

## A review of the Palaeozoic lithostratigraphy of east Johor, Malaysia

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**Abstract:** A revision on the Palaeozoic lithostratigraphy of east Johor has been made. The Palaeozoic of east Johor comprises of the Mersing Formation, Murau Formation, Dohol Formation, Linggiu Formation, Sedili Volcanic, Jasin Volcanic and Pengerang Tuff. The pre-Permian Mersing Formation, the oldest known rock unit is entirely made up of metamorphosed sedimentary rock of shallow marine origin. Unconformably overlying this unit is the Murau Formation which developed in a small continental faulted basin. The siliciclastic Dohol Formation containing late Early to early Middle Permian Sumalayang limestone as well as the Late Permian Linggiu Formation are also unconformably overlying the Mersing Formation, as are the volcanic units of Pengerang Tuff, Sedili and Jasin Volcanics. The three volcanic units are thought to be contemporaneous and are closely related to the Early to Middle Permian Dohol Formation and the overlying Late Permian Linggiu Formation. The absence of volcanic clasts in the Murau Formation indicates that the later is a pre-volcanic, hence pre-late Early Permian formation. The shallow marine Linggiu Formation and the associated volcanic rocks are the youngest Palaeozoic formation in east Johor.

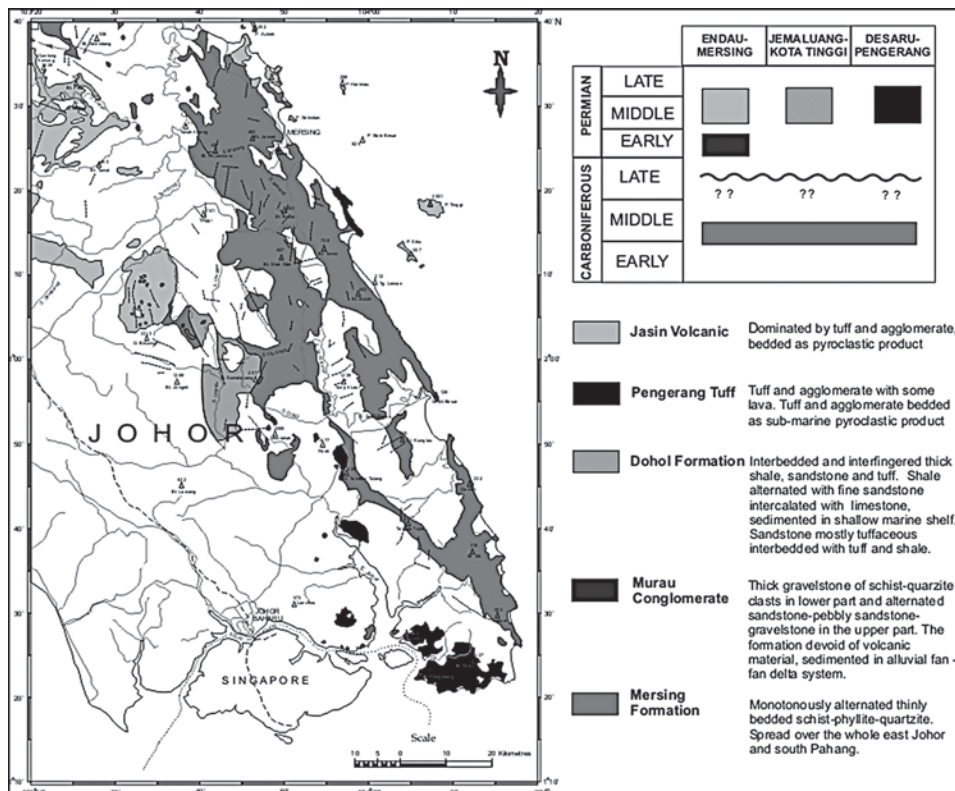
**Abstrak:** Penilaian semula terhadap litostratigrafi Paleozoik Johor timur telah dilakukan. Batuan Paleozoik Johor timur terdiri daripada Formasi Mersing, Formasi Murau, Formasi Dohol, Formasi Linggiu, Vulkanik Sedili, Vulkanik Jasin dan Tuf Pengerang. Batuan pra-Perm Formasi Mersing merupakan batuan tertua yang terbentuk oleh batuan sedimen termetamorf asalan enapan laut cetek. Batuan Formasi Murau terbentuk dalam lembangan sesar daratan, menindih tak selaras di atas Formasi Mersing. Batuan silisiklastik Formasi Dohol yang mengandungi batu kapur Sumalayang (akhir Perm Awal – awal Perm Tengah) serta Formasi Linggiu (Perm Akhir) juga menindih tak selaras di atas Formasi Mersing. Unit-unit batuan vulkanik lain iaitu Tuf Pengerang, Vulkanik Sedili dan Vulkanik Jasin juga menindih tak selaras di atas Formasi Mersing. Ketiga-tiga unit batuan vulkanik ini dikatakan berkembang pada sela masa yang hampir sama dan berkait rapat dengan Formasi Dohol yang berusia Perm Awal hingga Perm Tengah dan Formasi Linggiu yang berusia Perm Akhir. Ketiadaan klas vulkanik dalam Formasi Murau mencadangkan formasi ini berusia pra-vulkanik atau pra-akhir Perm Awal. Enapan laut cetek Formasi Linggiu dan batuan vulkanik yang berasosiasi dengannya adalah unit litostratigrafi Paleozoik termuda di timur Johor.

### INTRODUCTION

Palaeozoic rocks are widely distributed throughout east Johor, dominated by metamorphic and volcanic rocks with minor lutaceous, arenaceous and rudaceous rocks and limestone (Figure 1). The metamorphic rock has been assigned to various lithostratigraphic units including the Mersing bed by Cook and Suntharalingam (1969), Mersing Group by Suntharalingam (1991) and Mersing Formation by Mohd Shafeea Leman *et al.* (2003). The age of this formation has not been determined with certainty, as is the case with several other rock units in east Johor. Up till now, the best dated rock formations in east Johor are the siliciclastic Dohol Formation with its fossiliferous limestone being dated as of late Early to early Middle Permian age (Igo *et al.*, 1979) and the Late Permian Linggiu Formation (Kon'no *et al.*, 1970). However, these formations have been grouped together with the metamorphic rock as part of the Mersing Group by Suntharalingam (1991). The volcanic rocks of east Johor occur in three separate areas and thus were named separately as the Jasin Volcanics (Chong, *et al.*, 1968; Cook & Suntharalingam 1969; Suntharalingam, 1991) in Mersing-Endau area, the Sedili Volcanic (Rajah, 1968) in Ulu Sedili area and the Pengerang Tuff (Grubb, 1968; Mohd Shafeea Leman *et al.*, 2003) in Pengerang – Tanjung

Belungkor area. The Sedili Volcanic is considered to be Permian in age by inference from its intimate relationship with the Dohol and Linggiu formations, but ages of the other volcanic units are still not known. Meanwhile, the rudaceous rock unit in Murau area is another problematic unit. It has been assigned to various lithostratigraphic units including as the Triassic Murau Conglomerate member of Tembeling Formation by Koopmans (1968), Jurassic-Cretaceous Murau Formation by Ahmad Jantan *et al.* (1988) and as a late Palaeozoic (Early Permian) Murau Formation by Surjono *et al.* (2003) and Mohd Shafeea Leman *et al.* (2003).

From the short review above, the Palaeozoic stratigraphy of east Johor is still obviously poorly understood. Thus, a comprehensive study on stratigraphic correlation of Palaeozoic rocks of east Johor in relation with the whole Eastern Belt of Peninsular Malaysia is needed. The current study was undertaken in order to establish a better stratigraphic correlation between various Palaeozoic rock units in east Johor. This paper will present some of the authors' views and will highlight some of the new findings of this research. In addition to some newly acquired data, previous works by Koopmans (1968), Rajah (1968), Chong *et al.*, (1968), Grubb (1968), Cook & Suntharalingam (1969), Suntharalingam (1991) and



**Figure 1.** Distribution of Palaeozoic rock in eastern Johor (after Mohd Shafeea Leman *et al.*, 2003).

Rajah (1986) will be used as references in the following discussion.

## LITHOSTRATIGRAPHY

The lithological column in east Johor (Figure 2) was developed based on the primary field data and previous works by various authors including Koopmans (1968), Foo (1983), Rajah (1968, 1986), Suntharalingam (1991) and many others. Palaeozoic rocks of east Johor are made up of the Mersing Formation (the oldest), Murau Formation, Dohol Formation, Linggiu Formation, Sedili Volcanic, Pengerang Tuff and Jasin Volcanic. At this moment, none of these lithostratigraphic units have been formally designated according to Malaysian Stratigraphic Guide published by Malaysian Stratigraphic Nomenclature Committee (1997). These formations can be briefly described as the following:

**Mersing Formation:** Hutchison (1989) regarded this rock unit as the basement rock in Johor extending along the coast from the bauxite-mining district of southeast Johor at Pengerang, through Desaru and Mersing to Endau area in Northeast Johor. On land, this rock unit occupies more than 50 percent of the area in eastern Johor and southeastern Pahang (Figure 1). The lithology of this rock formation consists of interbedded phyllite, schist, quartzite, slate and metaquartzite (Figure 3). It was first mentioned as the Mersing Beds by Cook & Suntharalingam (1969), but Suntharalingam (1991) renamed it as the Mersing Group in which he included the Dohol and Linggiu Formations. Mohd Shafeea Leman *et*

*al.* (2003) later suggested that the metamorphic rock unit of east Johor to be re-named as the Mersing Formation, omitting the non-metamorphic Dohol and Linggiu Formations.

The Mersing Formation has been strongly folded, faulted and intruded by granite. Tajul Anuar Jamaluddin (1996), Tajul Anuar Jamaluddin & Mustaffa Kamal Shuib (1999) believed that the Mersing Formation has been subjected to at least three phases of deformation starting in the Late Middle Permian until post Cretaceous (?) time. According to Suntharalingam (1991), the metamorphic rock was a result of metamorphism upon deep-sea clastic sediments. However, the occurrence of some medium size cross-beds within grain-supported sandstone observed in this study suggests that at least some of the protolith of the Mersing metamorphic rocks are of shallow marine origin. Foo (1983) also inferred a shallow marine to mixed condition of depositional environment for the oldest sediment in the eastern belt, supposedly including the Mersing Formation.

The age of this metamorphic rock unit was interpreted as Carboniferous – Permian (Drummond, 1962), Pre-Carboniferous (?) (Grubb, 1968), Early Carboniferous-Early Permian (Foo, 1983) and Permian age (Suntharalingam, 1991). However, correlation with other formations nearby, suggests that it is likely to be pre-Permian in age. The Mersing Formation is apparently the only source rock for the overlying younger formations such as the Murau and Dohol Formations both of which have been interpreted as Permian rocks. These younger

PERIOD	EASTERN ZONE (after Foo, 1983)		GUNUNG BELUMUT AREA (after Rajah, 1986)	HULU SEDILI AREA (after Suntharalingam, 1991)	EASTERN JOHOR (This paper)
CRETACEOUS			'Tebak Formation': Massive cross-bedded sandstone with mudstone and grit	Panti Sandstone: Predominantly massive cross-bedded sandstone, minor mudstone and shale	Tebak Formation': Pebbly sandstone, Massive cross-bedded sandstone
JURASSIC			Unconformity	Murau Conglomerates: Predominantly red polymict conglomerate interbedded with subordinate shale, sandstone and mudstone	
TRIASSIC			Tengkil Granite Lengkur Granite Belumut Granite	Unconformity Jemaluang Granite Lengkur Granite Muntahak Granite	Granite intrusion
PERMIAN	Kuantan Group (Calcareous series, Pahang Volcanic Series, Arenaceous series)	DOHOL FORMATION	'Sedili Volcanic Formation': Acid to intermediate pyroclastic and lavas  'Linggiu Formation': (i) shale, sandstone, tuff & lava (ii) sandstone, siltstone, conglomerate, shale, tuff & lava  Dohol Formation: Shale, phyllite, slate, siltstone, sandstone, grit, metaquartzite, tuff, lava and limestone (Sumalayang Limestone Member)	Jasin volcanics: Acid pyroclastic  Mersing group: Phyllite, slate, schist, hornfels and quartzite including Dohol and Linggiu Formations.	Unconformity South Linggiu Formation Panglima Tuff Dohol Formation Sedili Volc. North Jasin Volc. A: Sumalayang Limestone member
CARBONIFEROUS		SUNGAI PERLIS BED			Murau Formation: breccia interbedded with sandstone and mudstone  Mersing Formation: Slate, schist, phyllite, metaquartzite

**Figure 2.** Stratigraphic column of eastern Johor and several stratigraphic column in other area as a comparison.

formations overlie the Mersing Formation unconformably.

**Murau Formation:** The name Murau Formation was first proposed by Ahmad Jantan *et al.* (1988) for the rudaceous rock unit developed along the east coast of Johor from Tanjung Sekakap to Tanjung Tenggara, with isolated occurrences at Pulau Batu Chawang (Ibrahim Abdullah *et al.*, 1991) and at Tanjung Leman (Suntharalingam, 1991). This formation comprises disorganized thick breccia, gravelstone and sandstone forming a thick rudaceous sequence deposited in a fan-delta system (Surjono *et al.*, 2003).

This rock unit was previously described by Koopmans (1968) as the Triassic Murau Conglomerate, a member of the Tembeling Formation. However, because of its geographic isolation, Burton (1973) suggested that the Murau Conglomerate should be taken out of the Tembeling Formation. Khoo (1977) upgraded the latter to the Tembeling Group with Murau Conglomerate being excluded from it. Later, Ahmad Jantan *et al.* (1988) suggested that the Murau rudaceous rocks unit to be upgraded to its own formal lithostratigraphic unit or formation, that is Murau Formation, based on their geographic position, probable paleobasin location, relationship with the underlying rock and lithology. They suggested a Jurassic-Cretaceous times for the age of formation.

The Murau Formation unconformably overlies the Mersing Formation (Figures 4a & 4b). The provenance for this sediment is the rock from the Mersing Formation itself. The absence of volcanic elements in the Murau rocks unit suggested that this formation was deposited earlier than the adjacent volcanic rocks, which have been interpreted as of Permian age. The depositional environment is interpreted to be a terrestrial (alluvial fan) to shallow marine based on their sedimentary structures such as crudely stratified cobble-boulder, cross-bedded gravelstone, grain supported sandstone, the presence of conglomerate clasts



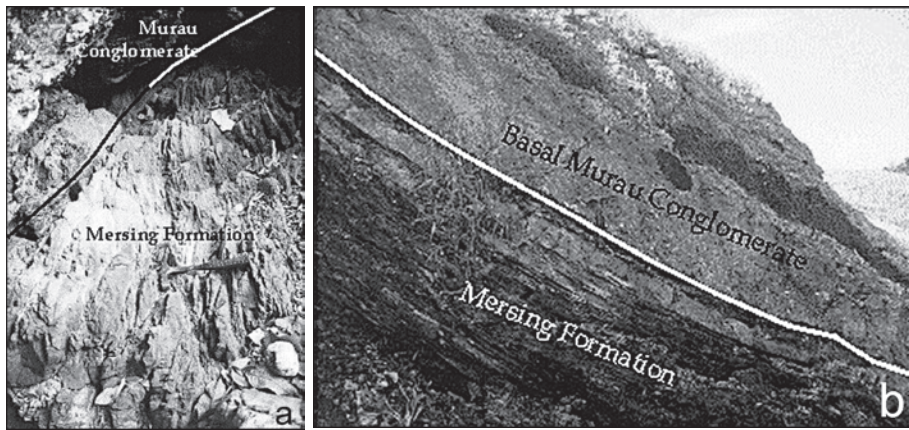
**Figure 3.** Alternation of thinly bedded quartzite and phyllite at Mersing beach.

within mudstone and the presence of bioturbation in the sandstone.

**Dohol Formation:** The Dohol Formation occurs in the eastern part of Gunung Sumalayang, mainly in the upper reaches of the Sungai Sedili and it is associated with the Sedili Volcanic (Rajah, 1968). This formation is composed of shale-siltstone-fine sandstone interbedding (Figure 5a) and thickly bedded claystone and thin beds of tuffaceous sandstone. A limestone unit named as the Sumalayang Limestone Member (Rajah, 1968; Rajah, 1970; Kon'no *et al.*, 1970; Igo *et al.*, 1979) occurs in the middle part of the formation. The limestone was found in the upper reaches of Sungai Sedili with maximum thickness of up to 8 meters (Figure 5b), and is locally highly fossiliferous (Figure 5d). This limestone is started by very thickly bedded in the bottom and medium bedded in the upper part with fine-grained, pale to dark-grey and is commonly cut by thin calcite vein.

The Dohol Formation are interpreted as a shallow marine origin based on their sedimentary structures such as planar crossbedding, grain supported sandstone and





**Figure 4.** Typical unconformities between Murau Conglomerate and Mersing Formation. a. Angular unconformity at Tanjung Murau b. Disconformity at Pasir Landa, near Tanjung Sekakap.

the associated fusulinid limestone and calcareous sandstone. In the Sumalayang area, this formation is unconformably overlain by the Cretaceous Tebak Formation. The age of this formation is assigned by Igo *et al.* (1979) as a late Early Permian to early Middle Permian, based on the its fusulinids of the Sumalayang Limestone Member.

**Linggiu Formation:** Rajah (1986) described the Linggiu Formation as a continuation of Dohol Formation in Belumut area. It was distributed from Bukit Tengkil area in south to eastern part of Gunung Chemendong in the north. Foo (1983) classified it as part of the Dohol Formation based on the similarity of the arenaceous component between them. However, Rajah (1968, 1986) divided the Linggiu Formation into two series, that are (i) shale, sandstone, tuff and lava and (ii) sandstone, siltstone, conglomerate, shale, tuff and lava (Figure 2). Based on these volcanic components, Rajah (1986) interpreted that the Linggiu Formation was deposited in the same period with the deposition of Sedili Volcanic. Kon'no *et al.* (1970) interpreted interfingering contact between the Linggiu Formation and Sedili Volcanic. The depositional environment of the Linggiu Formation and its contemporaneous Sedili Volcanic were inferred in a littoral of shallow marine, meanwhile the age of the Linggiu Formation is late Permian as indicated by the presence of abundant Late Permian Flora in this formation (Kon'no *et al.*, 1970).

**Sedili Volcanic:** Based on the stratigraphic correlation of lithological logs from the eastern flank of Gunung Sumalayang, we interpret that the Dohol Formation is interfingering with the volcanic rock (Figure 6) that is possibly as a part of Sedili Volcanic by Rajah (1968). This volcanic unit is mainly composed of tuffaceous sandstone and claystone interbeds and agglomerate and tuff interbeds (Figure 5c).

Rajah (1968) described this rock unit as Sedili Volcanic Formation which is characterized by thick sequence of both flows and pyroclastic rocks which occurs mainly in the Gunung Chemendong, Sungai Ulu Sedili and Gunung Sumalayang areas. The major part of the succession comprises both acid and intermediate types

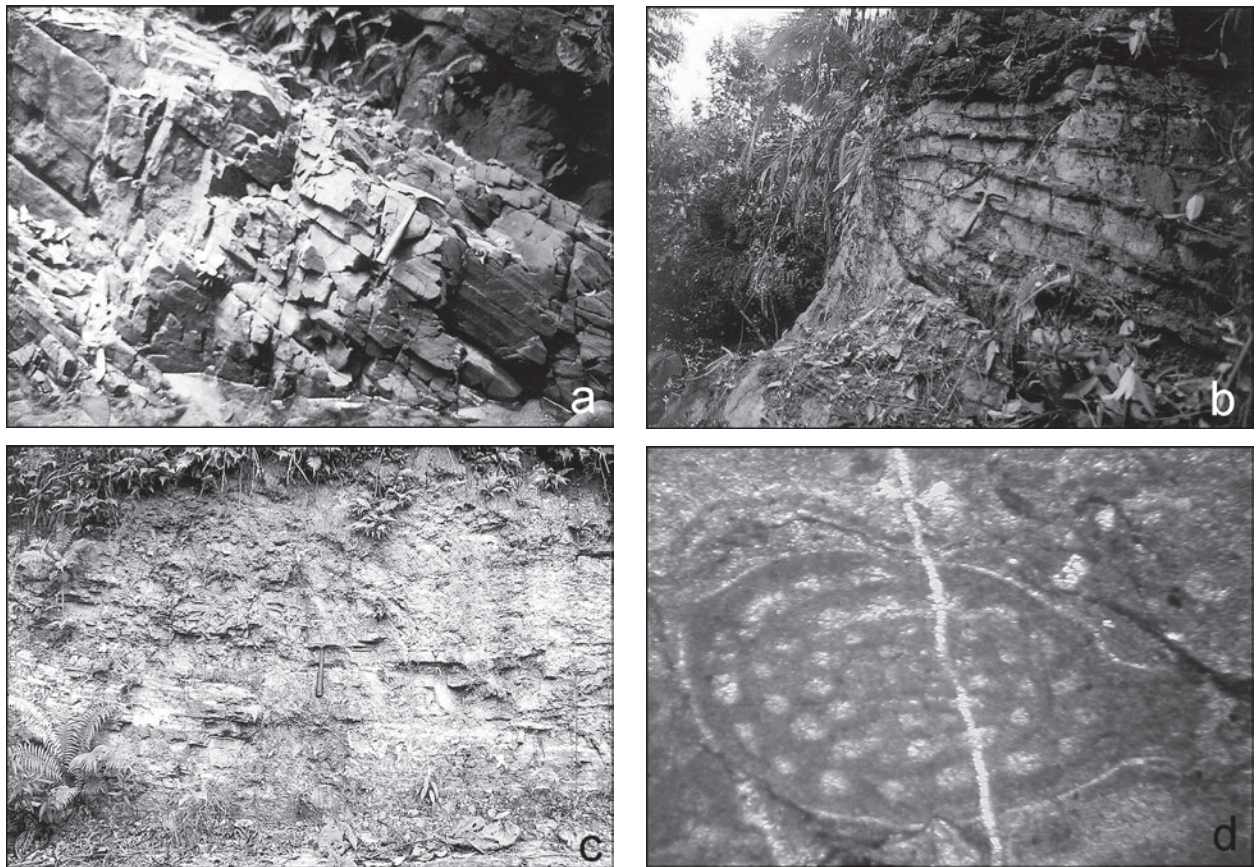
but does include subordinate basic phases. These rocks are generally dark grey to greenish grey, locally are buff and pinkish grey, composed by ignimbrite lithic tuff, agglomerate and volcanic ash.

**Jasin Volcanic:** The term Jasin volcanic was referred by Chong *et al.* (1968), Cook & Suntharalingam (1969) to welded and non-welded ash-flow tuffs, ash-fall tuffs and minor lava flows in the Mersing-Endau area. According to Suntharalingam (1991) this rock occurred in three separates places; (i) as a small extension of volcanic rocks in the Gunung Belumut area, (ii) along the northwest-southeast rigde, north of Sungai Susur Rotan and (iii) to the north of Gunung Panti Barat. Volcanic rocks with similar characteristics are also found in the eastern coast of northern Johor, from Tanjung Penyabung to offshore Pulau Sibul.

In the eastern coast of Johor, this volcanic unit is represented mainly by agglomerate and tuff of pyroclastic origin (Figure 7a) and resedimented pyroclastic rock such as the tuffaceous siltstone (Figure 7b). The latter was deposited above the pyroclastic rock as seen in the Tanjung Penyabung area. Thin beds of tuffaceous siltstone forming a sequence of up to 30 meter thick, flat bedding with sharp contact, occasionally with normal grading suggests that the Jasin Volcanic was deposited in a subaqueous environment. Chong *et al.* (1968) interpreted a Triassic time for the age of the Jasin Volcanic but later, Suntharalingam (1991) inferred that the Jasin Volcanics could have been laid down in Late Permian to early Triassic time.

**Pengerang Tuff:** The name of Pengerang Tuff was given to the volcanic rock exposed in Bukit Pengerang and the surrounding areas in southeastern Johor (Mohd Shafeea Leman *et al.*, 2003). Several types of volcanic rocks such as andesitic to rhyolitic lava flow, tuff and agglomerate are found. The agglomerate widely distributed in Teluk Belungkor area is a pyroclastic rock consisting of falls and flows (Figures 7c and 7d), deposited during the same period of volcanism.

The variety of volcanic rocks in the southern part of Johor was interpreted by Grubb (1968) as a result of a series of volcanic eruptions. Grubb (1968) inferred that



**Figure 5.** Representative outcrops of Dohol Formation and Sedili Volcanic. a. Alternation of claystone-siltstone-fine sandstone of the Dohol Formation in the upper reaches of Sungai Sedili. b. Bedded limestone within thick mudstone as a member of Dohol Formation in eastern flank of Gunung Sumalayang. c. Alternating tuff and tuffaceous siltstone of Sedili Volcanic near Sungai Sedili, eastern flank of Gunung Sumalayang. d. A fusulinid from the thin section of the upper part of Sumalayang Limestone.

the initial phase of eruption was relatively quiescent, becoming mildly explosive at the later phase. This activity produced lava flows, followed by the main explosive period that produced the pyroclastic rocks.

Based on its texture and sedimentary structure, the Pengerang volcanic was interpreted to be deposited in an aqueous environment (Grubb, 1968), while Surjono *et al.* (2004) inferred a shallow marine environment for this pyroclastic rocks and lava flows. Volcanic rocks in southeastern Johor were assigned to Carboniferous to Triassic age by Grubb (1968) as they were believed to be equivalent to “the Pahang Volcanic Series”. Foo (1983), however inferred that the ignimbrites in south Pahang and Johor were deposited unconformably overlying the Permian phyllite during the Early Triassic showing a change of depositional environments from submarine to subaerial. However, due to the similarity in rocks characteristics, the authors suggest that the Pengerang Tuff was deposited during the same period as the Jasin volcanic that is Late Permian to Triassic.

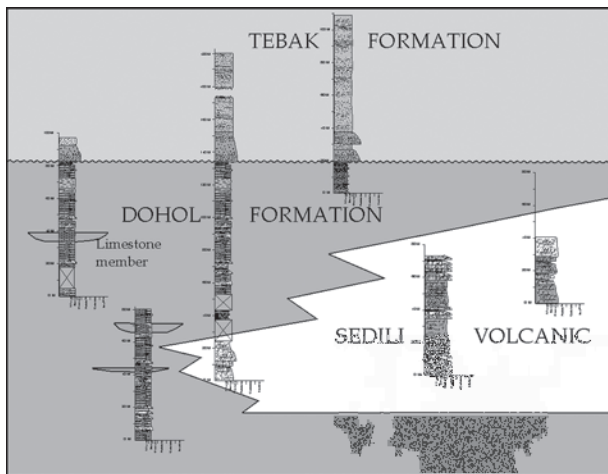
## AGE OF FORMATIONS

Of all the formation deposited during the Palaeozoic period, only the age of the Dohol and Linggiu Formations can be determined with certainty. The age of the Dohol

Formation was determined by Igo *et al.* (1979) as late Early to early Middle Permian based on fusulinids found in the Sumalayang Limestone Member. Igo *et al.* (1979) called the Sungai Sedili fauna for fossil assemblages in Sumalayang Limestone Member and among fusulinid recorded by them are *Cuniculinella globosa*, *Cuniculinella zulmartensis*, *Eoparafusulina malayensis*, *Parafusulina chungii*, *Parafusulina johorensis*, *Parafusulina yini* and others. The Linggiu Formation was assigned to Late Permian by Kon’no *et al.* (1970) based on the presence of abundant flora such as *Lepidodendron cf. chosenense*, *Tingia subcabonica*, *Paratrizygia koboensis*, *Annularia shirakii* and many others. Kon’no *et al.* (1970) determined 41 species of flora that was collected from outcrop in Sungai Linggiu area, Southwest of Bukit Tengkil.

The Sedili Volcanic that interfingers with the Dohol and Linggiu Formations is interpreted to have been deposited throughout Middle to Late Permian time. The Dohol and Linggiu Formation are also partly composed of volcanic material possibly derived from the adjacent Sedili Volcanic. Jasin Volcanic and Pengerang Tuff are both having similar rock types with the Sedili Volcanic, and thus are probably deposited in the same period with the sedimentation of the Dohol and the Linggiu





**Figure 6.** Stratigraphic correlation of Dohol Formation-Sedili Volcanic and Tebak Formation based on the lithological log measured in the upper reaches of Sungai Sedili and eastern flank of Gunung Sumalayang.

Formations.

The age of the Murau Formation can be interpreted based on the absence of volcanic clasts although volcanic rocks are well developed in the surrounding areas. The clasts of Murau Formation are composed entirely of metamorphic rocks of the Mersing Formation. This suggests that the Murau Formation is the oldest rock in the Eastern Johor after the Mersing Formation. The age is possibly pre-late Early Permian. The Mersing Formation, being the basement to the various Permian rock formations must have been deposited long before the Permian Period, possibly during Carboniferous (Grubb, 1968) or perhaps older. A major tectonic event must have taken place after the deposition of the Mersing Formation. This resulted in the metamorphism, folding and uplifting of the pre Murau rocks. All of the formation in Palaeozoic era were intruded by Mesozoic granite and subsequently capped by the Tebak and Panti Formation of Late Jurassic – Early Cretaceous age (Kon'no *et al.*, 1970).

## CONCLUSIONS

The geological history in East Johor began with the deposition of the Mersing Formation during the pre-Permian time. This was followed by a period of uplifting and metamorphism. Subsequent to the phase of denudation of the Mersing Formation, sedimentation of the Murau Formation took place, followed by the Dohol and Linggiu Formations. Volcanic activity was intense during the time of the deposition of the Dohol and the Linggiu Formations and resulted in the deposition of the Sedili, Jasin and Pengerang Volcanics.

We suggest that the names Mersing Group and Mersing Bed be abandoned in favour of the name Mersing Formation. We believe that the metamorphic rocks of east Johor which acted as the basement to the younger metamorphosed rocks should be established as a formation by itself. The Murau Formation should be used to refer to

rudaceous rocks consisting essentially of metamorphic clasts that are found along eastern coast of Johor from Tanjung Sekakap to Tanjung Tenggara. The Dohol Formation and its Sumalayang Limestone Member is well dated and there is no controversy about its stratigraphic status. The age of the Linggiu Formation is also well dated from its flora fossils, whereas the age of the Sedili Volcanic is interpreted based on its intimate relationship with the established Dohol and Linggiu Formations. The Sedili, Jasin and Pengerang Volcanics still need further reinterpretation, whether they stand as formation itself or could be grouped into a new formation. The true relationship between the Dohol and overlying Linggiu Formations is another aspect that requires further investigation.

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**Figure 7.** Representatives of Jasin and Pengerang Volcanics. a. Volcanic bomb in the pyroclastic rock produced by ballistic fallout of pumice fragments at Tanjung Arong Baharu. b. Thinly bedded tuffaceous siltstone representing resedimented pyroclastic rocks at Tanjung Penyabung. c. Agglomerate with boulder clasts in the lower part of the succession at Teluk Belungkur. d. Thin beds of lapilli in the upper part of the succession at Teluk Belungkur.

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