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Significance of Mesozoic Radiolarian Chert in Sabah and Sarawak

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Abstract

Mesozoic radiolarian cherts are exposed in west Sarawak and Sabah. The cherts are dated by detailed studies of the radiolarian faunas. The oldest datable chert is from the Serian Volcanics which is Plienbachian-Toarcian, Early Jurassic. The chert sequence at the base of Pedawan Formation yielded late Tithonian-Berriasian radiolarians. Three different ages were identified from the chert blocks of the Lubok Antu mélange; late Tithonian, Valanginian to Barremian and Albian-Cenomanian. The age of the chert from the ophiolitic and mélange associations in Sabah ranges from Valanginian to Cenomanian. The environment of deposition is determined by using rock association. All the cherts were deposited in deep-marine environment. The occurrence of bedded chert was very much related to the plankton productivity. There were high productivities during the Early Jurassic and Early to early Late Cretaceous.

Kesignifikan Chert Radiolaria Mesozoik di Sabah dan Sarawak

Abstrak

Cert radiolaria yang berusia Mesozoik terdapat di bahagian barat Sarawak dan Sabah. Penentuan usia chert ini dibuat menggunakan kajian terperinci terhadap fauna radiolaria. Maklumat cert tertua terdapat dalam batuan dasar Formasi Serian Volkanik iaitu Plienbachian-Toarcian, Jurasik Awal. Jujukan cert pada bahagian dasar Formasi Pedawan menunjukkan kehadiran radiolaria yang berusia akhir Tithonian-Berriasian. Tiga usia yang berbeza dikenalpasti pada bongkah cert di mélange Lubuk Antu; akhir Tithonian, Valangianian-Berramian dan Albian-Cenomanian. Sekitaran pengendapan ditentukan berdasarkan perkaitan di antara batuan. Kesemua cert ini merupakan endapan sekitaran laut dalam. Kehadiran cert berlapis dikaitkan dengan produktiviti plankton yang sangat tinggi pada masa Jura Awal dan awal Kapur Akhir.

INTRODUCTION

Radiolarian cherts are exposed mainly in the western part of Sarawak and in the eastern and northern parts of Sabah (Figure 1). The occurrence of Mesozoic radiolarian faunas in Sarawak was first described by Hinde (1900) mainly from the Lupar Valley. More radiolarian cherts were reported from the Lupar Valley (Haile, 1957), the Sematan and Lundu area (Wolfenden,1963), the Bako National Park area (Wilford, 1965) and the Penrissen area (Wilford and Kho, 1965). In Sabah, the radiolarian chert was found in the "Chert Spilite Formation" (Fitch, 1955; Wilson, 1963). The identification of the radiolarian faunas from the studies were mainly based on the thin sections. Tan (1980) summarises the distribution of siliceous deposits in Sabah and Sarawak.

Recently, radiolarian fossils were retrieved from the chert by using hydrofluoric acid. More research has also been carried out to review and revise the previous works (Leong, 1977; Tan, 1979; Basir Jasin and Sanudin Tahir, 1988; Basir Jasin, 1991; Basir Jasin and Sanatulsalwa Hasan, 1992; Basir Jasin, 1992; Basir Jasin and Haile, 1993, Aitchison, 1994, Basir Jasin and Aziman Madun 1995; Basir Jasin, 1996). More information was obtained from the results of the studies.

This paper briefly reviews the new information to refine the age determination, the stratigraphy and the environment of deposition of the chert sequence in Sabah and Sarawak.

GEOLOGICAL SETTING

The oldest radiolarian chert is found in the chert-dacitic tuff sequence overlying the Serian Volcanics and the Sadong Formation in the vicinity of Binong Pass. The sequence consists of thinly bedded chert, interbeds with dacitic tuff. The sequence is unconformably overlain by the Kedadom Formation. The basal part of the Kedadom Formation consists of basal conglomerate. The Kedadom Formation is in part interfingering and in part conformably overlain by the Bau Limestone. The Bau Limestone was deposited in a shallow marine environment during the Late Jurassic. The Bau Limestone is conformably overlain by the Pedawan Formation. The radiolarian chert is found at the base of the Pedawan Formation. The chert is interbedded with tuffaceous mudstone. Glass shards of volcanic origin are present in the tuffaceous mudstone (Basir Jasin and Uyop Said, 1998).

Radiolarian chert was also reported from the Lupar Valley. The chert occurs as blocks ranging from a few

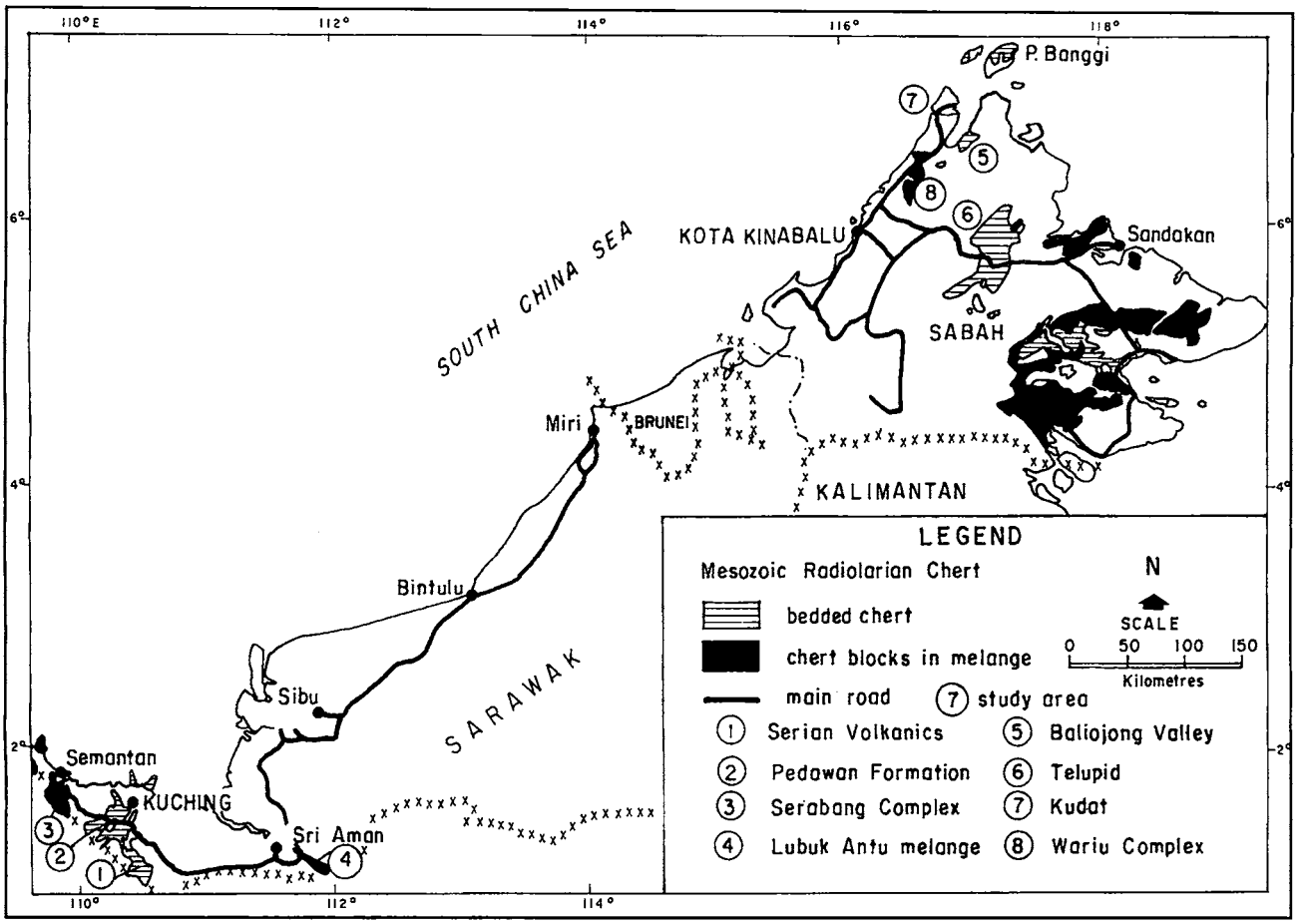

Figure 1: Distribution of Mesozoic chert.

metres to 5.5 km in diameter. The chert is included in the Lubok Antu mélange (Haile, 1957; Tan, 1979). The Lubok Antu mélange is a chaotic rock unit composed of blocks and fragments of cherts , mudstone, sandstone, hornfels, limestone, basalt, gabbro and serpentinite of various sizes embedded in pervasively sheared mudstone matrix. Radiolarian chert pebbles were also discovered from the pebbly sandstone in the Lupar Formation. The Lupar Formation was deposited by turbidity currents during the late Cretaceous.

The chert blocks are also found in the Serabang Formation. The chert of the Serabang Formation occurs as lenses in the predominantly argillaceous rocks with minor arenaceous rocks, fragments of slate, lenses of conglomerate, calcsilicate hornfels, marble and metamorphosed gabbro, dolerite and basic lava (Wolfenden, 1963). Most of the chert blocks are recrystalised.

The Serabang Formation was originally described by Wilford (1955). The Serabang Formation has been redefined by Haile (1961) and re-described by Haile and Wolfenden (in Wolfenden, 1963). The Serabang Formation contains slaty shale, slate, hornfels, blocks and fragments of conglomerate, greywacke, limestone, chert, tuffite and basalt embedded in slaty matrix. The term formation is not appropriate because the rock assemblage is a mélange. It is more appropriate to be called the Serabang Complex (Basir Jasin and Aziman Madun,1996). The Serabang Complex is thermally metamorphosed as a result of the intrusion of ademellite bodies of Gunung Pueh and Gunung Gading during the Late Cretaceous.

In Sabah, the bedded radiolarian chert is found associated with spilite, pillow lava, basalt and daibase. The rock association was included in the Chert-Spilite Formation (Fitch, 1955; Wilson, 1963; Leong, 1974). This association represents an ophiolite sequence. The radiolarian chert is also found as blocks in chaotic deposits containing blocks of tuff, tuffaceous rocks, mudstone, sandstone, limestone and volcanic rocks. The rock association is a mélange which has previously been named as the Wariu, Ayer, Kuamut and Garinono Formations. This rock association is more appropriatly called a mélange complex.

RADIOLARIA, AGE AND LITHOSTRATIGRAPHY

The oldest radiolarians were retrieved from the chert-dacitic tuff sequence in the vicinity of Binong Pass, Serian. Twenty-seven taxa of Radiolaria were identified (Basir Jasin *et al.*, 1996; Basir Jasin and Uyop Said, 1998). The occurrence of *Parahsuum simplum* Yao, *Parahsuum*

directiporatum (Rust), *Praeconocaryomma media* Pessagno and Poisson, *Praeconocaryomma decora* Yeh, *Paracanoptum anulatum* (Pessagno and Poisson), *Canutus izeensis* Pessagno and Whalen, and *Canoptum rugosum* (Pessagno and Poisson) suggests that the radiolarian faunas belong to the *Parahsuum directiporatum* Zone of Nishizono *et al.* (1997). The whole dacitic tuff-chert sequence was deposited during Pliensbachian-early Toarcian, Early Jurassic (Figure 2).

The dacitic tuff-chert sequence is included in the Serian volcanics because they are genetically related (Basir Jasin and Uyop Said, 1998a). The age of the Serian volcanics ranges from Late Triassic to Early Jurassic. The dacitic tuff-chert sequence is unconformably overlain by the Kedadom Formation.

Fifty-three taxa of Radiolaria were identified from ten samples collected from the Tubeh and Pang Bau areas (Basir Jasin and Uyop Said, 1998b). These taxa are very much different from those identified by G. F. Elliott (in Wilford and Kho, 1965). Most of the radiolarian faunas in the present material have been recorded mainly in the Tethyan realm. The occurrence of index species such as *Loopus primitivus* (Matsuoka and Yao) in the section near Bau indicates that the age of the lower part of the chert belongs to Unitary Association Zone 12 of Baumgartner *et al.* (1995). The occurrence of *Artocapsa* (?) *amphorella* Jud and *Hsuum raricostatum* Jud, *Syringocapsa longitubus* Jud, *Obesacapsula rusconensis umbriensis* Jud, *Angulobracchia* (?) *rugosa* Jud and *Cinguloturris cylindrica* Kemkin & Rudenko suggests that the age of the top part belongs to Unitary Association Zone 13 to 15. The age of the whole chert ranges from the Unitary Association Zone 12 to 15, late Tithonian to Berriasian (Figure 3). It seems that there was no break in sedimentation at the Jurassic-Cretaceous boundary. The occurrence of *Obesacapsula rusconensis umbriensis* Jud in sample T 2 indicates that the chert near Tubeh is of the same age.

The chert blocks from the Lubok Antu mélange yielded three assemblages of Radiolaria (Basir Jasin, 1996). Assemblage I is composed of 17 taxa. The occurrence of *Parvicingula excelsa* and *Ristola altissima* indicates the *Ristola altissima* Zone, late Tithonian, Late Jurassic. Assemblage II consists of 21 species. The occurrence of *Cerops septemporata* is indicative of the middle Valanginian to Barremian age. Assemblage III contains 18 species. The presence of *Obecapsula somphedia, Holocryptocanium barbui, Squinabollum fissilis, Pseudodictyomitra pseudomacrocephala, Novixitus weyli, Novixitus mclaughlini, Rhopalosyringium majuroensis, Stichomitra communis, Holocryptocanium tuberculatum, Thanarla praeveneta* indicates the late Albian-Cenomanian age (Figure 4). Three different ages of the chert blocks were recognised, i.e. late Tithonian, middle Valanginian to Barremian and Albian-Cenomanian.

The shale from the Serabang Complex mélange yielded some Radiolaria. Eleven taxa were identified (Basir Jasin

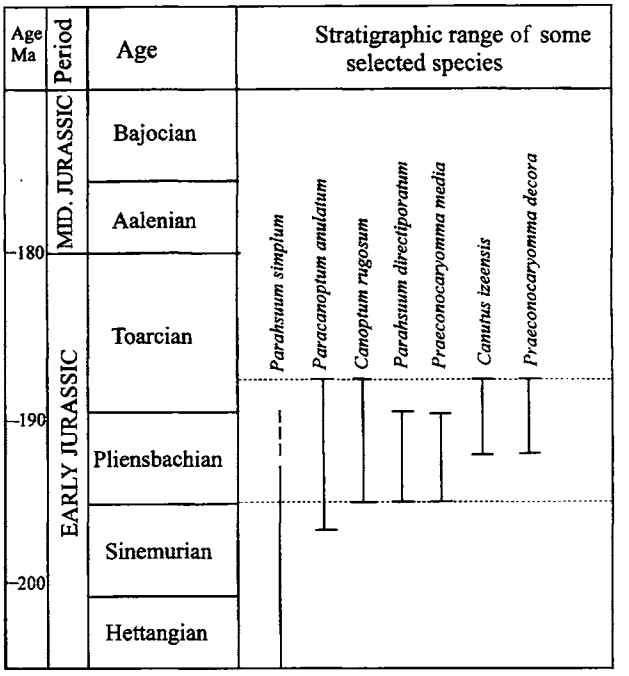

Figure 2: Stratigraphic distribution of selected Radiolaria from the dacitic tuff-chert sequence.

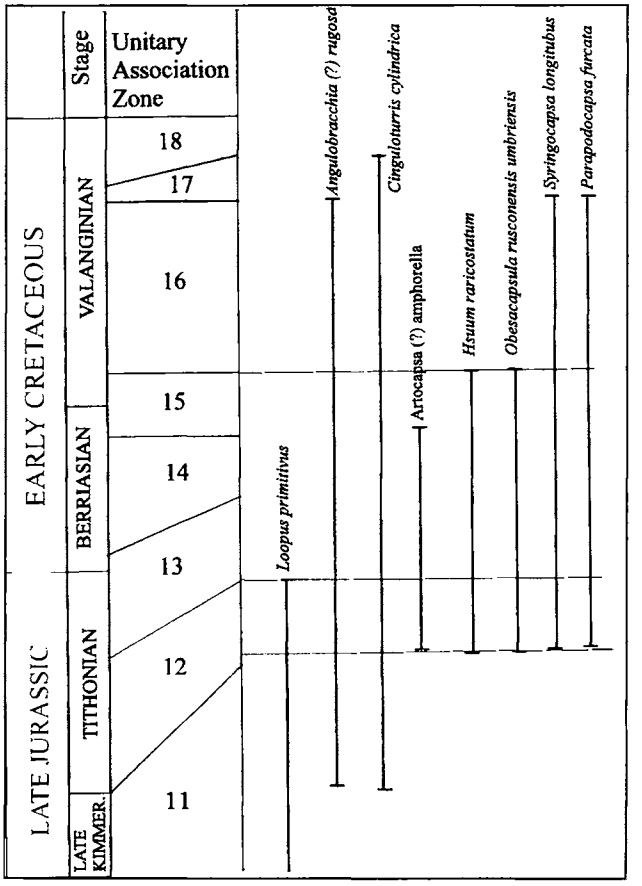

Figure 3: Stratigraphic distribution of selected Radiolaria from chert of the Pedawan Formation.

and Aziman Madun, 1996). The occurrence of *Archaeodictyomitra lacrimula* indicates that the age of the shale is Lower Cretaceous (Valanginian to Aptian). The mudstone is probably the matrix of the complex and the radiolarians can be used for dating the complex.

Radiolarian chert pebbles form the pebbly sandstone of the Lupar Formation yielded nine species of Radiolaria i.e. *Acaeniotyle umbilicata, Thanarla conica, Archaeodictyomitra vulgaris, Archaeodictyomitra lacrimula, Archaeodictyomitra* sp., *Eucyrtis micropora, Eucyrtis* sp., *Sethocapsa* sp., and *Xitus* spicularius. This assemblage indicates the age is Hauterivian to Barremian. This assemblage resembles the Assemblage II of the chert blocks from the Lubok Antu mélange. Both cherts were probably of the same origin.

Radiolarian chert from the ophiolitic association in Sabah is exposed in the Kudat, Pulau Banggi, Baliojong Valley, Telupid, Segama Valley and Pulau Timbun Mata. Several radiolarian assemblages were identified from Kudat (Basir Jasin and Sanudin Tahir, 1988), Baliojong Valley (Basir Jasin and Sanatulsalwa Hasan, 1992; Basir Jasin and Tongkul, 2000) and Telupid (Basir Jasin, 1992). The age of the radiolarian chert in Sabah was thought to be Valanginian to Barremian, Early Cretaceous (Leong, 1977; Basir Jasin, 1991). The age of the chert has been revised based on the work of Baumgartner *et al.*, (1995). The common age-diagnostic taxa are *Archaeodictyomitra lacrimula, Pseudodictyomitra carpatica, pantanellium squinaboli*, and *Dictyomitra pseudoscalaris*. This assemblage is indicative of Valanginian to Aptian. There is no diagnostic species which can be used to differentiate Valanginian, Hauterivian and Barremian. The youngest radiolaria assemblage consists of *Pseudodictyomitra pentacolaensis, Dictyomitra gracilis, Thanarla veneta, Dictyomitra obesa, Pseudodictyomitra pseudomacrocephala*, and *Xitus mclaughlini* which indicates that the age of the topmost radiolarian chert is Aptian-Cenomanian (Basir Jasin, 1999; Basir Jasin and Tongkul, 2000). The age of the chert sequence ranges from Valanginian to Cenomanian (Figure 5). A similar age was obtained from the chert blocks in the Wariu (Basir Jasin, 1999) and Ayer Complexes (Aitchison, 1994). The radiolarian chert blocks of the mélange were derived from the ophiolitic chert association.

Radiolarian chert provides more information about the age of the Mesozoic formations in Sarawak and Sabah (Figure 6). The age of the Serian Volcanics ranges from Late Triassic to Plienbachian-Toarcian Early Jurassic. This formation is separated from the younger Kedadom Formation by middle Triassic unconformity. The age of the Kedadom Formation is middle Kimmeridgian to early Tithonian, Late Jurassic based on the presence of bivalve *Neoburmesia iwakiensis* Yabe and Saito and fragment of ammonites *Lithaceros* or *Subpalnites* (Wilford and Khoo, 1965). The Kedadom Formation is partly interfingering and partly overlain by the Bau Limestone. The Bau Limestone is overlain by tuffaceous mudstone and

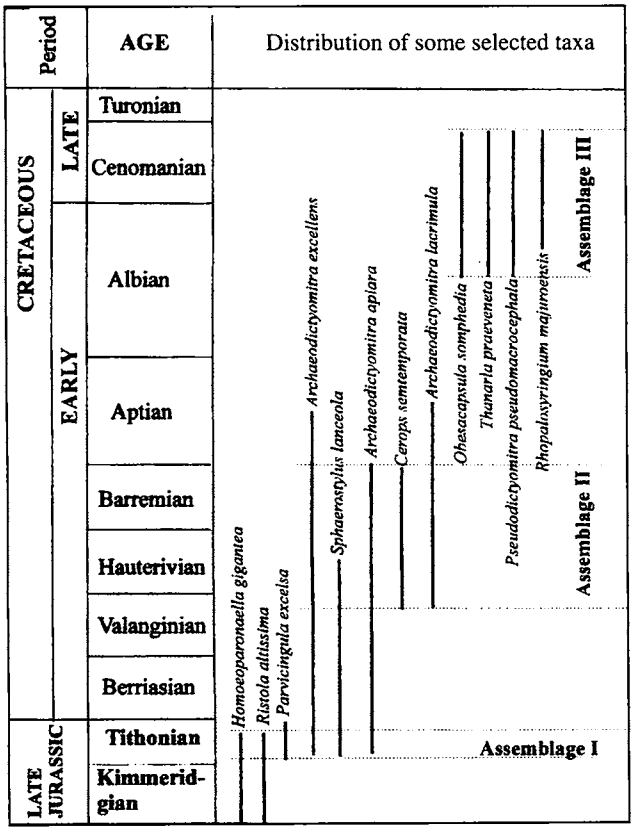

Figure 4: Stratigraphic distribution of selected Radiolaria from the chert blocks of the Lubok Antu Mélange.

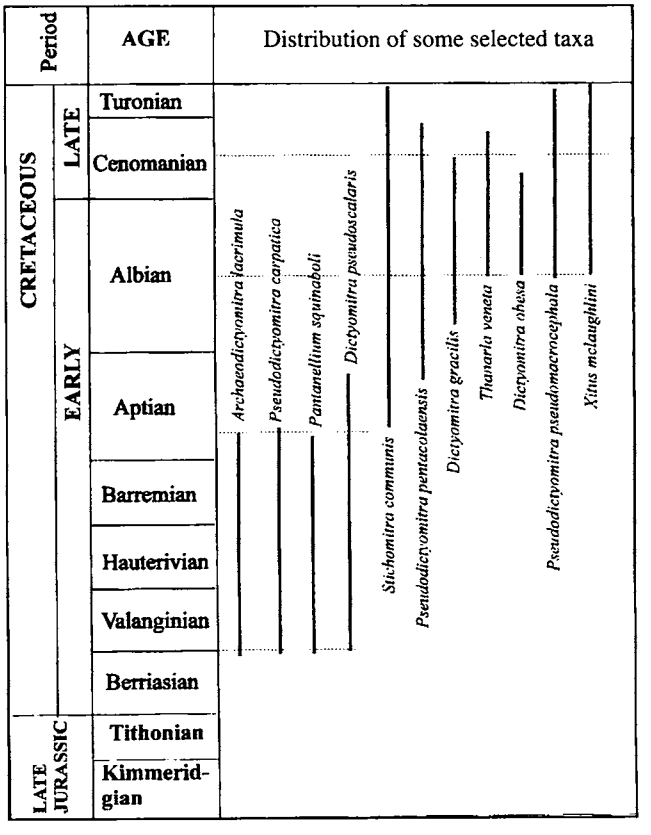

Figure 5: Stratigraphic distribution of selected Radiolaria from the chert blocks of ophiolitic and mélange association.

radiolarian chert which form the base of Pedawan Formation. The chert yielded radiolarian assemblages indicating an age late Tithonian (latest Jurassic) to Berriasian (early Cretaceous). The age of the chert is partly equivalent to that of chert blocks in the Lubuk Antu Complex mélange. There was no interfingering observed between the lower part of the Pedawan Formation and Bau Limestone. The contact between the formations are exposed in the vicinity of Binong Pass and at Pang Bau.

The occurrence of radiolarians in the shale matrix in the Serabang Complex suggests that the age of the complex is Early Cretaceous which is partly equivalent to the age of the chert blocks in the Lubok Antu complex mélange. (Basir Jasin and Aziman Madun, 1996; Basir Jasin, 1996). The chert blocks of the Lubok Antu complex mélange are probably of the same age as the chert of the Sejingkat Formation (Figure 7). Since the radiolarians in the Sejingkat chert are poorly preserved the age cannot be properly assigned.

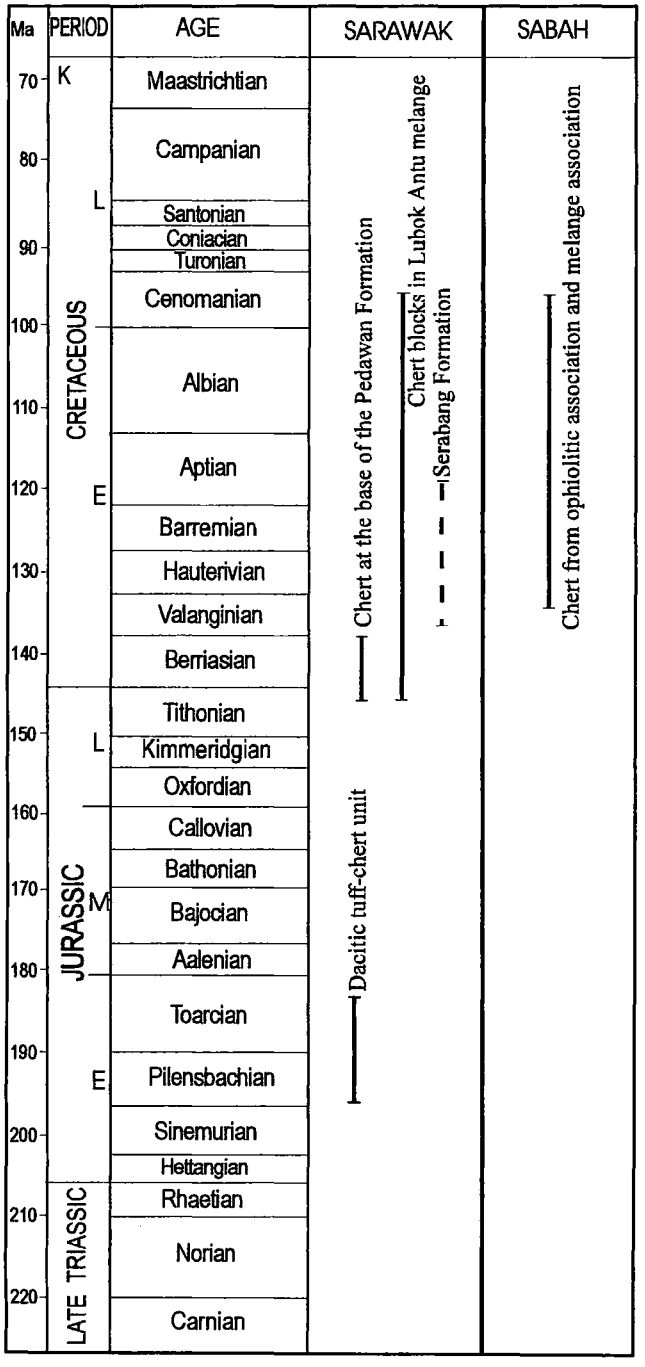

Figure 6: The age of the cherts based on radiolarian fauna.

The chert sequence in Sabah yielded radiolarian faunas indicating an age from Valanginian to Cenomanian (Figure 8). No younger radiolarians were identified from the chert. This age was obtained from both bedded cherts in the ophiolitic association and chert blocks of the mélange association. Better lithostratigraphic boundaries can be constructed based on the radiolarians. It is evident that the chert was quite wide spread during the Early Cretaceous in both Sarawak and Sabah. The chert in Sarawak is older and becomes younger towards Sabah.

DEPOSITIONAL ENVIRONMENT

The Early Jurassic radiolarians are retrieved from the dacitic tuff-chert sequence exposed in the vicinity of Binong Pass. The dacitic tuff-chert sequence is composed of rhythmically bedded dacitic tuff interbeds with cherts and mudstone. The sequence is underlain by volcanics rocks which consist of agglomerate and andesite. The Serian Volcanics is predominantly a basalt andesite association which has tholeiitic affinity indicating that they were formed on the oceanic side of an island arc (Hon, 1975). The rock association is equivalent to the Island Arc Chert Association of Jones and Murchey (1986). The dacitic tuff-chert unit was probably deposited in an oceanic environment very close to an island arc.

At the base of the Pedawan Formation the chert is underlain by mudstone and the Bau Limestone. A vertical change in lithology from shallow water carbonate to radiolarian chert characterised a subsidence-induced environment. The rock association is a subsidence association (Jones and Murchey, 1986). There was a rapid subsidence of the environment during the latest Jurassic-Early Cretaceous, which was accompanied by an increased influx of dacitic tuff and clastic material of the Pedawan Formation (de Coo and Lau, 1977; Tan, 1986). The presence of radiolarian chert indicates a transgression or subsidence at the Jurassic-Cretaceous boundary. There was no break in sedimentation observed during the Late Jurassic-Early Cretaceous time.

The occurrence of radiolarians in the shale matrix in the Serabang Complex indicates that the mélange was deposited in a deep water environment probably near a deep sea trench. The Serabang complex was probably developed during Early Cretaceous, which represents a short-lived subduction zone that rapidly migrated to the Lubok Antu zone. The complex was probably the extension of the Boyan Mélange (Basir Jasin, 1996).

The origin of chert blocks in the Lubuk Antu mélange is still obscure. The chert was probably deposited in a deep

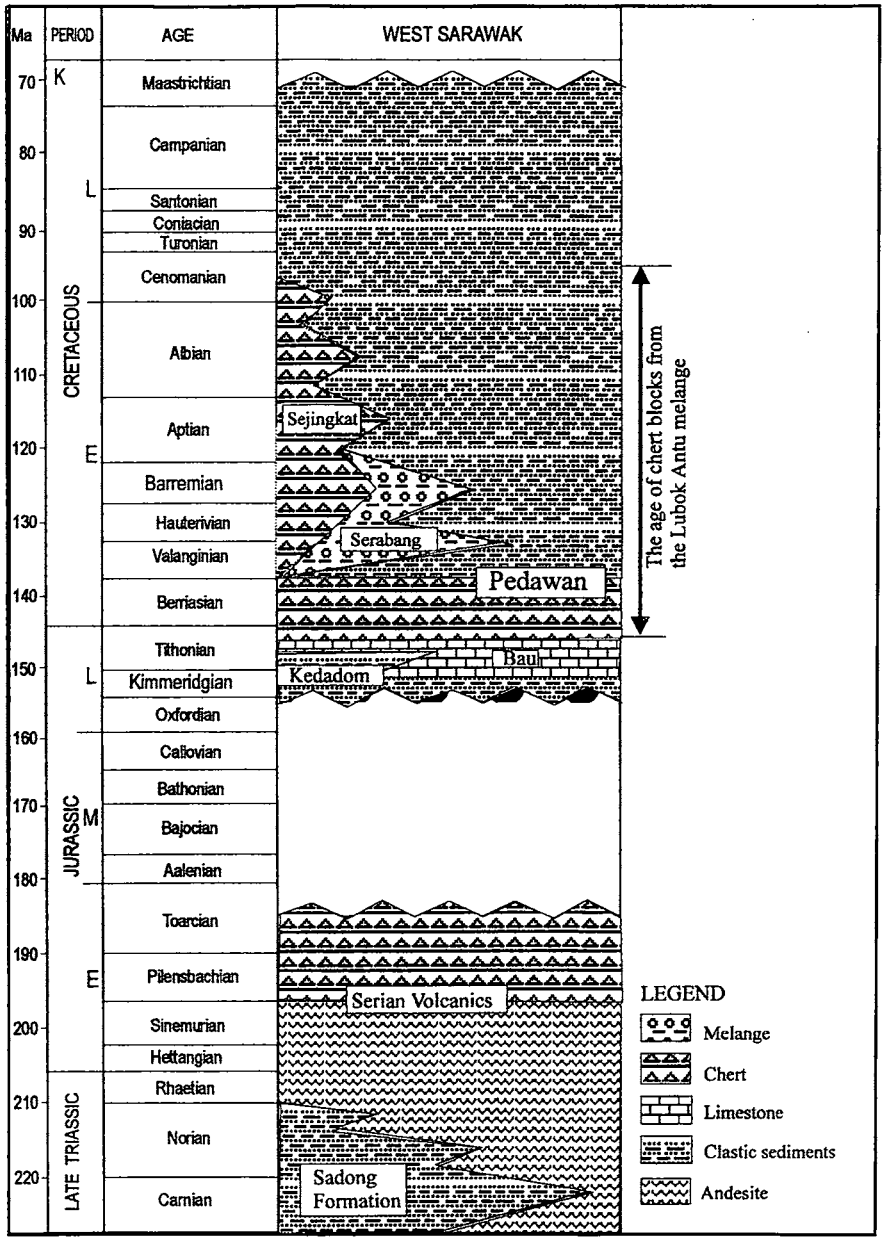

Figure 7: Lithostratigraphy Mesozooic chert bearing rocks of west Sarawak.

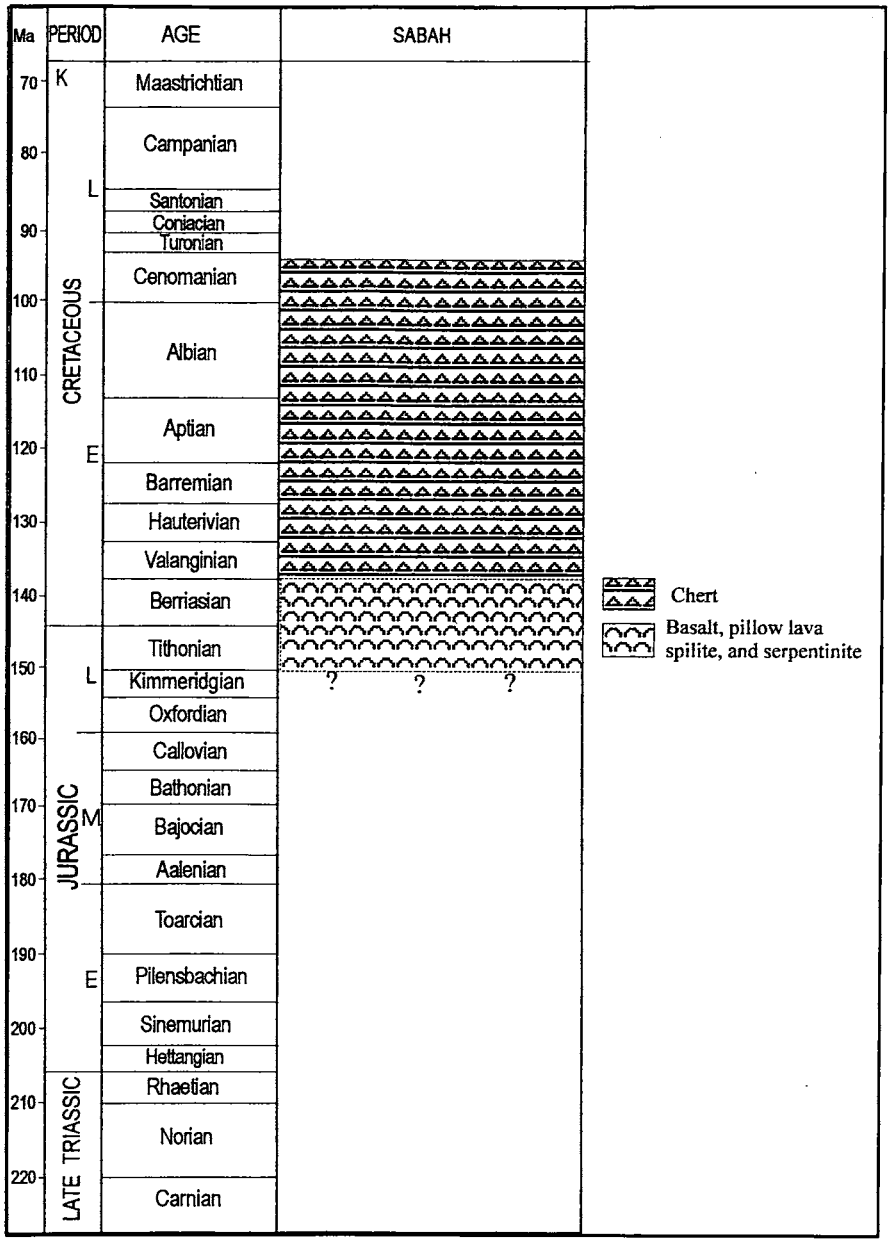

Figure 8: Lithostratigraphy of the Mesozooic chert in Sabah.

marine environment during the Late Jurassic to Cenomanian, early Late Cretaceous. There is no evidence to show an ophiolite-chert association in the surrounding area. Haile *et al.*, (1994) discovered that the mafic rock in the area is younger than the chert. The early Cretaceous radiolarian chert pebbles found in the Lupar Formation were derived from the same source (Basir Jasin, 1994). They were eroded and transported to the deep water environment by turbidity current during the Late Cretaceous.

The ophiolite-chert association is well-exposed in Sabah. The association is characterised by the occurrence of gabbro, serpentinite, spilite and pillow lava capped by red radiolarian chert. The association represents oceanic crust which developed at the spreading centre. The bedded chert at places such as Baliojong Valley and Telupid, is interbedded with turbiditic sandstone. This suggests that the area was close to the continental shelf where clastic material was transported to the basin by episodic turbidity currents. The depositional environment for the chert was probably a marginal basin (Basir Jasin, 1999).

PALEOCEANOGRAPHIC SIGNIFICANCE

More than 98% of radiolarian opal tests dissolve in the water column and on the sea-floor prior to burial (Jones and Murchey, 1986). The formation of bedded radiolarian chert is therefore, very much related to the high productivity of radiolarian faunas. The high productivity of the faunas is associated with the supply of nutrient and siliceous material. The occurrence of volcanic material in the Early Jurassic radiolarian chert in the Serian Volcanics and the late Jurassic-Early Cretaceous Radiolarian chert at the base of Pedawan Formation indicates a high productivity of radiolarian faunas, which was associated with the supply of nutrient and siliceous material by the volcanic activities. Other chert accumulations such as Cretaceous radiolarian deposits from the Serabang Complex, Lubok Antu mélange and ophiolitic chert association were related to the upwelling of the nutrient-rich water mass which is very common a marginal basin setting (Jenkyns and Winterer, 1982; Hein and Karl, 1983).

The deposition environment of the Mesozoic bedded chert in Sarawak and Sabah must have been far away from sources of terrigenous material. The supply of clastic material was rarely transported to the basin by turbidity currents. The absence of calcareous planktonic foraminifera and nannofossils indicate that the chert was deposited below the calcite compensation depth. During the Mesozoic there were at least two episodes of high plankton productivity i.e. Early Jurassic and Early Cretaceous-early Late Cretaceous.

CONCLUSIONS

Radiolarian cherts are very important in determining the ages of siliceous rocks in Sarawak and Sabah. The discovery of Early Jurassic radiolarian chert refutes the occurrence of early Jurassic to late Jurassic unconformity (Tan, 1986). The unconformity is only from Aalenian to Oxfordian, which separates the Serian Volcanics and the Kedadom Formation. Other bedded radiolarian chert indicate ages ranging from Tithonian (latest Jurassic) to Cenomanian (early Late Cretaceous). The radiolarian chert sequence at the base of the Pedawan Formation separates it from the Bau Limestone. The chert was deposited in relatively deep marine environment while the Bau Limestone was deposited in shallow marine environment.

The rock associations of the cherts can be used for interpreting the depositional environments. The dacitic tuff-chert association was deposited in oceanic environment very close to an island arc. The chert-limestone association at the boundary between the Bau limestone and the Pedawan Formation shows basinal subsidence during late Tithonian-Berriasian. The chert blocks of the Lubok Antu mélange were originally deposited in a deep marine environment and later underwent tectonic processes and were deposited as chaotic (mélange) deposits during early Tertiary. The ophiolite-chert association in Sabah was deposited in an oceanic environment at the spreading centre of a newly formed marginal basin.

The presence of chert also indicates high radiolarian productivity which was associated with either volcanic activities or upwelling in the marginal basin. This high productivity event in the late Jurassic to early Late Cretaceous gives some clues about the age of the radiolarian chert in Sarawak and Sabah. All radiolarian cherts in Sarawak and Sabah were deposited during high plankton productivity. It implies that the Sejingkat Formation was most probably deposited during this time.

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