

Clarification of stratigraphic correlation and dating of Late Cainozoic alluvial units in Peninsular Malaysia

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Abstract: Numerous mine exposures, drillholes and marine seismic profiles have facilitated detailed study of the Late Cainozoic alluvium in Peninsular Malaysia. In 1979, Daud Batchelor, building on the work of D. Walker and others proposed a regional Late Cainozoic stratigraphic scheme incorporating the traditional division of “Old Alluvium” and “Young Alluvium”, and correlated Indonesian offshore units of Aleva and others. The important distinction between Old Alluvium (OA) and Young Alluvium (YA) in presently emergent areas of the Sundaland continent shows that the OA comprises less well sorted generally aggrading alluvial fan/plain deposits of broad palaeochannel systems while the YA infills V-shaped valleys incising the palaeo-landscape. These units reflect a major intervening palaeogeomorphological change. The Transitional Unit erected by Batchelor in 1979 was deposited during transition between the two dominant regimes. In 1988 Batchelor published evidence for dating these units using eustatic sea level and climatic changes, palaeomagnetism, vertebrate palaeontology and radiocarbon dating. Suntharalingam in 1983 formally erected Late Cainozoic stratigraphic units including the continental Simpang Formation and Beruas Formation. He correlated the Simpang Formation with the Old Alluvium of Walker and believed it to be Pleistocene, and the Beruas Formation with Walker’s the Young Alluvium. A difference in views exists on dating of the Simpang Formation/OA. Batchelor in 1988 demonstrated that its age extends from Late Pliocene to Early Pleistocene time, prior to the Brunhes normal magnetic period (>0.775 Ma Before Present; BP), while the YA/Beruas Formation was determined as Late Pleistocene to Holocene. In 1993, Kamaludin and others suggested however, that the Simpang Formation dates until the Late Pleistocene based on “young” radiocarbon dates (28 ka BP to 67 ka BP). The present study argues strongly against such young OA/Simpang Formation ages and believes instead that young dates attributed to the OA have either (1) been wrongly attributed and actually derive from younger units, or (2) the original carbon has been contaminated with young carbon near the dating limit of the C-14 method. The former case is apparent where the upper sequence in the Pantai Remis area, Perak, attributed to the Simpang Formation/OA by Kamaludin and others, is from my own studies believed to be mainly YA/Beruas Formation, as prefigured in the Teluk Mengkudu sequence published by Batchelor in 1988 (Table 2). As the prime YA equivalent, it is recommended that the Beruas Formation/YA be extended to include alluvium deposited from the beginning of the Wurm glacial period (Marine Isotope Stage 4) at around 75,000 years BP.

Keywords: Peninsular Malaysia, Late Cainozoic stratigraphy, Old Alluvium, Simpang Formation, Young Alluvium, Beruas Formation, palaeomagnetic dating

INTRODUCTION

This article is intended to clarify aspects of the Late Cainozoic Era of Peninsular Malaysia that have become confused, as it is essential to have a firm foundation for future research in this critical time period in this fascinating corner of the world; important from perspectives of climate and sea level change, effects on the Sundaland land mass, and human and megafauna migrations.

The key issues involved are firstly, the geological ages that have been specified for the two main stratigraphic units, the Simpang Formation (‘Old Alluvium’) and the Beruas Formation (‘Young Alluvium’) in the important reference, the *Stratigraphic Lexicon of Malaysia* (Lee *et al.*, 2004), and secondly, the assignment of Late Pleistocene sediments in the Lumut-Dindings area, Perak, to the Simpang Formation, rather than mainly to the Beruas Formation. The necessity is also stressed for the adoption of an intervening unit between the Simpang Formation and the Beruas Formation, the Transitional Unit which was erected by Batchelor (1979a,b) although Walker (1956) had prefigured a member of this, his “Organic Mud/Peat”.

The interpretations provided below are based on 40 years of the author’s research and mining experience in Late Cainozoic deposits of Southeast Asia since 1971. Investigations include more than 100 tin mine exposures in Perak, Perlis, Selangor, Malacca, Singapore, and the Indonesian Tin Islands, many thousands of drillholes, onland and offshore, and marine seismic profiles interpreted from Perak, Malacca and Indonesia.

REGIONAL SETTING AND PALAEOENVIRONMENTAL CHANGES

Peninsular Malaysia represents part of Sundaland, which is the landmass extension of the Eurasian Plate that stood above the sea during Pleistocene low sea level phases. Batchelor (1979a) from his interpretation of global eustatic sea level changes during the Late Cainozoic believed that high Middle Miocene sea levels fell during the Late Miocene and began rising again in the Pliocene. He developed a Quaternary sea level curve using deep sea foraminiferal oxygen isotope ratios adjusted to show sea levels below present sea level since the beginning of Quaternary time.

Figure 4(a) of Batchelor (1979a) reflects the peak condition of the Sundaland continent during Late Pliocene to Middle Pleistocene time when the bulk of alluvium formed. His Figure 4(b) shows today's geography as well as the striped zone that was subject to repeated rapid coastline movements as eustatic sea levels rose above the continental shelf break level especially during Middle and Late Pleistocene interglacial periods and retracted to depths c.120 m below sea level during glacial periods.

The key characteristics of Quaternary glacio-eustatic sea level changes and accompanying palaeoclimatic changes in the west Sundaland region, appear as follows:

Low sea level (glacial¹) periods: cooler seawater temperatures, more continental climate, more seasonal and drier due to less raincloud formation with larger land areas lying further from the sea; less climax rainforest, more savannah pine woods and grasslands; landscape aggradation and peneplanation (Verstappen, 1975; Batchelor 2015). Note: Could also be represented by valley incision if the interglacial period valleys in coastal areas maintain their incised character as the base level of erosion is lowered during the subsequent (glacial) lowering of sea levels.

Higher sea level (interglacial) periods: warmer seawater temperatures, more insular tropical climate with higher evaporation/rainfall; tropical climax rainforest more common; strong vegetation cover and growth enhance lineal valley stream incision from perennial streams. Soil development favoured (Verstappen, 1975; Batchelor, 2015).

Compared to conditions prevailing today, vegetation cover of the Sundaland region during the Last Glacial Maximum (LGM) was believed to be less extensive (Cannon *et al.*, 2009). Such conditions also likely existed during Early and Middle Pleistocene glacial periods. Pollen derived from Old Alluvium in Selangor indicates cooler, drier conditions when a central grassland savannah and pine woodlands corridor facilitated migration of rich Pleistocene megafaunas into the region (Bird, *et al.*, 2005).

LATE CAINOZOIC GEOLOGICAL EVOLUTION AND REGIONAL STRATIGRAPHY

The maximum age of the oldest Late Cainozoic alluvial unit, the Boulder Beds, is dated as younger than the coal measure sequences, which they overlie at Bukit Arang in Kedah and Perlis, and Batu Arang in Selangor (Hutchison and Tan 2009). These coal measures have however, not been definitively dated. The Batu Arang Beds were considered as Late Miocene to Pliocene (Roe, 1953), Early Miocene for lower seams (Mahendran *et al.*, 1991), or even Eocene-Oligocene (Ahmad Munif, 1993). Given that Anderson and Muller (1975) showed similarities in formation of a Brunei coal deposit during mid-Miocene high sea levels with the widespread peat swamps forming today under high sea level and rainfall conditions, it could be assessed that many Sundaland coals formed during known Middle/Late Miocene and Early Pliocene high eustatic sea level phases.

1 "Glacial" and "interglacial" stages refer to European and American chronologies from temperate climes.

According to Haq *et al.* (1987), the most significant fall of Pliocene global sea levels occurred at the end of their TB3.6 substage, dated about 3.7 Myr Before Present (BP; Late Pliocene). Commencing then with major eustatic sea level lowering when weathered bedrock became widely exposed, stages of Late Cainozoic geological evolution involved:

(Stage 1) long periods of landscape stability with deep weathering of exposed basement in Mio-Pliocene time during the maximum extent of the Sundaland continent.

(Stage 2) Sea levels and precipitation began to rise first initiating slumping of disintegrated mineralised regolith downslope to form piedmont fans (Boulder Beds), later reworked by increasingly active braided fluvial processes which facilitated aggrading alluvial plains (Old Alluvium). Episodic more pluvial (interglacial) phases caused downcutting forming broad channel features and better sorted alluvium.

(Stage 3) The various sedimentary facies developed in the respective piedmont-braid plain-braided trunk channel environments of Stages 2 and 3 are reflected in facies models proposed by Rust and Koster (1984). Significant change in depositional styles occurred around Middle Pleistocene time coeval with the Transitional Unit, with landscape peneplanation and pedogenesis.

(Stage 4) From Late Pleistocene time onwards typical 'modern' fluvial deposition (Young Alluvium) filled incised V-shaped valleys, together with contiguous high sea level coastal paralic and marine sediments.

Together with results of his own research and investigations, Batchelor (1979a,b) adopted Walker's (1956) main stratigraphic units from the Kinta Valley, Perak, of Boulder Beds, Old Alluvium, and Young Alluvium, extended understanding of their genesis, relationships and geochronologies, and proposed a regional Late Cainozoic stratigraphic scheme (Figure 1) incorporating the traditional division of "Old Alluvium" and "Young Alluvium". He also correlated the Indonesian offshore units erected by Aleva *et al.* (1973), i.e. Older Sedimentary Cover, Alluvial Complex, and Younger Sedimentary Cover. Batchelor (1979a,b) noted

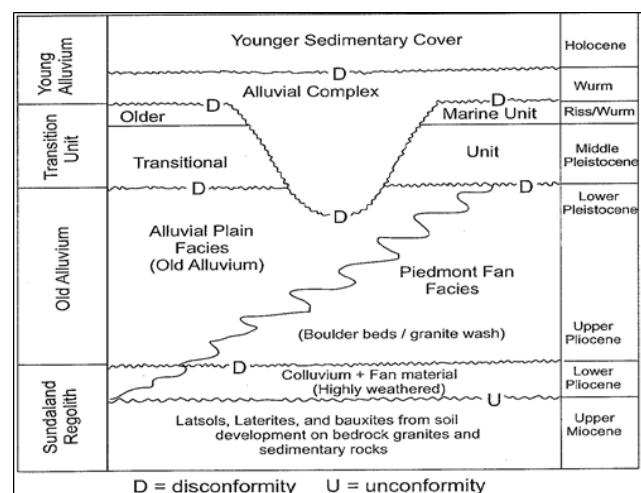


Figure 1: Upper Cainozoic Stratigraphic Scheme for Peninsular Malaysia – western Indonesia (Batchelor 1979a,b).

Walker's identification of an "Organic mud" depositional phase *between* the OA and YA deposition, and incorporated this member within the Transitional Unit which he erected as a new stratigraphic unit. Evidence provided below indicates an extensive time period for the Transitional Unit, which is infrequently mapped. This seems due to its frequent removal by subsequent erosional phases, or its being covered by younger sediments and lying in the subsurface.

The important distinction between the Old Alluvium (OA) and the Young Alluvium (YA) in emergent and nearshore areas of the Sundaland continent is that the OA comprises less well sorted generally aggrading alluvial fan and plain deposits of broad palaeochannel systems while the YA infills V-shaped valleys incised into the landscape. The Transitional Unit was deposited during transition with peneplanation between the two dominant regimes. Dating of these units has been conducted using palaeomagnetism, palynology, and radiocarbon dating (Batchelor, 1988) and correlated with eustatic sea level and climatic changes. Table 1 summarises the typical features of the Late Cainozoic stratigraphic units.

Suntharalingam (1983a), *formally* erected Upper Cainozoic stratigraphic units for Peninsular Malaysia, including the continental Simpang Formation and Beruas Formation. He correlated the Simpang Formation with the Old Alluvium of Walker (1956) and believed it to be Pleistocene, and the Beruas Formation with Walker's Young Alluvium. Consequently the Simpang Formation/OA and the Beruas Formation/YA are generally used interchangeably in this article. Suntharalingam noted that the Simpang Formation comprises two members – the Lower Sand Member and Upper Clay Member. The latter is believed equivalent to the "Tough Clay Unit" of Batchelor (1979a,b). Suntharalingam also cited a Pleistocene shelly marine clay

and sand unit, the Kempadang Formation, recognised in Pahang coastal areas south of Kuantan (Suntharalingam and Ghani 1986). This unit is believed likely equivalent to Batchelor's (1979b) 'Old Marine Unit' (i.e. uppermost member of the Transitional Unit). The Lower Marine Clay Member of the Kallang Formation (Bird *et al.*, 2006) in Singapore is also a probable equivalent of the 'Old Marine Unit'.

Although the Simpang Formation was designated as Pleistocene, this was a general assignment since no dating evidence was provided (Suntharalingam 1983a) to support that its deposition covered the *whole* of the Pleistocene. Indeed it is surprising that Suntharalingam (1983b) in his Late Cainozoic correlation chart for Perak, ignored the other schemes depicted therein (Sivam 1969; Batchelor 1979b; Suntharalingam and Teoh 1980) that suggested that the Young Alluvium extended into the Late Pleistocene, and that the Old Alluvium was older than Late Pleistocene. Within the ambit of Dutch technical assistance to Malaysia, Bosch (1988) (arbitrarily) defined the period of deposition of the Simpang Formation to terrestrial deposition before the Last Glacial Maximum (LGM). This wording implies that Simpang Formation deposition continued to Late Pleistocene time. This young age assignment is disputed strongly by Batchelor (1979a,b) and herein. Suntharalingam (1987) restricted the Beruas Formation to Holocene (only) and replaced the term "Young Alluvium" with Beruas Formation. This approach was followed in subsequent government mapping and publications, such as by Kamaludin (1990) wherein the Simpang Formation became synonymous with the chronological period, Pleistocene, and Beruas Formation with the Holocene, as follows: Gula Formation – marine Holocene; Beruas Formation – terrestrial Holocene; Simpang Formation – terrestrial Pleistocene.

Table 1: Typical Features of Late Cainozoic Stratigraphic Units in Peninsular Malaysia.

Young Alluvium (YA)/Beruas Formation (of Suntharalingam 1983a) comprises unconsolidated, fluvial and lacustrine deposits and swamp peats, usually limited to positions adjacent to present-day streams. YA often comprises channel sands occurring basally while topstratum (floodplain) muds deposited by linear streams become more prominent coastwards.
The Transitional Unit comprises differentiated members, such as laterite formed on the underlying Old Alluvium, sheet wash deposits, carbonaceous deposits including the "Organic Mud" of Walker (1956), intraformational conglomerates with slumping from dissolution of underlying limestone bedrock, fluvial braided stream alluvium typically represented by gravelly basal channel lag and bar deposits with overbank muds uppermost. Quartz granules are often covered with a ferruginous, carbonaceous, or lutaceous coatings. In coastal areas an Old Marine Unit, probably equivalent to the Kempadang Formation (of Suntharalingam 1983a) may be found uppermost. The TU is generally encompassed by disconformities top and bottom, with the overlying YA/Beruas Formation and underlying OA/Simpang Formation, respectively.
The Old Alluvium (OA)/Simpang Formation (of Suntharalingam 1983a) comprises semi-consolidated deposits that overlie scattered occurrences of boulder beds and bedrock. It is typically represented by poorly-sorted, crudely-bedded gravelly channel and bar sands. A Tough Clay Member frequently occurs uppermost. Most OA has a granitic derivation. Organic matter occurs infrequently. It is dominantly of fluvial origin (Sivam 1969). A type section of the OA was formally designated in Singapore (Public Works Department 1976). Whereas the OA represents a downstream alluvial plain facies, the Boulder Beds (BB) are a coarser piedmont fan facies occurring adjacent to bedrock scarps. The BB can often be distinguished by their fan-shaped outlines and inclusion of sheet-flood/debris flow deposits. The BB and OA are believed to be correlatable offshore with the "Older Sedimentary Cover" (OSC) of Aleva <i>et al.</i> (1973). Facies models for the interfingering relationship between the (distal) Old Alluvium and (proximal) Boulder Beds facies are provided by Rust and Koster (1984). Close similarity of these models should be noted with the proximal fan and distal alluvial plain facies, assigned to the OSC, identified in Lumut-Dindings offshore, Perak (Batchelor, 1979b).
The Sundaland Regolith represents deep soil development of red/yellow latosols and laterites within basement rock of the "Sunda Peneplain", and derived red-beds of colluvial and fan material.

Table 2: Comparison of Characteristic Features displayed by the Simpang Formation/Old Alluvium and Beruas Formation/Young Alluvium in Peninsular Malaysia.

Distinguishing Feature	Simpang Formation/Old Alluvium	Beruas Formation/Young Alluvium
Palaeogeomorphology	Aggraded over large areas or infilling broad valleys overlying bedrock (or Boulder Beds, BB); planated or eroded upper surface	Inland: Fill V-shaped present valleys incised into planated landscape. Flat upper surface. Coastal: blanketing topstratum deposits
Depositional environment	Terrestrial/fluviol: Alluvial fan and braided plain; with piedmont fan facies (BB); crude bedding only; oxidising environment	Terrestrial/fluviol. Linear (confined) or meandering streams. Good bedding.
Environmental changes	Little obvious effect from sea level or climatic changes	Frequent numerous facies types developed laterally and vertically
Sediment type / Maturity	Often massive, poorly sorted gravelly clayey sands, sandy clays, gravels	Differentiated facies: generally better sorted channel/bar sands; overbank muds
Thickness	Often > 30 m thick	Generally < 30 m thick on land
Colour	Grey and whitish/cream	Brownish and darker colours common; sometimes grey
Slumping	More common	Rare or absent
Organic content	Uncommon	Common including peat swamp facies
Consolidation	Semi-consolidated	Unconsolidated
Soil development	Lateritic soil profile or crust developed uppermost	Weak soil development

Insufficient dating research had been conducted however, to support such chronological boundaries for the two main lithostratigraphic units (i.e. full equivalency of the lithostratigraphic units with global chronologic units). It also clearly differed from Batchelor's (1979a,b) datings. Further, as Dutch support focussed only on the "Quaternary", the fact seems to have been overlooked that the "Tertiary sediments underlying the Quaternary deposits ... cannot be differentiated from the Quaternary deposits" (Suntharalingam, 1983) implying that the Simpang Formation/OA extends into the Late Tertiary. This situation had earlier been indicated by Batchelor (1979a,b).

Table 2 provides the distinguishing sedimentological and stratigraphic features to enable differentiation between the Old Alluvium/Simpang Formation and the Young Alluvium/Beruas Formation.

DATING OF LITHOSTRATIGRAPHIC UNITS

Batchelor (1988) provided the detailed evidence for dating of the Late Cainozoic lithostratigraphic units discussed above. Not surprisingly, given that the age of the bulk of the alluvium lies beyond the range of the radiocarbon dating method, but with the limited occurrence and limited evolutionary changes occurring within fossil assemblages, palaeomagnetism using detrital remanent magnetism proved to be the most useful technique to be applied during the 1980s. Palaeomagnetic research was conducted at this time at the then well-established palaeomagnetic laboratory at the University of Malaya Geology Department (refer Haile and Watkins, 1972). Mahaney (1984) saw significant advantages with using these techniques and commented that the results of palaeomagnetic work were becoming more reliable and "paleomagnetic dating of Quaternary sediments has a bright future and will play a strong role in the correlation and dating of Quaternary deposits".

Two critical cases can be cited to demonstrate that the time period represented by the boundary between the Old Alluvium (Simpang Formation) and the overlying Transitional Unit contains the magnetic polarity reversal boundary between the Matuyama Reversed Epoch/Chron and the Brunhes Normal Epoch/Chron. This boundary has been dated to approximately 775,000 years BP (Channell *et al.*, 2010). The first case is shown as Figure 4 in Batchelor (1988) where within an alluvial tin mine at Puchong, Selangor, the uppermost OA unit, the Tough Clay Unit, was found to be reversely magnetised (i.e. deposition during the Matuyama Reversed Epoch), while the disconformably overlying intraformational conglomerate member of the Transitional Unit was found to have normal magnetism (Brunhes Normal Epoch). The second case studied was at the former Serdang Brickworks pit, Selangor, where incipient laterite formed on the uppermost OA there, with slumped Transitional Unit (TU) equivalents above it (Stauffer and Batchelor 1978). Both laterite and TU were found to have formed within the Brunhes Normal Epoch while the underlying OA itself was reversely magnetised (Matuyama Reversed Epoch).

In summary, the extensive palaeomagnetic studies carried out by Batchelor (1988) and Haile and Watkins (1972) on the alluvial deposits in Peninsular Malaysia indicate that the Transitional Unit and Young Alluvium / Beruas Formation, were deposited during the Brunhes Normal Epoch (Present to 775,000 years BP) while the bulk of the Old Alluvium/Simpang Formation was deposited during the Matuyama Epoch (Figure 2), which extended from 2.588 Ma to 0.773 Ma BP. The boundary between the Matuyama and Gauss epochs at 2.588 Ma BP has now been widely accepted as the beginning of the Quaternary period (Cohen and Gibbard 2010). Some normally magnetised samples obtained from deeper (older) levels of the Old Alluvium at a few sites are interpreted as having been deposited during

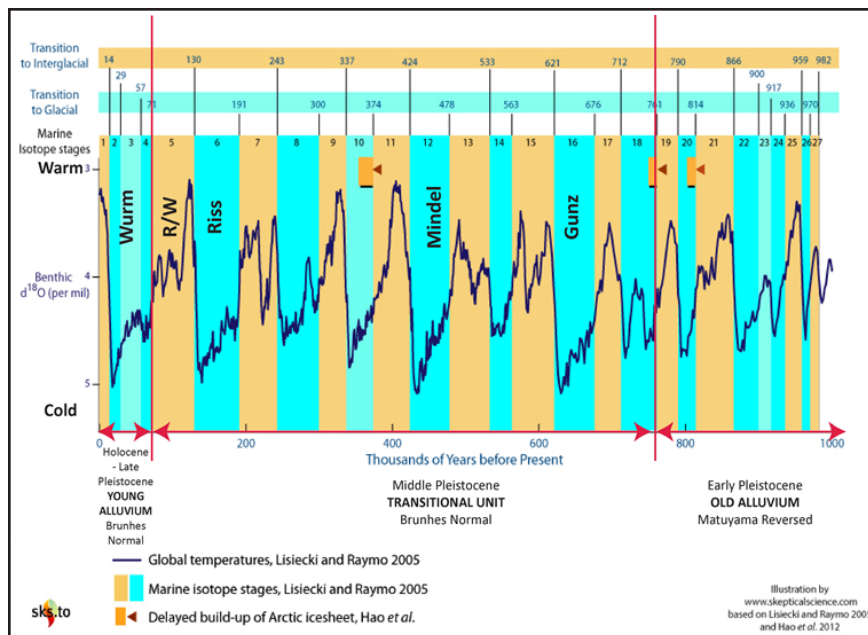


Figure 2: Dating of the main Late Cainozoic stratigraphic units in Peninsular Malaysia (refer Batchelor 1979a,b) with reference to Quaternary Marine Isotope Stages (MISs), glacial and interglacial events, and palaeoclimatic changes (based on Lisiecki and Raymo 2005 and www.skepticalscience.com).

either the Early Pleistocene Jaramillo (0.9-1.06 Myr BP) or Olduvai (1.67-1.87 Myr BP) events. All of the Old Alluvium/Simpang Formation has thereby been confirmed to be older than 775,000 years BP, which supports the earlier indicated age of Late Pliocene to Early Pleistocene (Batchelor 1979b). This dating is further supported by the finding of tektites (dated around 785,000 years BP) within tin-bearing beds of the Gambang tinfield in Pahang, as reported by Raj *et al.* (2009), since the Simpang Formation/Old Alluvium is the main host for alluvial tin deposits in Malaysia (Batchelor 1979a; Suntharalingam 1983a). The tektite meteoric event occurred within 12.0 ka -16.5 ka *before* the Brunhes-Matuyama reversal event as corroborated by the horizon of deep sea microtektites lying stratigraphically just below the B-M polarity reversal horizon, based on estimated sedimentation rates (Haines *et al.*, 2004).

Suntharalingam (1983a) believed the Beruas Formation is a lithostratigraphic equivalent of the Young Alluvium of Walker (1956). Evidence was provided by Batchelor's (1983) research to demonstrate that the Young Alluvium in Peninsular Malaysia extends into the Pleistocene, while Bosch (1988) believed it comprises deposits extending back to the LGM (i.e. MIS 2 starting 29,000 yr BP). Earlier however, Batchelor (1979b; 1988) had proposed that the Young Alluvium should include deposits of the (earliest) Wurm (glacial) period, which is now placed at the beginning of MIS 4, commencing 71,000 years BP. Known Young Alluvium deposits older than the (currently defined Beruas Formation) Holocene include those in Table 3 below, as well as older fluvial alluvium and lacustrine clay deposits identified by Batchelor (1983). The latter exist in the Serdang Clay Pit, Selangor above and below the dated 30,000 year BP volcanic ash horizon. Ash horizons of similar age exist in Perak, Pahang, and Ampang and Serdang in Selangor, and have been mapped as a distinct soil series (Halu series) by government agronomists in Lenggong, Perak

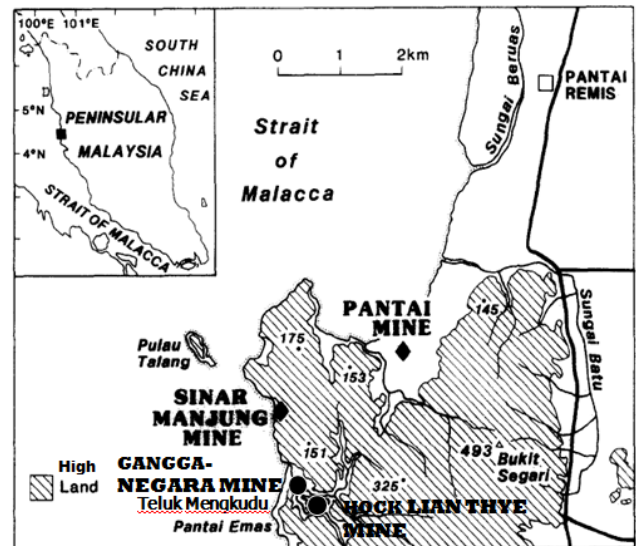


Figure 3: Location of the Lumut- Dindings areas investigated by Batchelor (1983, 1988), Abdullah Salleh (1983) and Kamaludin *et al.* (1993). Modified from Kamaludin *et al.*, (1993).

and Raub, Pahang (e.g. Law 1967; Stauffer and Batchelor 1978; Batchelor 1983). Soil series developed on Pleistocene older (post-Old Alluvium/Simpang Formation; i.e. Young Alluvium) fluvial deposits have been mapped in western peninsular states as the Sitiawan, Sogomana, and Manik series (Batchelor 1983). Evidence is also provided below from a stratigraphic re-assessment in the Pantai Mine, Perak that Beruas Formation sediments there extend to >60,000 years BP (see Figure 5 and discussion).

LUMUT-DINDINGS INVESTIGATIONS BY BATCHELOR, KAMALUDIN AND OTHERS

Figure 3 shows the former tin mines investigated in the vicinity of the Segari Granite in the Lumut-Dindings area, Perak. The sequences of the Gangganegara and Hock

Lian Thye mines and offshore submarine deposits were investigated by Batchelor (1983) and discussed in Batchelor (1988). The nearby Pantai and Sinar Manjung mines were studied by Kamaludin *et al.* (1993, 1997). Quaternary deposits of the Lumut-Dindings coastal and offshore area are amongst the most detailed studied in Peninsular Malaysia.

Kamaludin *et al.* (1993) referred to my 1988 publication, but did not mention that I had erected the Mengkudu Alluvium as a Young Alluvium equivalent, and the Lumut Sand-Clay Unit as an OA/Simpang Formation equivalent, within the area of their published study. Batchelor (1988; Table 2) described the Mengkudu Alluvium as comprising sandy peats, carbonaceous clays and channel sands. Mapped sections of the two mines studied are provided in Batchelor (1983). Figure 4 taken in the Hock Liam Thye mine clearly



Figure 4: Arrows indicate the disconformity between basal (darker) carbonaceous deposits of the 'Mengkudu alluvium' (Young Alluvium/Beruas Formation equivalent; refer Batchelor 1988) and topmost 'Tough Clay Unit' of the Lumut Sand-Clay unit (Old Alluvium/Simpang Formation equivalent) below, Gangganegara No. 2 Mine, Teluk Mengkudu, Perak.

shows the disconformity existing between the Lumut Sand-Clay Unit (i.e. Simpang Formation) and the Mengkudu Alluvium (Beruas Formation). This unconformity would be expected to be present in the nearby Pantai Mine but Kamaludin *et al.* (1993) did not identify Beruas Formation equivalents previously mapped there by his Geological Survey of Malaysia (PKM) colleague, Abdullah M. Salleh (1983). However, except for the uppermost beds, Kamaludin *et al.* (1993) attributed the sequences studied in the Pantai Mine and Sinar Manjung mines largely to the Simpang Formation/Old Alluvium. Carbon-14 and thermoluminescence dating results from the Pantai and Sri Manjung mines ranging from 28,000 to >67,000 years BP were all attributed by them to the Simpang Formation. In their subsequent study, Kamaludin and Azmi (1997) published detailed palynological profiles of the previously studied mine sections. Mangrove pollen (representing marine incursions) in an upper zone, as well as in near basal beds, were (erroneously) considered to be derived from the Simpang Formation. The presence of these marine intercalations is wholly contradictory to Kamaludin's (1990) own view stated in his earlier report on Seberang Prai, Penang and Kuala Kurau, that "Sediments of the Simpang Formation are interpreted as having been deposited by **fluvial processes in a terrestrial environment** during the Pleistocene **when sea level was well below the present.**"

Kamaludin *et al.* (1993) concluded that the (supposedly) "Old Alluvium sequence exposed in the Pantai Mine represents Late Pleistocene sediments with some recent marine reworking. The Simpang Formation in Perak, and presumably much of the Old Alluvium in the region, is thus Late Pleistocene in age". In reality however, the marine incursions in the dated sequence, the abundant peat, and the frequent facies changes indicate this sequence mainly comprises *not* Old Alluvium (Simpang Formation) but a YA/Beruas Formation sequence, with incursions of marine/paralic formations. I believe the deposits mainly belong to the Sitiawan Member and the Peat Member of the Beruas Formation, as previously mapped by Kamaludin's colleague, Abdullah Saleh (1983) and published in the PKM 1981 Annual Report.

My own interpretation (Figure 5) differs significantly from Kamaludin *et al.* (1993). It is probable that the near-basal beds within the sequence found to contain mangrove

Table 3: Older Radiocarbon Dates on Young Alluvium Equivalents in Peninsular Malaysia.

C-14 Age (yr BP)	Lab No.	Stratigraphic Position	Material	Location	Reference
>39,900	I3975	Peat within Young Alluvium	Log	Tebbas Mine, Tg. Rambutan, Perak	Sivam (1968, 1969)
>39,900	I3976	Peat within Young Alluvium	Log	Sui Sim Mine, Tg. Rambutan, Perak	Sivam (1968, 1969)
>39,900	I6703	Peat in Younger Channel Fill	Wood	Liam Yap 1 Mine, Ulu Yam Baru, Selangor	Lean (1972)
>40,000	I10183	Peat just below 30,000 yr BP volcanic ash	Wood, peat	Selangor Brickworks, Serdang	Stauffer <i>et al.</i> (1980)
>42,000	NZ4745A	Peat just below 30,000 yr BP volcanic ash	Peaty clay	Selangor Brickworks, Serdang	Batchelor (1983)

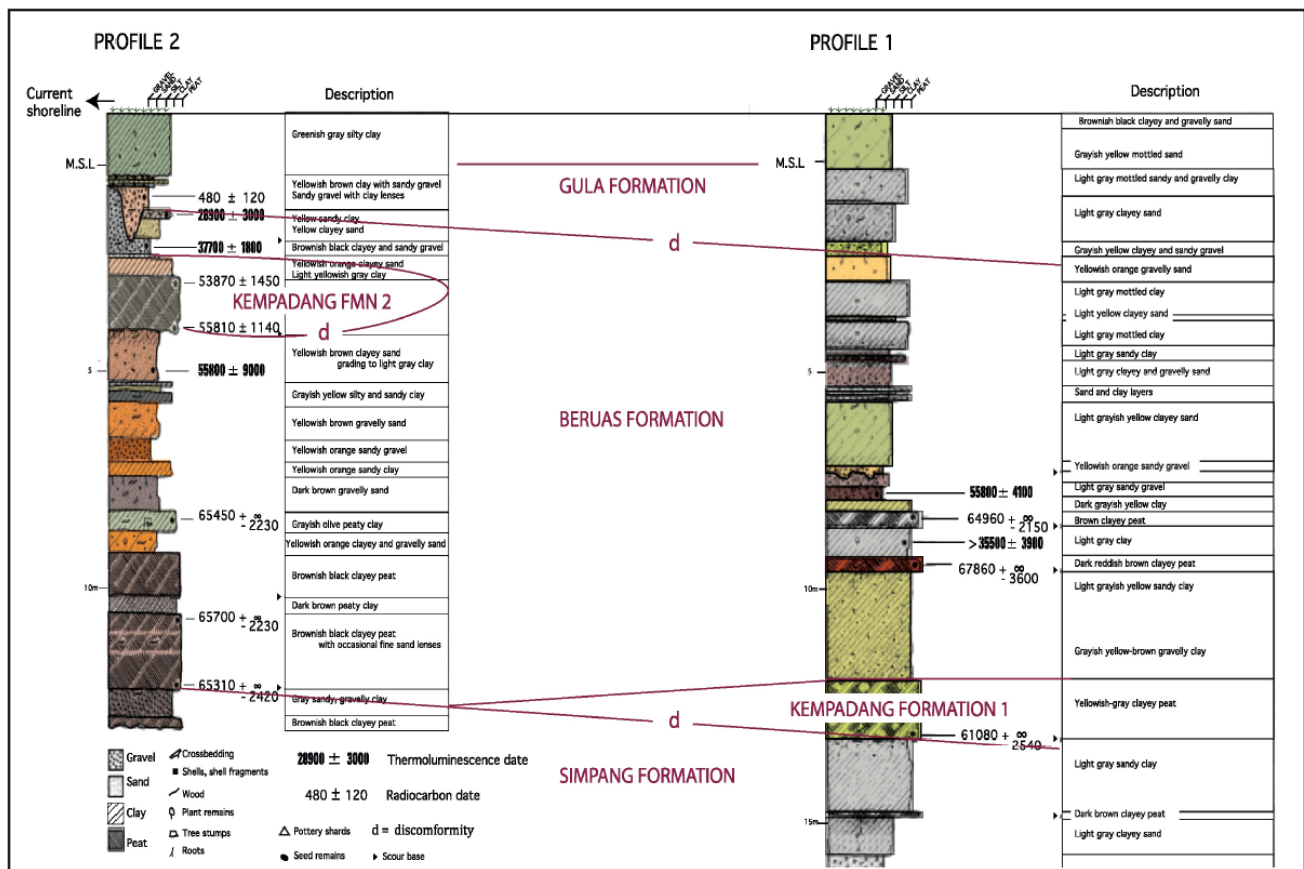


Figure 5: Lithological descriptions, chronological datings, and stratigraphic correlations between Profiles 1 and 2, Pantai Mine, Pantai Remis, Perak. Modified after Kamaludin *et al.* (1993) and Kamaludin and Azmi (1997).

pollen reflecting a marine incursion, are equivalent to the Paralic Member (of the Transitional Unit) identified by Batchelor (1988) in the adjacent offshore area. This member is an equivalent of the 'Old Marine Unit' (Batchelor 1979, Figure 1) and probably equivalent to the Kempadang Formation of Suntharalingam (1983a), which also typically occurs overlying the Simpang Formation (Raj *et al.*, 2009). Batchelor (1979b) interpreted the 'Old Marine Unit' as having been deposited during the Riss-Wurm interglacial high sea level phase, which is dated to Marine Isotope Stage 5 (MIS5), 71,000 to 130,000 years BP. The Pantai Mine lithological sequence of Kamaludin *et al.* (1993) is re-interpreted below, based on the data provided. Lithostratigraphic units represented in the section represent formal units previously designated by Suntharalingam (1983a): Gula Formation, Beruas Formation, Kempadang Formation, and Simpang Formation. The following summarises key features of these units as reinterpreted by Batchelor in this article.

Gula Formation (GF) of marine/paralic sediments with abundant mangrove pollen is represented by the uppermost sediments, which overlie the Beruas Formation sediments separated by a disconformity. GF comprises fossiliferous beach sands and soft greenish grey mud. The sea and living mangrove trees grow today only a few hundred metres distance from Profile 2 (Figure 5). Age of the GF here is indicated from one C-14 date of 480 ± 120 yr BP (Kamaludin *et al.*, 1993).

Beruas Formation as mapped by Abdullah Salleh (1983) in the Bukit Segari area comprises mainly peat (Peat member) and alluvium and flood-plain deposits (Sitiawan member). Parts with mottling may have affinity with the Segari member comprising colluvium from the Segari Granite. Age of deposits here is indicated from thermoluminescence dates ranging from $28,900 \pm 3,000$ to $>55,800$ yr BP, and C-14 dates of $>64,960 \pm$ yr BP (Kamaludin *et al.*, 1993). This latter C-14 date however, can really only depict an age of $\geq 60,000$ yr BP (refer discussion below).

The **Kempadang Formation** was originally defined by Suntharalingam and Ghani Ambak (1986) as Pleistocene marine sediments identified in boreholes in Pahang, south Perak and Selangor. Studies had not however, been conducted by them to define more specifically its age. Ghani Ambak (1983) had referred to this unit in the Kuantan area by the name "Older Marine Unit". As two separate Pleistocene marine deposits have been identified in the Lumut-Dindings area, Perak, they are named **Kempadang Formation 1** (older/lower) and **Kempadang Formation 2** (younger/higher). In Telok Datuk, Selangor, the Kempadang Formation overlies the Simpang Formation and is overlain by the Beruas Formation. At this stratigraphic position it is equivalent to the Old Marine Unit of Batchelor (1979a), believed deposited during the Riss-Wurm high sea level phase (i.e. MIS 5).

The **Kempadang Formation 2** comprises a basal dark brown clayey peat and overlying yellowish orange clayey sand, both containing abundant mangrove pollen. The Formation inter-fingers and both disconformably overlies and underlies yellowish clayey sands of the interpreted Beruas Formation. Age is indicated from C-14 dates of $53,870 \pm 1450$ and $55,810 \pm 1140$ yr BP (Kamaludin *et al.*, 1993). As discussed at length by Kamaludin *et al.* (1997), this deposit records an interstadial high sea level phase within Marine Isotope Stage 3 (57,000 to 29,000 yr BP; Figure 2) when relative was interpreted to be 4.3m below present mean sea level (MSL). **Kempadang Formation 1** is represented by the yellowish-grey clayey peat with abundant mangrove pollen that directly overlies disconformably the underlying Simpang Formation, and underlies interpreted Beruas Formation alluvium. It was believed deposited during MIS 5 with relative sea level lying 14.6 m below present MSL. Age is indicated from one C-14 date of $>61,080$ yr BP (Kamaludin *et al.*, 1993). This latter C-14 date however, can really only depict an age of $\geq 60,000$ yr BP (refer discussion below).

Simpang Formation is represented in both profiles at Pantai Mine as greyish sandy gravelly clay or gravel. It is believed that no thermoluminescence or radiocarbon dates reported by Kamaludin *et al.* (1993) were derived from confirmed Simpang Formation/Old Alluvium sediments at the Pantai Mine. The Sinar Manjung mine was less well studied.

Kamaludin *et al.* (1993) stated themselves that the oldest age measurable with the accelerator mass spectrometer (AMS) used for their C-14 dating at Nagoya University is 60,000 years BP (reliable measurable age limit) and that their “dead carbon” reference was dated at 62,000 to 72,000, years BP. Consequently, all C-14 dates from Pantai Mine measured as older than 60,000 years BP should be considered as absolute minimum ages. Only radiocarbon ages of less than 60,000 years BP can be considered as valid dates. This is also the maximum limit for AMS dating as stated by Andrew Snelling (2011).

VALIDITY OF CARBON-14 DATES REPORTED FOR YOUNG ALLUVIUM AND OLD ALLUVIUM

In support of their interpreted Late Pleistocene ages for the Simpang Formation, Kamaludin *et al.* (1993) had sought support from other published radiocarbon dates supposedly derived from the Old Alluvium/Simpang Formation. My interpretation however, is that these dates are erroneous and that young dates previously attributed to OA have either (1) been wrongly attributed and actually derive from younger units (e.g. YA), or (2) the original carbon has been contaminated with young carbon, a common situation near maximum range of the C-14 method. The former case is apparent where the upper sequence in the Pantai Remis area of Perak attributed to Simpang Formation/OA by Kamaludin *et al.* (1993), is from my own studies believed to be mainly Beruas Formation, as prefigured in the Teluk Mengkudu sequence published in Batchelor (1988; Table 2)

and described in Batchelor's (1983) thesis. This is also likely the case with the $36,420^{+1255}_{-1085}$ years BP date published by Haile and Ayob (1968). Because a number of dissimilar stratigraphic units occur at Sungai Besi, Kuala Lumpur while the stratigraphic context of dated horizons was not given, it is uncertain whether the dated peat actually derived from OA. Ayob (1965) had stated that Sungai Besi peats are the youngest deposits, which post-date the OA. It is therefore likely that the young peat dated at Sungai Besi is not an OA equivalent (Batchelor 1983). In case of the young date of $41,600^{+2160}_{-1570}$ years BP of Batchelor (1983) obtained for the Simpang Formation/Old Alluvium, the Hannover dating laboratory advised this date near the measurement limit is not reliable. Further, the $42,000^{+1600}_{-1400}$ years BP date reported by Suntharalingam *et al.* (1984) is also not reliable as it lies near the method measurement limit. All other C-14 dates for Old Alluvium are beyond the limit for the methodology; i.e. 40,000 yr BP for conventional β -dating, or 60,000 yr BP for accelerator mass spectrometry (AMS) dating (see Kamaludin *et al.*, 1993: 200; Snelling, 2011).

Table 3 lists the radiocarbon dates, which lie beyond the measurement limit for the radiocarbon method, and have been specified by their authors as being derived from the Young Alluvium. As techniques improved this limit increased, particularly after AMS dating techniques became used. These old dates on Young Alluvium/Beruas Formation equivalents confirm that the Beruas Formation extends beyond 40,000 years BP. Consequently, the older Simpang Formation/Old Alluvium could not possibly be younger than 40,000 years BP.

CONCLUSIONS AND RECOMMENDATIONS

Various evidences but particularly palaeomagnetic dating results, indicate that the Simpang Formation of Suntharalingam (1983a), equivalent to the Old Alluvium of Walker (1956) in Perak, is of Late Pliocene to Early Pleistocene age. Its deposition did not extend into Middle or Late Pleistocene time beyond the Matuyama Reversed Epoch (to 775,000 yr BP). The review of data from my own investigations in the Lumut-Dindings Perak area (Batchelor 1979a,b; 1983; 1988), and those of government geologist Abdullah Mohammad Salleh (1983), indicate that the bulk of coastal Perak sediments investigated and dated by Kamaludin *et al.* (1993) are most likely Beruas Formation and Kempadang Formation equivalents, not the Simpang Formation.

Evidence has been provided that Young Alluvium deposition extends from the present-day to beginning of the Wurm glacial (i.e. 0 to 75,000 years BP), including in the area investigated by Kamaludin *et al.* (1993). The Beruas Formation of Suntharalingam (1983a) should not therefore arbitrarily be restricted to the Holocene but should also include deposits as old as 75,000 years BP.

The “Transitional Unit” of Batchelor (1979b) should be formally accepted as comprising variegated deposits including the Organic Muds of Walker (1956), intraformational mudstone conglomerate (Batchelor, 1988),

fluvial sands, and the 'Old Marine Unit' of Batchelor (1979a,b). It spans the beginning of Middle Pleistocene time (775,000 years BP) until end of the Riss-Wurm interglacial period (MIS 5), 75,000 years BP.

Further investigation of the Kempadang Formation is needed in the type area near Kuantan, Pahang to determine whether its deposition resulted from high eustatic sea levels during the Riss-Wurmian interglacial period (MIS 5) or the Wurmian interstadial (MIS 3). If it is found that the Kempadang Formation there was formed during Riss-Wurmian time, then the Wurmian interstadial deposits confirmed by Kamaludin Hassan *et al.* (1993) and Kamaludin and Azmi (1997) in the Pantai Mine could be designated as a new marine-paralic formation, which I propose be called the "Sera Formation" after Teluk Sera, which is the nearest geomorphological feature to the Pantai mine.

Finally, the present writer believes that sediments deposited in major 'modern' river catchments should ideally each have their own separate formation established within Late Pleistocene-Holocene time since these catchments are generally well-defined and separate from each other. On this basis there is a strong argument that future use of the Beruas Formation should be restricted geographically and not used throughout Peninsular Malaysia. However, terrestrial lithostratigraphic units deposited during Early Pleistocene-Pliocene time show less variability and are more widespread. Using *regional* formation names (e.g. Simpang Formation, Old Alluvium) then is considered more appropriate.

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