

Malampaya Sound Group : a Jurassic-Early Cretaceous accretionary complex in Busuanga Island, North Palawan Block (Philippines)

Abstract

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Busuanga Island is considered an accretionary complex primarily composed of Middle Permian to Jurassic chert (Liminangcong Formation), Middle Jurassic to Early Cretaceous clastics (Guinlo Formation) and limestone units of various ages, with minor melange bodies (Bicatan Melange), collectively called as the Malampaya Sound Group. These rocks are regarded as offscraped sedimentary deposits from a subducted oceanic plate that developed imbricate structure during the Jurassic-Early Cretaceous accretion. The lithologic transition from chert to siliceous mudstone to terrigenous clastics indicates facies change from pelagic to terrigenous condition brought by a plate movement from an open ocean to the subduction zone. The siliceous mudstone units, which mark the end of chert deposition and the beginning of clastic deposition, are classified into three different ages in Busuanga Island, and found to be younging from north to south. This provides a major basis for defining three belts composing Busuanga Island : the Northern, Middle and Southern Busuanga belts. The Northern Busuanga Belt is composed of Middle Permian to Middle Jurassic (probably Aalenian) chert followed by Bathonian-Callovian (JR4-JR5) siliceous mudstone and Callovian (JR5) terrigenous clastics. The Middle Busuanga Belt has its topmost chert deposit at Bajocian-lower Bathonian (JR4), siliceous mudstone interval from upper Bathonian to lower Oxfordian (JR5-JR6), and terrigenous clastics at Oxfordian (JR6). The Southern Busuanga Belt shows the transition from lower-middle Tithonian (JR8) chert to upper Tithonian-Berriasian (KR1) siliceous mudstone. The subsequent deposition of terrigenous clastics, supposedly overlying the siliceous mudstone, is considered occurring within the Lower Cretaceous.

The offscrape accretion period of these three belts probably occurred during the Middle Jurassic for the Northern Busuanga Belt, Late Jurassic for the Middle Busuanga Belt and Early Cretaceous for the Southern Busuanga Belt. These chert-clastic sequences of the Malampaya Sound Group are also found correlative with the Togano Group of the Southern Chichibu Terrane of SW Japan.

Key words : Busuanga, North Palawan Block, Liminangcong Formation, Guinlo Formation, Malampaya Sound Group, chert-clastic sequences, accretionary complex, radiolarian, Jurassic, Bicatan Melange, Togano Group

Introduction

The progressive studies on chert-clastic sequences that eventually established the Mesozoic accretion-subduction complexes in East Asia have attained the essential role in understanding the region's tectonic

framework. After a few decades of continuous geologic works particularly in Japan, the NE-SW trending subduction zone along the eastern margin of Asian landmass during the Mesozoic, as earlier proposed by Hamilton (1979), has finally become evident in the stratigraphy and geologic structure of the

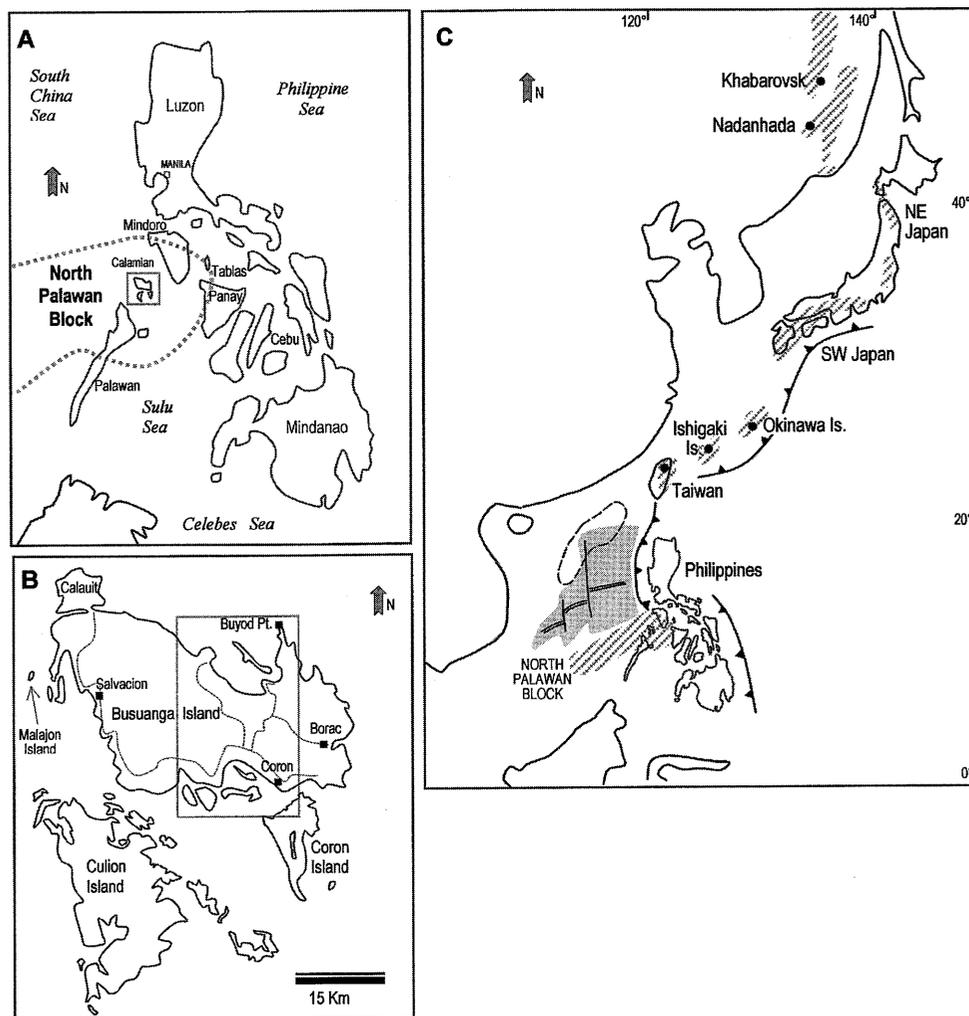


Fig. 1. (A) The North Palawan Block, in the western central Philippines. (B) The Calamian Islands and location of the study area. (C) The Jurassic accretionary complex in East Asia (Isozaki et al., 1988 ; Matsuda and Isozaki, 1991 ; Mizutani and Kojima, 1992 ; Kojima and Kametaka, 2000). The dashed lines indicate the probable location of the North Palawan Block before the mid-Oligocene opening of the South China Sea (Holloway, 1982).

region. Following its acceptance, geologic researchers worldwide did substantial review on recognized chert-clastic complexes in this modern tectonic perspective. Heretofore, ongoing developments on tectonic studies in East Asia in collaboration with radiolarian works successfully amassed sufficient amounts of data whereby terrane correlation within the region have already become possible.

The chert-clastic complex in the North Palawan Block (Fig. 1 A) has long been intended for review and further research to complement the progress of study in the region's chert-clastic complexes especially in Japan. That the structural framework of Busuanga Island considered as an array of parallel folded structures oriented NE-SW in the western side and NW-SE in the central and eastern portion (Bureau of Mines and Geosciences (BMG), 1984) needs to be reviewed to ascertain its comparability with East Asian chert-clastic complexes. Following the tectonic dis-

coveries in mid 1980's, Isozaki et al. (1988) proposed the subduction-accretion framework for the North Palawan Block quite similar to the then newly recognized subduction-accretion complexes in SW Japan. Faure and Ishida (1990) further proposed that the North Palawan Block is an olistostrome with its chert and limestone bodies serving as olistoliths set in Middle-Late Jurassic mudstone matrix. In the absence of follow-up geologic, structural or tectonic works during the last decade, however, our modern theory on the Mesozoic events transpiring the North Palawan Block remained unsubstantiated.

Nevertheless, radiolarian works in Busuanga Island continuously increased particularly during the last decade. These works such as Cheng (1989, 1992), Tumanda (1991 a, 1991 b, 1994), Yeh (1992), Yeh and Cheng (1996, 1998), Tumanda-Mateer et al. (1996), and Zamoras and Matsuoka (2000 a) have gradually portrayed general characteristics of the chert-clastic

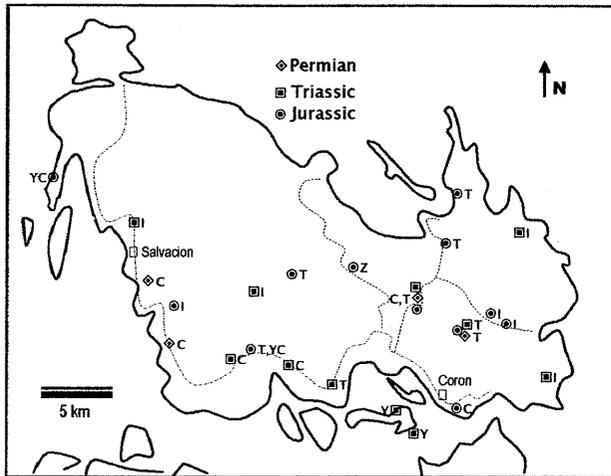


Fig. 2. Sample locations of previous radiolarian works. C : Cheng (1989, 1992), I : Isozaki et al. (1988), T : Tumanda (1991 a), Y : Yeh (1992), YC : Yeh and Cheng (1996, 1998), Z : Zamoras and Matsuoka (2000 a).

sequences in Busuanga Island (see Fig. 2). The reports on the occurrence of Permian, Triassic and Jurassic chert sequences, and Jurassic clastics as well, can already give an impression of apparent continuity. In fact, Tumanda (1991 a) had already proposed a radiolarian biostratigraphic zonation of the Middle Permian to Lower Jurassic chert sequences. These developments in radiolarian research have already offered potentially important contribution to the necessary further studies in Busuanga Island or in the North Palawan Block.

In this work the general scope covers the Permian, Triassic and Jurassic stratigraphy of the North Palawan Block but the emphasis remains on the Jurassic portion. The significance of the Jurassic portion is that it is the stage when the lithologic transition from chert to clastics occurred, not observed in the Triassic and Permian sequences in North Palawan. This transition specifically indicates a paleoenvironmental change typical to those with pelagic settings that gradually approach toward a continent, the formational process theory of accretion-subduction complexes. In this advanced stage of chert-clastic sequence studies, understanding the complex lithologic and radiolarian assemblages would not be as crucial as experienced by earlier researchers. The development of well-defined accretion-subduction models for East Asia has significantly facilitated our understanding of the North Palawan Block's tectonic framework.

This paper attempts to present the geology of Busuanga Island and its role in understanding the Upper Paleozoic to Mesozoic stratigraphy and tectonics of the North Palawan Block. It starts with a brief presentation of radiolarian data from selected samples, followed by detailed geological, paleontological and age descriptions of selected areas. The ages

or biostratigraphic zone assignments particularly for Jurassic samples are referred from the zonal scheme for the Western Pacific and Japan proposed by Matsuoka (1995). Succeeding sections are the revision of the Upper Paleozoic-Mesozoic stratigraphy of the North Palawan Block and the characterization of the chert-clastic sequences including the subdivision of Busuanga Island into three belts. Later discussions include the geologic structure of the accretionary complex, its formative process, and its correlation with corresponding complexes in Japan.

The area covered in this study is the easily accessible central portion of Busuanga Island (Fig. 1B). Unlike the east and western sides of Busuanga Island the central portion manifests simple topographic configuration quite reflective of its geologic structures as well as lithologic distribution. This significantly guides in planning for an appropriate mapping strategy. Its road network connecting villages to Coron town generally cut across the chert-clastic sequences, which favorably provide us exposures for data gathering. An approximate total of 20 km of north-south section can be traced across central Busuanga Island from Buyod Point to Coron.

Outline of the geology in Busuanga Island

The North Palawan Block is considered a continental fragment (Hashimoto and Sato, 1973; Hamilton, 1979) which integrates the northern half of Palawan Island, the Calamian Islands, the Reed Bank, SW Mindoro, NW Panay and Tablas Islands (Holloway, 1982; McCabe et al., 1982). Its stratigraphy shows a distinct sequence of Upper Paleozoic to Mesozoic sedimentary rocks not found in the younger Philippine Island arc. This evidence combined with magnetic anomaly data from the South China Sea (Taylor and Hayes, 1980) firmly supports the model that the North Palawan Block originated from the Asian mainland. Its southward drift was driven by a sea-floor spreading from mid-Oligocene to early Miocene based on South China Sea's east-west trending magnetic lineations dated 32–17 Ma (Taylor and Hayes, 1980). Holloway (1982) further elaborated the crustal movement of the North Palawan Block with palinspastic reconstruction of tectonic plates from the Jurassic accretion-subduction setting, through the incipient stage of crustal migration when the South China Sea opened, and finally its collision with the Philippine Island arc system. Recent studies on Mesozoic accretion-subduction widely believe that the North Palawan Block was positioned alongside with SW Japan's accretion subduction complexes and Taiwan in between (e.g., Isozaki et al., 1988; Matsuda and Isozaki, 1991; Mizutani and Kojima, 1992; Isozaki, 1997; Kojima and Kametaka, 2000) (Fig. 1C).

There are about five major stratigraphic works conducted in the North Palawan Block: Hashimoto and

Sato (1973), BMG (1981), Wolfart et al. (1986), Isozaki et al. (1988) and JICA-MMAJ (1990) in cooperation with BMG. These works gradually developed more complex stratigraphy following the discovery of new data from expanded areas of the North Palawan Block. However, these stratigraphic columns are made prior to the inception of the Mesozoic accretion-subduction framework as the encompassing explanation of the chert-clastics-limestone complex. Certain modifications are proposed in this present work including revised geologic map and section, redefinition of lithostratigraphic units and revision of its stratigraphic column. The formational names, Liminangcong Formation for the chert sequences and Guinlo Formation for the clastic sequences, are retained while the sporadic limestone bodies are treated in one category as limestone units. These Paleozoic-Mesozoic sequences are collectively referred to as the Malampaya Sound Group (see Fig. 7). Further discussion on this appears in later section.

Geological and paleontological descriptions for selected areas

Geologic studies for chert-clastic sequences primarily require radiolarian analysis to stratigraphically distinguish one chert or clastic outcrop from another. Recognizing which chert is Permian, Triassic or Jurassic in the field has been regarded difficult as no reliable physical distinctive characteristics associate with these different ages. The radiolarian occurrence in Busuanga Island therefore offers indispensable data in the analysis of its geology.

In this study, the samples collected from the central portion of Busuanga Island generally yield fair radiolarian contents. The siliceous mudstones generally contain well preserved radiolarians in remarkable abundance much better than chert and terrigenous mudstone samples. Most chert samples contain recrystallized forms while terrigenous clastic samples have fewer radiolarian occurrences. Table 1 shows the partial list of identified radiolarian species from selected samples, mostly Jurassic. Figures, descriptions and elaborate characterization of these assemblages will appear in another paper in the near future.

The sections investigated are grouped into seven areas namely (1) Bican Peninsula, (2) Decabobo-San Nicolas, (3) Buwang, (4) Guadalupe-Mabintangin, (5) Decalachiao-Maricaban-Cabilauan, (6) Pangarawan River and (7) southern Busuanga (see Fig. 3 for locations; Fig. 4 for the geologic map). Included in the discussion of each section are the lithologic description, geologic structure, radiolarian data and age. Certain emphasis is given to Jurassic sections, which are discussed in terms of biostratigraphic zonation unlike the more generalized Triassic and Permian sections.

1. Bican Peninsula

A good geologic section of roughly 6 km is exposed along the western coast of Bican Peninsula, north of Decabobo village. The strata dip variably from NW in the central portion, to NE in the northern and southern portion but it can be generalized as northward dipping. This long coastal section shows relatively better or clearer exposure since the outcrops are fresh and the strata are cut perpendicular to the coastline. The chert appears as white-colored with black layers in the north, while it is red-colored farther south. Its radiolarian occurrences between Buyod Point and Dipalirong Point are not well represented due to notably poor preservation. Two samples collected near Buyod Point, B10-02 and B10-05 contains poorly to moderately preserved radiolarians of probably Middle Triassic radiolarians. These include *Spinotriassocampe annulata* (Nakaseko and Nishimura), *S. carnica* Kozur and Mostler, *Pentactinocarpus awaensis* (Nakaseko and Nishimura) and *Triassocampe* spp. Another chert sample B17-21 taken near Dipalirong Point is also considered Triassic based on the presence of *Triassocampe* sp.

A limestone-basalt-chert melange is observed about 2 km south of Buyod Point at the foot of another unnamed peak. This melange body is composed of highly indurated micritic limestone and basalt with minor chert. Its components range in size from pebble to boulder. Limestone clasts generally have larger size and basalt of smaller size. Occasionally, the pebble size component shows a mixture of limestone and basalt serving as the matrix of the cobble sized limestone. The proportion of basalt and limestone varies from limestone-dominated, equal limestone-basalt proportion to basalt-dominated. In limestone-dominated portion, the limestone clasts tend to amalgamate and, in the process, swallow the basalt resulting to a massive limestone appearance, while the basalt components are reduced to forming vein-like structures. At the base of this melange, can be observed a bedded chert block of probably Permian age (B10-13). Below the bedded chert block, a chaotic array of parallel oriented volcanoclastics and limestone in shear contact with one another. In the basalt-dominated portion, cobble-sized fragments described as olivine basalt are contained in a volcanoclastic matrix. In one horizon, lensoid shaped pebble limestone clasts are set oriented parallel in green basaltic matrix. In the lowermost portion of the outcrop also appears amygdaloidal basalt as clasts.

Another melange type is observed in two outcrops in Buyod area, south of the limestone-basalt-chert type. The first outcrop appears sandwiched between sandstone and chert strata. It is basically composed of 2-3 cm thick sandstone layers, set in a dark green to black mudstone matrix. Recurrence of similar melange type is observed at its south after an interval of

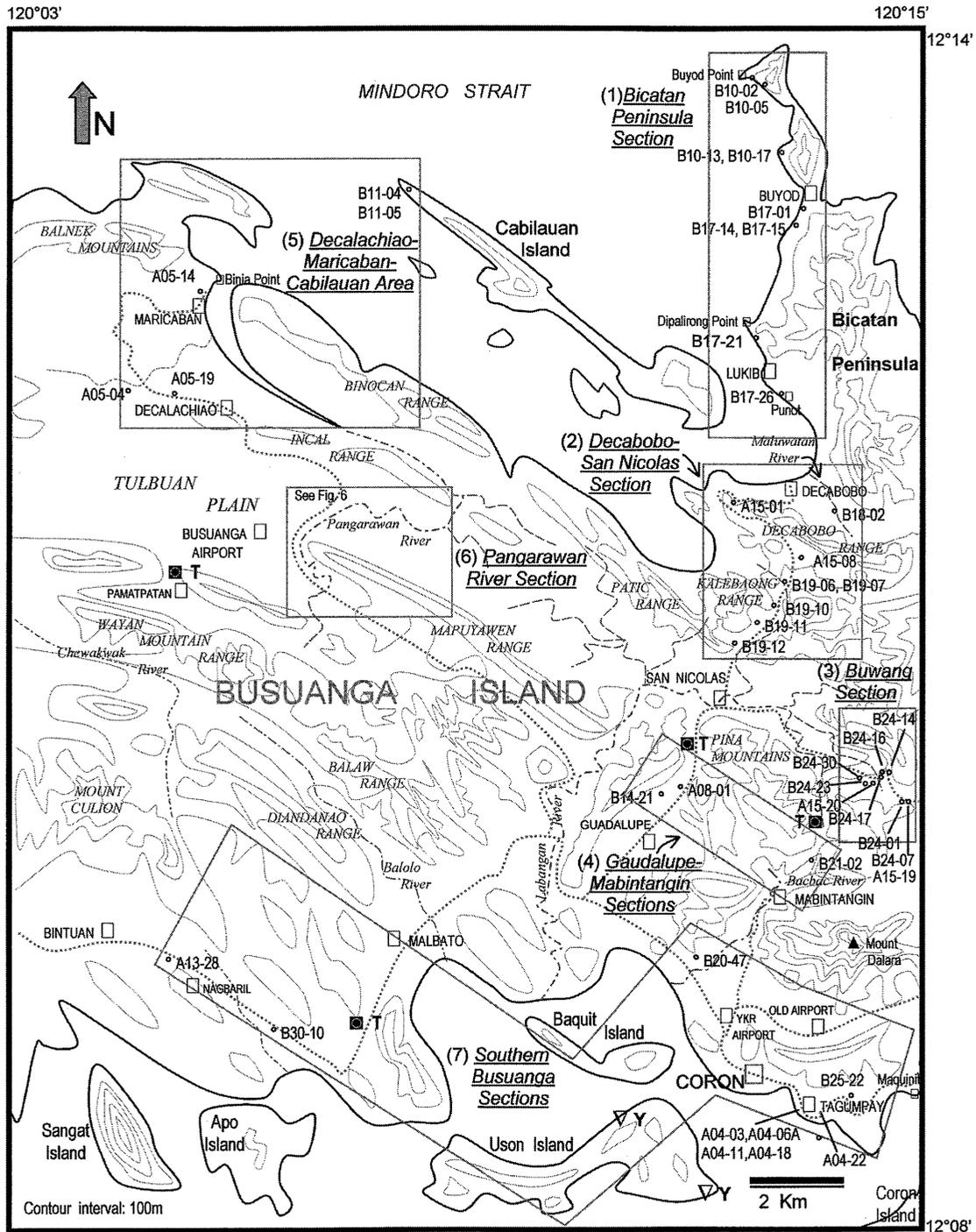


Fig. 3. Location of the sections or areas and sampling points. Samples from previous works included in the discussion are indicated : ■ T for Tumanda (1991 a) and ▽ Y for Yeh (1992).

a chert sequence. It contains thinly layered components composed of sandstone and occasionally chert. The matrix is composed of highly sheared dark green to black mudstone, which resembles slate. The samples from this area have no diagnostic radiolarians, instead, opaque materials with radiolarian shapes have been observed. These two types of melange will be referred to as the Bican Melange.

The frequent occurrence of the clastics in Bican

Peninsula in alternation with chert horizons portrays similar structural features common in the central portion of Busuanga Island, although no apparent topographic features correspond to its occurrence. The clastics that appear structurally underlying the Bican Melange consistently dip NW, but their contact is unknown. Sample B10-17, black mudstone, contains poorly to moderately preserved radiolarians including *Dictyomitrella (?) kamoensis* Mizutani and

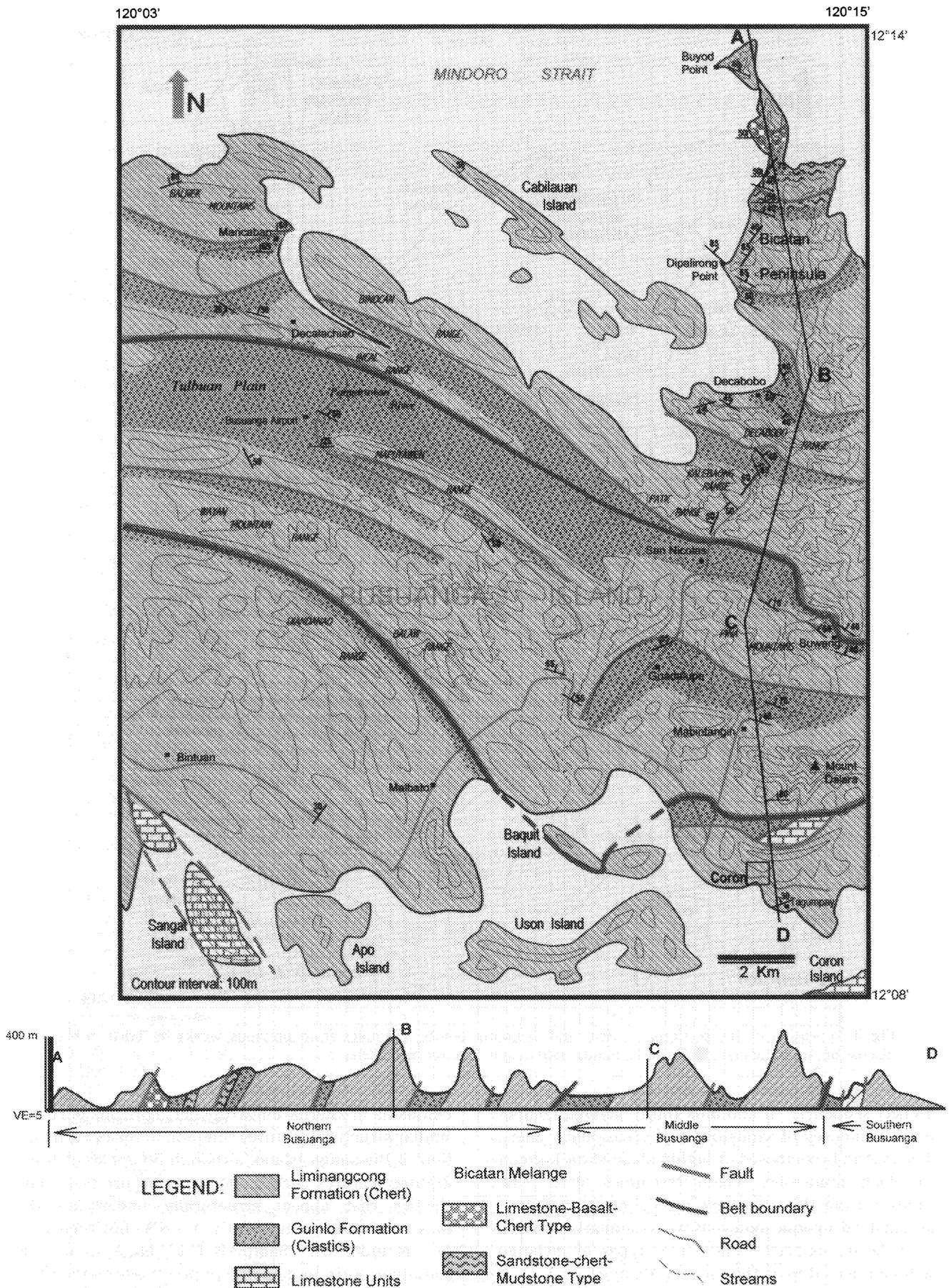


Fig. 4. The geologic map and section of the central portion of Busuanga Island showing the Northern, Middle and Southern Busuanga belts.

Kido, and *Eucyrtidiellum* sp., probably of JR4-JR5 (Middle Jurassic) age. Two samples, B17-14 and B17-15, from a mudstone outcrop similarly contain *Tricolocapsa plicarum* Yao, *Dicolocapsa conoformis* Matsuoka, *Archaeodictyomitra suzukii* Aita and *Mirifusus* sp., which also probably represent JR4-JR5 (Bajocian to Callovian). In Lukib village, appears bedded sandstone of up to 50 cm thick, dipping north. Another outcrop of terrigenous mudstone-sandstone sequence can be observed in Punot area, wherein massive and highly fractured sandstone intercalates with black mudstone. Sample B17-26 taken from the mudstone outcrop is highly terrigenous with rare radiolarian occurrence but the presence of *Tricolocapsa tetragona* Matsuoka indicates upper JR4 to lower JR5 (Bathonian). Its occurrence in this locality was previously reported in Tumanda (1991a).

2. Decabobo-San Nicolas

South of Bicanan Peninsula follows a section from Decabobo to San Nicolas village transecting three mountain ranges namely, Decabobo Range, Kalebaong Range and Patic Range all composed mainly of chert. These mountain ranges alternate with narrow valleys all presumably composed of clastics. From the northern end of this section, along the Maluwatan River, east of Decabobo village, limited occurrence of black mudstone with fine-grained sandstone intercalation appears. Massive medium-grained sandstone also occurs in interval with the mudstone-sandstone intercalation. Sample B18-02, dark gray to brown mudstone is highly terrigenous with rare radiolarian occurrence. The presence of *Tricolocapsa conexa* Matsuoka is insufficient for age determination, but the occurrence of JR5 clastics at its north and south suggests that its age is also JR5. At the NW end of Decabobo Range, a blue-gray to black finely laminated chert (A15-01) yields many saturniids such as *Kozurastrum* sp. aff. *K. quinquespinosa* (Kozur and Mostler) and *Kozurastrum* sp. suggesting a Late Triassic age. At the SW side of Decabobo Range, a light brown NE dipping siliceous mudstone contains *T. tetragona*, *T. conexa*, *T. plicarum*, *Stylocapsa tecta* Matsuoka indicative of JR5 or upper Bathonian to Callovian age (A15-07, A15-08). This clastic body appears in fault contact with the base of the Decabobo Range chert, and serving as the footwall of the thrust chert unit. The samples collected south of the siliceous mudstone, B19-06 and B19-07 (mudstone samples) have no radiolarians but terrigenous materials.

Two chert mountain ranges stretched parallel to Decabobo Range follow at its SW after the clastics, namely, the Kalebaong Range and the Patic Range. Chert exposures across Kalebaong Range exhibit wavy beds with widely varying dip directions. Samples B19-10 (dark blue chert) and B19-11 (red chert) indicate Middle Permian based on the appear-

ance of *Albaillella* sp. and *Pseudoalbaillella* sp. Its contact with the adjacent JR5 (upper Bathonian to Callovian) clastics is unknown. The Patic Range sections farther SW similarly exhibit wavy structures of thinly bedded red chert. Its sample B19-12 abundantly yields moderate to well preserved Middle Triassic radiolarians, among them *Triassocampe campanilis* (Kozur and Mostler) and *Pseudostylosphaera japonica* (Nakaseko and Nishimura).

3. Buwang area

The road between the villages of San Nicolas and Borac crosses a mountain range via a 250-m high saddle composed of clastics, which lies between two roughly 400-m high chert peaks (Fig. 5). The considerably weathered outcrop in the saddle area appears rather complex, as different sedimentary rocks crop out with vague lithologic contacts. Three sedimentary rock types are encountered in the saddle area: muddy chert, mudstone, and sandstone. The muddy chert is mint green and relatively soft, with undefined bedding structure. Its radiolarian content from samples B24-01 to B24-04 is high but poorly preserved. The bluish gray siliceous mudstone samples B24-07 and A15-19 contain moderately preserved radiolarian assemblage characterized by frequent occurrence of *Stylocapsa* (?) *spiralis* Matsuoka, *Stichocapsa robusta* Matsuoka and *T. conexa* indicative of JR6 (upper Callovian-Oxfordian).

In another outcrop of at least 50 m below the saddle pass, occurs thinly bedded greenish chert with weak laminations and dipping north with varying dip angles. Sample A15-20 contains moderately preserved radiolarians such as *Hsuuum medium* (Takemura), *Bipedis* sp., *Canesium* sp. aff. *C. lenticum* Blome, indicative of JR2 (upper Pliensbachian-Toarcian). Sample B24-30, reddish when fresh having *Parvicingula* sp. aff. *P. nanoconica* Hori and Otsuka, also belongs to JR2. Farther down, chert sample B24-23 shows the occurrence of *Laxtorum* (?) *jurassicum* Isozaki and Matsuda, and *Parahsuuum grande* Hori and Yao, indicating JR3 (Aalenian). Sample B24-17, a pinkish maroon chert sample with fine bed-parallel strands, contains *Tympaneides charlottensis* Carter, *Hexasaturnalis hexagonus* (Yao), *Tritrabs simplex* Kito and De Wever and *L.* (?) *jurassicum*, also indicative of JR3.

This JR2, JR3 and JR6 chert-clastic sequence is bounded in the north by Permian chert sequence. An outcrop around 200 m north of the saddle pass along the steeply sloping road, crops out generally thickly bedded chert, which is part of the northern chert peak. Its samples B24-14 and B24-16 contain *Pseudoalbaillella fusiformis* (Holdsworth and Jones) and *Albaillella levis* Ishiga, Kito and Imoto, respectively, indicating Middle and Late Permian. This chert body is apparently in thrust fault contact over the younger JR6 clastics and JR2 to JR3 chert at its

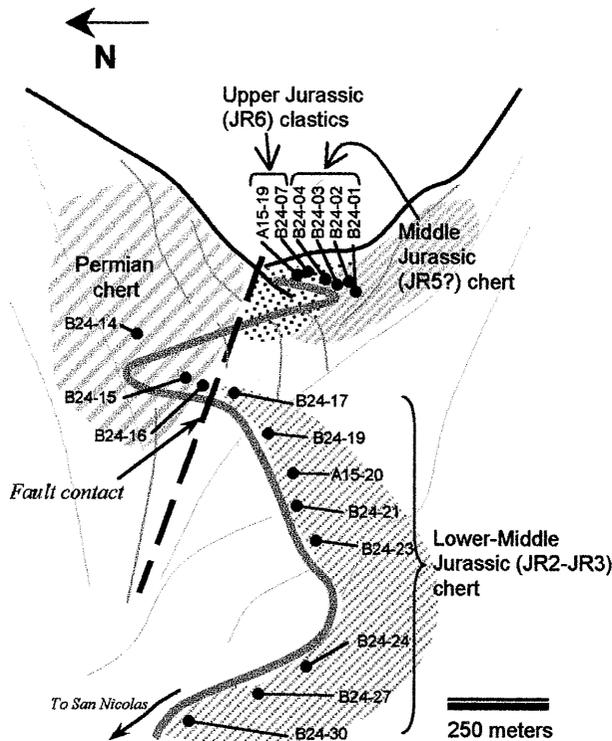


Fig. 5. A section of the road connecting San Nicolas and Borac villages in the elevated Buwang area (Fig. 3) showing the Permian and Jurassic chert exposures generally northeast-dipping. The Lower-Middle (JR 2–JR 3) chert sequence exhibits wavy fold structures often parallel to the road and outcrop surface resulting to repetitive age trend of samples along the road. The Middle (?) Jurassic (JR 5?) chert and the Upper Jurassic (JR 6) clastics in the saddle portion. The fault structure is considered a contact between the lower section of the Northern Busuanga Belt (Permian chert) and the upper section of the Middle Busuanga Belt (Jurassic chert-clastic sequence).

south.

4. Guadalupe-Mabintangin

A continuous section of roughly 200 m long clastic sequence crops out along a small headwater tributary near the Guadalupe area, revealing an alternation of mudstone, sandstone and pebbly sandstone. These different types of clastics appear in repetitive manner and their dip direction is widely variable. Mudstone commonly intercalates with thinly bedded fine-grained sandstone. Coarse-grained massive sandstone intervals along the sequence range in total thickness from around 30 to 70 m with bed thickness of 1 to 3 m. Several samples were collected mostly from the mudstone beds, but most of these are highly terrigenous with rare radiolarian occurrence. Samples B 14–21 and A 08–01 contain *S. (?) spiralis*, indicating JR 6 (upper Callovian-Oxfordian).

In Mabintangin another clastic outcrop, roughly 8 m thick, is exposed along the NE tributary of the Bacbac River. It is composed of mudstone, characterized by

brown, gray and black color; bed thickness ranging from 3 to 6 cm; and laminated, with minor fine-grained sandstone occurrence. Sample B 21–02 contains palynomorphs and very few radiolarians. It is highly probable that this particular outcrop is the same Mabintangin section sampled and reported by Fontaine (1979) as having abundant Late Triassic–Early Cretaceous palynomorph, *Classopollis*. Despite the low radiolarian occurrence, a well preserved *S. (?) spiralis* has been found with *T. conexa*, and *Protunuma* sp. that strongly correlates with the Guadalupe clastic section.

Fontaine (1979) assumed that this JR 6 clastic outcrop in Mabintangin conformably overlies the chert sequence composing Mt. Dalara. Our field data conforms to this view although the chert samples owing to poor preservation hardly verify their biostratigraphic relationship. A section across the Pina Mountains north of this locality along a north-bound stream reportedly reveals a chert sequence of wide age range from Late Permian, Triassic to Early Jurassic (Tumanda, 1991 a, 1991 b). Apparently this generally north-dipping Pina Mountain chert sequence is in fault contact with the adjacent southern Upper Jurassic clastics in the Mabintangin area.

5. Decalachiao-Maricaban-Cabilauan

At least 1 km NW of Decalachiao village, a clastic sequence of mudstone and sandstone appears as a road section. The light brown siliceous mudstone commonly features trace fossils having black lensoid outlines oriented parallel to the bed. A moderately preserved JR 5 (late Bathonian-Callovian) radiolarian assemblage is observed in sample A 05–04 having *T. plicarum*, *T. conexa*, *S. tecta* and *Parvicingula dhimenaensis* Baumgartner. The upsection of this siliceous mudstone appears to be represented by the nearby massive arkosic sandstone although contact is not exposed. A fault contact probably exists between this clastic sequence and the Upper Permian chert (A 05–19) which contains *Albaillella protolevis* Kuwahara and *A. levis*. Minor occurrence of basalt has also been noted adjacent to the Permian chert but its exposure is highly weathered.

In the coastal Maricaban village a terrigenous mudstone-sandstone sequence is exposed. This clastic body appears belonging to a separate stratigraphic unit NW of that in Decalachiao as they are intervened by a chert horizon. Maricaban sample A 05–14 contains *T. conexa*, *S. tecta*, *T. plicarum*, *D. (?) kamoensis*, *A. suzukii*, *T. tetragona*, *P. dhimenaensis* and *Hsuum brevicostatum* (Ozoldova), an assemblage signifying JR 5 zone that closely resembles that in Decalachiao siliceous mudstone. Another chert horizon in the north, the Balnek Mountain Range, bound the clastic sequence of Maricaban. This chert unit is sampled from Binian Point but no diagnostic radiolarians have been found.

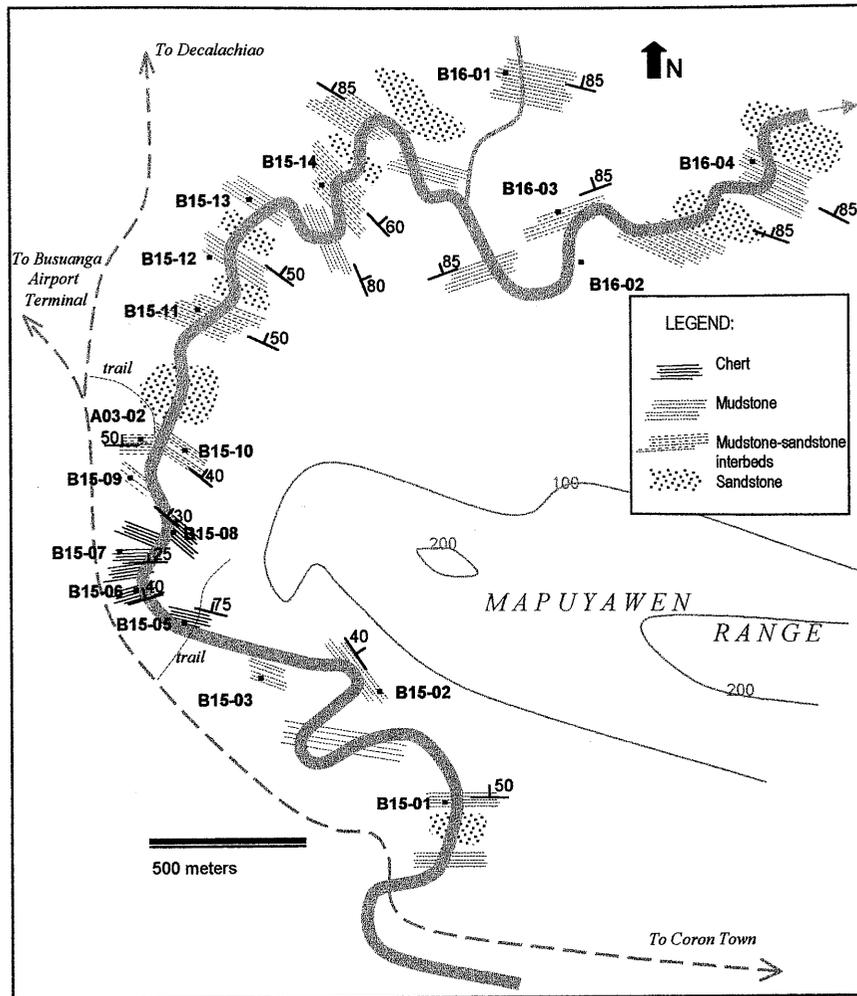


Fig. 6. The Pangarawan River section exposing the lithologic transition from chert to clastics of the Middle Busuanga Belt. Locations of B15-05 to B15-08 show the topmost portion of the chert sequence of JR 4 (Bajocian-lower Bathonian). Two siliceous mudstone samples B15-03 of JR 5 (Bathonian-Callovian), and A03-02 (or 990303-02 in Zamoras and Matsuoka, 2000 a) of JR 6 (upper Callovian-Oxfordian) represent the transitional facies. Samples B15-10 to B16-04 belong to the terrigenous clastic facies of JR 6.

In the NW tip of the long narrow Cabilauan Island, a NE dipping blue-gray colored chert has been observed of at least 10m outcrop thickness, with generally thin beds of 2cm in average. Two samples, B11-04 and B11-05 from this site show JR 2 (upper Pliensbachian-Toarcian) radiolarian assemblage such as *P. nanoconica*, *Parvincingula* spp., *Bipedis* sp., *Eucyrtidiellum* spp. and abundant multicyrtyd forms.

6. Pangarawan River

At least 6-km stretch of the Pangarawan River was traversed starting from the headwaters in the vicinity of abandoned Mapuyanen Mines down to Incal Range foothills (see Fig. 6). It is revealed along the section incised by the river that a Jurassic clastic sequence exists in the Tulbuan Plain but already overlain by a Quaternary chert conglomerate, which often reaches up to 10m of thickness. From the headwaters of the river, the Jurassic clastics started appearing past the bridge near the Busuanga Airport road with the ap-

pearance of NE-dipping black mudstone interbedded with thick sandstone layers. Sample B15-03 taken from a siliceous mudstone outcrop in this locality yields a JR 5 (late Bathonian to Callovian) assemblage of *T. tetragona*, *T. plicarum*, *T. conexa*, *P. dhime-naensis*, *A. suzukii*, *Hsuuum maxwelli* Pessagno, *Amphi-pyndax tsunoensis* Aita and *Protunuma turbo* Matsuoka. At the NW end of the Mapuyawen Range chert where it seems to taper out, appears chert outcrop that apparently plunges beneath the Tulbuan Plain. Its chert sample B15-07 described as black with average thickness of 3cm contains abundant but poorly to moderately preserved radiolarians such as *Parahsuuum stanleyense* (Pessagno), *P. officerense* (Pessagno and Whalen), *Higumastra winteri* Baumgartner and Kito, *Eucyrtidiellum unumaense* (Yao) and *Parahsuuum* spp. Another sample, B15-08, approximately 10m stratigraphically above B15-07, characterized as muddy chert, abundantly contains moderately to well pre-

served JR 4 (Bajocian-early Bathonian) radiolarians such as *Mirifusus fragilis* Baumgartner, *Hsuum hisuikyoense* Isozaki and Matsuda, *Tricolocapsa* (?) *fusiformis* Yao, *Archicapsa* (?) *pachyderma* (Tan), *T. plicarum*, *H. winteri*, *Parvicingula* spp. and *Sethocapsa* spp. This rich assemblage without *T. conexa* occurrence is considered a representative of JR 4, which is also the most likely age of B15-07. The remarkable change in lithologic character from black chert (B15-07) to muddy chert (B15-08) in this sequence suggests a transitional stage of its paleoenvironmental condition.

About 100 m downstream appears the clastic sequence described as concordantly NE dipping gray-colored siliceous mudstone. This is the sample location of the siliceous mudstone A 03-02 (or 990303-02) in Zamoras and Matsuoka (2000 a) that has been assigned to JR 6 (upper Callovian to lower Oxfordian) based on the common appearance of *S. (?) spiralis*, *S. tecta*, *D. conoformis*, *Guxella nudata* (Kocher) and *G. sp. aff. G. nudata*. The stratigraphic upsection over sample A 03-02 is a long sequence of highly terrigenous mudstone-sandstone interbeds characterized by poor radiolarian occurrence. The appearance of *S. (?) spiralis* being the essential zonal indicator is last observed in sample B15-12. Although it has not appeared in all succeeding samples along this section, the terrigenous clastic portion is entirely considered JR 6. Sample B16-04, the last sample along this river traverse, containing *S. tecta*, *T. conexa*, *H. maxwelli*, *Protunuma* sp., *D. conoformis*, *G. nudata* and *Zhamoidellum ventricosum* Dumitrica, is also considered part of the upper section of the clastics.

7. Southern Busuanga

Three sampling localities represent Southern Busuanga namely, Nagbaril-Bintuan in the west, and Dipulao and Tagumpay areas in the east. In these southern portions of Busuanga Island, the chert sequences include Middle and Upper Jurassic, not encountered in the northern portions. Sample A 04-03, brown chert (gray-colored when fresh), contains JR 8 (Tithonian) assemblage based on *Mirifusus guadalupensis* Pessagno, *Ristola altissima altissima* (Rüst), *Loopus primitivus* (Matsuoka and Yao) and *Archaeodictyomitra apiarium* (Rüst). Near the topmost chert horizon, sample A 04-06A (about 120 cm above A 04-03) contains well preserved radiolarians such as *Cinguloturris carpatica* Dumitrica, *Mirifusus dianae minor* Baumgartner and *M. guadalupensis*, likewise representing JR 8 (Tithonian). Just above the topmost chert horizon, a siliceous mudstone sample, A 04-11, yields well preserved radiolarians namely, *C. carpatica*, *M. dianae minor*, *Solenotryma ichikawai* Matsuoka and Yao, *Pseudodictyomitra carpatica* (Lozyniak), *L. primitivus*, *Eucyrtidiellum pyramis* (Aita), *Pantanelium oligoporum* (Vinassa), *Bistarkum irazuense* (Aita), *A. apiarium*, *R. altissima altissima*,

Protovallupus spp. and *H. maxwelli*. Approximately 3 m above A 04-11, another siliceous mudstone sample (A 04-18) shows very similar assemblage. The occurrence of *P. carpatica* associated with *E. pyramis* indicates that the biohorizon of these samples has already crossed the KR 1 or the *P. carpatica* Zone of Matsuoka (1995) but still within Tithonian. The presence of *H. maxwelli*, which supposedly disappeared around the end of Kimmeridgian, will be further studied.

Sample B25-22, a greenish gray chert taken from the Tagumpay area along the road to Maquinit, contains moderate to well preserved radiolarians with *Parahsuum* (?) *grande* Hori and Yao, *Eucyrtidiellum* (?) *quinatum* Takemura, *Hsuum matsuokai* Isozaki and Matsuda, *Parahsuum* sp. cf. *P. levicostatum* Takemura and *P. sp. cf. P. cruciferum* Takemura. This assemblage probably represents the JR 3 (Aalenian) of southern Busuanga. Sample B20-47 from Dipulao area, between Km Posts 4 and 5 along the Coron-Salvacion road contains *Unuma* sp. cf. *U. echinatus* Ichikawa and Yao, *Parahsuum izeense* (Pessagno and Whalen), *Bernoullius rectispinus rectispinus* Kito, De Wever, Danelian and Cordey, *Eucyrtidiellum* sp. aff. *E. quinatum*, *H. medium*, *Zartus* sp. and *Trillus* sp. This sample is indicative of JR 2-JR 3 (upper Toarcian to lower Aalenian), probably slightly older than B25-22.

In the Nagbaril area, near Km Post 23 along the Coron-Salvacion Road, another muddy chert sequence appears. Sample B30-10 contains moderately to well preserved *S. (?) spiralis*, *A. tsumoensis*, *S. funatoensis*, *S. oblongula*, among others, indicative of JR 6 (Oxfordian). In another outcrop, near Km Post 24, a chert exposure was sampled (A 13-28) containing well preserved JR 5 (Callovian) radiolarian assemblage, such as *T. conexa*, *S. tecta*, *A. suzukii*, *H. brevicostatum*, *T. plicarum* and common *E. ptyctum*. This sampled chert outcrop however appears to be part of a transported large block as it is in contact with a soil horizon at its base. But since it is the only chert sample that represents JR 5 in Southern Busuanga Belt, its analysis has become important.

Revision of the Upper Paleozoic to Mesozoic stratigraphy

The new geologic and paleontologic data gathered in this study from the central Busuanga Island have provided adequate bases for the revision of the Upper Paleozoic to Mesozoic stratigraphy of the North Palawan Block in general. The lithologic transition from chert to siliceous mudstone and to terrigenous clastics coupled with the gradually younging succession of radiolarian assemblages has clearly defined the relationship between the chert and the clastics. This discovery leads to the integration of the chert sequences of various ages as a single unit that is overlain by the clastic sequences, also considered as one unit (Fig. 7). Associated limestone occurrences, sepa-

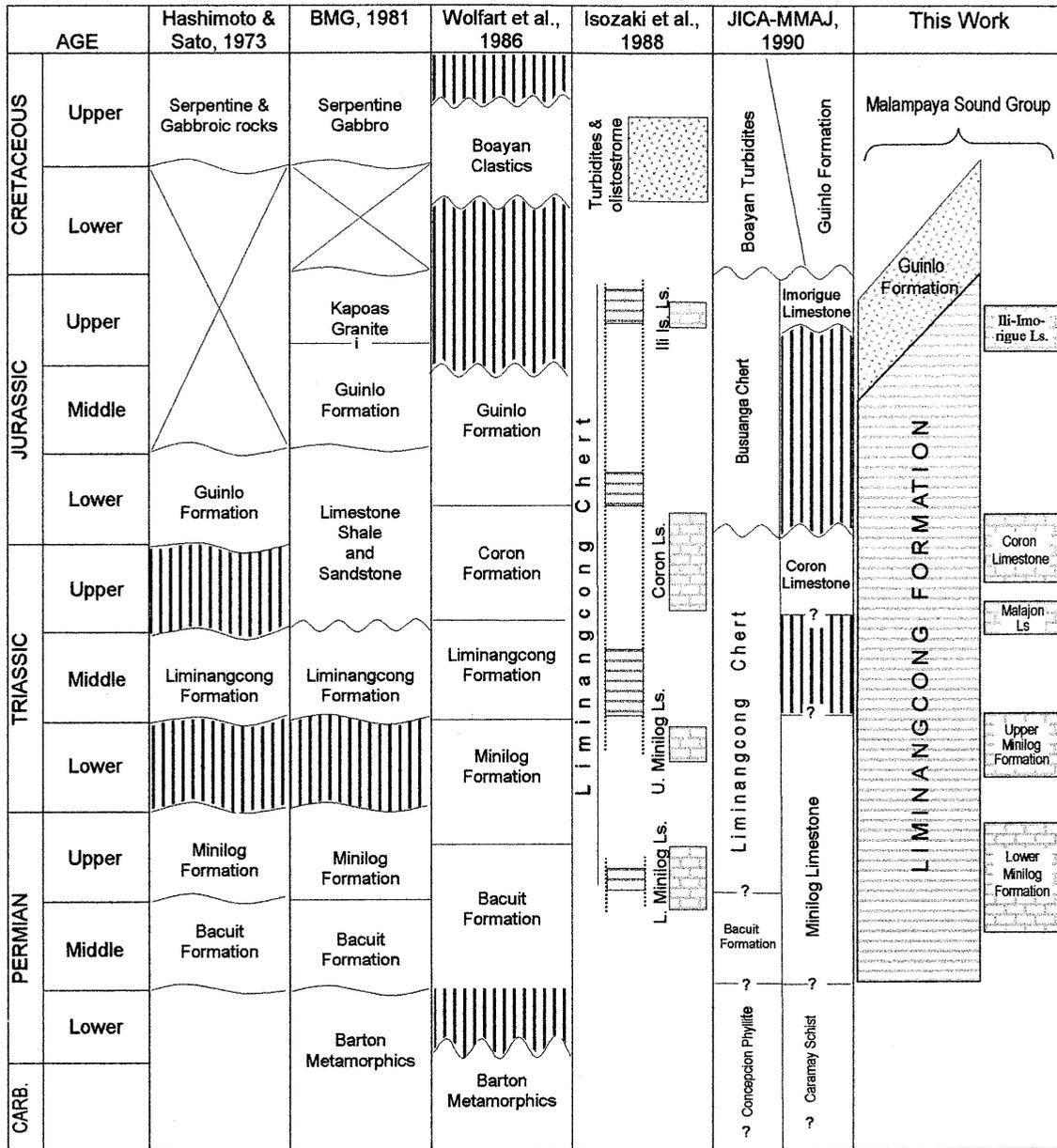


Fig. 7. Previous stratigraphic columns for the Upper Paleozoic and Mesozoic of North Palawan as compared with the modified version in this present work. The limestone units include (Upper and Lower) Minilog Formation (Hashimoto and Sato, 1973; Wolfart et al., 1986; Amiscaray, 1987), Malajon Limestone (Hashimoto et al., 1980), Coron Limestone (Wolfart et al., 1986), and Ili and Imorigue Limestones (Bassoullet, 1983; Beauvais, 1983; Fontaine et al., 1983).

rately studied and defined by several previous workers, are regarded belonging to one category. Although most of these limestones are not part of the current study, their inclusion in the stratigraphy is considered essential to represent a comprehensive Upper Paleozoic to Mesozoic stratigraphic column. But no additional fossil data on the limestones are included in this paper since this work focuses on the chert-clastic sequences. Melange bodies have also been encountered but their occurrence is rather limited to a few localities, thus, considered minor. Hence this paper considers three major units namely; the Limintangcong Formation (chert), the Guinlo Forma-

tion (clastics) and the limestone units; and a minor unit, the Bicanan Melange.

1. Malampaya Sound Group

Author : Hashimoto and Sato (1973).

Original Definition : A collective name for Bacuit Formation, Minilog Formation, Limintangcong Formation and Guinlo Formation.

Redefinition : A collective name for Limintangcong Formation, Guinlo Formation, limestone units and melange bodies (such as the Bicanan Melange).

Distribution : This group was originally identified in northern Palawan Island, Linapacan Island and Culion Island. Subsequent correlation of the chert

sequence in Busuanga Island as part of the Liminangcong Formation (BMG, 1981) had also expanded the distribution of this group.

Age : Liminangcong Formation, Middle Permian through Jurassic ; Guinlo Formation, Middle Jurassic to Early Cretaceous ; limestone units, Permian to Late Jurassic.

2. Liminangcong Formation

Author : Hashimoto and Sato (1973) ; further works include BMG (1981), Wolfart et al. (1986), Isozaki et al. (1988).

Historical review : Following the discovery of Permian and Jurassic cherts in Busuanga Island, the Liminangcong Formation of Hashimoto and Sato (1973), which was originally considered as Middle Triassic chert, was subdivided into Liminangcong Chert for the Triassic portion, and Busuanga Chert for the Jurassic portion (JICA-MMAJ, 1990), while Bacuit Formation was adopted for the Permian chert (Wolfart et al., 1986). Isozaki et al. (1988) considered the Permian to Jurassic chert sequences as a single unit, Liminangcong Chert.

Original definition : Bedded hematite-bearing chert containing radiolarians ; intercalated with slumping bed, black slate and reddish tuff layers ; occasionally banded.

Redefinition : Bedded chert sequences of highly varied characteristics, commonly intercalated with clayey layers, distributed in the northern part of Palawan Island and the Calamian Islands.

Original type locality : Liminangcong Coast, Palawan Island. Present study is mainly based on the data from the Calamian Islands as its chert and clastic exposures have better radiolarian contents and preservation.

Lithology : This dominantly chert unit is characterized by color variations ranging from deep red, maroon, flesh color, light green, dark or light gray, beige, white to black that often differ from the actual interior color. Conspicuous color banding is occasionally encountered with deep red color in the mid-layer portion and lighter shades such as light green or light brown at the upper and lower margins of each bed. Its bed thickness ranges from less than 1 to 30 cm ; older chert sequences are relatively thicker than younger chert sequences. It occasionally exhibits lamination with varying laminar thickness as well as distinctness. Its degree of induration also varies from the relatively softer muddy chert to highly indurated chert. The clayey intervals appear light gray to light brown color with common thickness of less than 1 cm, but occasionally reach more than 2 cm. This unit is generally highly folded and commonly faulted.

Thickness : Its apparent thickness is at least 2000 m based on the chert sequence across Mt. Dalara. However, its actual thickness is probably only a few hun-

dred meters.

Contacts : Stratigraphically underlying unit unknown ; Guinlo Formation conformably overlies.

Fossils : At least 500 radiolarian species have already been described or encountered based on this ongoing work and previous radiolarian works of Isozaki et al. (1988), Cheng (1989, 1992), Tumanda (1991 a, 1991 b, 1994), Yeh (1992), Yeh and Cheng (1996, 1998), Tumanda-Mateer et al. (1996). Occurrence of radiolarians in chert samples normally depends on the degree of preservation ; abundant when the preservation is moderate to good, rare or absent when recrystallization or any form of alteration prevails.

Age : Middle Permian to Late Jurassic. Most of the chert exposures in the Calamian Islands are of Triassic age. Middle to Late Permian and Jurassic chert outcrops are rather occasional and less extensive. Tumanda (1991 a) defined four interval zones (I.Z.) for the Middle to Upper Permian ; *Follicucullus monacanthus* I.Z., *F. scholasticus* I.Z., *Latentifistula similiculis* I.Z. and *Neoalbaillella ornithoformis* I.Z. ; eight interval zones for the Lower to Upper Triassic, *Pactarentinia koikei* I.Z., *Hozmadia altipedaria* I.Z., *Pseudostylosphaera japonica* I.Z., *Triassocampe deweveri* I.Z., *Emiluvia cochleata* I.Z., *Capnuhosphaera* I.Z., *Capnodoce* I.Z. and *Livarella* I.Z. For the Jurassic portion, seven out of eight zones of the Jurassic radiolarian biostratigraphy for the Western Pacific and Japan (Matsuoka, 1995) have been certainly represented by chert samples from various locations, namely, *Parahsuum simplum* Zone (JR 1), *Trillus elkhornensis* Zone (JR 2), *Laxtorum* (?) *jurassicum* Zone (JR 3), *Tricolocapsa plicarum* Zone (JR 4), *Tricolocapsa conexa* Zone (JR 5), *Stylocapsa* (?) *spiralis* Zone (JR 6) and *Loopus primitivus* Zone (JR 8).

3. Guinlo Formation

Author : Hashimoto and Sato (1973) ; further works by BMG (1981) and Wolfart et al. (1986).

Historical review : From Guinlo Point, Palawan Island, where Hashimoto and Sato (1973) described this unit, BMG (1981) extended the Guinlo Formation to Busuanga Island referring to the extensive mudstone-sandstone-conglomerate succession. This was modified as King Ranch Formation (BMG, 1984) with the same reference to the clastic sequence in Busuanga and later considered it as a matrix of an olistostrome (Faure and Ishida, 1990).

Original definition : Unfossiliferous white coarse-grained massive sandstone with conglomerate interbeds (Hashimoto and Sato, 1973).

Redefinition : A succession of siliceous mudstone and terrigenous interbeds of mudstone, sandstone and conglomerate, distributed in northern Palawan Island and the Calamian Islands.

Type locality : Guinlo Point, Palawan Island is the original type locality for the Guinlo Formation. However, many subsequent studies of this unit refer

to the exposures in Busuanga Island where stratigraphic and paleontologic data are better. In this study as well, all data from the clastics are gathered from Busuanga Island.

Lithology : The siliceous mudstone is characterized as moderately indurated, light brown to light gray, 2–5 cm bed thickness and primarily composed of radiolarians, terrigenous quartz and clay minerals. It serves as the base of the clastics and right on top of the chert sequence. The terrigenous mudstone portion appears gray to black dominated by siliciclastics with dark organic matters frequently including palynomorphs. It is moderately or highly indurated with 1–5 cm thick beds. Its radiolarian content is substantially lower compared to siliceous mudstone. The sandstone portion is generally characterized as highly indurated, massive or thickly bedded (40 cm to 5 m), medium to coarse-grained with arkosic composition. The coarser facies of the clastics composed of pebble conglomerate is not frequently encountered compared to mudstone and sandstone. Mudstone-sandstone intercalation is observed common in the lower or mid stratigraphic sections while the massive sandstone portion predominates in the upsection.

Thickness : Maximum thickness is approximately 2000 m along the Pangarawan River section.

Contact : Conformably overlying the Liminangcong Formation ; also commonly in fault contact with the lower stratigraphic sections of Liminangcong Formation ; no overlying unit was observed in the study area.

Fossils : At least 200 radiolarian species have been encountered based on this work plus Tumanda-Mateer et al. (1996) and Zamoras and Matsuoka (2000 a). Palynomorphs earlier reported by Fontaine (1979) have also been encountered in our samples.

Age : Middle Jurassic to Early Cretaceous. JR 4 (Bajocian to early Bathonian) age is the probable age of the clastics in the Bicanan Peninsula containing poorly preserved radiolarians such as *T. plicarum*, *D. (?) kamoensis*, *A. suzukii* and *Eucyrtidiellum* sp. The JR 5 (late Bathonian to Callovian) radiolarian assemblage is represented by *T. tetragona*, *T. conexa*, *T. plicarum* and *P. turbo*, observed in siliceous and terrigenous mudstones from various locations. The JR 6 (latest Callovian to Oxfordian) assemblage, basically indicated by the occurrence of *S. (?) spiralis*, has been observed in both siliceous and terrigenous mudstone. The JR 8 (early-middle Tithonian) assemblage, represented by *L. primitivus*, *M. guadalupensis*, *R. altissima altissima* and *A. apiarium*, is encountered in Tagumpay which is considered as the topmost chert section of the Southern Busuanga Belt. The KR 1 (late Tithonian-Berriasian) assemblage includes *Protovallupus* spp., *M. diana minor*, *P. carpatica*, *L. primitivus*, *S. ichikawai* and *E. pyramis* as observed from a siliceous mudstone section overlying the chert

sequence in Tagumpay. The terrigenous mudstone and sandstone, which presumably overlie this KR 1 siliceous mudstone is assigned to middle-upper KR 1 or much younger zones within the Lower Cretaceous.

4. Limestone units

Historical review : A number of limestone bodies occur sporadically around the Calamian Island Group and in the northern Palawan Island with ages ranging from Middle Permian to Late Jurassic. Among the previously studied are Middle Permian to Lower-Middle Triassic Minilog Formation, Triassic Malajon Limestone, Upper Triassic-Lower Jurassic Coron Limestone and Upper Jurassic limestone from Ili Island and Imorigue Island (Hashimoto and Sato, 1973; Fontaine, 1979; Hashimoto et al., 1980; Bassoulet, 1983; Beauvais, 1983; Wolfart et al., 1986; Amiscaray, 1987).

Lithology : Minilog Formation, described as black or white limestone, more or less recrystallized, partly bedded and oolitic, with its lower horizon appearing as black partly oolitic limestone and the upper horizon as black massive, somewhat bituminous (Hashimoto and Sato, 1973); Minilog Formation, subsequently described as wackestone and biomicrite (Amiscaray, 1987); Coron Limestone, described as massive to bedded, light to dark gray, crystalline, reefal, oolitic or conglomeratic (Wolfart et al., 1986); Ili Limestone as wackestone to packstone (Bassoulet, 1983).

Distribution : The limestone units furthermore include the Coron Limestone (Coron Island, south of Busuanga Island), Minilog Formation (Bacuit Bay in the northern part of Palawan Island), Malajon Limestone (Malajon Island, west of Busuanga Island), Ili Limestone (Ili Island, south of Culion Island or east of Linapacan Island) and Imorigue Limestone (nearby NE coast of Palawan Island).

Contacts : In fault contact with either the Liminangcong Formation or the Guinlo Formation.

Fossils : The lower section of the Minilog Formation contains *Verbeekina verbeeki* (Geinitz), *Neoschwagerina megasphaerica* Deprat, *N. margaritae* Deprat, *N. craticulifera* (Schwager), *Nankinella orbicularia* Lee, *Yabeina globosa* (Yabe), among other large foraminifera (Amiscaray, 1987); the upper section of the Minilog Formation contains conodont species such as *Acodina* sp., *Gladiogondolella* cf. *tethydis* (Huckriede), *Parachirognathus* sp. and *Spathognathodus gondolelloidea* (Bender) (Wolfart et al., 1986); Malajon Limestone with conodont *Epigondolella abneptis* (Huckriede) (Hashimoto et al., 1980); Coron Limestone with Sphinctozoa [Porifera], *Girvanella*, Dasycladaceae [Algae], *Hemigordius-Triasina* [Foraminifera] and pelecypod *Paramegalodus* (Wolfart et al., 1986); Ili Limestone contains foraminifera such as, *Pseudocyclammina lituus* (Yokoyama), *Protopeneroptis* sp., *Salpingoporella johnsoni* (Dragastan), *Pycnoporidium*

lobatum (Yabe and Toyama), *Nautiloculina oolithica* Muhl (Bassoulet, 1983); *Ptychochaetetes ponticus* (Deninger), *Cladocoropsis mirabilis* Felix and *Cladocoropsis memoria-naumanni* (Yabe) (Beauvais, 1983).

Age: The lower section of Minilog Formation – Middle to Late Permian based on high occurrence of many fusulinid species (Amiscaray, 1987); the upper section of Minilog Formation – Lower to Middle Triassic (late Scythian to early Anisian) based on conodont assemblage of *Acodina* sp., *G. cf. tethydis*, *Parachirognathus* sp. and *S. gondolelloidea* (Wolfart et al., 1986); Malajon Limestone – Lower Norian based on the index fossil *E. abneptis* (Hashimoto et al., 1980); Coron Limestone – Rhaetian based on the occurrence of *Paramegalodus* (Wolfart et al., 1986); Ili Limestone – Late Jurassic (Kimmeridgian) based on the association of *P. lituus*, *Protopeneroplis* sp., *S. johnsoni*, *P. lobatum* and *N. oolithica* (Bassoulet, 1983); Imorigue Limestone – Late Jurassic based on *P. ponticus* (Deninger), *C. mirabilis* Felix and *C. memoria-naumanni* (Yabe) (Beauvais, 1983).

5. Bican Melange (*new name*)

Type locality: Buyod area, Bican Peninsula, Busuanga Island.

Definition: Composed of either the limestone-basalt-chert melange or the sandstone-chert-mudstone melange.

Lithology:

1. Limestone-basalt-chert melange: This is described as poorly layered melange composed of highly indurated micritic limestone and basalt with minor bedded chert. Its components range in size from pebble to boulder. Limestone clasts generally have larger size and basalt smaller size. The pebble size component composed of limestone and basalt occasionally serves as the matrix of the cobble-sized limestone. The proportion between limestone and basalt conspicuously varies from limestone-dominated to basalt-dominated. The coarser limestone-dominated portion occurs in the upper section while the finer basalt-dominated portion occurs at the base of the section. The limited chert component, of probably Permian age, appears immediately above the basalt-dominated portion. The basalt-dominated portion is composed of volcanoclastics; occasionally with olivine basalt cobble-sized fragments contained in similarly basaltic matrix. Its apparent thickness is approximately 100 m.

2. Sandstone-chert-mudstone melange: It is basically composed of layered sandstone and minor chert slabs oriented parallel in a mudstone matrix. The sandstone slabs are described as gray-colored, fine-grained, well sorted, well indurated and with thickness ranging from 1 to 5 cm. The chert slabs vary in color from dark gray to brown, thickness from 3 to 5 cm, well indurated without radiolarians. The matrix is described as highly sheared dark green to black

mudstone with texture resembling a flow structure. Likewise, no radiolarians have been recovered from the mudstone matrix. Its apparent thickness is about 100 m.

Comparison: This unit probably occurs in other parts of Calamian Islands and north Palawan. Similar melange reportedly occurs in northern Palawan Island (Faure and Ishida, 1990).

Chert-clastic sequence in Busuanga Island

The age analysis of the chert-clastic sequences across parallel alternating mountain ranges and narrow valleys using radiolarians has proven that these constitute a series of similar sedimentary sequences that progressively differ in age. Their age differences are distinguished through the age of the lithologic transition from chert to clastics. In determining a transition age, clear chert-to-clastics sections are ideally important. But in areas where no such outcrop has been found its transition age assignment is at least based on the siliceous mudstone.

The lowermost section of the Liminangcong Formation is Middle Permian (see Fig. 7) while the topmost section shows progressively younging age: probably JR3 (Aalenian) in the north, JR4 (Bajocian-early Bathonian) in the middle and JR8 (Tithonian) in the south of Busuanga Island. Consequently, the siliceous and terrigenous clastics (Guinlo Formation), which overlie the chert sequences, range from JR4–JR5 (Bajocian to Callovian) in the north, to JR5–JR6 (late Bathonian to early Oxfordian) in the middle, and to JR8–KR1 (Tithonian to Berriasian-early Valanginian) in the south (Fig. 8). This progressive younging in age for lithologic transitions becomes essential basis in delineating three distinct belts composing the accretionary complex of Busuanga Island (Fig. 4).

1. Three belts of the accretionary complex in Busuanga Island

(1) Northern Busuanga Belt

This belt covers the areas of Bican Peninsula, Maricaban, Decalachiao, Cabilauan Island, Decabobo, Patig Range, and the mountain ranges north of the Buwang section. As shown in the geologic section (Fig. 4) the Northern Busuanga Belt appears to include more chert-clastic sequences than the Middle and Southern Busuanga belts. Its representatives for the Middle to Upper Permian portion are the sections in Kalebaong, Buwang, and Decalachiao. Its Middle Triassic section is represented by exposures in Patig Range and Buyod Point while its Upper Triassic is found in Decabobo Range. The only Jurassic chert section representing the Northern Busuanga Belt is in Cabilauan Island with JR2 (late Pliensbachian-Toarcian) assemblage.

As its chert-to-clastics transition exposure has not been encountered yet, its topmost chert sequence is

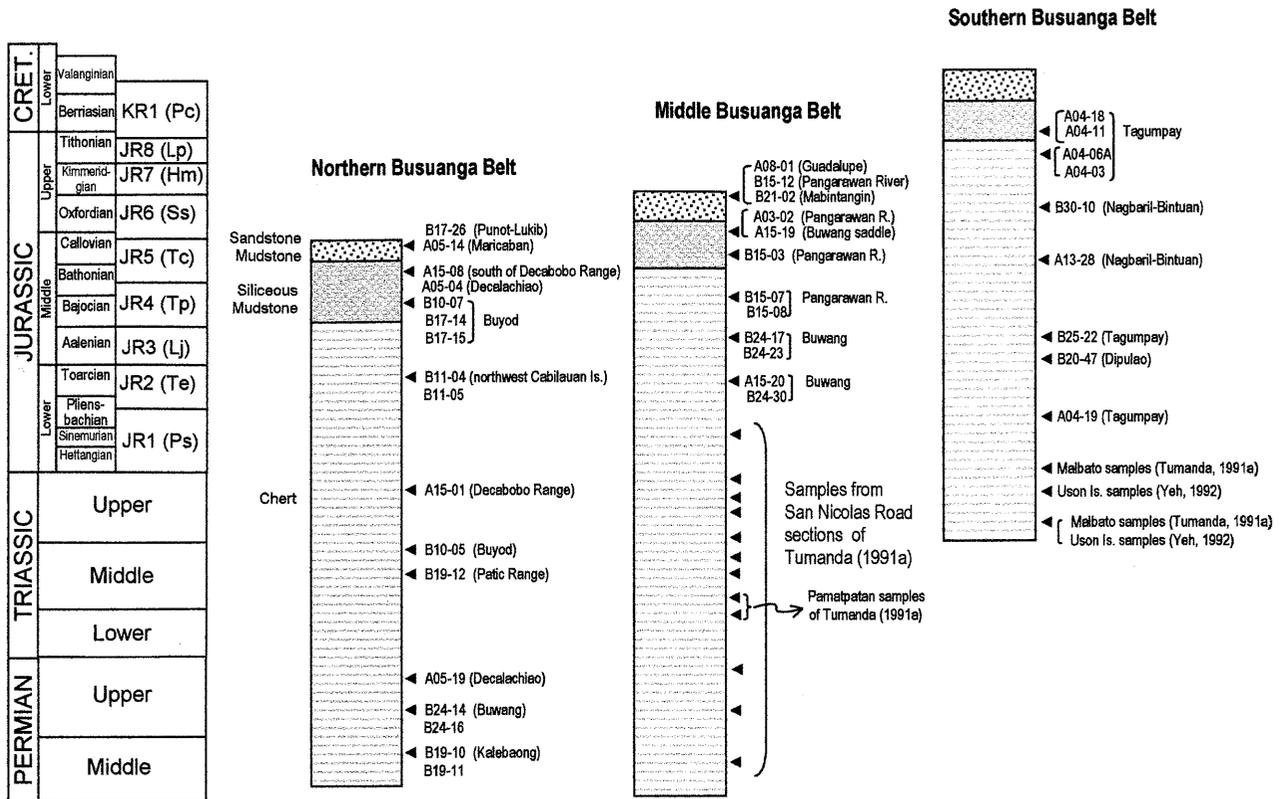


Fig. 8. Reconstruction of the oceanic plate stratigraphy for the three belts of the Malampaya Sound Group in Busuanga Island. Plotted samples for the Middle Busuanga Belt include the San Nicolas Road and Pamatpatan samples of Tumanda (1991a) to represent the Triassic to Permian portion. Southern Busuanga Belt samples include the Malbato samples of Tumanda (1991a) and Uson Island samples of Yeh (1992) to represent the Triassic portion (See Fig. 3 for sample locations).

assumed as Aalenian, while the siliceous mudstone portion begins probably from JR 4 (Bajocian-lower Bathonian) to JR 5 (upper Bathonian-Callovian). The JR 5 siliceous and terrigenous mudstones in northern outcrops of Busuanga Island such as those found south of Decabobo Range, Decalachiao and Maricaban have become its distinctive characteristic. The absence of JR 6 or younger radiolarian assemblage in these clastics essentially distinguishes the Northern Busuanga Belt from the subsequent belts.

(2) Middle Busuanga Belt

The appearance of *S. (?) spiralis* in the terrigenous clastics in the mid-portion of Busuanga Island has become the distinctive marker for the Middle Busuanga Belt. This radiolarian, the principal indicator of JR 6 or *Stylocapsa (?) spiralis* Zone for the upper Callovian-lower Oxfordian age, has been encountered in the clastics of Buwang, Mabintangin, Guadalupe and Pangarawan River or Tulbuan Plain. Between the Patic Range and San Nicolas, the boundary between the Northern Busuanga Belt and the Middle Busuanga Belt has been located. The basis of which is that the age of the terrigenous mudstone in the north of Patic Range is JR 5, while in the south it is JR 6. This boundary runs subparallel to the NW-SE trends of the chert-clastic sequences as shown in the

geologic map (Fig. 4). The thrust-fault contact between two chert-clastic sequences in Buwang (Fig. 5), as indicated by juxtaposed Permian chert and Jurassic clastics, is also considered a continuation of this boundary.

The best section of chert-to-clastics transition so far discovered is the one exposed along the Pangarawan River. Despite its discontinuous outcrops, the lithologic transition can be observed from black chert to siliceous mudstone, and to terrigenous mudstone-sandstone interbeds. It is accompanied by a remarkable change from JR 4 (Bajocian-early Bathonian) radiolarian assemblage in chert to JR 5 (late Bathonian-Callovian) assemblage in siliceous mudstone. The upsection of the siliceous mudstone further proves to have JR 6 (late Callovian-early Oxfordian) assemblage based on *S. (?) spiralis*. The succession of terrigenous clastics of mudstone and sandstone follows wherein *S. (?) spiralis* can also be found. Terrigenous mudstones containing *S. (?) spiralis* have been observed in Pangarawan, Guadalupe, Mabintangin and Buwang (Fig. 8).

Cheng (1989) and Tumanda (1991a) have already studied the lower stratigraphic sections of this belt particularly the Permian to Triassic exposures along the San Nicolas Road. Other sections in Tumanda

(1991a) such as Pamatpatan and Mabintangin-Pina Mountains are also considered part of the Middle Busuanga Belt. Based on Tumanda (1991a), the Middle to Upper Permian section of this belt is exposed along the San Nicolas and Mabintangin-Pina Mountains sections. The upper Lower and lower Middle Triassic are represented by the Pamatpatan section, south of Tulbuan Plain while subsequent interval zones from mid-Middle Triassic to Upper Triassic are found along the San Nicolas Road section. From the same section Tumanda (1991a) further defined the earliest Jurassic Interval Zone, *Parahsuum simplum* I.Z., which is equivalent to JR 1 or *Parahsuum simplum* Zone of Matsuoka (1995). A stratigraphic continuation of the JR 1 San Nicolas section is apparently shown by the JR 2 (upper Pliensbachian-Toarcian) and JR 3 (Aalenian) chert samples from the Buwang section. The occurrence of JR 4 (Bajocian-lower Bathonian) chert along the Pangarawan River, which is the topmost chert for the Middle Busuanga Belt, more or less completes the representation of the chert sequence for this belt.

(3) Southern Busuanga Belt

It represents the youngest group of accreted sequences in Busuanga Island. The JR 8 (lower-middle Tithonian) chert and the KR 1 (late Tithonian-Berriasian) siliceous mudstone in Tagumpay highlight the distinction of the Southern Busuanga from the Middle and Northern Busuanga belts. Its occurrence has clearly established the younging polarity of Busuanga Island's accretionary complex from north to south.

The boundary between the Middle and the Southern Busuanga belts is tentatively located south of Mount Dalara in the east, and SW of Wayan-Balaw Mountain Ranges in the west. Both west and east boundary traces presumably meet across Bacuit Island (Fig. 4). The distinctive characteristic of the Southern Busuanga Belt is that its chert sequences are much younger including JR 5, JR 6 and JR 8 ages. In the Northern and Middle Busuanga belts, JR 5 and JR 6 are already represented by clastic sequences while no JR 8 sequence has been found. Moreover, the lithologic transition of the Southern Busuanga Belt from chert to siliceous mudstone occurs in JR 8 (Tithonian), much younger than the JR 3–JR 4 (Aalenian-Bajocian) and the JR 4–JR 5 (Bathonian) transition ages of the Northern and Middle Busuanga belts, respectively.

The lithologic transition from chert to siliceous mudstone in Tagumpay is accompanied by moderately to well preserved JR 8 (Tithonian) radiolarians. This siliceous mudstone probably extends up to the earliest Cretaceous as shown in the stratigraphic column of the Southern Busuanga Belt (Fig. 8). The terrigenous clastics over the siliceous mudstone should therefore have an Early Cretaceous age. In

the southern areas of Busuanga Island, however, terrigenous clastics have not been encountered yet. Probable sites of the Early Cretaceous clastics south of Mt. Dalara and Balolo River valley are covered by Quaternary chert conglomerate.

The Lower to lower Middle Jurassic of the Southern Busuanga Belt is found in the Tagumpay (JR 1 and JR 3) and Dipulao (JR 2–JR 3) chert sections. The JR 5 and JR 6 chert samples from Nagbaril-Bintuan represent the upper Middle Jurassic and lower Upper Jurassic of the Southern Busuanga Belt. For the Triassic portion, the Upper Triassic samples of Yeh (1992) from Uson Island and Tumanda (1991a) from the Malbato section are considered representative of the lower section of the Southern Busuanga.

Discussions

1. Geologic Structure

The linear topographic features exhibiting elongated narrow mountain ranges and valleys in Busuanga Island were previously interpreted as a simple sequence of folded structures (BMG, 1984). The chert mountain ranges accordingly constitute the core of anticlines, and the intermittent valleys are synclines with overlying clastic deposits, serving as the upsection of the chert-clastic sequence. Subsequent contentions to such model were earlier hinted in the works of Isozaki et al. (1988) and Faure and Ishida (1990), both proposing more complex Mesozoic scenarios for the North Palawan Block. Isozaki et al. (1988) considered the chert and limestones as primarily oceanic deposits, then secondarily peeled off from the subducting oceanic plate, and subsequently juxtaposed with trench-fill turbidites and olistostromes (sandstone/mudstone) in an ancient subduction zone. Its lithologic assemblage and mode of occurrence are accordingly similar to the Paleozoic and Mesozoic subduction complexes in SW Japan and North America.

In this work Busuanga Island is considered as an accretion-subduction complex composed of juxtaposed accreted chert-clastic sequences, in line with the proposal of Isozaki et al. (1988). Each constituent sheet in this complex is characterized by a chert sequence in the lower section and clastic sequence in the upsection. The strata dip generally northward, with its topmost section in fault contact with the base (chert) of the adjacent sheet at its north, and its lowermost section in fault contact with the top of the subsequent sheet at its south. Such feature characterizes the imbricate framework of the Malampaya Sound Group in Busuanga Island, resulting to apparent alternation of chert and clastics sequences.

2. Formative process of the Malampaya Sound Group

The general succession from chert to clastics in North Palawan is interpreted as a facies change fol-

lowing the gradual plate movement from a remote oceanic environment toward the subduction zone. Its Middle Permian to Upper Jurassic chert sequences record a long depositional history reflective of a long duration of pelagic environment, as previously recognized by Isozaki et al. (1988). Before the deposition of the clastics occurred, the travelling oceanic plate must have originated from a considerably far distance across a very wide paleo-ocean to accumulate such thick chert sequences from Middle Permian up to Middle or Upper Jurassic. The beginning of clastic deposition as represented by the siliceous mudstone marks its transition from pelagic to hemipelagic condition. This lithologic transition indicates the near approach of the travelling oceanic plate toward the subduction zone. The subsequent deposition of terrigenous clastics reflects its final transition from hemipelagic to turbidite deposition, while the coarsening from terrigenous mudstone into sandstone signifies the closer approach to the continental margin (Matsuoka, 1984; Matsuda and Isozaki, 1991).

It therefore implies that the offscrape accretion event of the oceanic chert-clastic sequences occurred immediately or even simultaneously with the deposition of the terrigenous clastics. With the Malampaya Sound Group in Busuanga Island exhibiting three belts distinguished by different ages of lithologic transition, three events of accretion are apparently indicated. The accretion timing of the Northern Busuanga Belt probably took place in the late Middle Jurassic based on its JR5 terrigenous clastics. The Middle Busuanga Belt's accretion would be in the Late Jurassic based on its JR6 terrigenous clastics while the Southern Busuanga Belt could have accreted during the Early Cretaceous as indicated by the KR1 base of the siliceous mudstone. These events apparently illustrate progressive accretion of chert-clastic sequences.

Modern interpretations of limestone bodies associated with chert-clastic sequences fall under the offscrape model for oceanic deposits during the subduction stage (Isozaki et al., 1988; Matsuoka, 1992). Prior to subduction, these limestone bodies, as illustrated by Sano and Kanmera (1988), originally developed as shallow facies deposits or carbonate build-ups on oceanic seamounts that radially grade away from the seamounts into chert as distal facies. Such scenario quite explains the sporadically distributed limestone bodies around the North Palawan Block. The Minilog, Malajon, Coron, Ili and Imorigue limestones are hereby interpreted as originally carbonate build-ups that formed independently on isolated seamounts of a past ocean. The range of their respective ages falling within Middle Permian to Late Jurassic may imply that seamount carbonate setting coexisted with the Middle Permian to Late Jurassic pelagic setting of the chert sequences. It is

during the subduction stage wherein these deposits underwent offscraping from the subducting oceanic plate and juxtaposed with chert-clastic sequences in an imbricate manner.

The Bicanan Melange most probably originates from the chert-clastic sequences and limestone units of the Malampaya Sound Group, and from the basaltic basement of these sedimentary rocks. The development of this melange most likely conforms to the model of Moore and Byrne (1987) for melange formation in accreting sediments. Accordingly, the accretion process at the subduction zone causes stratal disruption of the submarine accretionary prisms that initiates progressive deformation of the young poorly consolidated sediments. Such mechanism is exemplified by the Shimanto accretionary complex of SW Japan wherein at the base of its constituent chert-clastic sequences, progressive deformational history indicating gradual underthrusting of sediments have been recorded (Mackenzie et al., 1987; Kimura and Mukai, 1991). The two types under the Bicanan Melange distinguished through lithologic components are considered undergoing the same tectonic process. The limestone-basalt-chert melange originates from the progressive deformation of its component materials without the clastics, whereas the sandstone-chert-mudstone melange is from a chert-clastic sequence without limestone and basaltic units involved.

3. Correlation between Jurassic accretion complexes of North Palawan and SW Japan

In the conceptualized Jurassic accretionary complex along the East Asian margin, the North Palawan Block has been considered the southernmost continuation so far discovered. As shown in Fig. 1C, this narrow zone has been traced from eastern Russia, NE China, NE and SW Japan and the Ryukyus, with the metamorphic complex in Taiwan as originally part of it (Isozaki et al., 1988; Matsuda and Isozaki, 1991; Mizutani and Kojima, 1992; Isozaki, 1997; Kojima and Kametaka, 2000). Hence, it is highly probable that the North Palawan Block, which originated from the southern part of China or in the vicinity of Taiwan (Taylor and Hayes, 1980; Holloway, 1982), can prove a close correlation to other Jurassic accretion complexes in East Asia.

Among the many chert-clastic sequences in SW Japan, it has been found that the Malampaya Sound Group closely correlates with the Togano Group or Subterranean of the Southern Chichibu Terrane (Fig. 9). The Togano Group is characterized by chert-clastic sequences forming a northward dipping imbricate structure (Matsuoka and Yao, 1990; Matsuoka, 1984, 1992). It is subdivided into five belts, namely, Ogawa Belt, Kobiura Belt and Nishiyama Belt (I, II, III). These belts have different ages of lithologic transition from chert to siliceous mudstone to coarse clastics, and observed younging from north to south. The

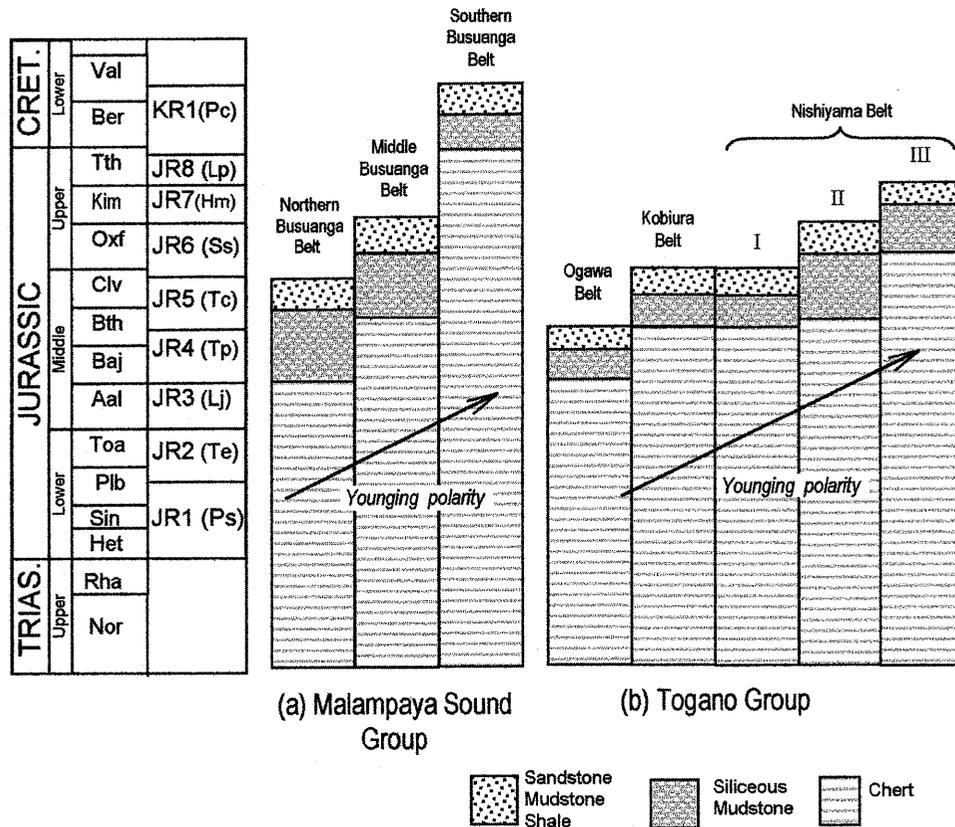


Fig. 9. Correlation between the Malampaya Sound Group and the Togano Group of the Southern Chichibu Terrane, SW Japan. (a) The Malampaya Sound Group composed of the Northern, Middle and Southern Busuanga belts characterized by the north-to-south younging polarity. (b) The Togano Group composed of Ogawa, Kobiura and Nishiyama (I, II, III) belts (Matsuoka, 1984 ; 1992).

systematic younging of the lithologic transition from Middle Jurassic in the Ogawa Belt to Upper Jurassic in the Nishiyama Belt III remarkably coincides with lithologic transition ages of the three belts of the Malampaya Sound Group. This similarity strongly indicates that the Malampaya Sound Group and the Togano Group have about the same accretion timing and formative process.

Beside the similarities in lithology, sequence, structure and age, the faunal assemblages between the two regions show close affinity. Zamoras and Matsuoka (2000 a) observed remarkable similarity of the late Callovian-early Oxfordian radiolarian assemblage from a siliceous mudstone in the Tulbuan Plain of Busuanga to those from the Sakawa area (Matsuoka, 1983) and Mt. Irazu area (Aita, 1987) in Shikoku, SW Japan. Based on these available data, therefore, we believe that the Malampaya Sound Group is correlative to the Togano Group of the Southern Chichibu Terrane. This correlation further confirms that the North Palawan Block is a southern extension of the Mesozoic accretionary complex of the East Asian margin and SW-NE Japan.

Summary

1. The revised Upper Paleozoic-Mesozoic stratigraphy of the North Palawan Block includes three major lithostratigraphic units namely, Liminangcong Formation, Guinlo Formation and limestone units, with minor melange bodies (Bicatan Melange) collectively called as the Malampaya Sound Group.
2. The linear topographic features of Busuanga Island, exhibited by alternating narrow mountain ranges and valleys, actually manifest an imbricate structure formed through juxtaposition of offscraped chert-clastic sequences.
3. The chert-clastic sequences in Busuanga Island generally exhibit lithologic transition from chert to siliceous mudstone to terrigenous clastics.
4. There are three belts defined in Busuanga Island based on the age of lithologic transition : (a) Northern Busuanga Belt, (b) Middle Busuanga Belt, (c) Southern Busuanga Belt. These belts feature a north-to-south younging polarity.
5. The close correlation between the Malampaya Sound Group in Busuanga Island and the Togano Group of the Southern Chichibu terrane in SW Japan is strong evidence that the North Palawan Block is a

southern extension of the Mesozoic subduction complexes of eastern Russia, NE and SW Japan and the Ryukyus.

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References

Aita, Y., 1987, Middle Jurassic to lower Cretaceous radiolarian biostratigraphy of Shikoku with reference to selected sections in Lombardy Basin and Sicily. *Sci. Rep. Tohoku Univ., Second Ser. (Geol.)*, **58**, 1-91.

Amiscaray, E. A., 1987, Permian Fusulinids and other microfossils from northwestern Palawan. *Rep. No. 2 of the IGCP Proj. 224 : Pre-Jurassic evolution of eastern Asia*, 85-104.

Bassoullet, J.P., 1983, Jurassic microfossils from the Philippines. *ESCAP-CCOP Tech. Bull.*, **16**, 31-38.

Beauvais, L., 1983, Jurassic Cnidaria from the Philippines and Sumatra. *ESCAP-CCOP Tech. Bull.*, **16**, 39-67.

Bureau of Mines and Geosciences (BMG), 1981, Geology and mineral resources of the Philippines, **1**, 1-406.

Bureau of Mines and Geosciences (BMG), 1984, Geological maps of Busuanga Island : Sheet nos. 2956 (I-II), 3055 (IV), 3056 (I-IV).

Cheng, Y., 1989, Upper Paleozoic and Lower Mesozoic radiolarian assemblages from the Busuanga Islands, North Palawan Block, Philippines. *Bull. Natn. Mus. Nat. Sci. (Taiwan)*, no. 1, 129-175.

Cheng, Y., 1992, Upper Jurassic Pantanelliidae (Pantaneliinae Pessagno, 1977 and Vallupinae Pessagno and MacLeod, 1987) from the Busuanga Islands, Philippines. *Bull. Natn. Mus. Nat. Sci. (Taiwan)*, no. 3, 1-49.

Faure, M. and Ishida, K., 1990, The Mid-Upper Jurassic olistostrome of the west Philippines : a distinctive key-marker for the North Palawan block. *Jour. SE Asian Earth Sci.*, **4**, 61-67.

Fontaine, H., 1979, Note on the geology of the Calamian Islands, North Palawan, Philippines. *ESCAP-CCOP Newsl.*, **6**, 40-47.

Fontaine, H., David, P., Pardede, R. and Suwarna, N., 1983, Marine Jurassic in Southeast Asia. *ESCAP-CCOP Tech. Bull.*, **16**, 3-30.

Hamilton, W., 1979, Tectonics of the Indonesian region. *U. S. Geol. Surv. Prof. Pap.*, no. 1078, 1-338.

Hashimoto, W. and Sato, T., 1973, Geologic structure of North Palawan and its bearing on the geological history of the Philippines. In Kobayashi, T. and Toriyama, R., eds., *Geol. Paleont. SE Asia*, **13**, 145-161.

Hashimoto, W., Takizawa, S., Balce, G.R., Espiritu, E. A. and Baura, C. A., 1980, Discovery of Triassic conodonts from Malajon and Uson Islands of the Calamian Island Group, Palawan Province, the Philippines, and its geological significance. *Proc. Japan Acad.*, **56**, ser. B, 69-73.

Holloway, N. H., 1982, North Palawan Block, Philippines - Its

relation to Asia Mainland and role in evolution of South China Sea. *Bull. Amer. Assoc. Petrol. Geol.*, **66**, 1355-1383.

Isozaki, Y., 1997, Jurassic accretion tectonics of Japan. *The Island Arc*, **6**, 25-51.

Isozaki, Y., Amiscaray, E. A. and Rillon, A., 1988, Permian, Triassic and Jurassic bedded radiolarian cherts in North Palawan Block, Philippines : Evidence of Late Mesozoic subduction-accretion. *Rep. No. 3 IGCP Proj. 224 : Pre-Jurassic Evolution of Eastern Asia*, 99-115.

JICA-MMAJ, 1990, Mineral deposits and tectonics of two contrasting geologic environments in the Republic of the Philippines. 1-121.

Kimura, G. and Mukai, A., 1991, Underplated units in an accretionary complex : Melange of the Shimanto Belt of the eastern Shikoku, southwest Japan. *Tectonics*, **10**, 31-50.

Kojima, S. and Kametaka, M., 2000, Jurassic accretionary complexes in East Asia. *Mem. Geol. Soc. Japan*, no. 55, 61-72.*

Mackenzie, J.S., Needham, D.T. and Agar, S.M., 1987, Progressive deformation in an accretionary complex : An example from the Shimanto belt of eastern Kyushu, southwest Japan. *Geology*, **15**, 353-356.

Matsuda, T. and Isozaki, Y., 1991, Well-documented travel history of Mesozoic pelagic chert in Japan : from remote ocean to subduction zone. *Tectonics*, **10**, 475-499.

Matsuoka, A., 1983, Middle and Late Jurassic radiolarian biostratigraphy in the Sakawa and adjacent area. Shikoku, SW Japan. *Jour. Geosci., Osaka City Univ.*, **26**, 1-48.

Matsuoka, A., 1984, Togano Group of the Southern Chichibu Terrane in the western part of Kochi Prefecture. *Journ. Geol. Soc. Japan*, **90**, 455-477.*

Matsuoka, A., 1992, Jurassic-Early Cretaceous tectonic evolution of the Southern Chichibu terrane, southwest Japan. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, **96**, 71-88.

Matsuoka, A., 1995, Jurassic and Lower Cretaceous radiolarian zonations in Japan and in the western Pacific. *The Island Arc*, **4**, 40-153.

Matsuoka, A. and Yao, A., 1990, Southern Chichibu Terrane. *IGCP Proj. 244 : Pre-Cretaceous Terranes of Japan*, 203-216.

McCabe, R., Almasco, J. and Diegor, W., 1982, Geologic and paleomagnetic evidence for a possible Miocene collision in western Panay, central Philippines. *Geology*, **10**, 325-329.

Mizutani, S. and Kojima, S., 1992, Mesozoic radiolarian biostratigraphy of Japan and collage tectonics along the eastern continental margin of Asia. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, **96**, 3-22.

Moore, J.C. and Byrne, T., 1987, Thickening of fault zones : A mechanism of melange formation in accreted sediments. *Geology*, **15**, 1040-1043.

Sano, H. and Kanmera, K., 1988, Paleogeographic reconstruction of accreted oceanic rocks, Akiyoshi, southwest Japan. *Geology*, **16**, 600-603.

Taylor, B. and Hayes, D. E., 1980, The tectonic evolution of the South China Sea Basin. In Hayes, D. E., ed., The tectonic and geologic evolution of Southeast Asian Seas and islands. *Geophys. Monogr.*, ser. **23**, 23-56.

Tumanda, F., 1991 a, Permian to Jurassic radiolarian biostratigraphy of Busuanga Island, Palawan, Philippines. *Doc. Sci. dissertation, Inst. Geosci., Univ. Tsukuba*, 1-212.

Tumanda, F., 1991 b, Radiolarian biostratigraphy in central Busuanga Island, Palawan, Philippines. *Jour. Geol. Soc. Phils.*, **46**, nos. 1-2, 49-104.

Tumanda, F., 1994, Permian radiolaria from Busuanga Island, Palawan, Philippines. *Jour. Geol. Soc. Phils.*, **49**, 119-193.

- Tumanda-Mateer, F., Sashida, K. and Igo, H., 1996, Some Jurassic radiolarians from Busuanga Island, Calamian Island Group, Palawan, Philippines. *In* Noda, H. and Sashida, K., eds., Prof. Hisayoshi Igo Commemorative Volume on Geology and Paleontology of Japan and Southeast Asia, 165-192.
- Wolfart, R., Cepek, P., Gramann, F., Kemper, E. and Porth, H., 1986, Stratigraphy of Palawan Island, Philippines. *Newsl. Stratigr.*, **16**, 19-48.
- Yeh, K., 1992, Triassic Radiolaria from Uson Island, Philippines. *Bull. Natn. Mus. Nat. Sci. (Taiwan)*, no. 3, 51-91.
- Yeh, K. and Cheng, Y., 1996, Jurassic radiolarians from the northwest coast of Busuanga Island, North Palawan Block, Philippines. *Micropaleontology*, **42**, 93-124.
- Yeh, K. and Cheng, Y., 1998, Radiolarians from the Lower Jurassic of the Busuanga Island, Philippines. *Bull. Natn. Mus. Nat. Sci. (Taiwan)*, no. 11, 1-65.
- Zamoras, L.R. and Matsuoka, A., 2000 a, Early Late Jurassic radiolarians from the clastic unit in Busuanga Island, North Palawan, Philippines. *Sci. Rep., Niigata Univ., Ser. E (Geology)*, no. 15, 91-109.
- Zamoras, L.R. and Matsuoka, A., 2000 b, Late Callovian-early Oxfordian radiolarians from the clastic unit in Busuanga Island, North Palawan, Philippines. *Paleont. Soc. Japan Abst. (The 2000 Annual Meeting)*, 41.

* : in Japanese with English abstract

(要旨)

Zamoras, L.R. and Matsuoka, A., 2001, Malampaya Sound Group: a Jurassic-Early Cretaceous accretionary complex in Busuanga Island, North Palawan Block (Philippines). *Jour. Geol. Soc. Japan*, **107, 316-336.** (ローレンス R. ザモラス・松岡 篤, 2001, マランパヤサウンド層群—フィリピン北パラワン地塊のジュラ紀-白亜紀古世付加体. 地質雑, **107**, 316-336.)

ブスアンガ島は、ペルム紀からジュラ紀にわたるチャート（リミナンコン層）とジュラ紀中世から白亜紀古世にわたる砕屑岩類（ギンロ層）から主として構成される付加体（マランパヤサウンド層群）よりなる。マランパヤサウンド層群は、全体として北に急角度で傾斜する覆瓦構造をなしている。同層群はチャート・砕屑岩シーケンスの剝ぎ取り付加によって形成されたと考えられる。放散虫の生層序学的検討により、チャートから珪質泥岩に移化する層準は、北から南に向かって系統的に若くなる年代極性をもつことが明らかになった。この年代の違いに基づき、ブスアンガ島のマランパヤサウンド層群分布域を、北帯、中帯、南帯の3帯に区分した。同層群の付加年代は、ジュラ中世から白亜紀古世にわたる。マランパヤサウンド層群は、西南日本南部秩父テレーンの斗賀野層群に対比される。

The Malampaya Sound Group in the Calamian Islands, North Palawan Block (Philippines)

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Fig. 1. The linear topographic expression of the chert-clastic sequences showing the chert mountain ranges (Balnek Mountains) with intervals of narrow valleys representing the clastics.

The Malampaya Sound Group is predominantly composed of chert (Liminangcong Formation), clastics (Guinlo Formation) and scattered limestone units that characterize the North Palawan Block (Zamoras and Matsuoka, 2001). In the Calamian Islands (grouping Busuanga, Coron, Culion and other smaller islands) the Liminangcong Formation is represented by Permian to Late Jurassic chert; the Guinlo Formation is represented by Middle-Late Jurassic to Early Cretaceous clastics.

The common succession from chert to clastics with generally conformable contact is thus referred to as a chert-clastic sequence. In Busuanga Island, linear topographic patterns reveal the parallel distribution of chert-clastic sequences dipping generally NW in the west, and NE in the central and eastern portions. This chert-clastic repetition indicates an imbricate structure typical to offscrape accretion complexes.

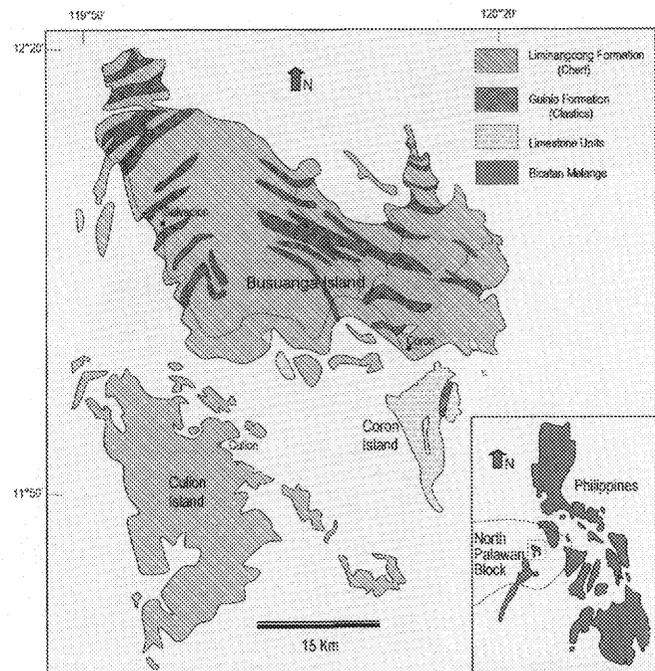


Fig. 2. Geologic map of the Calamian Islands (Busuanga, Culion, Coron and smaller islands).



Fig. 3. The Tulbuan Plain composed of Jurassic (late Callovian-Oxfordian) clastics (Guinlo Formation).



Fig. 4. Typical thinly bedded Triassic chert sequence (part of the Liminancong Formation).



Fig. 5. Late Triassic Coron Limestone viewed in Cayangan Lake in Coron Island.

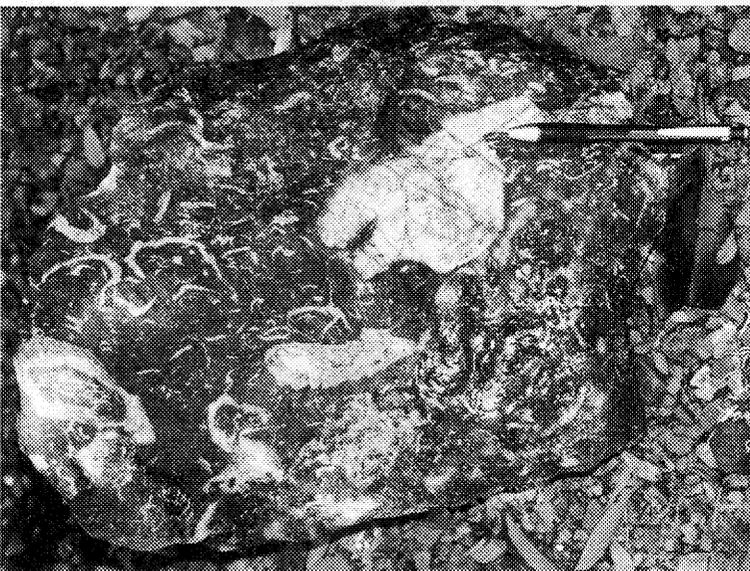


Fig. 6. Molluscan assemblages reflective of lagoonal environmental setting of the Coron Limestone. The pelecypod fossils probably include *Paramegalodus* which was reported by Wolfart et al. (1986).

Reference

- Wolfart, R., Cepek, P., Gramann, F., Kemper, E. and Porth, H., 1986, Stratigraphy of Palawan Island, Philippines. *Newsl. Stratigr.*, **16**, 19-48.
- Zamoras, L.R., and Matsuoka, A., 2001, Malampaya Sound Group: a Jurassic-Early Cretaceous accretionary complex in Busuanga Island, North Palawan Block (Philippines). *Jour. Geol. Soc. Japan*, **107**, 316-336.