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The geology and stratigraphic framework of the Kuching Zone Sarawak: Current understanding and unresolved issues

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Abstract: The geological record of the Kuching Zone extends back in time to more than 300 million years ago. The rock units in the area records a complex history of sedimentation, magmatism and tectonism in the Mesozoic and Cenozoic times. Pre-Upper Carboniferous metamorphic rocks are the oldest rock. Exposure of the younger metamorphic rocks of Late Mesozoic have been assigned to various formations with uncertain protoliths and origin, and have been interpreted to be related to Cretaceous-Cenozoic accretionary setting. Some of the significant events that have occurred include the deposition of clastic sediment with volcanic flow and pyroclastic during Carboniferous to Triassic, and deposition during Jurassic-Cretaceous was siliciclastic-typed sediment. Cretaceous granitoid intruded this sequence before deposition of paralic siliciclastic sediment of Cretaceous to Miocene age. Although the geology of this zone is relatively well studied, many of the interpretations are still debatable due to the complex geology and insufficient biostratigraphic data and dating of the igneous and metamorphic bodies. Several major unresolved issues still remain unanswered. This paper highlights the current understanding and unresolved issues of rock units in Kuching Zone, proposes an updated stratigraphic framework which incorporating igneous and tectonic events, and an updated geological map integrating information from previous published reports and new field investigations.

Keywords: Geology, stratigraphic framework, Kuching Zone, West Sarawak

INTRODUCTION

Sarawak can be divided into three (3) different tectonostratigraphic zones, which are; Kuching Zone (West Sarawak), Sibu Zone (Central Sarawak) and Miri Zone (East Sarawak). The rock units become younger and display a decrease in stratigraphic and structural complexity towards the eastern part (Haile, 1974). Kuching Zone is interpreted to be the northward extension of West Borneo Basement in Kalimantan into Sarawak (Madon, 1999). This zone and the West Borneo Basement are included into the 'West Borneo Block' which was interpreted as part of the Sundaland continental terrane (Hutchison, 1989). The earliest geological study in this research area was a survey carried out in 1845 by Hiram William, a geologist sent by the British Admiralty (Tan, 1993). The early scientific studies in West Sarawak were influenced by the richness of ore minerals.

The rock units in the research area records a complex geological history due to sedimentation, magmatism and tectonism during Mesozoic and Cenozoic times. As mentioned by Tan (1986), undated Pre-Upper Carboniferous Kerait Schist and Tuang Formation were considered to be the oldest rocks in this zone due to similarities with the Pinoh Metamorphic in Kalimantan (Tan, 1986). Exposures of the younger metamorphic rocks of Late Mesozoic age have been assigned to various formations with uncertain protoliths and origin, and have been interpreted to be related to the Cretaceous-Cenozoic accretionary setting. During Jurassic until Cretaceous, deposition of siliciclastic sediments occurred. This sequence was later intruded by the Cretaceous granitoids before the deposition of Cretaceous-Miocene paralic siliciclastic sediments. Triassic sedimentary rocks and the occurrence of volcanic rocks indicate magmatic activity from the Triassic to Early Jurassic. Breaks in the sedimentary records are represented by major unconformities which are apparent between the pre-Upper Carboniferous and Carboniferous-Permian rocks, between the Carboniferous-Permian and Triassic rocks, between Triassic and Upper Jurassic rocks, and between the Upper Cretaceous and Lower Tertiary rocks (Tan, 1986).

Numerous geological researches of different aspects had been carried out in the Kuching Zone, yet the interpretations are still debatable. This report highlights the current understanding and unresolved issues of this zone by utilizing previous published reports. All stratigraphic and geological events data of the area were integrated to reconstruct and update the stratigraphic framework of the region. Field investigations were conducted at outcrops along Jalan Lundu-Bau, exposed along the

newly constructed Pan Borneo Highway. The results are incorporated into the updated geological map of the zone.

METHODOLOGY

In this paper, we reviewed and evaluated previous published reports to highlight the current understanding and unresolved geological issues related to this region. Data and information for stratigraphy and tectonic of the Kuching Zone were compared, contrasted and integrated to reconstruct an updated stratigraphic framework, incorporating igneous and tectonic events. Field investigations were conducted to update the geological map based on the current exposed outcrops.

RESULTS AND DISCUSSION

Current understanding and unresolved issues

Even though there has been much research conducted in Kuching Zone, some of the interpretations are still questionable. This research reviews the previous published reports and has identified some of these issues. Table 1 lists the major rock units occurring in this zone, summarizing the current understanding and unresolved issues.

Stratigraphic framework

The reconstruction of stratigraphic framework of Kuching Zone (West Sarawak) proposed in this paper involved data from stratigraphic and tectonic events. For stratigraphic analysis, four (4) sources have been evaluated, which are stratigraphic columns generated by Tan (1986), Tate (1991), Geological Survey of Malaysia (1995) and Hutchison (2005), as shown in Figure 1.

The stratigraphic column by Tan (1986) differentiate the occurrence of rock units in three different areas – eastern, central and western. The Sebangan and Serian Volcanic Formations were not included. Stratigraphic gaps, igneous rock unit and tectonic events were not defined. The types of lithology are shown, however the boundary and contact for the different rock formations were not included. Tate (1991) has conducted a research to investigate the correlation of rock units in Sarawak and Kalimantan. The stratigraphic column includes rock units of different areas in Sarawak and Kalimantan. However, his table lacks some formation, which are Sebangan, Sejingkat, Serabang and Kayan Sandstone Formations. Kerait and Tuang Formation were placed under one unit

Table 1: The current understanding and unresolved issues on the geology of Kuching Zone.

Carboniferous metamorphic basement
Current understanding:
• Kerait Schist was older than Terbat Formation due to its metamorphic characteristics and it is more strongly deformed (Pimm, 1965).
• Based on the discovery of the schists, it is believed that the protolith is sedimentary rocks of deep marine turbidite environment (Hutchison, 2005).
Unresolved issues:
• There is no proper age dating conducted to this metamorphic basement (Tan, 1986; Tate, 1991). The Pinoh Metamorphic is also undated and assumed to be Paleozoic (Breitfeld *et al*., 2017), thus the interpretation is unsatisfactory.
• Their contacts have never been reported.
Upper Triassic rock units
Current understanding:
• The sedimentary formations represent sediments derived from a landmass that was dominated by the active Serian Volcanic arc and deposited in adjacent neritic seas (Hutchison, 2005).
• Serian Volcanic Formation is reported to be interfingering with the Triassic Sadong Formation (Wilford & Kho, 1965) and is therefore concluded to be Triassic (Breitfeld *et al*., 2017).
• Jagoi Granodiorite reported as I-typed granitoids (Ting, 1992) and local alteration resulting in silicification, sericitization and chloritization (JICA, 1985).
• Sadong Formation is interpreted to represent an estuarine to neritic deposit with periodic brackish water influence (Lietchi *et al*., 1960 and Wilford & Kho, 1965) interpreted as Triassic due to discovery of Krusin flora with Cathyasian affinity (Kon'no, 1972).
Unresolved issues:
• Jambu Volcanics are lithologically similar to the Serian Volcanics (Tate, 1991), however their relationship remains unknown.
• Age dating and reported a wide range of ages for the Jagoi Granodiorite (Breitfeld *et al*., 2017).
• A strong unconformity between the Sadong Formation and Terbat Formation is still doubted and Hutchison (2005), suggests that the contact maybe locally faulted.

Upper Jurassic and Cretaceous formations

Current understanding:

- The Sadong Formation overlies the Serian Volcanic Formation at the eastern part; to the western part of the research area, the Sadong unit is overlain unconformably by Pedawan and Bau Limestone Formations (Hutchison, 2005).
- Foraminifera was identified in the Bau Limestone Formation and this fauna indicates a general Upper Jurassic age and marked uniformity over a wide area (Bayliss, 1966).
- Bau Limestone Formation is considered to be continental shelf deposit, supported by the discovery of corals (Hutchison, 2005).
- The Pedawan Formation generally overlies the Bau limestone and contains contemporaneous volcanic material (Wilford & Kho, 1965 and Supriatna *et al*., 1993) it indicates a switch from a calcareous shallow marine environment to a clastic-dominated deeper marine depositional environment (Breitfeld *et al*., 2017).
- Pedawan Formation reported had undergone strong thermal metamorphism of the pyroxene hornfel facies (Tan, 1993).

Cretaceous formations

Current understanding:

- The shale of mélange matrix has yielded radiolarian and eleven (11) taxa have been identified (Jasin & Madun, 1996 and Jasin, 2000) and suggests the Serabang Formation as Serabang Complex.
- The Sejingkat Formation shows strong similarities with rock units in Lupar Valley, and has been suggested to be of Mesozoic age, probably Early Cretaceous (Tan, 1979).

Unresolved issues:

- Long range radiolarian ages reported was found in the chert. Thus, the age of Sejingkat Formation is uncertain (Wilford, 1965).
- The existence of Sebangan Formation is questionable due unexposed outcrops. There is no fossil reported and no age dating was ever done.

Upper Cretaceous and Tertiary formations

Current understanding

- Three palynological zones were erected for the Kayan Sandstone (Muller, 1968). The presence of bivalve fossil, and the discovery of pollen indicates that the formation is a delta deposit of Late Cretaceous to Early Eocene age.
- Lithological variations of Silantek Formation were reported and thus, proposed three distinct members: namely the Basal Sandstone Member, Temudok Member and Upper Silantek Redbed Member (Tan, 1982).
- Fossils that can be found in Silantek Formation are bivalves, echinoids, foraminifera, gastropod, nano-fossil, and several type of plant fossils.
- Plateau sandstone in the Bako peninsular, interpreted the succession to be deposits of alluvial sandy braided channel system with high bedload. Johansson (1999) proposed a new name, the Bako Sandstone which is a sub-group of the Bako Sandstone Group.

Unresolved issues:

- Silantek Formation was interpreted to overlie unconformably upon the Sadong Formation and Serian Volcanic Formation; however, no contact has been reported (Hutchison, 2005).
- The relationships between the Tertiary Kayan, Silantek, Plateau Sandstone and Bako Formations have never been discussed.

Cretaceous plutonism

Current understanding:

- Cretaceous plutonism consists of granite, gabbro, dolerite and hybrid rocks, where hybrid rocks are formed by extensive reaction produced by gabbro and Cretaceous intrusion (Kirk, 1968).
- Plutonic rocks are mostly confined to the southern section of Kuching zone.

Unresolved issues:

- The calc-alkaline series in West Sarawak reported was formed by predominantly felsic plutonic rocks. However, the tectonic significance is unknown (Hutchison, 2005).

Tertiary intrusive

Current understanding:

- The Tertiary and Cretaceous intrusive rocks in Kuching Zone are probably genetically related. They show geochemical characteristics corresponding to both high-K calc-alkaline and calc-alkaline rocks (Tan, 1993).

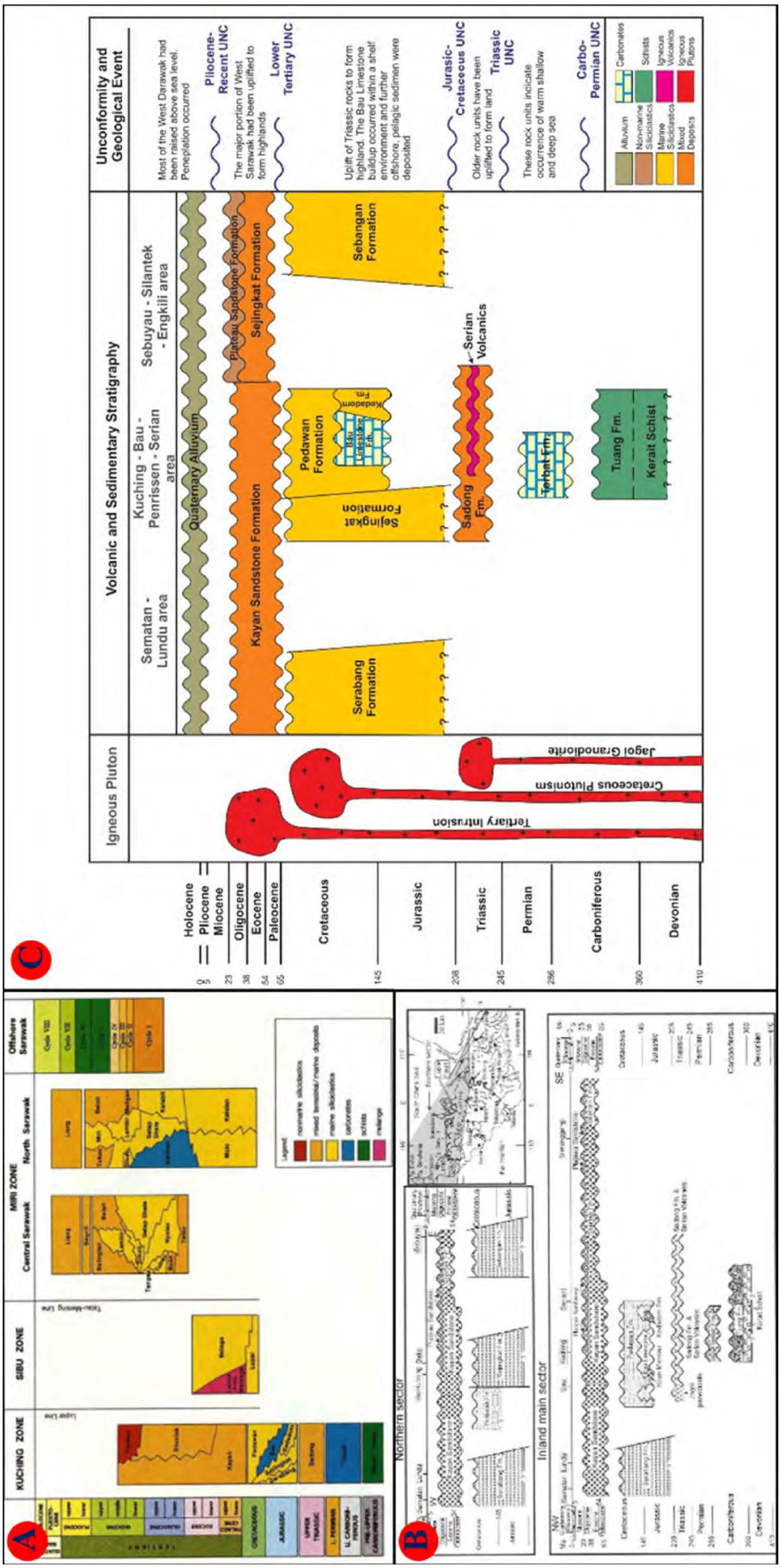

Figure 1: Stratigraphic charts and frameworks by (A) Geological Survey, 1995; and (B) Hutchison, 2005. Figure 1C is a newly proposed, updated stratigraphic chart based on the incorporation of published data, which includes igneous bodies and tectonic events.

and the intercalation of Serian Volcanic with Sadong Formations were not displayed. No unconformities, igneous rock units and tectonic events are indicated.

The stratigraphic column by the Geological Survey of Malaysia (1995) is a simple stratigraphic column that included every zones present in Sarawak (Madon, 1999). There are no unconformities, igneous units and tectonic events shown. Sebangan and Serian Volcanic Formations are not included, and Kerait Schist and Tuang Formation are considered as one-unit rock of pre-Upper Carboniferous age. While, Hutchison (2005) also attempted to compile data from previous research into a stratigraphic column. He divided the Kuching Zone into two different sectors, which are northern main inland, and northern coastal sectors. The stratigraphic column identifies the unconformities and determines the stratigraphic gaps present, and also igneous rock units. However, there is no description on tectonic events and some formations are excluded – these are the Silantek and Kayan Formations. However, this is the most updated stratigraphic chart.

All the four stratigraphic charts show some differences; all charts do not incorporate the tectonic events and the major igneous rock units, the Cretaceous-Tertiary Intrusion and Jagoi Granodiorite.

Paleogeographic development studies conducted by Tan (1986) has divided the Kuching Zone into five (5) time spans. These are Carbonaceous-Permian, Triassic, Jurassic-Cretaceous, Lower Tertiary and Pliocene-Pleistocene. During Carbonaceous-Permian times, rock distribution in the research area was limited; these rock indicated the occurrence of warm shallow and deep water. These rock have been uplifted and widespread subaerial volcanism gave rise to Serian Volcanics during Triassic. During Jurassic-Cretaceous age, Triassic rocks were uplifted to form highlands. The Bau Limestone build-up occurred within a shelf environment; further offshore, pelagic sedimentation resulted in the Sejingkat Formation, Serabang Formation and Sebangan Formation. Major portion of the West Sarawak had been uplifted by the Lower Tertiary and by Pliocene-Pleistocene, most of the West Sarawak had been raised above sea level.

In this paper, we propose an updated stratigraphic framework, which includes the rock units distribution, unconformities, igneous rock units, alluvium and significant geological events, based on the incorporation of data from published reports.

Geological map

Field investigation were conducted on the outcrops exposed due to the construction of Pan Borneo Highway along Jalan Lundu-Bau. The results from this investigation were integrated into previously published geological map. There are six (6) previous geological maps of the Kuching Zone identified which were generated by Haile (1954), Wilford (1955), Lietchi *et al.* (1960), Tan (1979, 1993) and Breitfeld *et al.* (2017). Maps produced by Haile (1954) and Wilford (1955) are the early versions of detailed maps of the area. Lietchi *et al.* (1960) published the first geologist map of Sarawak, including Brunei and North Borneo. The classification of rocks in these early maps are based only on their lithology and age, without the proper nomenclature of the sedimentary formations. Tan (1986) carried out a detailed study on the geology of the zone together with the classification of the rocks according to sedimentary formation and their respective ages. Tan (1979, 1993) mapped and categorized the igneous plutons in this zone into Cretaceous Igneous and Tertiary Igneous. He also mapped and classified the different sedimentary formations within West Sarawak. Breitfeld *et al.* (2017) updated the geological map of West Sarawak. However, they did not include some sedimentary formations.

We incorporated new data from recent fieldwork into the previous maps to produce an updated geological map.

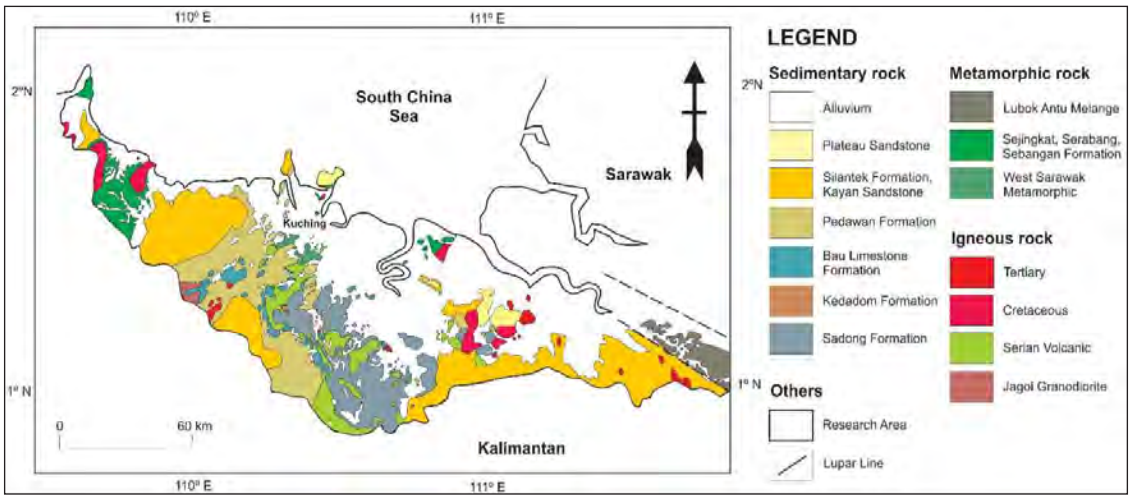

Figure 2: An updated geological map of Kuching Zone (West Sarawak).

Based on the mapping conducted, some areas at Jalan Lundu-Bau exposed sections of the Kayan Sandstone Formation. The outcrops showed thick cross-bedded sandstone instead of alluvium; this contradicted the information on lithology given from the previous maps. Figure 2 shows the updated geological map of Kuching Zone.

CONCLUSION

The geology of Kuching Zone is very complex, and the interpretations concerning the geological history are still arguable and not fully resolved. This paper compiled and summarized the current understanding and unresolved issues of this zone by utilizing previous published reports. This paper has also incorporated stratigraphic and tectonics data from the previous published report to produce an updated tectonostratigraphic framework of Kuching Zone, which incorporated significant geological and plutonic events. This framework includes the distribution of rock units, unconformities, igneous rock units, alluvium, and significant geological events. A revised geological map of Kuching Zone is proposed by integrating six (6) published geological maps and updated with data from field investigation, which were conducted at the outcrops within Jalan Lundu-Bau exposed due to the Pan Borneo Highway construction. The extension of Kayan Sandstone Formation has been recognized, which this area was previously mapped as alluvium. As for recommendations, this paper propose detail biostratigraphic and structural studies on the Kuching Zone (West Sarawak) to be carried out in the future. These studies may help to resolve many of the highlighted issues in this paper.

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