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The Madai-Baturong Limestone in eastern Sabah and its new interpretation as a seamount

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Abstract: The shallow marine Lower Cretaceous Madai-Baturong Limestone of east Sabah is surrounded by deep water ophiolitic rocks such as cherts, turbiditic greywackes and spilitic basalts belonging to the Chert-Spilite Formation. A new interpretation that it is a seamount carbonate is proposed because of: the extreme purity of the carbonates and the lack of terrigenous detrital inputs into the limestone, its intimate relationship with the surrounding typical deep water ophiolitic rocks, and its large size and yet limited lateral extend. The development of fissures filled with younger Upper Cretaceous limestone breccias with volcanic input in its matrix enclosing blocks of the older limestone indicating exposure and erosion of the top of the limestone which must have remained near the paleosea-level lends further support to the hypothesis. The smaller limestone bodies interbedded with the Chert-Spilite Formation rocks could be blocks which have slumped off the topographically higher seamounts into the deeper parts surrounding them.

INTRODUCTION

The Madai-Baturong Limestone has always seemed out of place both in its geographic location and in the stratigraphic column for eastern Sabah. What is a shallow marine limestone doing in the midst of deep water spilitic basalts, cherts and turbiditic greywackes of equivalent age both stratigraphically and geographically? Leong (1999) just noted that the shallow marine algal, oolitic and massive Madai-Baturong Limestone appears to be the lateral equivalent of the deeper marine limestones and radiolarian cherts of the Chert-Spilite Formation without offering an explanation. I used to assume that these limestone bodies were just olistrostromes of shallow marine carbonate build-ups that had slumped into deeper waters until I saw the enormous size of the two hills. There was also the general lack of slumped bedding and the extreme purity of the limestones to contend with if they were indeed olistrostomes. My curiosity was aroused when I noted that minor limestones had been recorded but not explained in ophiolite sequences in a textbook (Fig. 9.14, p.199 in Montgomery and Dathe, 1994) that I was using in one of my classes.

OCCURRENCE

The lenticular beds of massive limestone associated with basaltic volcanic rocks, chert, and greywacke found scattered along the southern edge of the Chert-Spilite Formation west of Kunak were first designated as the Madai-Baturong Limestone Member of the Formation by Kirk (1962). The main occurrences (Fig. 1) are at Mount Madai, its type locality, and the adjacent hills where the maximum thickness exceeds 609 meters (2,000 feet), and at Mount Baturong (305 meters or 1,000 feet) and a smaller body near Supad Batu. The east-west elongated hills of Mount Madai (Fig. 2) and Mount Baturong (Fig. 3) measure about 3.5 km and 2.5 km respectively. Other small occurrences have been reported in the upper Binuang and Tingkayu Valleys. The limestone member extends along the general strike of the Chert-Spilite Formation for at least 38 kilometers (24 miles).

STRATIGRAPHY AND AGE

Leong (1974) evaluated the stratigraphy of the limestone commencing with a fine-grained non-detrital limestone at its base exposed at Baturong, succeeded by oolitic limestone exposed at all three outcrops mentioned, and overlain by detrital limestone at Madai.

Adams and Kirk (1962) assigned a Late Cretaceous age for the Madai limestone based on pelagic foraminifera in two breccias and in the main part of the limestone above the lower breccia. The lower (southern) breccia contains a rich Campanian fauna while the upper (northern) one a much poorer fauna indicative only of a general Senonian age. Derived foraminiferal limestone blocks in the lower breccia are older and Cenomanian in age. Previous age determinations of the Madai limestone based on algae (Elliot, 1958 and 1960) were typical Early Cretaceous. The absence of typical Upper Cretaceous algae was difficult to reconcile with a Campanian age for the Madai limestone. There is no direct foraminiferal evidence for the Late Cretaceous age of the limestone at Baturong but algae and the problematical organism *Hensonella* and the small simple species of *Dictyoconus*, all suggest it is Early Cretaceous.

Leong (1974) subsequently raised the Madai-Baturong Limestone to Formation status based on his belief that it was an older formation that preceeded the deposition of the Chert-Spilite Formation based on his new field and palaeontological evidence. He believed that the limestone is Early Cretaceous in age by excluding the Upper Cretaceous foraminifera-bearing limestone breccias found on the northern and southern sides of Mount Madai which he believed to post-date the deposition of the limestone. He questioned the apparent interbedding relationship of the southern breccia and the main limestone mass reported by Adams and Kirk (1962) and proposed that the Madai-Baturong Limestone pre-dated the Chert-Spilite Formation and was probably Lower Cretaceous with a possible range from the Upper Jurassic. Fontaine and Ho (1989), confirmed the Cretaceous age of the limestone using the caprinid rudists they found eliminating the Late Jurassic extension.

If the Madai-Baturong Limestone is part of the ophiolite sequence (Hutchison, 1992), an Early Cretaceous age is more likely as the deep-marine cherts in the sequence have been dated as Early Cretaceous from Valanginian to Barremian (Leong, 1977; Basir Jasin, 1991) or Cenomanian (Basir Jasin, 2000).

A PROBLEM WITH DEPOSITIONAL ENVIRONMENTS

A problem was created for the early geologists because the Madai-Baturong Limestone is a typical clear, shallow warm water limestone complete with oolites, shallow marine benthic foraminifera, gastropods, bivalves (Fig. 4) and abundant detrital organic debris much of which is algal in nature (Kirk,1962; Adams and Kirk, 1962; Leong, 1974). Indeed, so confident were they of their interpretation of the depositional environment, that Adams and Kirk (1962) declared that the benthic foraminifera and algae are of shallow water (lagoonal) type; the almost complete absence of pelagic foraminifera suggests that the region was only intermittently in direct contact with, or else was well away from, the open sea.

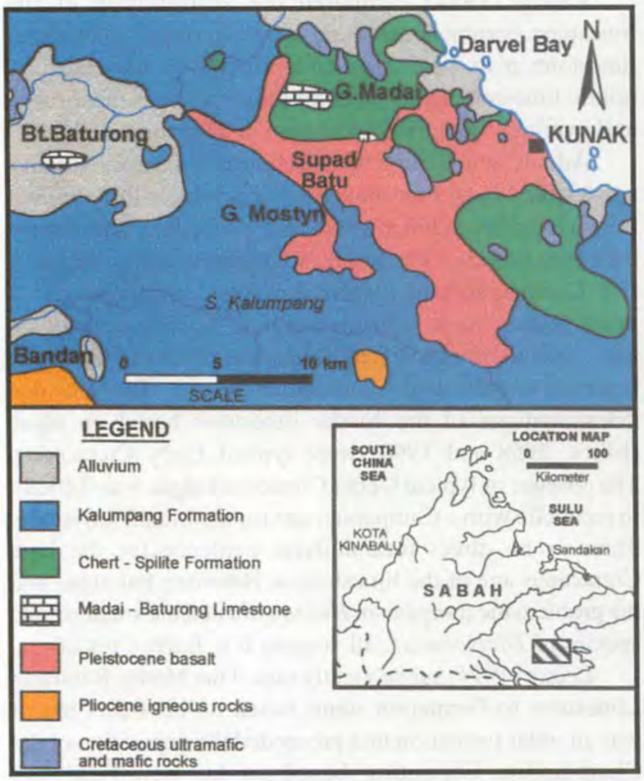

Figure 1. Location map and geological setting of Madai-Baturong Limestone in east Sabah.

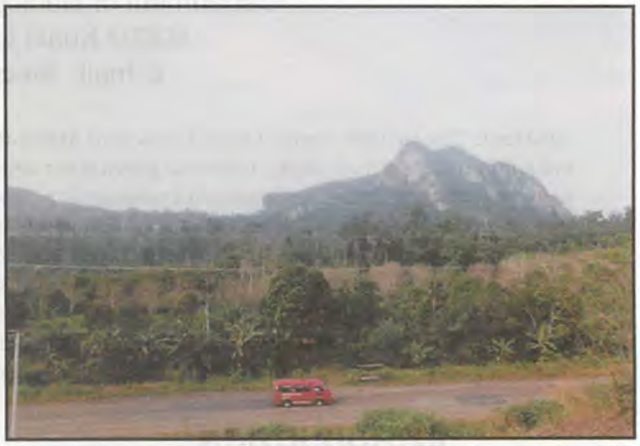

Figure 2. Photograph of Mount Madai taken facing south.

Figure 3. Photograph of Mount Baturong taken facing south.

Figure 4. Photograph of bands of thick shelled bivalve fossils in northwestern part of Baturong.

What was this shallow water limestone doing in the midst of deep water ophiolitic rocks? Adams and Kirk (1962) had rightly observed that with the exception of Mount Baturong which was surrounded by Quaternary alluvium, all occurrences of the limestone are known to be enclosed by basic volcanic rocks, chert, and greywacke. They were puzzled that although the field relationships of the rocks suggest that the limestone is interbedded with the Chert-Spilite Formation, two main objections needed to be addressed, namely,: (1) rocks of Chert-Spilite facies are generally believed to form in a deep water environment, but the Madai-Baturong limestone was clearly formed in shallow water; (2) blocks of igneous rock would be expected to occur in at least the lower of the two breccias but so far they have been found in neither. They proffered two possible explanations for the difference in facies. Firstly, that the limestone outcrops originated as a penecontemporaneous deposit with the Chert-Spilite rocks, but at a higher submarine level, and reached its present position by sliding *en masse* down the steep slope of a tectonic fore-deep. Secondly, that the larger outcrops which have no clear continuity with the surrounding strata could possibly be part of an older formation protruding through the Chert-Spilite Formation in a series of fault-bounded inliers. They, however, recognised the difficulty of explaining the presence of the small limestone occurrences on that hypothesis.

Leong (1974), on the other hand, tried to argue that the limestone is older than the Chert-Spilite Formation and had been deposited in lagoonal and shoal areas lapping in a nonconformable fashion on the then submerged Crystalline Basement. He disputed the interbedded relationship between the southern breccia and the main limestone mass suggested by Adams and Kirk (1962) by pointing out that the breccias were more likely later younger fissure fillings with Upper Cretaceous foraminifera which post-dated the massive white Lower Cretaceous or older Madai limestone. He cited the presence of blocks of oolitic limestone in the Lower Malubuk area to support his interpretation that the breccias with reddish brown mud matrix occur as fissure-fillings in the oolitic limestone. He also deduced that at least parts of the Madai-Baturong limestone appear to have been exposed to erosion in Late Cretaceous or Early Tertiary time as the volcanic limestone conglomerate of the Chert-Spilite Formation on Pulau Timbun Mata contains subrounded, apparently waterworn fragments of oolitic limestone, lithologically similar to those at Madai and Supad Batu. He tried to explain the complete lack of Crystalline-Basement fragments in the Madai-Baturong Limestone by suggesting that during its deposition, the major part of the Basement rocks were submerged and therefore not exposed to erosion.

Ravichanthar Subramaniam (1991) essentially built on Leong's (1974) idea that the limestone was deposited along an extensive shelf margin and proposed that Madai and Baturong are remnants left by extensional faulting during Early to Middle Miocene times. Basir Jasin (1991) proposed that the Madai-Baturong Limestone was deposited on a horst while the chert was deposited in the deep waters of the adjacent grabens during the Early Cretaceous. He also introduced the name Sabah Complex for the Chert-Spilite Formation as a lithodemic unit sequence composed of peridotite, serpentinite, basalt, spilite, pillow lava and chert but he excluded the Madai-Baturong Limestone from the Complex and treated the Limestone as a separate formation.

LIMESTONE BRECCIAS AND FISSURE FILLINGS

There are essentially two limestone breccias reported from Mount Madai by previous workers. The first is a 1 m thick limestone breccia found on the northern part of the hill that contains blocks of rock similar to the rest of the hill, small pieces of chert (possibly volcanic in origin), and large blocks of shattered oolitic limestone. It contains blocks up to a foot across and scattered pelagic foraminifera including *Globigerina*, a Tertiary genus, and other Tertiary planktonic species alongside Upper Cretaceous assemblage such as *Globotruncana* and *Heterohelix* which Leong (1974) interpreted as reworked material. He interpreted it as a slump breccia similar to those of the Miocene Kuamut Formation sitting disconformably on the Madai Baturong Limestone because of its chaotic nature.

The second breccia (Fig. 5) is located on the southern side of the Madai hills, east of the Madai Cave entrance. It is 1.2 m thick and consists of blocks of typical Madai limestone up to 1.06 m across embedded in a red, laminated matrix composed almost entirely of pelagic foraminifera (Kirk, 1962) giving a diagnostic Late Cretaceous age. Because of the irregularity of shape and lack of sorting of the blocks and the similar ages of the pelagic foraminifera in the blocks and matrix, Kirk (1962) suggested that disturbances of the original lamination of the red matrix by the included blocks indicate that they were dropped into a soft sediment during the course of formation by local brecciation of a partially formed limestone. He also made the interesting inference that the deep red colouration of the bed and the presence of chloritic and limonitic flecks in the matrix indicate that the brecciation may have been due to volcanic activity.

Leong (1974), however, believes that the southern breccias were deposited by infilling of solution fissures by broken-up limestone from eroded parts of the Madai limestone which were later cemented and covered by reddish mud containing the Upper Cretaceous foraminifera. He further supported his hypothesis by referring to similar fissure-filling in oolitic limestone blocks observed in the Lower Malubuk area. He wrote that this would explain the anomalous occurrence or contamination by Upper Cretaceous foraminifera in the massive white Madai limestone and he reassigned these southern breccias to the younger Chert-Spilite Formation.

I agree with Leong's (1974) interpretation that the breccias are most likely to be fissure fillings. Similar fissure fillings have been reported from Permian seamount limestones of the Mino terrane in Japan (Sano and Kojima, 2000) which I visited during an ISRGA Field Workshop in Japan (2001). At Hachiman, Triassic cave deposits were found in Permian limestone which was quite puzzling to earlier researchers because no outcrops of Triassic limestone capping seamounts were present as all of them had been eroded away except what were preserved in the caves which had developed in the Permian limestones. These so-called caves at Hachiman in Japan were small fissure fillings (Fig. 6) which were hardly distinguishable from the host limestone except for some slightly more reddish colouration.

A SUGGESTED SOLUTION

As pointed out by Adams and Kirk (1962), the smaller limestone bodies which could be olistrostromes that have slid down and been embedded within the deep water penecontemporaneous deposits of the Chert-Spilite Formation. Mount Madai and Mount Baturong, however, posed a problem because they are so huge by comparison that they suggested the possibility of them being faulted inliers of an older formation to explain their presence. This explanation was also used by Leong (1974 and 1999) who favoured an older Madai-Baturong Limestone located beneath the Chert-Spilite Formation.

I first saw the Madai limestone in 1993 (Fig. 7) when I was enroute to the Dent Peninsular from Tawau and it was much larger than expected. Prior to that encounter, I had thought that the shallow water limestone was just a small olistrostrome that had slid into the deeper environment as proposed by Adams and Kirk (1962). My interest in its origin was rekindled when I attended an IGCP 411 conference in Yichang (Three Gorges) in China in 1999 where I was introduced to the subject of seamount carbonates by Prof. Liu Benpei. He and his co-workers (Liu *et al.*, 1991, 1993) had interpreted shallow water carbonates sitting on top of seamount volcanics in the southern part of the Changning-Menglian belt during the Hercynian-Indosinian stage as seamount carbonates. Such carbonates are lithologically very pure without any terrigenous clastic intercalations and they have a continuous

Figure 5. Limestone breccia located 75m southeast of the southern entrance to the Madai Caves.

Figure 6. Outcrop of Permian seamount limestone with Triassic cave deposits (T) from Hachiman, Mino terrane, Japan.

Figure 7. Photograph of northern entrance to Madai Caves taken in 1993 facing southwest.

relationship with the underlying volcanics. These seamounts in China did not form an extensive uniform carbonate platform but instead existed as several isolated small platforms capping different seamounts or continental shelfs. This situation is not unlike Madai-Baturong; their isolation may not be due to an originally connected platform being dissected by erosion as suggested by Leong (1974) but was most likely due to their original isolation as seamounts on volcanic highs jutting above the oceanic sea-floor corroborated by the extreme purity of the Madai-Baturong limestone and total absence of terrigenous clastics. An interesting present day example of a similar oceanic island would be the nearby Pulau Sipadan located 35 km south of Semporna. It was formed by corals growing on top of an extinct undersea volcano which rises 600 m from the present seafloor. The sand on its beaches is made up entirely of calcareous material with no terrigenous input. Chemical analyses of the limestone from Madai, Baturong and Supad Batu show that the limestone from all the outcrops is uniformly pure, with low magnesia and insoluble matter content (Leong, 1974). Another similarity of the Madai-Baturong limestone with the seamount carbonates of Liu *et al.* (1991, 1993) is their close association with volcanics. Leong (1974) mentions that some of the brecciated limestone, partly oolitic, and oolitic or pisolitic limestone lithologically similar to the Madai-Baturong Limestone scattered throughout the area are contaminated by volcanic inclusions.

CONCLUSION: A NEW INTERPRETATION FOR THE ORIGIN OF MADAI-BATURONG LIMESTONE

The Madai-Baturong limestone is most probably a couple of seamount limestones instead of erosional remnants of an extensive limestone platform sitting on top of the Crystalline-Basement as proposed by Leong (1974) or faulted inliers as proposed by Kirk (1962). This is mainly based on: (1) the extreme purity of the carbonates and the lack of terrigenous detrital inputs into the limestone; (2) its intimate relationship with the surrounding typical deep water ophiolitic rocks; (3) its large size and yet limited lateral extent, and (4) the development of fissures-filled with younger Upper Cretaceous limestone breccias with volcanic input in its matrix enclosing blocks of older limestone argues against the limestone being emplaced as an olistostrome. The shallow water limestone deposition must have continued into the Late Cretaceous when it was exposed to erosion to create the fissure-filled Upper Cretaceous breccias and this would not have been possible if the limestone had slid down into the deep ocean floor as an olistrostrome after being deposited during the Early Cretaceous. The smaller limestone bodies interbedded with the Chert-Spilite Formation rocks could well be blocks which have slumped off topographically higher seamounts into the deeper parts surrounding them.

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