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Synsedimentary Tectonic Control of the Permo-Triassic Central Basin Sedimentation

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Abstract

The sediments in the Central basin can be divided into 2 depositional sequences. The first depositional sequence (Permian-Early Triassic) consists of continental sediments at its base that grade into shallow marine and then to deeper marine at the top. The sequence marks the opening of the basin. The second sequence (Middle Triassic to Late Triassic) begins with deep marine turbidites and volcaniclastics that grade into shallow marine sediments to the top. These sequences mark the rifting of the basin and then followed by the initiation of the gradual closure of the basin. Numerous direct evidences for syn-sedimentary tectonism are found within the strata of the Central Basins. These include slumps, syn-sedimentary normal and strike-slip faults, syn-sedimentary folds, and shale injection structures. The evidence that comes from these syndepositional structures is that sedimentation has been continuous with transcurernt fault movements. From the sedimentological and syndepositional structural characteristics, the Permo-Triassic Central Basin can be considered to have a graben-like configuration. The graben had a roughly N-S trend and is defined as follows: 1) The graben has its western and eastern margins as the Bentong-Raub Zone and the Lebir Fault Zone, respectively. 2) It has a shallow rapidly subsiding platform along the margins and the northern part. 3) It has a deep basinal area in the central and axial areas represented by the Semantan formation. 4) The transitional zone is defined as the area inboard of the basin characterized by intimate relations between volcanism, tectonism and sedimentation. The nature of the margin fault zones with steeply dipping faults that have the downthrown side into the basin and exhibiting dextral transpressive and transtensive character suggest that the basin is a strike-slip control basin.

Pengawalan Tektonik Sinsedimen Semasa Pengenapan Lembangan Tengah Perm-Trias

Abstrak

Sedimen di lembangan Tengah boleh dibahagikan kepada 2 jujukan endapan yang utama. Jujukan endapan yang pertama (Perm- Trias Awal) terdiri daripada sedimen kebenuaan didasarnya dan berubah kepada laut cetek dan seterusnya laut dalam di bahagian atas. Jujukan ini menunjukkan pembukaan lembangan. Jujukan yang kedua (Trias Tengah hingga Trias Akhir) bermula dari turbidit laut dalam dan volkanoklastik yang menggred kepada sedimen laut cetek ke atas. Ini menunjukkan pencapahan lembangan diikuti oleh perubahan gradual penutupan lembangan. Pelbagai bukti nyata untuk tektonik sinsedimen dijumpai disepanjang strata Lembangan Tengah. Ini termasuk nendatan, sinsedimen normal dan gelinciran jurus, lipatan sinsedimen dan struktur injeksi syal. Bukti daripada struktur sinendapan ini menunjukkan bahawa sedimentasi berterusan dengan tektonik mencapah. Berdasarkan sifat struktur daripada sedimentologi dan sinsedimen, Lembangan Tengah Permo-Trias dianggap berbentuk graben. Graben ini mempunyai arah U-S dan ditafsirkan seperti berikut: 1. Graben ini mempunyai pinggir barat dan timur yang terdiri daripada zon sesar Bentong-Raub dan zon sesar Lebir. 2. Ia mempunyai penurunan pentas cetek sepanjang pinggir serta dibahagian utara. 3. Ia mempunyai kawasan lembangan yang dalam dibahagian tengah dan kawasan paksi diwakili oleh Formasi Semantan. 4. Zon peralihan dikenalpasti sebagai bahagian lain selain daripada lembangan yang dicirikan oleh perhubungan rapat diantara volkanisme, tektonik dan sedimentasi. Sifat biasa pinggir zon sesar terdiri daripada kemiringan yang tajam yang mempunyai lemparan-turun ke arah lembangan dan menunjukkan pergerakan mencapah dan menumpu kekanan yang membuktikan bahawa lembangan ini dikawal oleh gelinciran jurus.

INTRODUCTION

The present Peninsular Malaysia's structural trend is said to be the result of tectonic development in the Mesozoic. Subduction-collision models assumed that the Mesozoic Central Basin of Peninsular Malaysia is a back-arc basin (Hutchison, 1973), a fore-arc basin (Mitchell, 1977; Sengor, 1986), or a fore-arc/intra-arc basin (Hutchison 1989). Extensional models assumed that the Central Basin is a central graben (Tan 1984, Khoo and Tan 1983) or a Triassic back-arc basin (Harbury *et al.*, 1990). Since the nature of the basin is disputed, the sedimentation, syndepositional structures, and volcanisms within and along the basin margins will be significant for elucidating the basin geometry and configuration.

SEDIMENTS OF THE CENTRAL BASINS

The sediments of the Central Basin illustrate the complete transgressive and regressive sequences that record the opening and closing of the basin. It records the transition from a seismically and tectonically active basin margin in the Permian to subsequent rifting in the Middle Triassic and finally its closure in the Late Triassic resulting in the development of an inter-montane basin from the latest Triassic to Cretaceous.

INTER-RELATIONSHIP BETWEEN SEDIMENTATION AND TECTONICS

The first depositional sequence (Permian-Early Triassic) consists of continental sediments at its base that grades into shallow marine and then to deeper marine at the top. The sequence marks the opening of the basin.

Sedimentation began with continental Raub Red Beds deposits and followed by a drastic upward change to limestones, pelites, volcaniclastics, volcanics, limestone conglomerates and diamictites. These indicate a sudden increase of subsidence rate and syn-sedimentary slope instability within the rifting area after a phase of denudation and erosion.

The diamictites and the coarse debris flow deposits found along the western and eastern margin of the basin represent imbricated debris flow closely related to the boundary faults. These deposits would also imply that the bounding faults must be steep with the downthrown side towards the basin. The diamictites and other coarse debris flow deposits found inboard of the basin, at the transition zone between the shallow and deep marine part, represent imbricated debris flow deposits closely related to intra-basinal faults.

It is found that the ratio of carbonate to pelitc rocks decreases from N to S and from the basin margins to the centre of the basin. Such a gradual change is indicative of a shallow platform facies along the basin margins and the N and deeper trough or rift deposits in the central region.

The second sequence (Middle Triassic to Late Triassic) begins with deep marine turbidites and volcaniclastics that grades into shallow marine sediments to the top. This sequence marks the rifting of the basin, followed by the initiation of the gradual closure of the basin.

In the central part of the basin, Middle Triassic rocks are characterized by a rapidly interbedded sequence of dark grey mudstone and tuffaceous mudstone intercalated with fine to coarse tuffs, minor conglomerates and some limestone lenses. These are predominantly slope deposits, deposited by turbidty current or debris flows. The proportion of pelites suddenly increases in the central part and northern part of the basin. However, in the south the increase in pelites is less distinct. This pattern indicates that the basin gets deeper in the centre and the north but still maintains shallow water conditions along the basin margins.

During the Late Triassic, the proportion of limestones, conglomerates, and thick beds increase everywhere in the basin except at the northeast. The whole basin gets shallower. At the northeastern part, the basin still retains its deep marine characteristic, indicating that the depocentre shifted to the north. The turbiditic character decreases. It gradually changes to shallow marine conditions. Volcaniclastics still predominates. These would suggest the gradual filling up of the basin and the slowing down of subsidence rate leading to the closure of the basin.

The third sequence (Latest Triassic to Cretaceous) overlies the second depositional sequence with a marked angular unconformity. It is predominantly continental in character but made up a very shallow marine sediments at its base. It marks the closure of the Permo-Triassic basin and the initiation of new successor basins.

SYNDEPOSITIONAL STRUCTURES IN THE PERMO-TRIASSIC STRATA

In the Late Permian to Early Triassic strata, the first recognizable structure to develop, apart from the commonly found slump structures, are listric normal faults found at Raub Town. Several listric normal faults exhibiting the typical growth fault geometry are found associated with dragged, tilted and truncated strata (intraformational unconformities) probably related to a deeper unexposed syndepositional fault. The syndepositional faults exhibit thicker layers in the hanging wall relative to the footwall. In one of the fault a layer of olistostromal materials fills the hanging wall. Unfaulted layers unconformably overlie the synkinematic strata.

Along the Bentong-Raub Zone, Late Permian to Triassic Red Beds and younger strata are in contact with Ordovician-Silurian Schist, and the Permo-Carboniferous Chert-argillite unit. Structural evidences suggest that the contact could be along a high-angle easterly dipping dextral strike-slip fault zone. The younger Red beds are found to the east of the fault on the hanging wall, i.e. younger rocks are on top of older rocks. It is interpreted that the Red beds were deposited on the downthrown side of a major fault with a significant normal displacement. This interpretation is consistent with the presence of numerous syndepositional faults in the Late Permian Raub Group strata.

Inboard of the basin, within the Middle Triassic to Late Triassic Semantan Formation strata along the Cinta Mani to Lanchang road, cuttings along the NNW trending Triassic conglomerate ridge exposes a thick sequence of conglomerate. The sub-vertical strata are predominantly made up of thick poorly sorted clast-supported conglomerates, intercalated with thinner beds of matrix supported conglomerates with minor thin coarse sandstone layers. The clasts are predominantly angular to tabular cherts. Several intraformational unconformities are recognized within the outcrop. These unconformities separated tilted strata associated with conjugate syndepositional faults and warping of strata into broad open folds. The sedimentological characteristics of the deposits suggest that the conglomerates were deposited by predominantly rock fall and debris flow processes. This would suggest that the conglomerates were deposited on or near to a major fault with a significant normal displacement. Continued subsidence would initiate the tilting and synsedimentary faulting and folding of the strata.

At Desa Bakti along the Karak-Temerloh road, near Lanchang, the volcaniclastic sequence has been folded into broad open to tight folds, exhibiting a typical concentric fold geometry with gentle westerly plunge. The syndepositional structures include slump folds, conjugate normal faults with graben geometry, negative flower structures, and shale injection structures.

The olistostomes are made up of predominantly very poorly sorted, angular to tabular, intraformational shale, volcaniclastics and sandstone clasts up to 2 m in diameter , in a volcaniclastic matrix. Some of the clasts still show layered characteristics. These features show that the clasts were derived from a very near source and that the debris flow processes were initiated by and deposited on the hanging wall of a nearby syndepositional sub-vertical fault striking northwesterly. This is supported by the presence a vertical syndepositional fault that separates a massive olistostome to the right from layered olistostromes to the left. The layers at the vicinity of the fault show open folds and warp and cut by sub-vertical northeasterly striking smaller faults exhibiting both normal and reverse displacements. These smaller faults further disrupted and tectonized the layers into stratal disrupted, small angular fault displaced blocks chaotically mixed with finer shale. Their displacements indicate that the bigger syndepositional fault is a strike-slip fault. The syndepositional characteristic of these faults and folds is well illustrated by the fact that the massive olistostromes to the right of the fault is relatively undeformed compared to the block to the left. These would suggest that the olistostromes were deposited while the strata was being tectonized.

The syndepositional structures found at Desa Bakti indicate that the strata were deposited on a continuously extending basin. The presence of syndepositional negative flower structure (tulip structure) is significant. In addition to the presence of strike-slip faults, it indicates that the basin extensional movements were accompanied by significant amount of strike-slip displacements. Thus, the sediments were deposited on a transtensional setting.

The Middle to late Triassic strata of the central basin contained 2 well-known biofacies: *Myophoria* and *Daonella* facies. From the distribution of both biofacies, Khoo (1993) deduced that the Middle to Late Triassic sea was deeper in South Kelantan and Central Pahang with *Daonella* biofacies, but deeper in North Pahang and South Pahang-Johore where *Myophoria* occur. The distribution of these two facies indicat that the Middle to Late Triassic seafloor did not always become deeper towards the centre of the basin. A N-S profile of the sea floor will appear to be wavy with two 'deeps' in between a 'high' in North Pahang and an extensive shallow shelf to the South in Johore.

These shallow-deep relationships can be governed by faulting of the seafloor. These faults would be oriented E-W or ENE-SSW, at a high angle to the bounding basin margin faults. In this scenario these faults could probably be normal or even strike-slip faults as a result of movements along the bounding faults. These faults may have played an important part by moving and accentuating the depocentres as well as creating major reliefs on the basin floor, facilitating the deposition of rockfall and debris flow deposits.

The syndepositional faults along the basin margin and inboard of the Permo-Triassic Central Basin revealed continued tectonic activities. The association of these structures with acid volcanic and volcaniclastic sediments reflects deep-seated tectonism. The synsedimentary basin margin fault with normal downthrow and significant dextral strike-slip component accompanied by similar faulting activities inboard of the basin support this interpretation.

INTER-RELATIONSHIP BETWEEN VOLCANISM AND TECTONICS

Extensive tracts of volcaniclastics interbedded with limestone occur along the basin margins. Here large limestone blocks enveloped by shale and siltstone matrix characterize the olistostromes that are intercalated with limestones and volcaniclastics. In the central part of the basin at Kg. Awah, andesitic rocks are associated with fossiliferous limestones, where limestone occurs as blocks in the andesite.

The intercalations of volcanics and volcaniclastics with diamictites and limestones along the basin margins suggest a strong correlation between volcanic activities, basin margin faulting and the changing subsidence rate. Volcaniclastics and volcanics tend to predominate in the axial and central part of the basin and slumping is common, indicating that the basin is deep seated and the deepening of the basin was the result of intra-basinal faulting.

The acid volcanics that are found are consistent with continental involvement during tectonic activities. This is also consistent with the geophysical data of Loke *et al.* (1983) where the Central Belt was suggested to have a thin continental crust. This would suggest that the continental crust beneath the Central basin had been thinned and extended.

BASIN MARGIN FAULTS

The boundaries of the Central basins are taken to be the Bentong-Raub Line to the west and the Lebir fault Zone to the east.

The Bentong-Raub Line

The structures found within the Bentong-Raub Zone are generally high-angle reverse faults and strike-slip faults

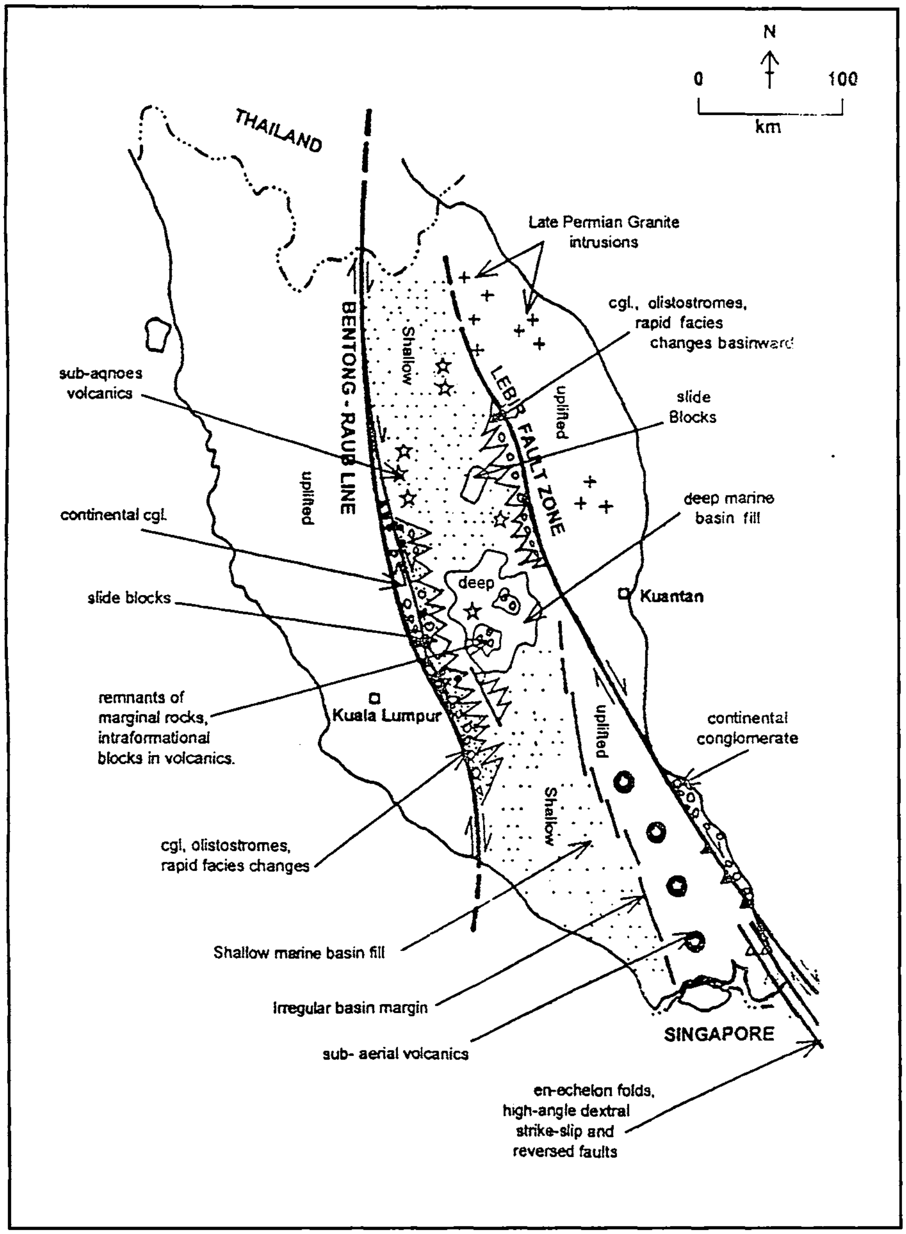

Figure 1: A sketch map showing the schematic distribution of the various depositional and structural elements found in the Central Basin, illustrating the graben-like configuration at the basin initiation stage.

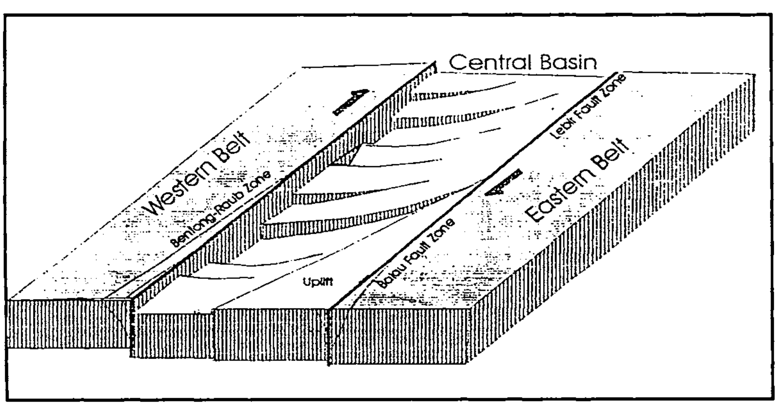

Figure 2: A pull-apart basin model for the Permo-Triassic Central Basin.

in low to very low-grade metamorphic conditions. The structures exhibit none of the typical characteristics of collisional suture zone such as low-angle thrusts, low-angle regional scale decollement and high-grade metamorphic (high-pressure metamorphism). These are taken to indicate that the dominant deformations occur in a dextral transpressive regime.

The Lebir Fault Zone

Mustaffa and Tajul (1999) reported that the Permo-carboniferous strata of SE Johore have undergone dextral transpressional deformations along the Balau fault Zone. This fault zone can be traced right into the Lebir Fault Zone to the north. They proposed that the Lebir fault Zone must have been a dextral strike-slip fault in the Permo-Triassic times and have undergone several reactivations later.

A PALAEOGEOGRAPHIC-GEODYNAMIC MODEL

From the above sedimentological and structural characteristics, the Permo-Triassic basin can be considered to have a graben-like configuration (Figure 1). The graben has a roughly N-S trend and is defined as follows:

- The graben has its western and eastern margins as the Bentong-Raub Zone and the Lebir Fault Zone, respectively.
- It has a shallow rapidly subsiding platform along the margins and the northern part.
- It has a deep basinal area in the central and axial areas represented by the Semantan formation.
- The transitional zone is defined as the area inboard of the basin characterized by intimate relations between volcanism, tectonism and sedimentations.
- The nature of the margin fault zones with steeply dipping faults that have the downthrow side into the basin and exhibiting dextral transpressive and transtensive character suggest that the basin is a strike-slip control basin i.e. a pull-apart basin (Figure 2).

TECTONIC EVOLUTION

During the Permo-Triassic time, the evolution of the Central basin of Peninsular Malaysia was the consequence of significant strike-slip displacements along the basin margin fault zones. The significant strike-slip movements leading to dextral transpressive deformation along the Bentong-Raub Zone and the Lebir Fault Zone lead to uplift of the bounding blocks flanking the Central Basin. At the same time the region in between the bounding fault zones underwent rapid subsidence.

The Permo-Triassic sediments and associated syn-sedimentary structures characterized the progressive opening of the basin. The Middle to Late Triassic sediments and syn-sedimentary structures testify to the rapid rifting and subsidence of the basin, during continuos dextral strike-slip motion. Transtension gave way to transpressional movements by Late Triassic, resulting in the gradual filling and finally the closure and inversion of the Triassic basin.

Continued strike-slip motions resulted in the uplift of the marine sediments accompanied by the opening of several small intermontane basins adjacent to the Lebir Fault Zone. Coarse continental sediments were deposited in the rapidly subsiding basins.

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