

Aptian to Turonian Radiolaria from the Darvel Bay Ophiolite Complex, Kunak, Sabah

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Abstract: The Darvel Bay Ophiolite Complex is located in Kunak District, southeast Sabah. The predominant rocks in the study area are peridotite, serpentinite, gabbro, basalt, pillow basalt and reddish-brown chert. The aim of the research is to establish the age and environment of deposition of radiolarian chert. Eighteen chert samples were collected from two new outcrops along the Kunak-Semporna road. Fifty six species of radiolarians were indentified and 40 species are used for age determinations. The radiolarians are divided into three assemblages. Assemblage I (Aptian to Albian) is characterized by the occurrence of *Sticomitra simplex*, *Crucella bossoensis*, *Xitus clava*, *Dictyomitra communis*, *Hiscocapsa asseni*, *Obeliscoites vinassai*, *Rhopalosyringium fossile*, *Paronaella grapevinensis*, *Stichomitra communis*, *Xitus spicularius*, *Phangalites perpicius*, *Triactoma cellulosa* and *Becus horridus*. Assemblage II (Albian to Cenomanian) consists of *Xitus mclaughlini*, *Pseudoaulophacus sculptus*, *Dictyomitra gracilis*, *Torculum coronatum*, *Dictyomitra montisserei*, *Pogonias prodromus*, *Pessagnobrachia fabianii*, *Sciadiocapsa speciosa*, *Crucella messinae*, *Dictyomitra obesa*, *Pseudodictyomitra languida*, *Tuguriella pagoda*, *Dictyomitra formosa*, *Acaeniotyle rebellis*, *Pseudoaulophacus putahensis*, *Quadrigastrum oculus*, *Pseudodictyomitra tiara*, *Diacanthocapsa euganea*, *Patellula helios* and *Stichomitra stocki* which represents Albian to Cenomanian. Assemblage III (Turonian) is composed of *Pseudotheocampe tina*, *Ultranapora cretacea*, *Alievium superbum*, *Dictyomitra multicostata* and *Patellula ecliptica*. The index fossil of Assemblage III is *Crucella cachensis*. The fossil assemblages show the age of radiolarian chert ranges from Aptian to Turonian, Cretaceous. The bedded chert which associates with mafic and ultramafic rocks represents a part of an ophiolite sequence. The bedded chert contains abundance of radiolarians, which reflects a high planktonic productivity probably related to upwelling of nutrient rich waters caused by the submarine volcanism activity. The absence limestone in the bedded chert, indicates that the radiolarians were deposited below the Calcite Compensation Depth level.

Keywords: Aptian, Turonian, Cretaceous, Radiolaria, Darvel Bay Ophiolite Complex, Kunak

INTRODUCTION

The Darvel Bay Ophiolite Complex (DBOC) proposed by Shariff *et al.* (1992) is composed of ultramafic, gabbro, amphibolite, basaltic dykes, plagiogranites, and basaltic rocks capped by red radiolarian chert. This complex was formerly known as Chert-Spilite Formation (Fitch, 1955). Leong (1974) reviewed the Chert-Spilite Formation and retained its name. The formation is not suitable term for a mixture of rocks such as igneous and sedimentary rocks. It is more appropriate to use the term complex. Basir (1991) suggested the term Sabah Complex to replace the Chert-Spilite formation. The distribution of Sabah Complex is similar to the Chert-Spilite Formation which outcropped in Banggi Island, Kudat, Taritipan, Tandek, Telupid, Segama Valley, and Timbun Mata Island (Figure 1).

The earliest radiolarian studies in Sabah, was carried out by Leong (1977) at the Upper Segama area. He indicated that the age of the radiolarian assemblage was Valanginian to Barremian, Lower Cretaceous. Later, more studies were conducted in several localities i.e. Bukit Pangaraban, Kudat (Basir *et al.* 1985; Basir & Sanudin 1988), Wariu Melange of Tempasuk-Menggaris, Kota Belud (Basir *et al.*, 1989), Mandurian (Basir & Sanatulsalwa, 1992), Telupid (Basir, 1992), Ayer Melange in Segama Valley (Aitchison, 1994) and Baliojong Valley (Basir & Tongkul, 2000). The results

of these studies indicate the age of radiolarians chert ranges from Valanginian to Albian, Early Cretaceous. The aim of the study is to identify and to establish the radiolarian assemblages, and to determine the age and depositional environment of the chert.

GEOLOGICAL SETTING

The study area is composed of two rock units namely, the Darvel Bay Ophiolite Complex and the Kalumpang Formation (Figure 2). The Darvel Bay Ophiolite Complex consists of radiolarian cherts associated with peridotite, serpentinite, spilite, and pillow basalt. The chert is reddish brown in color, highly weathered and exposed along the Kunak-Semporna Road. The chert sequence comprises thinly bedded chert interbeds with siliceous shale. The thickness of chert ranges from 1 to 10 cm. The bedded chert is strongly folded and underlain by the mafic and ultramafic rocks. The age of the complex is Early Cretaceous based on the radiolarian chert and radiometric dating of mafic rock (Leong, 1977; Basir, 2000; Graves *et al.*, 2000). The rock association is considered as an ophiolite sequence which represents an oceanic crust (Shariff *et al.*, 1992; Basir, 1991, 2000; Hutchison, 2005). The Darvel Bay Ophiolite Complex is unconformably overlain by the Kalumpang Formation.

The Kalumpang Formation was first introduced by

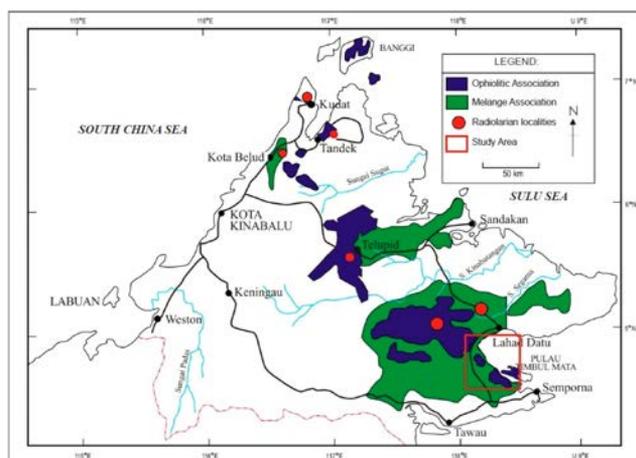


Figure 1: Distribution of chert in ophiolitic and melange association in Sabah (Basir 2003).

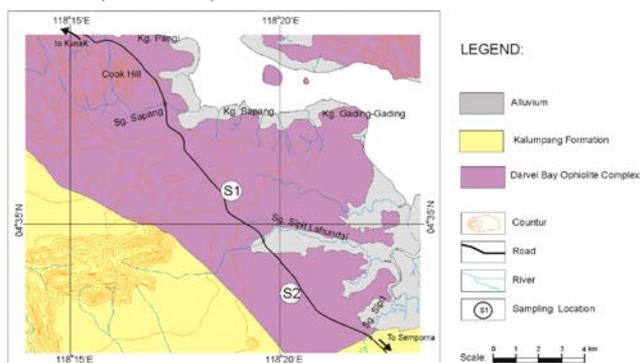


Figure 2: Geological map of study area located in southeast Kunak, Sabah.

Kirk (1962) which consists of interbedded mudstone and shale with sandstone, conglomerate, limestone and tuff. The formation is divided into two members namely, the Sipit Limestone Member and the Sebatik Sandstone-Shale Member. The Kalumpang Formation was deposited during high volcanic activity and sedimentation in Miocene. The boundary between the Darvel Bay Ophiolite Complex and the Kalumpang Formation is not exposed and roughly delineated in the field.

MATERIAL AND METHOD

Eighteen samples of chert were collected from two outcrops; ten samples (samples S101 to S110) were collected from section S1 and eight samples (samples S201 to S208) from section S2 along the Kunak-Semporna Road (Figure 3). Section S1 is located at 16 km from the Kunak town along the Kunak-Semporna Road, the Sipit Lahundai River. Section S2 exposed at 22 km from the Kunak town. Both outcrops consist of reddish brown chert interbedded with siliceous shale. The chert is classified as radiolarite and contains of more than 80% of radiolarian skeletons.

The chert samples were crushed into small fragments (1cm to 2cm) and soaked in dilute hydrofluoric acid for about 24 hours (Pessagno & Newport, 1972). The samples were rinsed with fresh water and dried. Radiolarians were

picked and identified under a binocular microscope. Well-preserved specimens were coated with platinum /gold and photographed by scanning electron microscope (SEM).

RESULT AND DISCUSSION

The samples from section S1 and S2 yielded abundant well-preserved radiolarians. A total of 56 species belong to 35 genera were identified and the distribution of each species is listed in Table 1.

The species consist of:-

- Acaeniotyle rebellis* O’Dogherty (Plate 3, figure 2)
- Alievium gallowayi* Pessagno (Plate 3, figure 10)
- Alievium murphyi* Pessagno (Plate 3, figure 11)
- Alievium superbum* (Squinabol) (Plate 3, figure 9)
- Amphypindax pseudoconulus* (Pessagno) (Plate 2, figure 6)
- Archaeodictyomitra chalilovi* (Aliiev) (Plate 1, figure 1)
- Becus horridus* (Squinabol) (Plate 3, figure 4)
- Crucella bossoensis* Jud (Plate 3, figure 18)
- Crucella cachensis* Pessagno (Plate 3, figure 20)
- Crucella messinae* Pessagno (Plate 3, figure 19)
- Cryptamphorella conara* Foreman (Plate 2, figure 15)
- Dactyliosphera maxima* (Pessagno) (Plate 3, figure 14)
- Diacanthocapsa euganea* Squinabol (Plate 2, figure 17)
- Dictyomitra communis* (Squinabol) (Plate 1, figure 7)
- Dictyomitra formosa* Squinabol (Plate 1, figure 4)
- Dictyomitra gracilis* (Squinabol) (Plate 1, figure 2)
- Dictyomitra koslovae* Foreman (Plate 1, figure 8)
- Dictyomitra montisserei* (Squinabol) (Plate 1, figure 3)
- Dictyomitra multicostata* Zittel (Plate 1, figure 6)
- Dictyomitra obesa* (Squinabol) (Plate 1, figure 5)
- Foremanina schona* Empson-Morin (Plate 1, figure 11)
- Hiscocapsa asseni* (Tan) (Plate 2, figure 14)
- Holocryptocarnium barbui* Dumitrica (Plate 2, figure 16)
- Lithocampe manifesta* (Foreman) (Plate 2, figure 11)
- Obeliscoites vinassai* (Squinabol) (Plate 2, figure 13)
- Paronaella grapevinensis* (Pessagno) (Plate 3, figure 16)
- Patellula ecliptica* O’ Dogherty (Plate 3, figure 13)
- Patellula helios* (Squinabol) (Plate 3, figure 12)
- Phangalites perspicuus* (Squinabol) (Plate 2, figure 7)
- Pessagnobrachia fabianii* (Squinabol) (Plate 3, figure 17)
- Pogonias prodromus* O’Dogherty (Plate 2, figure 12)
- Praeconocaryomma univrsa* Pessagno (Plate 3, figure 1)
- Pseudoaulophacus florensis* Pessagno (Plate 3, figure 7)
- Pseudoaulophacus pargueraensis* Pessagno (Plate 3, figure 8)
- Pseudoaulophacus putahensis* Pessagno (Plate 3, figure 6)
- Pseudoaulophacus sculptus* (Squinabol) (Plate 3, figure 5)
- Pseudodictyomitra languida* O’Dogherty (Plate 1, figure 9)
- Pseudodictyomitra tiara* (Holmes) (Plate 1, figure 10)
- Pseudotheocampe tina* (Foreman) (Plate 2, figure 9)
- Quadrigastrum oculus* O’ Dogherty (Plate 3, figure 15)
- Rhopalosyringium fossile* (Squinabol) (Plate 2, figure 8)
- Sciadiocapsa speciosa* (Squinabol) (Plate 2, figure 18)
- Stichomitra communis* Squinabol (Plate 2, figure 2)
- Stichomitra parapedhia* Bragina & Bragin (Plate 2, figure 5)
- Stichomitra simplex* (Smirnova & Aliiev) (Plate 2, figure 1)
- Stichomitra stocki* (Campbell & Clark) (Plate 2, figure 4)

RADIOLARIANS SPECIES	Assemblage I			Assemblage II						Assemblage III		Assemblage I		Assemblage II						Assemblage III		
	Section S1											Section S2										
	S101	S102	S103	S104	S105	S106	S107	S108	S109	S110	S201	S202	S203	S204	S205	S206	S207	S208				
<i>Archaeodictyomitra chalilovi</i> (Aliev)											■											
<i>Stichomitra simplex</i> (Smirnova & Aliev)		■									■											
<i>Dactyliosphaera maxima</i> (Pessagno)											■											
<i>Xitus clava</i> (Parona)											■											
<i>Crucella bossoensis</i> Jud	■	■									■	■		■								
<i>Hiscocapsa asseni</i> (Tan)	■	■																				
<i>Triactoma cellulosa</i> Foreman	■	■	■			■																
<i>Stichomitra communis</i> Squinabol	■		■			■		■			■	■	■		■	■						
<i>Rhopalosyringium fossile</i> (Squinabol)											■	■	■		■	■						
<i>Pseudoaulophacus florensis</i> Pessagno											■	■	■		■	■						
<i>Holocryptocarnium barbui</i> Dumitrica		■			■		■				■				■	■	■					
<i>Theocapsomma comys</i> Foreman											■					■	■					
<i>Dictyomitra formosa</i> Squinabol	■		■	■	■	■	■	■		■	■	■	■	■	■	■	■					
<i>Dictyomitra koslovae</i> Foreman	■	■				■	■	■		■	■	■	■	■	■	■	■					
<i>Xitus spicularius</i> (Aliev)	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■					
<i>Pseudotheocampe tina</i> (Foreman)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					
<i>Cryptamphorella conara</i> Foreman	■	■	■							■	■	■	■	■	■	■	■					
<i>Pseudoaulophacus pargueraensis</i> Pessagno	■	■	■							■	■	■	■	■	■	■	■					
<i>Alievium superbum</i> (Squinabol)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					
<i>Theocampe salillum</i> Foreman	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					
<i>Praeconocaryomma universa</i> Pessagno	■	■	■			■	■	■	■	■	■	■	■		■	■	■					
<i>Lithocampe manifesta</i> (Foreman)	■	■	■			■	■	■	■	■	■	■	■		■	■	■					
<i>Tuguriella pagoda</i> (Squinabol)	■	■	■	■	■					■	■				■	■	■					
<i>Dictyomitra communis</i> (Squinabol)											■											
<i>Phangalites perspicuus</i> (Squinabol)											■											
<i>Becus horridus</i> (Squinabol)											■											
<i>Paronaella grapevinensis</i> (Pessagno)											■											
<i>Pogonias prodromus</i> O'Dogherty												■										
<i>Dictyomitra obesa</i> (Squinabol)												■	■		■							
<i>Pessagnobranchia fabianii</i> (Squinabol)				■	■	■		■				■	■		■							
<i>Dictyomitra gracilis</i> (Squinabol)				■	■	■	■	■				■	■		■							
<i>Xitus mclaughlini</i> Pessagno				■	■	■		■				■	■		■	■						
<i>Torculum coronatum</i> (Squinabol)				■	■	■		■				■	■		■							
<i>Crucella messinae</i> Pessagno				■	■	■	■	■				■	■		■	■	■					
<i>Pseudoaulophacus putahensis</i> Pessagno				■	■	■		■				■	■		■	■	■					
<i>Acaeniotyle rebellis</i> O'Dogherty				■	■	■		■				■	■		■	■	■					
<i>Pseudodictyomitra tiara</i> (Holmes)				■	■	■		■				■	■		■	■	■					
<i>Sciadiocapsa speciosa</i> (Squinabol)				■	■	■		■				■	■		■	■	■					
<i>Dictyomitra montisserei</i> (Squinabol)				■	■	■		■				■	■		■	■	■					
<i>Diacanthocapsa euganea</i> Squinabol				■	■	■		■				■	■		■	■	■					
<i>Pseudoaulophacus sculptus</i> (Squinabol)				■	■	■		■				■	■		■	■	■					
<i>Foremanina schona</i> Empson-Morin				■	■	■		■				■	■		■	■	■					
<i>Pseudodictyomitra languida</i> O'Dogherty				■	■	■		■				■	■		■	■	■					
<i>Stichomitra tosaensis</i> Nakaseko & Nishimura				■	■	■		■				■	■		■	■	■					
<i>Obeliscoites vinassai</i> (Squinabol)				■	■	■		■				■	■		■	■	■					
<i>Stichomitra parapedia</i> Bragina & Bragin				■	■	■		■	■			■	■		■	■	■					
<i>Alievium gallowayi</i> (White)				■	■	■		■				■	■		■	■	■					
<i>Quadrigastrum oculus</i> O'Dogherty				■	■	■		■				■	■		■	■	■					
<i>Amphypindax pseudoconulus</i> (Pessagno)			■									■	■		■	■	■					
<i>Crucella cachensis</i> Pessagno								■	■	■					■	■	■					
<i>Dictyomitra multicostata</i> Zittel								■	■	■					■	■	■					
<i>Stichomitra stocki</i> (Campbell & Clark)							■	■	■						■	■	■					
<i>Alievium murphyi</i> Pessagno																■	■					
<i>Patellula ecliptica</i> O'Dogherty																■	■					
<i>Patellula helios</i> (Squinabol)																■	■					
<i>Ultranapora cretacea</i> (Squinabol)									■								■					

Table 1: Distribution of radiolarian species in samples from sections S1 and S2.

Stichomitra tosaensis Nakaseko & Nishimura (Plate 2, figure 3)

Theocampe salillum Foreman (Plate 2, figure 10)

Theocapsomma comys Foreman (Plate 2, figure 20)

Torculum coronatum (Squinabol) (Plate 1, figure 16)

Triactoma cellulosa Foreman (Plate 3, figure 3)

Tuguriella pagoda (Squinabol) (Plate 1, figure 12)

Ultranaora cretacea (Squinabol) (Plate 2, figure 19)

Xitus clava (Parona) (Plate 1, figure 13)

Xitus mclaughlini Pessagno (Plate 1, figure 14)

Xitus spicularius (Aliev) (Plate 1, figure 15)

The common species in chert samples of section S1 are *Alievium superbum*, *Cryptamphorella conara*, *Dictyomitra farmosa*, *Dictyomitra koslovae*, *Praeconocaryomma universa*, *Pseudotheocampe tina*, *Theocampe salillum*, and *Xitus spicularius*. *Pseudoaulophacus pargueraensis* and *Pseudoaulophacus putahaensis* are only dominant in chert samples from section S2. The rare species are *Alievium gallowayi*, *Alievium murphyi*, *Archaeodictyomitra chalilovi*, *Becus horridus*, *Dactyliosphaera maxima*, *Diacanthocapsa euganea*, *Dictyomitra communis*, *Dictyomitra montisserei*, *Obeliscoites vinassai*, *Paronaella grapevinensis*, *Patellula helios*, *Phangalites perspicuus*, *Pogonias prodomus*, *Pseudodictyomitra languida*, *Pseudoaulophacus sculptus*, *Quadrigrasrum oculus* and *Ultranaora cretacea*.

Radiolarian Age

Only 40 selected species are used to determine the age of the radiolarian chert. Determination of radiolarians age is based on O’ Dogherty (1994). These faunas can be clustered

in three assemblages namely Assemblage I, Assemblage II and Assemblage III (Figure 4).

Assemblage I is characterized by the occurrence of *Stichomitra simplex* which presents in sample S102 and S201 of section S1 and S2, respectively. The other species which present in this assemblage are *Crucella bossoensis*, *Xitus clava*, *Dictyomitra communis*, *Hiscocapsa asseni*, *Rhopalosyringium fossile*, *Paronaella grapevinensis*, *Stichomitra communis*, *Xitus spicularius*, *Phangalites perspicuus*, *Triactoma cellulosa*, *Becus horridus*, and *Dactyliosphaera maxima*. The lower boundary of this assemblage is marked by the first appearance of *Stichomitra simplex*, *Stichomitra communis* and *Paronaella grapevinensis*. The upper boundary is marked by the final appearance of *Stichomitra simplex*. Assemblage I corresponds to the *A. umbilicata* zone (Sanfilippo & Riedel, 1985), *Costata* subzone (Thurrow, 1988) and *C. pythiae-T. conica* zone (Vishnevskaya, 1993; O’ Dogherty, 1994). The subzonal markers, *A. umbilicata*, *C. pythiae-T. conica* and *T. costata* are not present in this assemblage but the occurrence of *Stichomitra simplex* and others species shows that the age is Aptian to Albian. This assemblage can be found in samples S101, S102, S103 in section S1 and sample S201 and S202 from section S2 (Figure 3).

Assemblage II is represented by the index species of *Xitus mclaughlini*. Other species presence in this assemblage are *Pseudodictyomitra tiara* *Pseudoaulophacus sculptus*, *Dictyomitra gracilis*, *Torculum coronatum*, *Dictyomitra montisserei*, *Pogonias prodomus*, *Pseudoaulophacus sculptus*, *Tuguriella pagoda*, *Pessagnobrachia fabianii*,

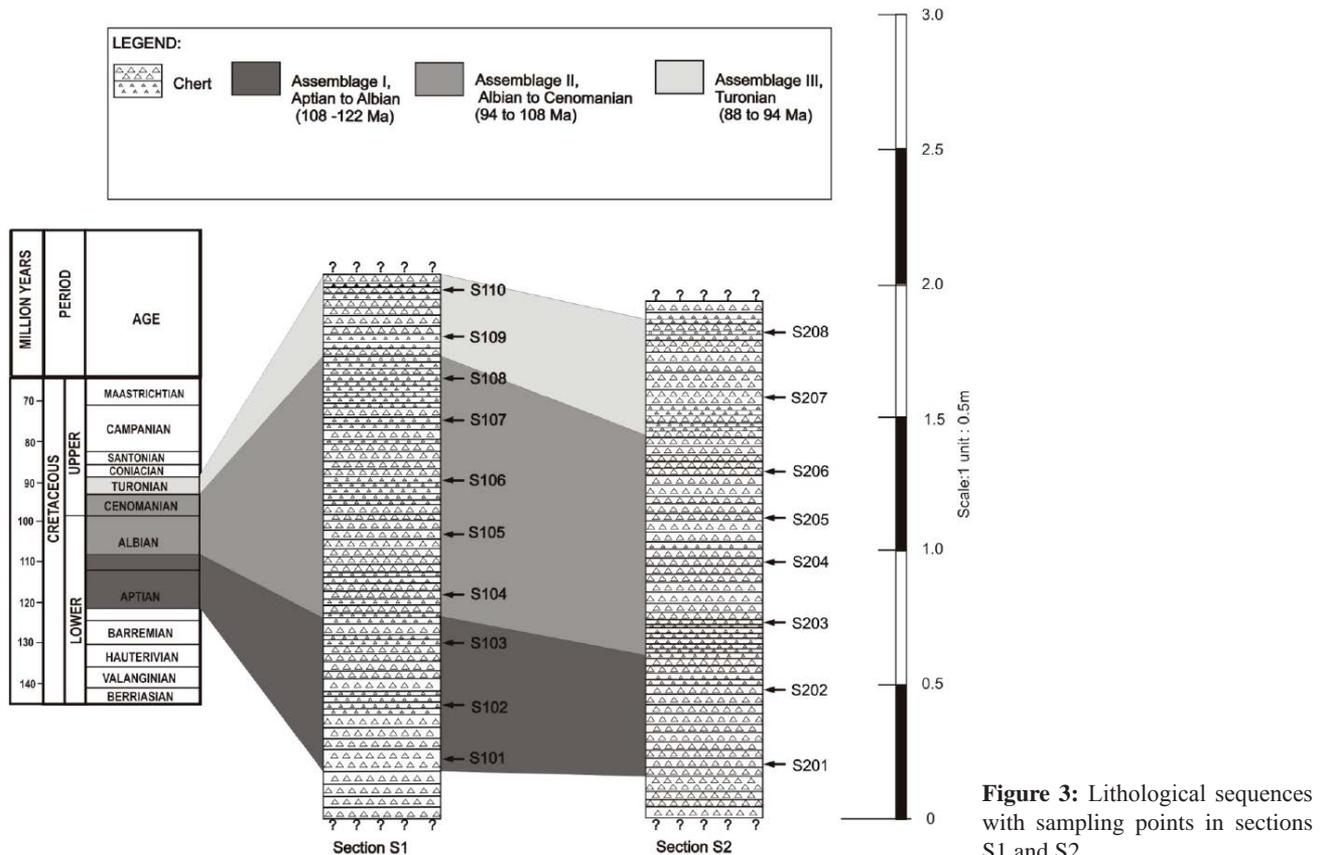


Figure 3: Lithological sequences with sampling points in sections S1 and S2.

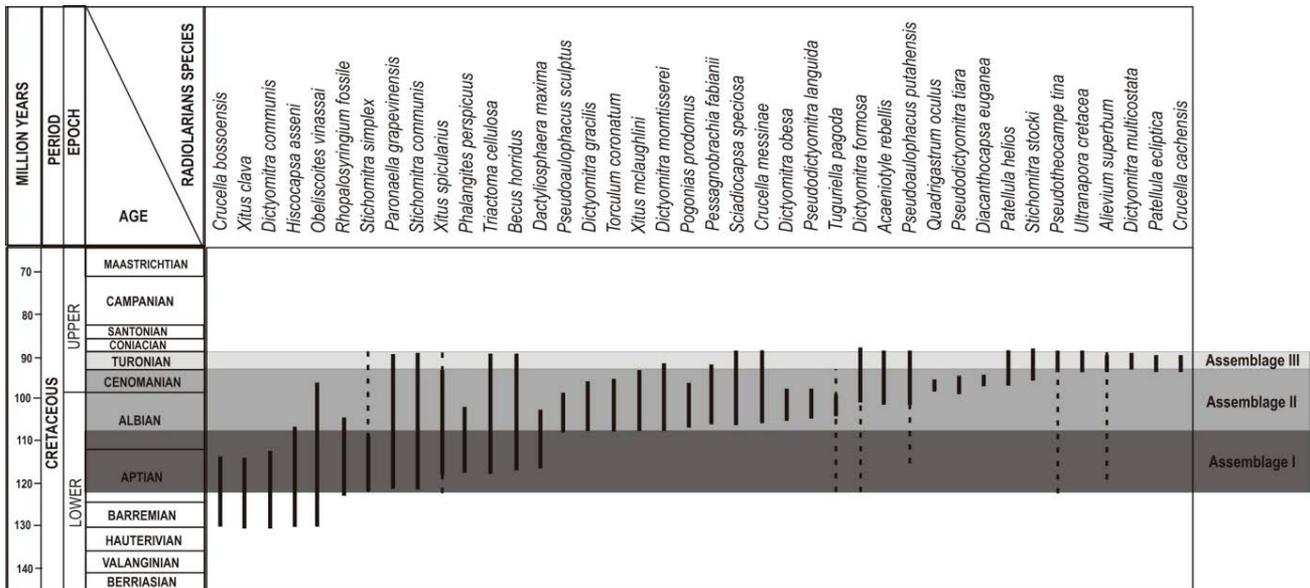


Figure 4: Stratigraphic distributions of selected species of radiolarians chert from the Darvel Bay Ophiolite Complex.

Sciadiocapsa speciosa, *Crucella messinae*, *Dictyomitra obesa*, *Pseudodictyomitra languid*, *Dictyomitra formosa*, *Acaeniotyle rebellis*, *Pseudoaulophacus putahensis*, *Quadrigastrum oculus* and *Diacanthocapsa euganea*. This Assemblage is recorded from samples S104 to S108 in section S1 and samples S203 to S206 in section S2 (Figure 3).

Assemblage II is comparable to the *O. somphedia* Zone of Schaaf (1981) and *P. pseudomacrocephala*-*H. barbui* Zone of Vishnevskaya (1993). The index fossils *Obeliscoites somphedia* and *Pseudodictyomitra pseudomacrocephala* are absent in the samples but *Holocryptocarcium barbui* is recorded in the samples. This assemblage is Albian-Cenomanian in age.

Assemblage III is composed of *Patellula helios*, *Stichomitra stocki*, *Pseudothecampe tina*, *Ultranapora cretacea*, *Alievium superbum*, *Dictyomitra multicostata*, *Patellula ecliptica*, and *Crucella cachensis*. The lower boundary is defined by the first appearance of *Crucella cachensis*. The upper boundary characterized by the extinction of most species including *Crucella cachensis*. The occurrence of *Crucella cachensis* suggests a Turonian age. This assemblage is equivalent to the *Alievium superbum* Zone proposed by Schaaf (1985) and O’Dogherty (1994) and the *Crucella cachensis* Zone of Thurow (1988). This Assemblage is recorded in samples S109 and S110 from section S1, and samples S207 and S208 from section S2. This assemblage is indicative of Turonian age.

The radiolarian of the Darvel Bay Ophiolite Complex in Kunak indicates that the age of chert is ranges from Aptian to Turonian (122 to 88 million years ago). This is a new age of the chert in the Darvel Bay Ophiolite Complex. The present age is different from that determined by previous study which suggested the age of the chert of Darvel Bay Ophiolite Complex from the Upper Segama area ranges from Valanginian to Barremian (Leong 1977).

Environment of Deposition

The Darvel Bay Ophiolite Complex consists of spilite, pillow basalt, peridotite, serpentinite and commonly overlies by ribbon chert. The rock association is considered as an ophiolitic chert association (Jones & Murchey, 1986) and represents the ophiolitic sequence of oceanic crust which developed on a spreading center. The ribbon chert with high abundance of radiolarians was possibly developed in a high productivity environment such as at an upwelling zone caused by submarine volcanism. The absent of clastic material suggests the depositional environment was far from the continental margin. The high percentage of nassellarians compared to spumellarians also indicate deep marine environment where the spumellarians are dominant at depths more than 2,000m (Vishnevskaya & De Wever, 1998; Armstrong & Brasier, 2006). The absence of calcareous sediment or bedded limestone suggests that the oceanic basin was deeper than the carbonate compensation depth (more than 3000m depth Matsuoka *et al.*, 2002; Basir, 2003). The spreading center was probably developed during Late Jurassic to early Early Cretaceous based on the age of mafic rock (Leong, 1974; Graves *et al.*, 2000). The spreading of seafloor produced initial layers of the volcanic rocks consisting of spilite, pillow basalt, peridotite and serpentinite (Shariff *et al.*, 1992; Graves *et al.*, 2000). The deposition of chert and siliceous shale took place later during the Early Cretaceous to early Late Cretaceous on top of igneous rocks.

CONCLUSION

The chert of the Darvel Bay Ophiolite Complex is indicative of an age ranged from Aptian to Turonian, Cretaceous (from 122 to 88 million years ago). The radiolarians are divided into three assemblages; Assemblage I (Aptian to Albian) characterized by the occurrences of *Stichomitra simplex*; Assemblage II (Albian to Cenomanian)

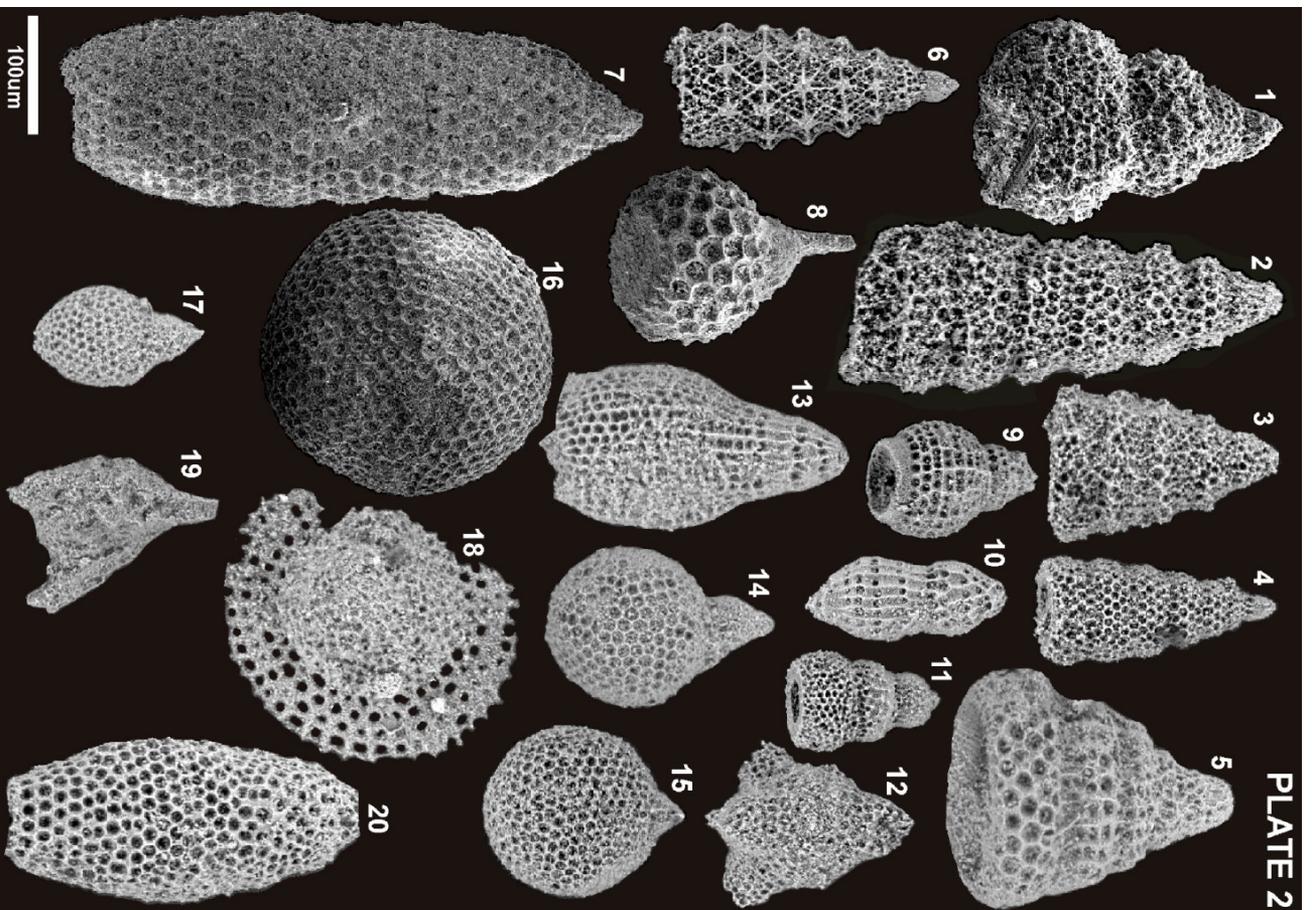
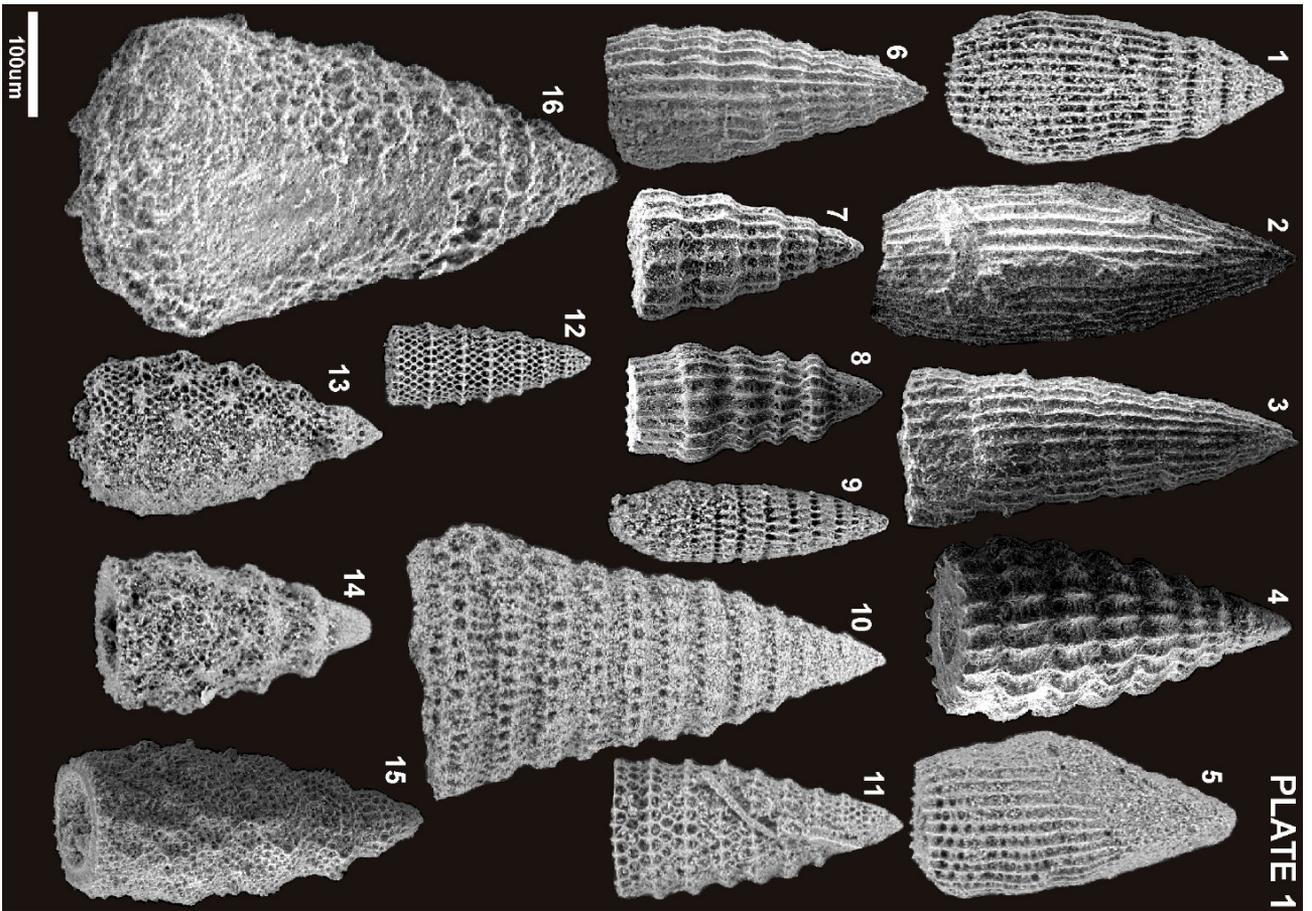
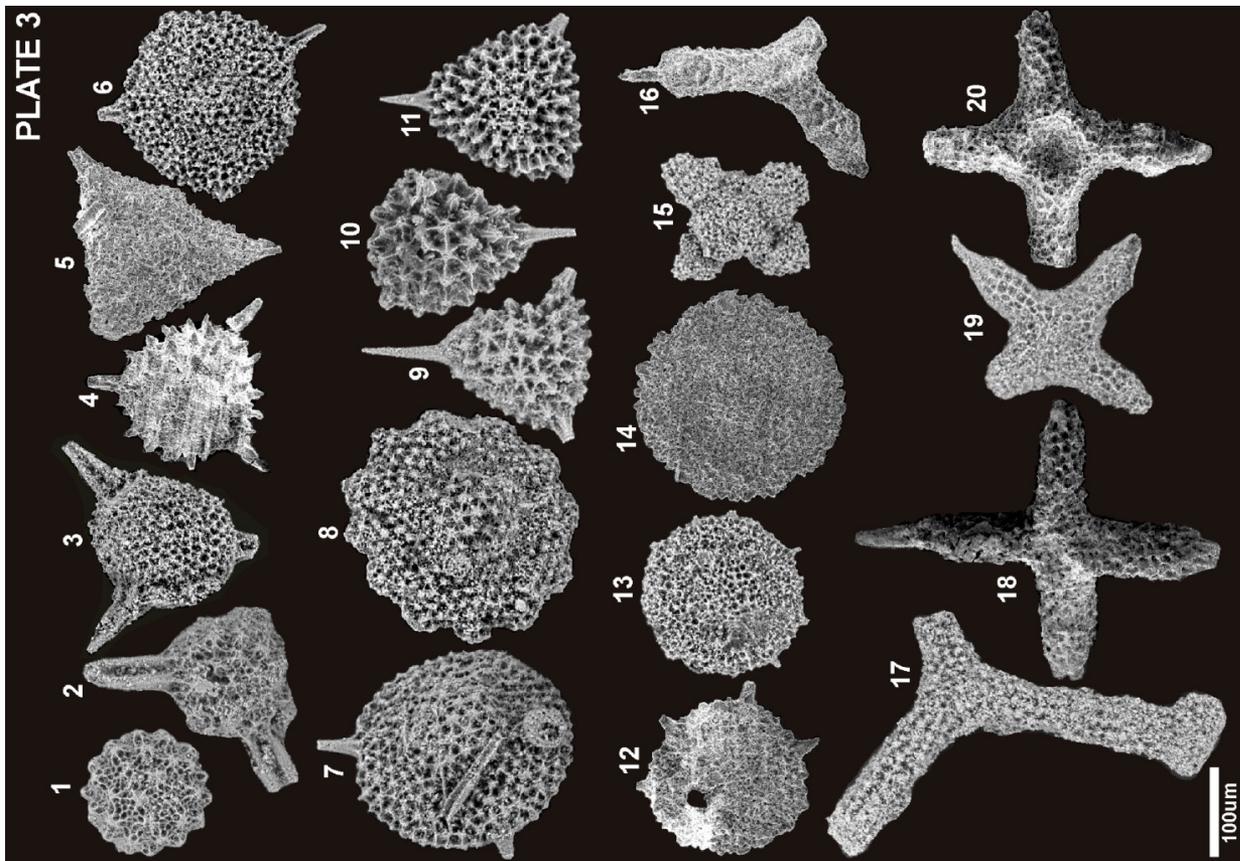


Plate 1: Photomicrographs of nassellarians in sections S1 and S2. (Scale bar = 100 µm).
 1. *Archaeodictyomitra chaililovi* (Aliev), 2. *Dictyomitra gracilis* (Squinabol), 3. *Dictyomitra montisserei* (Squinabol), 4. *Dictyomitra formosa* Squinabol, 5. *Dictyomitra obesa* (Squinabol), 6. *Dictyomitra multicosata* Zittel, 7. *Dictyomitra communis* (Squinabol), 8. *Dictyomitra koslovae* Foreman, 9. *Pseudodictyomitra languida* O'Dogherty, 10. *Pseudodictyomitra titara* (Holmes), 11. *Foremanina schona* Empson-Morin, 12. *Tuguriella pagoda* (Squinabol), 13. *Xitus clava* (Parona), 14. *Xitus mclaughlini* Pessagno, 15. *Xitus spicularius* (Aliev), and 16. *Torculum coronatum* (Squinabol)

Plate 2: Photomicrographs of nassellarians in sections S1 and S2 (cont.). (Scale bar = 100µm).
 1. *Stichomitra simplex* (Sirmova & Aliev), 2. *Stichomitra communis* Squinabol, 3. *Stichomitra tosaensis* Nakaseko & Nishimura, 4. *Stichomitra stocki* (Campbell & Clark), 5. *Stichomitra parapedia* Bragina & Bragin, 6. *Amphypindax pseudocoenulus* (Pessagno), 7. *Phangalites perspicuus* (Squinabol), 8. *Rhopalosyringium fossile* (Squinabol), 9. *Pseudothecampe tina* (Foreman), 10. *Theocampe salillum* Foreman, 11. *Lithocampe manifesta* (Foreman), 12. *Pogonias prodromus* O'Dogherty, 12. *Obeliscites vinassai* (Squinabol), 13. *Hiscocapsa asseni* (Tan), 14. *Cryptamphorella conara* Foreman, 15. *Holocryptocarium barbui* Dumitrica, 16. *Diacanthocapsa euganea* Squinabol, 17. *Sciadiocapsa speciosa* (Squinabol), 18. *Ultranapora cretacea* (Squinabol), and 19. *Theocapsomma comys* Foreman

Plate 3: Photomicrographs spumellarians in sections S1 and S2. (Scale bar = 100µm).
 1. *Praeconocaryomma universa* Pessagno, 2. *Acaenioyle rebellis* O'Dogherty, 3. *Triactoma cellulosa* Foreman, 4. *Becus horridus* (Squinabol), 5. *Pseudoaulophacus sculptus* (Squinabol), 6. *Pseudoaulophacus putahensis* Pessagno, 7. *Pseudoaulophacus florensis* Pessagno, 8. *Pseudoaulophacus parguerensis* Pessagno, 9. *Alievium superbum* (Squinabol), 10. *Alievium gallowayi* Pessagno, 11. *Alievium murphyi* Pessagno, 12. *Patellula helios* (Squinabol), 13. *Patellula eclipitica* O'Dogherty, 14. *Dactylosphiera maxima* (Pessagno), 15. *Quadrigasterium oculatus* O'Dogherty, 16. *Paronaella grapevinensis* (Pessagno), 17. *Pessagnobrachia fabianii* (Squinabol), 18. *Crucella bossoensis* Jud, 19. *Crucella massinae* Pessagno, and 20. *Crucella cachenis* Pessagno



recognized by the presence of *Xitus mclaughlini* and Assemblage III (Turonian) represented by the occurrences of *Crucella cachensis*. The association of chert with mafic and ultramafic rocks represents of an ophiolitic sequence in an oceanic crust which possibly developed close to a spreading center of a marginal basin.

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