Geological Society of Malaysia Annual Geological Conference 2000
September 8–9 2000, Pulau Pinang, Malaysia

The Olistostromes in the Bentong Area, Pahang and their Tectonic Implications

MUSTAFFA KAMAL SHUIB

Department of Geology, University of Malaya
50603 Kuala Lumpur, Malaysia

Abstract

Two types of olistostromes are recognized in the Bentong area. They are a) olistostromes that are intercalated with cherts and b) olistostromes that are intercalated with sandstone/shale layers. The features found within the various olistostrome outcrops indicate that they are gravity flow deposits in which several types of mass transport were operative. They have been deformed by sub-vertical dextral and sinistral strike-slip faults. The bedded cherts contain radiolaria suggesting that the bedded chert-olistostrome association were deposited in a deep marine environment. However, the olistostrome-sandstone/shale association shows a marked contrast in lithology and environment of deposition. They are very shallow marine to continental sediments. The position of the red layers within the chert-argillite stratigraphy is unknown but could possibly be unconformably overlying the olistostromes bedded chert association (chert-argillite unit). It is concluded that the chert-argillite unit was not deposited on the floor of a wide ocean, but on a basin that received abundant continental derived detritus, very near to the continental margin. Dextral transcurrent movements had resulted in the the uplift and inversion of the chert-argillites. This also leads to the development of pull-apart basins filled with shallow marine to continental sediments and olistostromes. These basins occurring along and within the Bentong-Raub Zone were inverted by the Triassic. By Late Triassic, these deposits would have been further tectonized in a dextral transpressive regime.

Olistostrom di Kawasan Bentong Pahang dan Implikasi Tektoniknya

Abstrak

Dua jenis olistostrom telah dikenalpasti di kawasan Bentong Pahang iaitu a) olistostrom yang bersaling seli dengan rijang dan b) olistostrom yang bersaling seli dengan lapisan batupasir/syal. Fitur ini dijumpai di pelbagai singkapan olistostrom menunjukkan bahawa ia adalah endapan aliran graviti hasil daripada beberapa bentuk pengangkutan jasad. Ia telah dicangga oleh sesar gelinciran submenegak menganan dan mengiri. Lapisan rijang ini mengandungi radiolaria mencadangkan lapisan rijang –olistostrom ini merupakan endapan sekitaran laut dalam tetapi olistostrom-batupasir/syal menunjukkan petanda yang berbeza dari segi litologi dan sekitaran pengendapan. Ia merupakan endapan sedimen laut cetek sehingga ke kebenuaan. Kedudukan lapisan merah dalam stratigrafi rijang-argilit masih belum dapat dikenalpasti tetapi kemungkinan menindih secara tidak selaras olistostrom yang berasosiasi dengan lapisan rijang (unit rijang-argilit). Dapat disimpulkan bahawa unit rijang-argilit tidak diendapkan di dasar lantai lautan luas, tetapi pada lembangan yang telah menerima bahan dari daratan yang paling hampir dengan pinggir benua. Pergerakan kekanan yang dihasilkan oleh pengangkatan dan pembalikan rijang-argilit menyebabkan pembentukan lembangan terik yang diisi oleh sedimen laut cetek hingga daratan dan olistostrom, disepanjang zon Bentong-Raub pada masa Trias telah membentuk lembangan. Pada Trias Akhir, endapan ini telah mengalami tektonik yang berterusan pada regim pergerakan kekanan.

INTRODUCTION

The Bentong-Raub Line or zone is an important structural lineament with a complex geology. It is characterized by a series of sub-parallel N-S trending lineaments. Within the zone, several small bodies of serpentinite are found in the Ordovician-Silurian schists. Bedded cherts that are intercalated with pelitic rocks, vocaniclastics and olistostromes of Devonian to Late Permian age belonging to the Chert-Argillite unit are also common. Overlying these strata are the non-fossiliferous continental Red Beds of probable Permo-Triassic age, followed by the Permo-Triassic shallow marine sediments of the Central Basin.

The Bentong-Raub Zone is widely interpreted as a major oceanic suture (Hutchison, 1977; Mitchell, 1981; Sengor, 1984; Metcalfe, 1988). Based on the occurrences of olistostromes and presence of structural imbrications of the deformed strata, Tjia (1989) and Tjia and Syed Sheikh Almashoor (1993) supported this interpretation. However, many authors, doubt that the Bentong-Raub Line represents a suture zone (Haile *et al.*, 1977; Tan, 1984; Khoo and Tan, 1983; Chakraborthy, 1993).

The position of the zone marking the limit of the Mesozoic sedimentary basin led Tan (1984) to suggest that the structure was an active normal fault during the Triassic. The interpretation found support from Harbury *et al.* (1990) who considered that the fault activities continued into the Cretaceous.

Tjia and Syed Sheikh Almashoor (1993) recognized several repeated slices of deformed strata and considered that these were due to west directed thrusting. However, the predominance of strike-slip faults and minor flower structures, and non-systematic repetition of lithologic units, led Mustaffa Kamal (1994) to suggest that the deformation in the Bentong-Raub zone was dextral transpressive in nature.

Mustaffa Kamal and Abd Hadi (1999), in proposing a new temporal stratigraphic sub-division of Peninsular Malaysia considered that the Bentong-Raub Zone represented a major fault with significant strike-slip motion that had been reactivated several times, and initiated and controlled the development of a number of successor basins. Mustaffa Kamal (2000) illustrated that by Late Permian, the Bentong-Raub Zone evolved into a dextral strike-slip fault zone with transtensional characteristics.

This contribution is aimed at presenting the various sedimentological and structural features found within the various olistostrome horizons in the Raub-Bentong area. Hamilton (1979) interpreted these deposits as subduction zone melange. Tjia (1988 and 1989) interpreted it as an olistostrome in a subduction zone setting but Chakraborthy and Metcalfe (1987) considered it as olistostrome developed in an extensional setting. Since the nature of the Bentong-Raub Zone is disputed, the nature of the olistostromes, their relationship with the bedded cherts, and the associated syn-depositional and tectonic structures within the basin will be significant for determining the nature of the Bentong-Raub Zone.

LITHOLOGY

The lithotype of the largest volume in the olistostromes of the Bentong Area are diamictites and pebbly mudstones. Pebbles and boulders are found floating in a pelitic and volcaniclastic matrix. They are matrix-supported rock types with no internal stratification. Three types of clasts can be distinguished: pebbles, boulders, and rarely megaliths. These clasts include sandstones, quartz, cherts, volcanics, tuffs, limestones, schists, conglomerates (some are sheared), and a rare occurrence of serpentinite clasts.

Two groups of olistostromes can be recognized in the Bentong area. They are described below.

Olistostromes that are intercalated with cherts

Where the olistostromes are in contact with bedded cherts, for example near to Cinta Manis, Taman Benus Jaya, and at the junction between Karak Highway and the road leading to Bentong from Karak, the contacts are always transitional in nature. Sub-parallel lenses of cherts in a pelitic matrix define the zone of contact. These lenses are ellipsoidal in shape and have been deformed and stretched into boudins and pinch and swell structures. Their arrangement in sheets suggests that they developed by stratal disruption.

Within the olistostrome proper, most blocks are irregularly sub-rounded to angular, many are approximately oblate spheroids but in a few locations they are distinctively prolate, and occur as tabular sheets. In most cases the matrix separates the blocks from one another. But in places they are attached in sheets defining a planar fabric (bedding) or wisps of sandstone that grades into the matrix. Most blocks are of pebble size but blocks up to 0.5 m in diameter are not uncommon. Some may range up to 2 m in diameter. They are poorly sorted. Most show sharply defined contact with the matrix but in others, the boundaries are ill defined. where the blocks and matrix seem to grade into one another. In Taman Benus Jaya, serpentinite occurs as a clast in the olistostrome.

Synsedimentary deformation

The smaller clasts of sandstone with transitional contact with the matrix form wisps in a pelitic matrix. The wisps show disruption by boudinaging. The boudins and pinch and swell structures are very irregular in shape with abundant bulbous protrusions and injection structures. The matrix is made up of small elongate and platy clasts that are alligned parallel to each other defining a planar primary fabric of foliation. This foliation tends to wrap around the larger clasts and blocks. Although much of the deformation of the sandstone wisps appears to have been accomplished in a ductile manner, fractures, strike-slip, and normal shear planes are found within them resembling the web structures of cataclastic shear zones. Much of the earliest deformation appears to be of a soft-sediment nature.

Tectonic deformation

At Taman Benus Jaya, the stratal-disrupted cherts and olistostromes have been intensely sheared. The northwesterly striking primary foliation has been transected by numerous N-S and NW trending dextral and to a lesser extent E-W trending sinistral shear planes. The clasts have been rotated in a clockwise manner.

Near Cinta Manis, apart from the synsedimentary slump folds, the bedded cherts have been folded into steeply NW plunging tight to isoclinal folds associated with a slaty cleavage within NNW trending fault zone bounded packages. Numerous sub-verticals NNW striking dextral strike-slip and reverse faults transect the strata. In places the faults exhibit positive flower structure. These early structures were further deformed by later easterly striking sinistral strike-slip faults. This deformation caused the strata and the early-formed cleavage along the fault zone to be folded into tight steeply plunging folds. Other smaller faults are also found that cut all the previously described structures. Similar structures can be found in the outcrop at the junction between Karak Highway and the road leading to Bentong from Karak.

These features are taken to indicate that the earliest deformation occurred in a dextral transpressive regime, followed a later sinistral strike-slip event.

Olistostromes that are intercalated with sandstone/shale layers

In Taman Industri Bentong and Taman Bukit Bentong, conglomerate and sandstone blocks with red matrix occur in the olistostromes that are intercalated with sandstone and shale sequence, which in places exhibit a distinct red matrix. Some lenses of limestone and deformed diamictites are also found. Most of the blocks are chaotic but some of the blocks have a planar arrangement. The contacts between the sandstone and conglomerate blocks and the more ductile matrix commonly exhibit irregular cusps and flame-like structures with matrix intruding into the blocks. In the conglomeratic blocks this phenomenon caused the blocks to disintergrate into individual clasts or smaller fragments. The sheets are composed of boulders and fragments of conglomerate and sandstone blocks. The disintergration of these sheets occur along well defined but irregular faults. Irregular cusps and flame-like structures characterize each block with matrix injections into the blocks. These would suggest that the conglomerates and sandstone were unlithified or partially lithified when they were faulted and disintegrated to form the olistostromes.

Synsedimentary deformation

The wisps of sandstone with transitional contact with the matrix show disruption by boudinaging and are very irregular in shape with abundant bulbous protrusions and injection structures. Although much of the deformation of the sandstone wisps appear to have been accomplished in a ductile manner, fractures, strike-slip, and normal shear planes are found within them resembling the web structures of cataclastic shear zones. Much of the earliest deformation appears to be of a soft-sediment nature. Generally, a set of NNW steeply dipping primary foliation tends to wrap round the clasts and wisps. Both the wisps and the foliations tend to be deformed in a ductile manner. The wisps are dragged along the foliations into 'Z'-shaped sigmoid and are cut by numerous strike-slip shear planes. Some of these wisps and clasts with transitional contact also have been cut by sub-perpendicular quartz veins, which in places are also deformed together with the foliations. These may indicate that the deformation continued into the partially lithified and lithfied stages.

Tectonic deformation

At Taman Bukit Bentong, numerous sub-vertical dextral shear planes have cut the sub-vertical foliations. Both the matrix and the wisps have been dragged into 'Z'-shaped asymmetry and the smaller clasts have been rotated clockwise. These features suggest that the earliest tectonic deformation occurred in a dextral strike-slip regime. Numerous N-S and NW-SE striking sub-vertical faults, dipping either east or west transected the olistostromes. These faults cut the sandstone into rhomboid shaped blocks. The presence of intensely developed sub-vertical faults associated with dextral shearing of the foliations is taken to indicate that the whole sequence have been deformed in a dextral transpressive regime.

In Taman Industri Bentong, in addition to the sub-vertical dextral strike-slip faults and shear-zones that deformed and folded the strata into steeply plunging folds, many later NNE striking sinistral strike-slip faults transects the sequence. Even later NE striking dextral strike-slip faults further transected these structures.

These features indicate that the olistostromes have undergone at least 3 faulting episodes. The first occurred in a dextral transpressive regime, the second gave rise to sinistral faults and the third are dextral strike-slip in character.

DISCUSSION

Depositional processes

The features found within the various olistostrome outcrops indicate that they are gravity flow deposits in which several types of mass transport were operative. A wide range of clast type and sizes ranging from pebbles to boulders, but lacking internal stratification and grading characterizes the olistostromes with diamictite or pebbly mudstone characteristics. These features suggest that the olistostromes originated by debris flow. The zone of stratal disruptions, characterized by elongate lenses, pull-apart and boudins which displays crude layering that is folded and faulted, originated as slides and slumps.

It is commonly found that the zone of stratal disruption grade upward into diamictites, suggesting that these diamictites almost certainly originated as slides and slumps. These evolved into debris flow deposits as the strata moved downslope from the upper slope, incorporating the other rock fragments and were further fragmented.

Stratigraphy of Bentong Area

The presence of schist and rounded serpentinite clasts and sheared conglomerate blocks in the olistostromes within the chert-argillite unit is taken to indicate that there was a phase of denudation and erosion before the deposition of the chert-argillite unit. This supports the interpretation that the chert-argillite unit is unconformably overlying the schists. The bedded cherts within the chert-argillite unit occur in several horizons intercalated with olistostromes and other lithologies. The bedded cherts contain radiolaria suggesting that the bedded chert-olistostrome association were deposited in a deep marine environment.

However, the olistostrome-sandstone/shale association shows a marked contrast in lithology and environment of deposition. The red matrix of some of the blocks in the olistostromes and the red nature of some of the layers intercalated with the olistostromes suggest that they were deposited in a more oxidizing environment. They are very shallow marine to continental sediments. The presence of deformed diamictites and olistostromal blocks within this olistostromes suggest that there was a phase of denudation and erosion before their deposition. The position of the red layers within the Bentong-Raub Zone stratigraphy is unknown but could possibly be unconformably overlying the olistostromes bedded chert association (chert-argillite unit). The association of sandstone and conglomerate with red matrix, shale and the occurrences of isolated limestone lenses seem similar to the lithologies found in the Permo-Triassic Raub-Bukit Koman area.

Depositional setting

The origin of the basin occupied by the olistostromes is a major issue. The olistostromes-bedded chert association is intercalated with deep-marine bedded cherts, turbidites, and volcaniclastics. The olistostromes contain such clasts as conglomerate, sandstones, limestones, shists, serpentinite, volcanics, and volcaniclastics, which are continental derived detritus. The bedded cherts are not associated with pillow basalts or pelagic sediments free from continental derived detritus. The deposition of the bedded chert is not continuous but always rapidly interrupted by olistostromes. No tectonic melanges are found associated with the olistostromes and bedded cherts. Moreover, these sediments were deposited on schists, which form the basement of the basin. These would indicate that the basin could be floored by continental crust.

The intercalation of the olistostrome with bedded cherts and turbidites with abundant volcaniclastics suggest that the olistostromes were deposited on the base of steep slopes or at the basin plains. The olistostromes occur in between and grade into undeformed strata. Their contacts are the typical conformable features of olistostromes. The association of synsedimentary normal faults and other extensional structures with these zones of stratal disruptions is an indicator that the triggering mechanism for the slides, slumps, debris flows and other mass transport processes must have been extensional faulting activities. No evidence of intrastratal movements between and within packages of unconsolidated or partly consolidated sediments along thrusts, typical of subduction zone melange is found.

These features are taken to indicate that sediments were deposited in a continuously and tectonically active basin that was undergoing intermittent uplifts and subsidence near a continental margin undergoing crustal extension. The evidences indicate that the deformations continued into the partially lithified and lithfied stages. The presence of numerous dextral strike-slip structures is taken to indicate that the basin was uplifted and inverted in a dextral transpressional regime.

The olistostrome-sandstone/shale association with red matrix exposures occur along isolated ridges within the terrain that define the chert-argillite unit. The olistostrome is characterized by stratal disruption along syndepositional extensional faults and deformation continued into the partial lithified, and lithified stages in a dextral transpressive regime. These features are taken to indicate that they occupied small isolated basins within the terrain of the chert-argillite unit. These small basins could possibly be sag or pull-apart basins along dextral strike-slip faults that uplifted and inverted the chert-argillite basin.

Tectonic implications

Evidences for deposition of the olistostromes and the bedded chert association in the Bentong-Raub area on the wide ocean floor is totally lacking. But there are numerous evidences for their deposition on a basin floor that is near to the continental margin in a basin that is undergoing crustal extension.

The basin could have been initiated by extensional faulting accompanied by intermittent normal and strike-slip faulting activities. During the Devonian to Permian, the turbidites, volcaniclastics and olistostromes could have been deposited during the short tectonically active phases and the bedded cherts during the long quiet periods in between the active phases. Tectonic activities would have been the triggering mechanism for the downslope gravity movements initiating the development of the olistostromes.

By Triassic, continued tectonic activities in a dextral

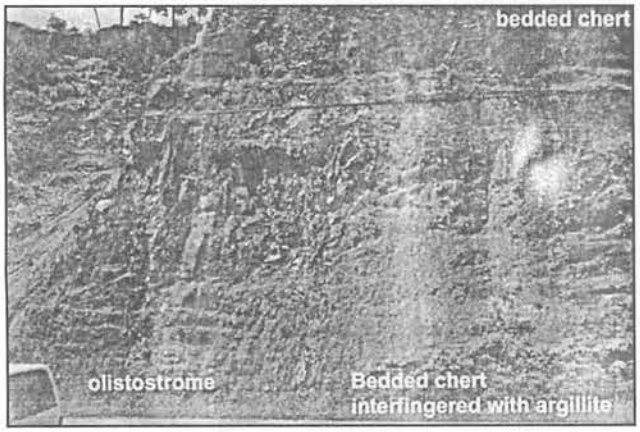

Figure 1: Photograph showing the intercalation between olistostromes (with angular, planar and sheeted megablocks) with sub-vertically bedded chert. Note the interfingering relation between the olistostromse and the bedded chert. Location: Near Cinta Manis.

Figure 2: Photograph showing the intercalation of olistostromes (with intraformational megablocks) with sandstone/shale layers with red matrix. Location: Taman Industri Bentong.

transpressive regime would initiate the uplift and deformation of the deep marine infillings resulting in the opening of small isolated sag or pull-apart basins along transtensional strands of the dextral transpressive fault zone. After a phase of denudation and erosion, the deposition of shallow to very shallow marine to continental sandstones and conglomerates followed within the small basins. This deposit, in turn undergoes stratal disruptions and downslope movements as a result of the continuos tectonic activities. At the same time, the Raub Red Beds were deposited along the margin of the Bentong-Raub Zone.

By late Triassic, these deposits would have been further tectonized in a dextral transpressive regime.

CONCLUSIONS

It is concluded that the chert-argillite unit was not deposited on the floor of a wide ocean, but in a basin that received abundant continental derived detritus, very near to the continental margin. The basin was inverted by dextral transcurrent movements that eventually resulted in the development of pull-apart basins along and within the Bentong-Raub Zone by Triassic. By Late Triassic, these deposits would have been further tectonized in a dextral transpressive regime.

REFERENCES

Chakraborthy, K.R. and Metcalfe, I., 1993. Occurrrences of diamictites in the Raub area- its possible extensions and tectonic implications. Geol. Soc. Malaysia Ann. Conf. Abstracts, *Warta geologi*, V13, p62-63

Haile, N. S., Stauffer, P. H., Krishnan, D., Lim, T. P. and Ong, G. B., 1977. Palaeozoic Red Beds and Radiolarian cherts: reinterpretation of their relationship in Bentong and Raub areas. *Bull. Geol. Soc. Malaysia*, 8, p 45-60

Hamilton, W., 1979. Tectonics of the Indonesian region, U.S. Geol. Surv. Prof. Pap. No. 1078,

Harbury, N.A., Jones, M.E., Audley-Charles, M.G., Metcalfe, I. and Mohamed, K.R., 1990. Structural evolution of Mesozoic Peninsular Malaysia. *Journal of the geological society of London*, Vol. 147, pp11-26

Hutchison, C.S., 1973. Tectonic evolution of Sundaland: a Phanerozoic synthesis. *GSM Bull.* 6: 61-86 [13 illus., 41 ref.]

Hutchison, C.S., 1977. Granite emplacement and tectonic subdivision of Peninsular Malaysia. *Geol. Soc. Malaysia Bull.*, 9, 187-208.

Hutchison, C.S., 1989. Geological Evolution of S.E. Asia. *Oxford Monograph on Geology and Geophysics* No. 12. Oxford Science Publications, Clarendon Press, 345p.

Khoo, T. T. and Tan, B.K., 1983. Geological evolution of Peninsular Malaysia.. *Proceedings Workshop on 'Stratigraphic corellation of Thailand and Malaysia' Hatyai Thailand* p 253-90

Metcalfe, I., 1988. Origin and assembly of south-east Asian continental terranes.in Audley-Charles, M.G. and Halam, A. (eds) *Gondwana and Tethys*. Geological Society special Publication, London,37. Pp79-100

Mitchell, A.H.G., 1981. Phanerozoic plate boundaries in Mainland S.E. Asia, the Himalayas, and Tibet. *Journal of the Geological Society of London*. 138, pp 109-122.

Mustaffa Kamal .S., 1994. Structures within the Bentong Suture Zone along Gua Musang - Cameron Highlands road. Abstract, *Warta Geologi*, 20(3): 232-233.

Mustaffa Kamal .S., 2000. The Mesozoic tectonics of Peninsular Malaysia - An overview. *Dyanamic straigraphy and tectonics of P. Malaysia, 3rd. seminar -The Mesozoic of Peninsular.* P106-126

Mustaffa Kamal Shuib and Abd. Hadi Abd. Rahman., 1999. A five fold stratigraphc and tectonic subdivision of Pen. Malaysia. *Dyanamic straigraphy and tectonics of P. Malaysia - Problems and issuea - A Thematic publication.* P38-63

Sengor, A.M.C., 1984. The Cimmerides of eastern asia: history of the eastern end of palaeo-tethys. *Memoires de la Societe geologique de France*, 147, p 139-167

Tan, B. K., 1984. The tectonic framework and evolution of the central Belt and its margin, P Malaysia. *Geological Soc. Malaysia Bull.* 17, p 307-22

Tan, B.K., 1994. Suture zones in Peninsular Malaysia and Thailand: implications for paleotectonic of Southeast. Journal of Southeast Asian Earth Science 13(3-5) , p 243-49

Tjia, H.D., 1988. Olistostrome in bentong area, Pahang. *Warta geologi* V13, p105-111

Tjia, H.D., 1989. The Bentong Suture Zone. *Proceedings of the Regional Conference on geology, Mineral and Hydrocarbon resources of Southeast Asia, GEOSEA 6, Jakarta July 1987*, p 73-85

Tjia, H.D. and Syed Sheikh, 1993. The Bentong suture zone in Ulu Kelantan, Peninsular malaysia IGCP 321 Gondwana dispersion and Asian Accretion, 3rd. International Symposium and Field excursion. Abstracts of papers p 70-71.