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Mélange on the Jerudong Line, Brunei Darussalam, and its regional significance

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Abstract: Southwards along the Jerudong Line, on the hillside east of the road between Pangkalan Batu and Kampong Masin, there is a zone of distinctive hummocky topography in contrast to the usual persistent sandstone strike ridges of the Berakas and Belait synclines. Active construction near Bukit Masin has revealed this topography to have resulted from disrupted stratigraphy. Convoluted and rolled blocks up to 3 m diameter of sandstone are embedded in Setap Shale. The outcrops are interpreted as a large olistostrome deposit. During deposition of the Belait Formation, the Jerudong Line was a submarine continental slope down which the yet unconsolidated sands slumped westwards into the deeper water part of the Baram Delta.

In a regional context, this Late Miocene continental slope extended northwards from the Jerudong Line, along the Morris Fault, curving northeastwards along the transition between the Inboard and Outboard belts of offshore Sabah. Slump scars characterize the length of this continental slope. Conventionally it is referred to as a wrench fault (Morris Fault and Jerudong Line) with 30 to 40 km of left-lateral post depositional displacement, based on offset of the interpreted palaeo-environments across the fault. These palaeo-environments have not been displaced and persist in their original relative depositional positions. The displacement is apparent because of considerably deeper water to the west of the Jerudong-Morris Fault continental slope. There are also no geological indicators along the Jerudong Line to prove wrench displacement.

INTRODUCTION

The geomorphology of Brunei Darussalam is dominated by persistent sandstone ridges with intervening mudstone valleys, both east of the Jerudong Line in the north-plunging Berakas Syncline and west of it in the Belait Syncline (Wilford, 1961). However, due south of Jerudong Hill, in the vicinity of Kampong Masin, Kampong Parit, and Kampong Pengkalan Batu (Fig. 1), there is a district of distinctive hummocky topography, composed of impersistent hills near the upper reaches of the Brunei River. The reason for this distinctive topography has until now remained uncertain. Brunei Darussalam is experiencing an economic boom and nearly every civil servant is building his own hillside house with readily available government loans. During my visit in April 1993, the hillside east of Kampong Parit (Fig. 1) was being extensively cleared for building, revealing the cause of the distinctive hummocky topography along the southern extrapolation of the Jerudong Line before it crosses the international border into Sarawak.

NATURE OF THE MÉLANGE

The western slope of the hill, between Kampong Masin and Kampong Pengkalan Batu, is of mudstone (Setap Shale) containing numerous medium to fine grained sandstone blocks. The blocks commonly range in diameter from 1 to 3 meters. They are characteristically rounded to ellipsoidal (Fig. 2). Closer inspection reveals that the rounding reflects the internal sandstone bedding, which is rolled-up and complexly convoluted (somewhat like a Swiss roll).

The blocks show no internal faulting nor are their surfaces fault planes, and their folding complexity (Fig. 2) and rounding, has to be interpreted as resulting from soft-sediment deformation, while yet wet and unlithified. The obvious conclusion is that the palaeo-environment was a submarine scarp down which the sandstone slumped and rolled into large 'snow-ball' clasts. The matrix of the submarine slide was mud (Setap Shale), and the resulting olistostrome slid downslope into deeper water.

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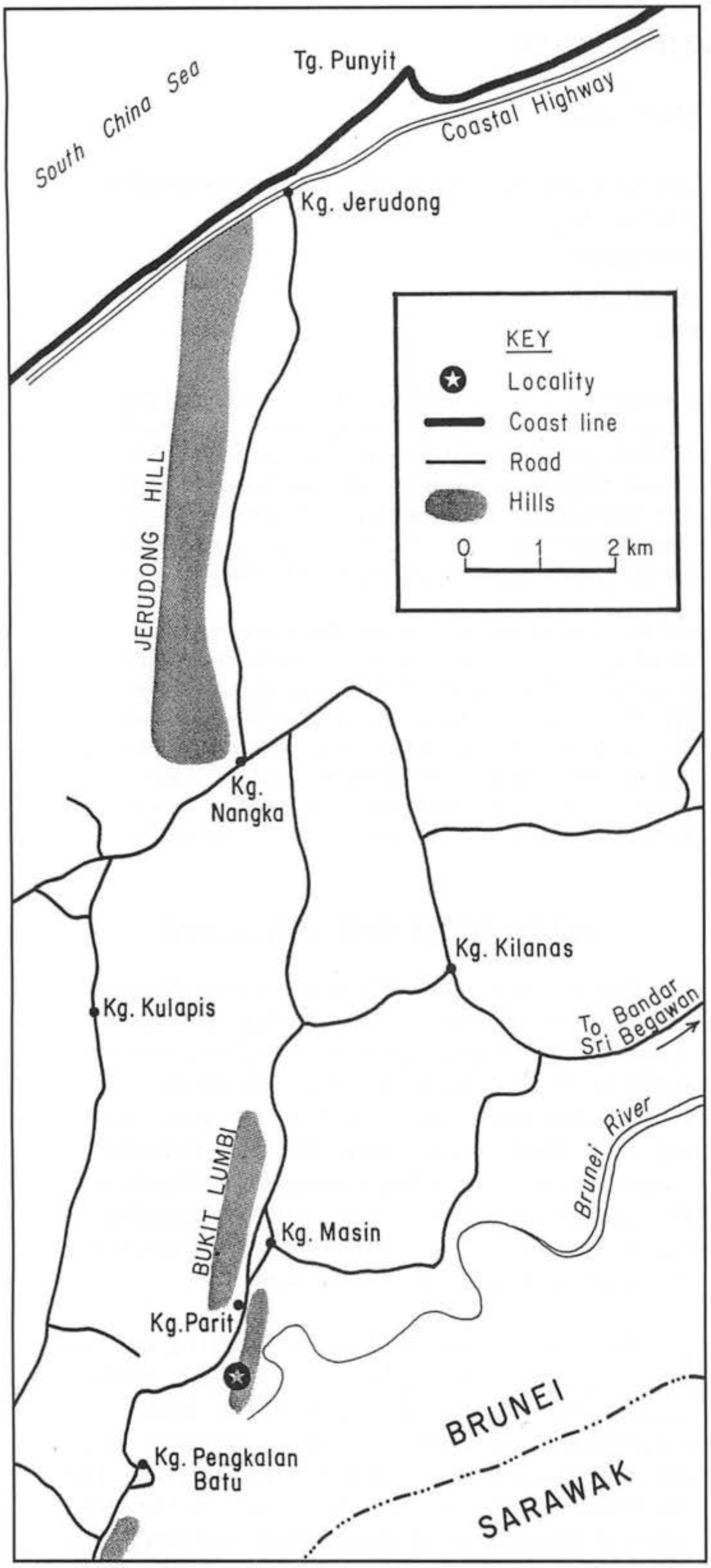

Figure 1. Sketch map of part of Brunei Darussalam, showing the mélange locality on the hillside between Kampong Masin and Pengkalan Batu in a district of distinctive hummocky topography south of Jerudong Hill.

REGIONAL EXTENT OF THE SLUMPS

Slump scars have been identified and described widely along approximately 150 km of the 250 km long Late Miocene offshore shelf edge (Levell and Kasumajaya, 1985). The shelf edge can be identified as the transition zone between the Inboard and Outboard belts (Tan and Lamy, 1990), extending southwestwards as the Morris Fault, and extrapolating onshore as the Jerudong Line (Fig. 3). Individual slump scars have been identified on seismic records and drilled into at a few localities, where their matrix has been shown to be of mudstone. The slump scar dimensions have a width of around 500 m, a down-slope extent of around 2 km, and they rest on a slope angle of 20 to 27°, representing an individual volume of 1.5 to 5.2 km^3. These slumps down the shelf edge had the potential to feed turbidite fans in the deeper sea beyond the slope, with a good example in the Tembungo Field. To the east of the Samarang Field, the Morris Fault has a downthrow to the west of as much as 1.1 km at the level of the Upper Miocene Unconformity. It has continued to be a fault scarp (continental slope) with the Pliocene sedimentary section west of the fault being approximately twice as thick as that east of the fault (Levell and Kasumajaya, 1985).

REGIONAL CONSIDERATIONS

Spectacular episodic uplift of the region east of the Jerudong Line, and southeast of the Morris Fault and transition zone (Fig. 3) is indicated by several unconformity surfaces (Levell, 1987; Tan and Lamy, 1990). The unconformities extended quite close to the continental slope, so that the fluvial system readily brought sands to the edge of the narrow continental shelf to spill over the slope into the bathyal area as slumps, such as the one described in this paper. The persistence of outer neritic to bathyal marine conditions west of the Jerudong Line and northwest of the Morris Fault and transition zone has been well documented by Rice-Oxley (1991). The existence of this prominent continental slope close to the coastline has allowed reservoir sands to be dumped into a deeper marine environment which was rich in good source rocks, creating an ideal situation for an oil basin. We know this basin as the Baram Delta, the most prolific part of which lies west of the Jerudong Line and Morris Fault.

East of the Jerudong Line and southeast of the Morris Fault and transition zone, the fluvio-marine Belait Formation rests unconformably on a land surface of folded and metamorphosed Temburong Formation, including the "Older Setap Shale" of

Figure 2. Photographs of two of the many rolled and convoluted sandstone blocks in the mudstone matrix mélange of the locality shown in Figure 1.

the Temburong District, seen east of Bangar as quartz-veined phyllite (James, 1984). Farther east this land surface must also have included outcrops of the Crocker Formation. By contrast, west of the Jerudong Line, there is conformity between the Setap Shale and the deeper water Miri Formation. The map of Wilford (1961) illustrates the problem of distinguishing the shallow marine to fluvial Belait Formation from the holomarine Miri Formation. Outcrops to the west of the Jerudong Hill should be called Miri Formation, being distinctly holomarine, while to the east of the Hill they can be confidently ascribed to the Belait Formation.

Because the Jerudong Line was a continental slope, with deep marine conditions on the west and land on the east (Fig. 4), the close proximity of an outer neritic palaeo-environment west of the Line with a coastal to fluvio-marine environment east of the Line existed during deposition of the Late Miocene Belait and Miri Formations. Accordingly it is wrong for James (1984) and Hazebroek *et al.* (1992) to have inferred a 30 to 40 km left-lateral subsequent wrench displacement across the Jerudong Line. Such a displacement is only apparent and was a direct result of the contrast in water depth across the Line. No geological features,

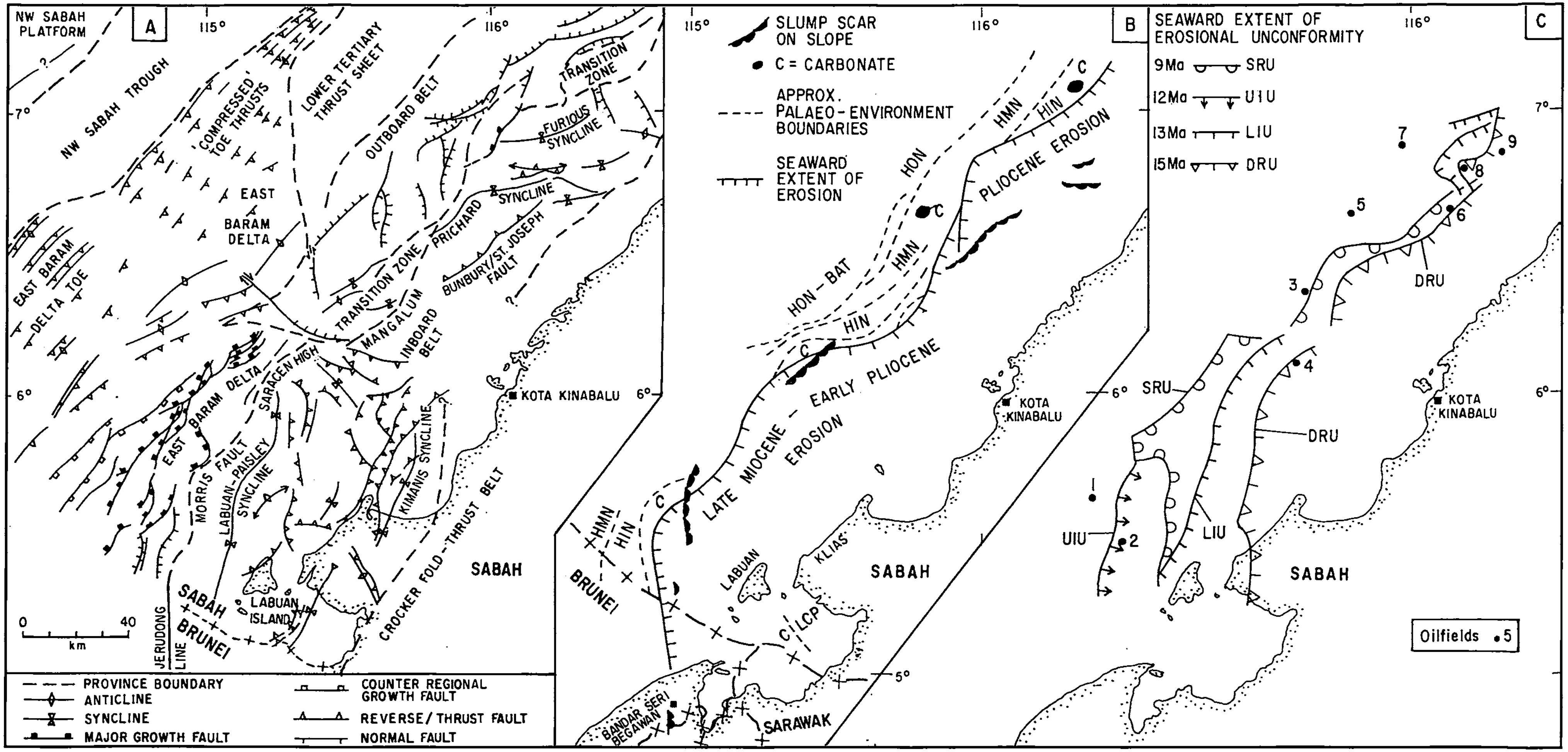

Figure 3. Mélanges, or slump scars typify the Late Miocene continental slope, known variously as the Jerudong Line, Morris Fault, and transition zone between the Inboard and Outboard belts of NW Sabah (A, after Tan and Lamy, 1990). Position of the late Miocene slump scars on the continental slope and depositional palaeo-environments (B, after Levell and Kasumajaya, 1985 and Rice-Oxley, 1991). H = holomarine, O = outer, M = middle, I = inner, N = neritic, C = coastal, BAT = bathyal. The positions of the continental slope are determined by various uplift episodes of the Crocker Ranges, resulting in prominent offshore unconformities (C, after Levell, 1987). U = unconformity, R = regional, D = deep, S = shallow, I = intermediate, L = lower, U = upper. Names of selected oilfields: 1 = Samarang, 2 = Glayzer, 3 = Erb West, 4 = Ketam, 5 = Tembungo, 6 = St Joseph, 7 = SW Emerald, 8 = Furious, 9 = Barton.

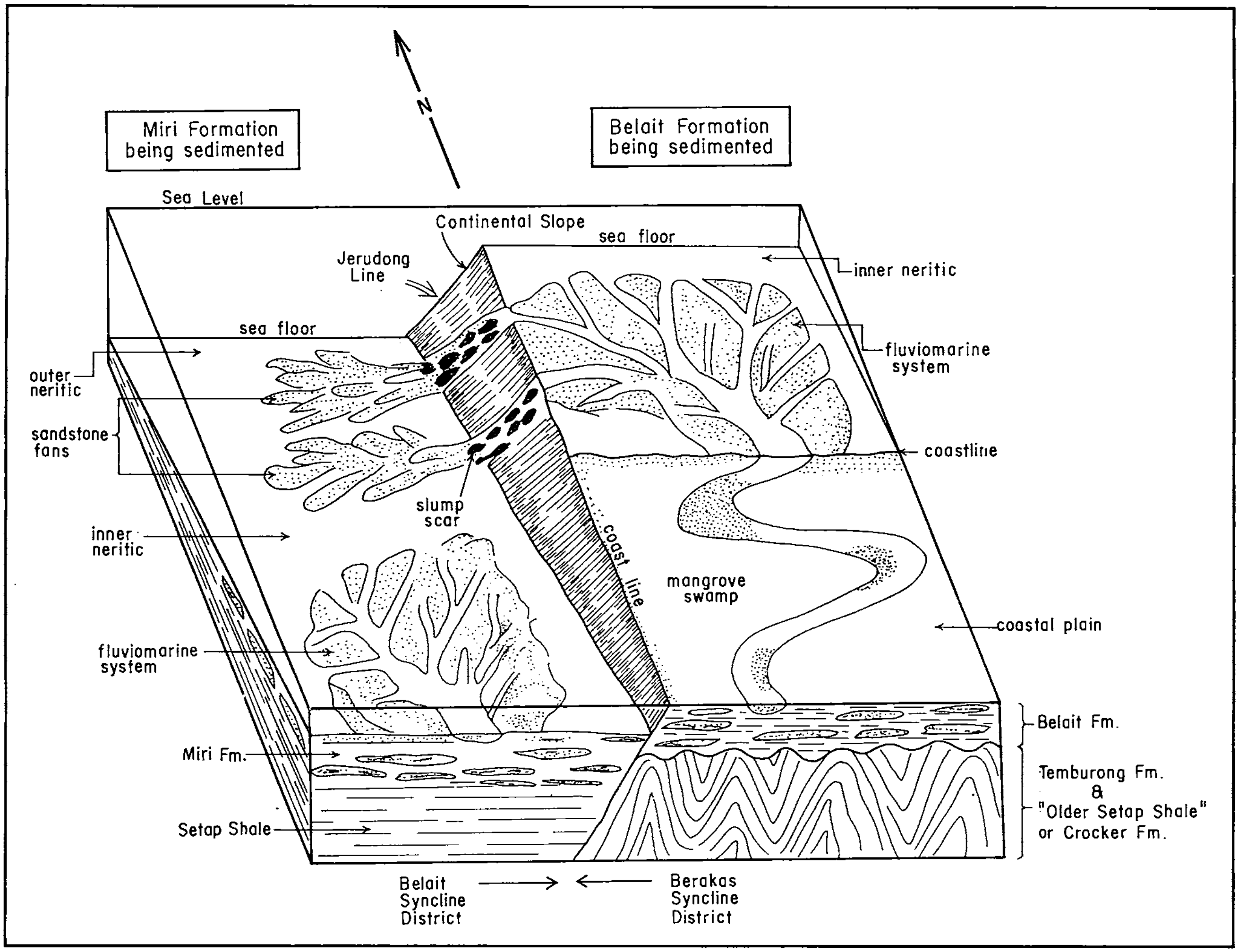

Figure 4. Sketch of the palaeo-environment during deposition of the Late Miocene Belait and Miri formations in Brunei Darussalam, looking north. The Jerudong Line is envisioned as a continental slope, east of which the Temburong and Crocker formations formed a land surface not far distant from the Jerudong Line and were unconformably overlain by the Belait Formation. Deeper water prevailed west of the Jerudong Line.

such as transverse folds, can be found in the field which would indicate wrench faulting along the Jerudong Line since deposition of the Belait and Miri Formations. All Jerudong Line features can be attributed to E-W compression.

If the continental slope represented by the Jerudong Line, Morris Fault, and the transition zone (Fig. 3) is to be interpreted as a major wrench fault system, then activity on this fault can be inferred to have ceased in the Middle Miocene.

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