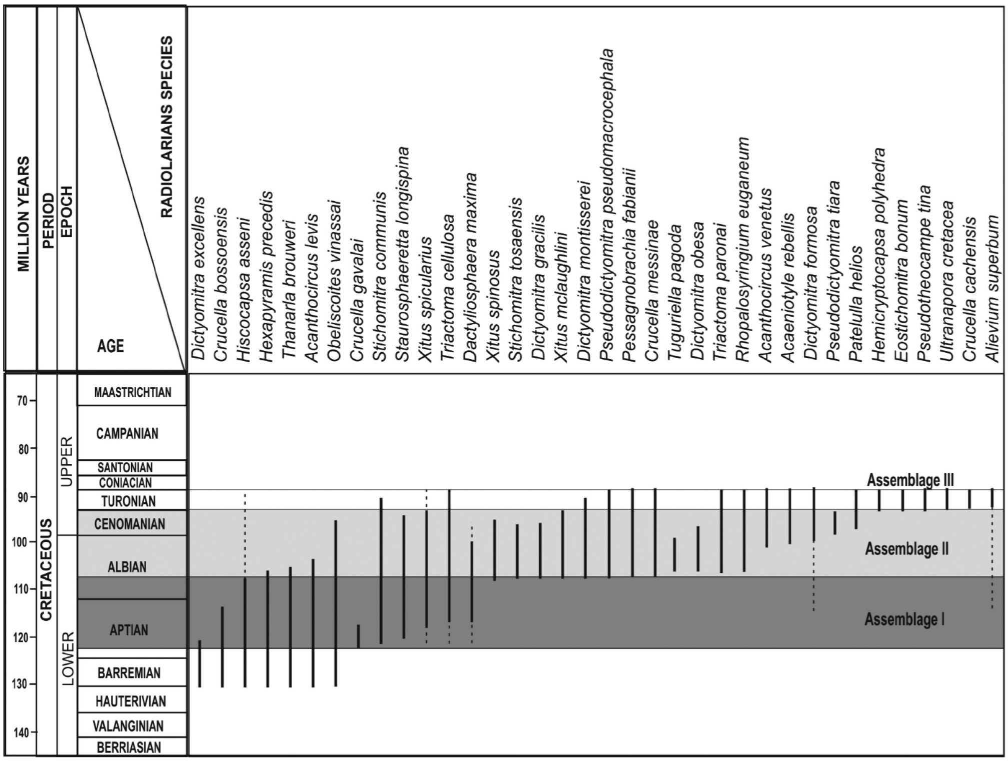

FIGURE 3. Stratigraphic distribution of selected species and their assemblages

Assemblage I consists of the following radiolarian association: *Dictyomitra excellence* (Tan), *Crucella gavalai* O'Dogherty, *Crucella bossoensis* Jud, *Hiscocapsa asseni* (Tan), *Hexapyramis precedis* Jud, *Thanarla brouweri* (Tan), *Acanthocircus levis* (Donofrio & Mostler), *Obeliscoites vinassai* (Squinabol), *Stichomitra communis* Squinabol, *Staurosphaeretta longispina* (Squinabol), *Xitus spicularius* (Aliev), *Triactoma cellulosa* Foreman and *Dactyliosphaera maxima* (Pessagno) (Plate 1). Assemblage I is characterized by the zonal marker *Crucella gavalai*. The lower boundary of this assemblage is marked by the first appearance of *Crucella gavalai* and the upper boundary is marked by the last appearance of *Hiscocapsa asseni*. This assemblage can be found in sample S101 in section S1 and samples S201 and S202 from section S2. The age range of this assemblage can be correlated to *Acaeniotyle umbilicata* Zone of Sanfilippo and Riedel (1985), Thurow (1988) and Schaaf (1981). In the present material the index fossil of *Acaeniotyle umbilicata* is absent. Assemblage I is comparable with the *Turbocapsula costata* subzone in *Turbocapsula* Zone introduced by O'Dogherty (1994). The subzonal marker of this subzone is absent in the present material but the occurrence of *Crucella gavalai* and other species exhibit similarity to radiolarian assemblage in *Turbocapsula costata* subzone. Assemblage I is indicative of Aptian to Albian in age.

Assemblage II yield the following radiolarian association: *Xitus mclaughlini* (Pessagno), *Xitus spinosus* (Squinabol), *Stichomitra tosaensis* Nakaseko & Nishimura, *Dictyomitra gracilis* (Squinabol), *Dictyomitra montisserei* (Squinabol), *Pseudodictyomitra pseudomacrocephala* (Squinabol), *Pessagnobrachia fabianii* (Squinabol), *Crucella messinae* Pessagno, *Tuguriella pagoda* (Squinabol), *Dictyomitra obesa* (Squinabol), *Triactoma paronai* (Squinabol), *Rhopalosyringium euganeum* (Squinabol), *Acanthocircus venetus* (Squinabol), *Acaeniotyle rebellis* O'Dogherty, *Dictyomitra formosa* Squinabol and *Pseudodictyomitra tiara* (Holmes) (Plate 2). This assemblage is represented by the zonal marker *Xitus mclaughlini*. Index species *Xitus mclaughlini* is found in sample S102 in section S1 and samples S203, S204, S206 and S209 in section S2. The lower boundary of the zone is marked by the first occurrence of *Xitus mclaughlini*, *Xitus spinosus*, *Stichomitra tosaensis*, *Dictyomitra gracilis*, *Dictyomitra montisserei*, *Pseudodictyomitra pseudomacrocephala*, *Pessagnobrachia fabianii*, *Crucella messinae*, the upper boundary is marked by the extinctions of *Xitus mclaughlini*, *Xitus spicularius* and *Pseudodictyomitra tiara*. Assemblage II corresponds to the *Obeliscoites somphedia* Zone of Schaaf (1981). The zonal marker *Obeliscoites somphedia* is absent in the present samples but the radiolarian composition is similar. According to Vishnevskaya (1993) and Bak (1999), this assemblage can be correlated to *Pseudodictyomitra pseudomacrocephala* and *Holocryptocarnium barbui* zones. The occurrence of *Pseudodictyomitra pseudomacrocephala* and *Holocryptocarnium barbui* are indicative of Albian to Cenomanian age. The present assemblage zone is equivalent to *Thanarla spoleoensis* zone and *Dactyliosphaera silviae* zones of O'Dogherty (1994). Although the zonal markers of *Thanarla spoleoensis* and *Dactyliosphaera silviae* are absents in the present samples, it has similar species

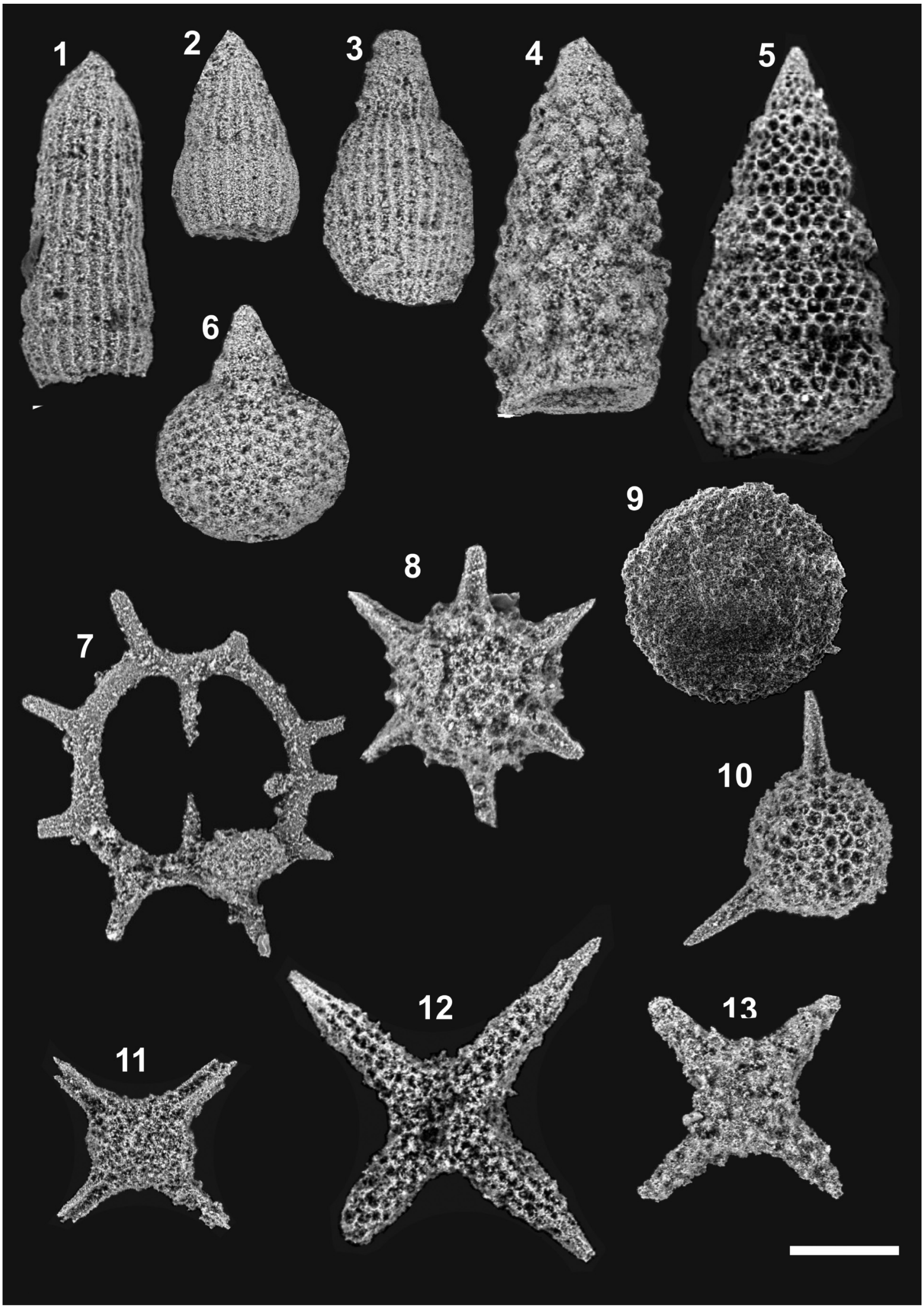

PLATE 1. Photomicrograph of Assemblage I. (Scale bar = 100 μm)

1. *Dictyomitra excellens* (Tan)
2. *Thanarla brouweri* (Tan)
3. *Obeliscoites vinassai* (Squinabol)
4. *Xitus spicularius* (Aliev)
5. *Stichomitra communis* Squinabol
6. *Hiscocapsa asseni* (Tan)
7. *Acanthocircus levis* (Donofrio & Mostler)
8. *Hexapyramis precedis* Jud
9. *Dactyliospahera maxima* (Pessagno)
10. *Triactoma cellulosa* Foreman
11. *Staurosphaeretta longispina* (Squinabol)
12. *Crucella bossoensis* Jud
13. *Crucella gavalai* O' Dogherty

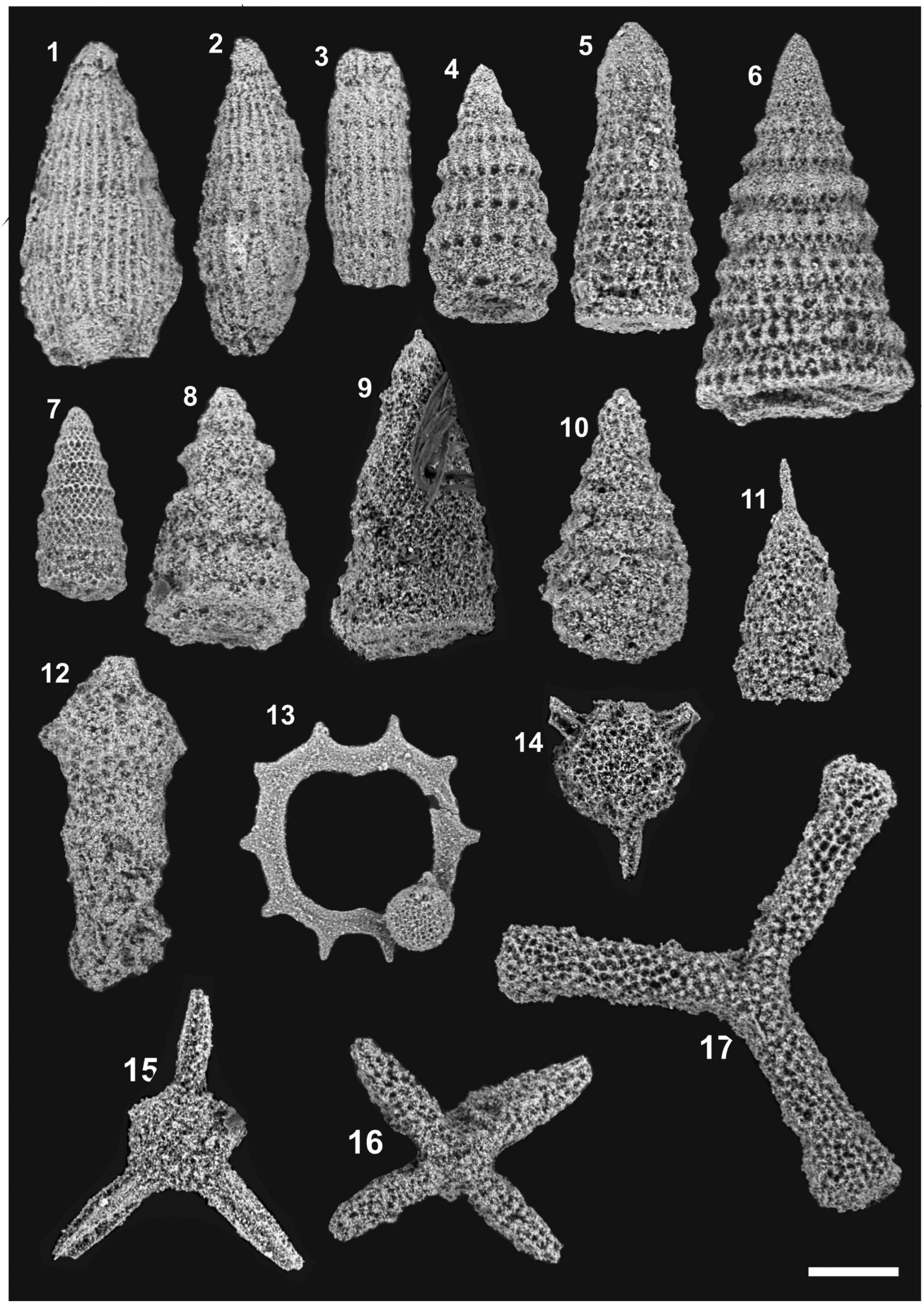

PLATE 2. Photomicrograph of Assemblage II. (Scale bar = 100 µm)

1. *Dictyomitra gracilis* (Squinabol)
2. *Dictyomitra obesa* (Squinabol)
3. *Dictyomitra montisserei* (Squinabol)
4. *Dictyomitra formosa* Squinabol
5. *Pseudodictyomitra pseudomacrocephala* (Squinabol)
6. *Pseudodictyomitra tiara* (Holmes)
7. *Tuguriella pagoda* (Squinabol)
8. *Xitus mclaughlini* Pessagno
9. *Xitus spinosus* (Campbell & Clark)
10. *Stichomitra tosaensis* Nakaseko & Nishimura
11. *Eostichomitra bonum* (Kozlova)
12. *Rhopalosyringium euganeum* (Squinabol)
13. *Acanthocircus venetus* (Squinabol)
14. *Acaeniotyle rebellis* O'Dogherty
15. *Triactoma paronai* Squinabol
16. *Crucella messinae* Pessagno
17. *Pessagnobrachia fabianii* (Squinabol)

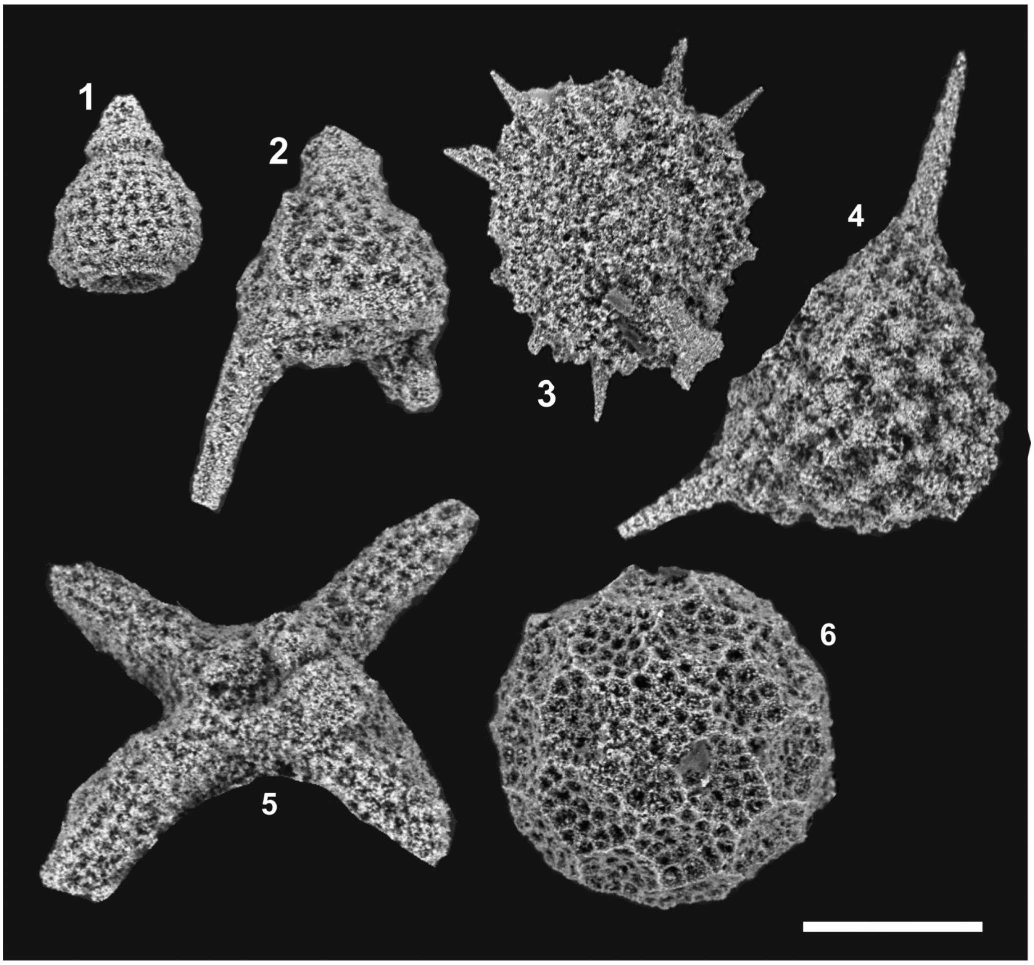

PLATE 3. Photomicrograph of Assemblage III. (Scale bar = 100 µm)

1. *Pseudotheocampe tina* (Foreman)
2. *Ultranapora cretacea* (Squinabol)
3. *Patelulla helios* (Squinabol)
4. *Alievium superbum* (Squinabol)
5. *Crucella cachensis* Pessagno
6. *Hemicryptocapsa polyhedra* Dumitrica

composition. This Assemblage is recorded from samples S102 in section S1 and samples S203, S204, S205, S206 S207, S208 and S209 in section S2.

Assembalge III consists of *Crucella cachensis* Pessagno, *Patellula helios* (Squinabol), *Hemicryptocapsa polyhedral* Dumitrica, *Eostichomitra bonum* (Kozlova), *Alievium superbum* (Squinabol), *Ultranapora cretacea* (Squinabol) and *Pseudotheocampe tina* (Foreman) (Plate 3). This assemblage is recognized by the zonal marker *Crucella cachensis* that indicates the Turonian age which can be found in sample S103 in section S1 and samples S210 and S211 in section S2. The lower boundary is marked by the last appearance of *Pseudodictyomitra tiara, Xitus mclaughlini* and *Xitus spicularius*. The upper boundary is defined by the final appearances of *Patellula helios*, *Hemicryptocapsa polyhedra*, *Eostichomitra bonum*, *Alievium superbum*, *Ultranapora cretacea* and *Pseudotheocampe tina*. Assemblage III is recorded in sample S103 in section S1 and samples S210 and S211 in section S2. This assemblage has similarity with *Alievium superbum* Zone (O'Dogherty 1994; Schaaf 1985) and *Alievium superbum-Thanarla veneta* Zone (Vishnevskaya 1993). The zonal markers *Thanarla veneta* is absent but *Alievium superbum* is present at almost all samples which means it has long stratigraphic range and cannot be use as zonal marker. The appearance of *Crucella cachensis* in assemblage III, the typical marker of the *Crucella cachensis* Zone of Thurow (1988) and it is assigned to Turonian. In summary, based on the radiolarian assemblages (I-III) from the Kuamut Melange prove that the age of chert blocks ranges from Aptian to Turonian, Cretaceous.

ENVIRONMENT DEPOSITION

Radiolarian chert blocks in the Kuamut Melange commonly associated with basalt, pillow basalt, peridotite and serpentinite. According to Jones and Murchey (1986), this rock association is classified as ophiolitic chert association. This association represents oceanic crust. The chert blocks were originally deposited in deep water environment based on three evidences. Firstly, the presence of high number of radiolarians suggests that the cherts were developed in a high productivity environment such as submarine volcanism zone. Secondly, the occurrence of thinly bedded cherts indicates that the chert layers were deposited far from continent and its environment of deposition was lacking in terrigenous supply (Basir 2000a). Thirdly, there are no trace of existence limestone layers interbedded with chert in the field. This suggests that the deposition of rhythmic bedded chert occurred at depth of below carbonate compensation depth level (CCD), where all carbonate material dissolved. The chert block of the Kuamut Mélange and the chert from ophiolitic chert association are of the same origin. The radiolarian assemblages show that the age of chert block from the Kuamut Melange is Aptian to Turonian.

The age of chert blocks cannot be used for age determination of the melange because they are embedded in the younger shale which forms the matrix. The age of planktonic foraminifera from shale matrix suggest the Miocene age (Basir et al. 1995; Basir 2002; Sanudin & Baba 2007). This rock association can be interpreted as Melange association of Jones and Murhcey (1986). This mélange association may occur on a subduction zone. The chert blocks of Kuamut Melange were originally deposited in deep marine environment at the spreading center during Aptian to Turonian age (Cretaceous). Later, underwent tectonic processes and were folded and faulted and incorporated with the younger sediments to form melange during Miocene. This deformation was probably related to the opening of Sulu Sea (Clennel 1991; Hutchison 1992; Rangin et al. 1990).

Conclusion

The age of chert blocks from Kuamut Melange range from Aptian to Turonian. The radiolarian assemblage from this chert blocks grouped into three Assembalge. Assemblage I, recognized by the zonal marker *Crucella gavalai* (Aptian to Albian), Assemblage II, characterized by the zonal maker *Xitus mclaughlini* (Albian to Cenomanian) and Assemblage III, marked by *Crucella cachensis* (Turonian). This is the first report on the age of the chert blocks from the Kuamut Melange. The age and the radiolarian assemblages of the chert blocks from the Kuamut Melange and those of the Darvel Bay Ophiolite Complex are very much similar. This suggests that both cherts are of the same origin. The cherts were first deposited on an oceanic crust in a deep marine environment during Aptian to Turonian, Cretaceous and later, underwent tectonic deformations and formed a mélange during Miocene.

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Basir Jasin
Geology Program
School of Environment and Natural Resource Sciences
Faculty of Science and Technology
Universiti Kebangsaan Malaysia
43600 Bangi, Selangor
Malaysia

Junaidi Asis*
Geology Program
School of Science and Technology
Universiti Malaysia Sabah
88999 Kota Kinabalu, Sabah
Malaysia

*Corresponding author; email: junaidiasis@gmail.com

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