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The Bukit Arang Tertiary Basin in Chuping, Perlis

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Abstract: The Bukit Arang Tertiary Basin extends from the Perlis-Thailand border at Bukit Arang-Bukit Tinggi southwards to the Chuping area of eastern Perlis. It is part of the larger Sadao Basin located across the border in Thailand. Another southern extension of this main basin is found in the vicinity of Bukit Kayu Hitam, north of Changlun, just a few kilometres to the east across the interstate boundary in Kedah. Based on sparse geological evidence, the original postulated areal extent of the basin within Perlis was approximately 26 square kilometres with a minimum thickness of about 200 m. Recent gravity data indicate that it is at least twice as large in area and up to 800 m thick.

The sediments consist of loose and partially consolidated gravels, sands, silts and clays of lacustrine and fluvio-deltaic origin of Late Tertiary age. They are underlain by shales, mudstones and siltstones of the Kubang Pasu Formation of Carboniferous age. Geophysical evidence suggests that this basement is uneven, with a ridge-like feature in a north-south orientation. The basement appears to be faulted as well with WNW-ESE and approximately N-S strikes.

Stratigraphically these Tertiary Beds can be correlated with the very similar strata of the Batu Arang Tertiary Basin of Late Oligocene to Late Miocene age in Selangor and with other Tertiary basins of similar lithology elsewhere in the peninsula.

The Bukit Arang Tertiary Beds contain several seams of low quality coal of not much economic significance. Good quality clay of possible commercial value is also present. There are traces of oil in the shales and small amounts of cassiterite have been reported from the sands. However, the main economic potential of these Tertiary Beds lies in their aquifers which are currently being exploited by the sugarcane plantations covering a large part of the area.

INTRODUCTION

Tertiary sedimentary deposits in Peninsular Malaysia are found in a number of small basins scattered around the western portion of the peninsula. With the exception of the Batu Arang Tertiary Basin in Selangor which was mined for coal, they have not attracted much attention. In contrast, the Tertiary basins offshore have been extensively explored for their hydrocarbon potential.

In Perlis the Bukit Arang Tertiary Basin was inferred (Jones, 1978) to extend in an approximately southwesterly direction from the Thai border at Bukit Arang-Bukit Tinggi towards Chuping (Fig. 1). It was estimated to be about 8 km long and 3.5 km wide, in the shape of a lobe, tapering towards the southwest and widening towards the Thai border, with an area of approximately 26 square kilometres. Its eastern boundary is within 3 to 4 km of the Kedah border to the east. A very similar outcrop occurs in Kedah at the Thai border in the vicinity of Bukit Kayu Hitam, north of Changlun. This appears to be roughly semi-circular in shape with an area of approximately 12 square kilometres (Jones, 1978). Both outcrops within Malaysian territory are most probably southern extensions of the much larger Sadao Basin (Chaodumrong *et al.*, 1983) located across the border in Thailand.

Historically, the presence of lignite-bearing sedimentary strata in Perlis was first reported by Scrivenor (1913) from the pits dug near Bukit Arang and Bukit Tinggi at the Thai border. They were named the "Bukit Arang Coal Beds". The term "Arau Formation" was proposed by Alexander *et al.* (1959) for all the Tertiary basin deposits in Peninsular Malaysia as a group. Willbourn (1926) described the results of three boreholes drilled in the vicinity of Bukit Arang by the Federated Malay States Railways Department between 1919 and 1921. The results of deep exploratory drilling by the Geological Survey Department in 1941, which was terminated abruptly by the Japanese invasion, was reported by Alexander (1947). A brief summary of all the known Tertiary deposits was given by Renwick and Rishworth (1966). Stauffer (1973) provided an account of what was known about the geology of the sediments up to then. A much more detailed description of the Bukit Arang deposits was published by Jones (1978).

A few boreholes, mainly for hydrological investigations, had been drilled in the basin and its vicinity at various times by the Geological Survey Department, the Drainage and Irrigation Department and the Public Works Department.

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Aw (1982) reported on investigations for coal in the area. A comprehensive geophysical study of the hydrogeology of Perlis was conducted by Arafin (1988). The delineation of the basin using the gravity method was described by Arafin *et al.* (1987).

GENERAL GEOLOGY

The general lack of surface exposures of the Bukit Arang Tertiary Beds presents practical problems in field mapping. This is due essentially to the loose and semi-consolidated nature of the deposits. They form low undulating country averaging 60 m above mean sea level with scattered low hillocks of up to 117 m in elevation, especially along the Perlis-Thailand border. The extent of these Tertiary Beds had been inferred from sparse information obtained from pits and drill holes, a few road cuts and scattered boulder beds on the surface. Generally the higher ground consists of gravels whilst clays constitute the lower ground within the stream valleys (Jones, 1978). The scrub vegetation originally covering the area has largely been replaced by commercial sugarcane plantations.

The partially consolidated and loose sediments of the basin consist predominantly of plastic clays of varied colouration. In addition shale, sandy clay, loose sand, feldspathic grit, gravel and poorly sorted boulder beds are found (Jones, 1978). Thin seams of lignite have been reported from various depths throughout the sedimentary section penetrated by boreholes (Willbourn, 1926 and Alexander, 1947). These are generally only about 15 to 30 cm thick. Bands of stiff clays up to 8 m in thickness, with colours ranging from chocolate-brown through light grey, black and green to white,

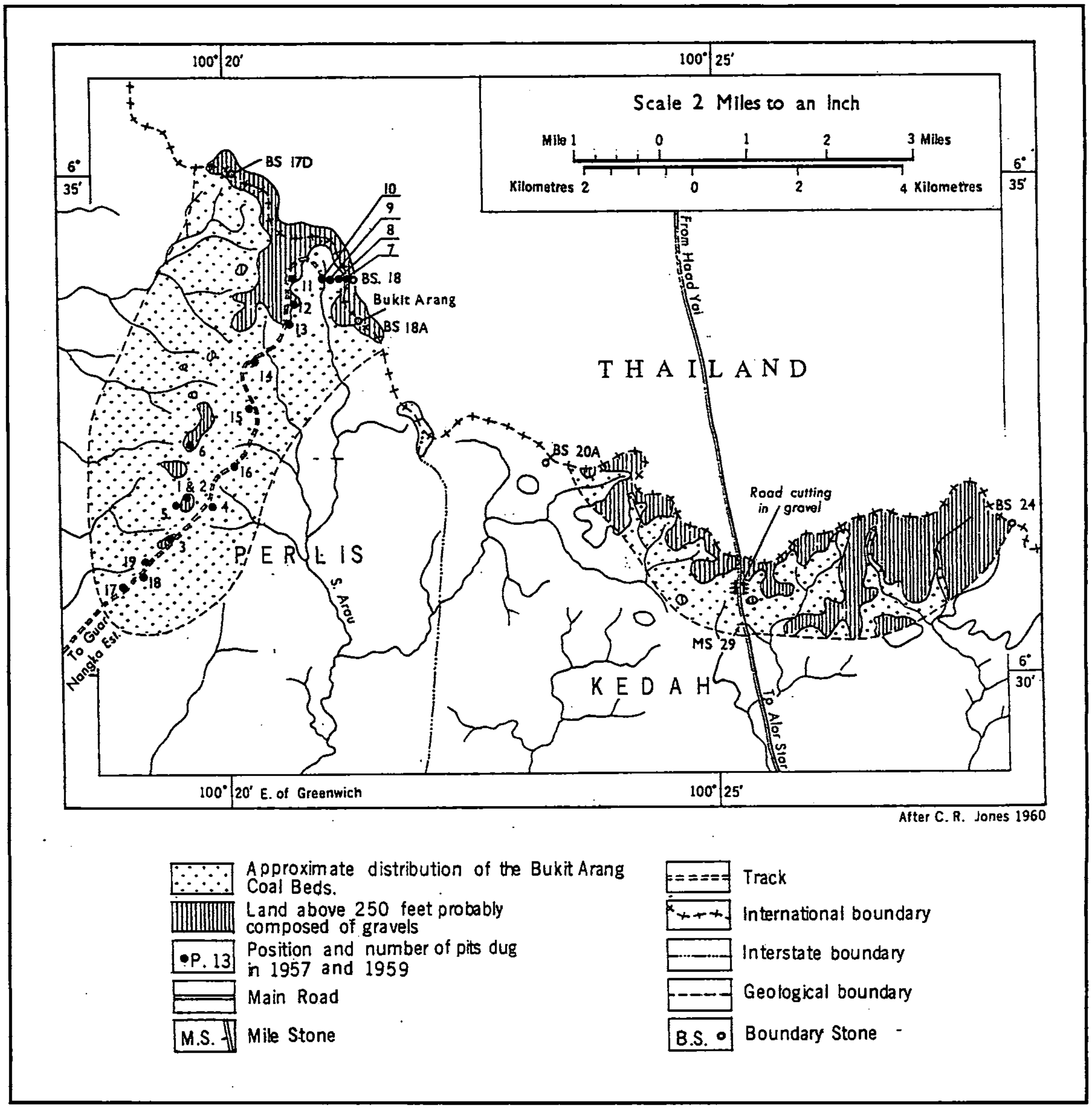

Figure 1. The Bukit Arang Tertiary Basin (after Jones, 1978).

were encountered in pits and boreholes. Small amounts of oil were also found in the shales, consistent with the reported presence of some very low-grade oil shales in the main Sadao Basin across the border in Thailand (Jones, 1978).

Near the surface the sediments tend to be poorly sorted and poorly bedded, forming lenticular or wedge-shaped bodies especially of gravel. These gravelly deposits predominate on the higher ground forming the low poorly-defined watershed at the Thai border. The well rounded waterworn boulders have a range of sizes up to 30 cm or more in diameter. Most of them consist of brown or grey quartzite, white vein quartz, some dark coloured cherty rock and occasional weathered granite. The presence of quartz-biotite hornfels and granite pebbles indicate their probable provenance in the extensions of the Sintok granite in southern Thailand. Some cassiterite and chiastolite have been reported from the sands and gravels (Jones, 1978).

Geological evidence of the minimum thickness of these Tertiary deposits was provided by the 1941 borehole which had to be abandoned at 180 m (600 feet) while still within the sediments (Alexander, 1947). Drilling in the Sadao Basin on the Thai side of the border indicated a thickness in excess of 300 m in the western subbasin and much shallower deposits in the eastern subbasin (Chaodumrong *et al.*, 1983). Gravity modelling of the Bukit Arang Tertiary Beds suggested a thickness of up to 800 m (Arafin *et al.*, 1987).

No fossil evidence of age has been recorded in the Bukit Arang Basin. However, the similarity of the general lithology and the coal seams to the Batu Arang Coal Beds in Selangor suggested a Late Tertiary age. Some fragments of gastropods and bivalves were reported from the clay beds in the adjacent Sadao Basin in Thailand but no age determination was done (Ukakimapan *et al.*, 1983).

Jones (1978) reported the results of a programme of digging pits up to 6 m deep into the sediments in an attempt to further delineate the deposits. The strata dip fairly uniformly to the east at about 10° generally, but greater dips of up to 45° were also recorded. Sedimentary structures, especially current bedding, indicate a deltaic or fluviatile environment. Abundant gravels with well rounded boulders were found. Locally, estuarine or lacustrine environments were indicated by the presence of narrow sinuous bands of clay in the topographic lows. All these suggest that this basin was a marginal facies to the larger lacustrine basin across the Thai border.

In comparison, this Sadao Basin north of the border covers more than 200 square kilometres. It consists of two smaller basins divided by a ridge of Carboniferous rocks. Lithologically they are very similar to the Tertiary Beds in Bukit Arang (Chaodumrong *et al.*, 1983).

STRATIGRAPHIC CORRELATION

The Tertiary deposits at Bukit Arang lie unconformably on the Carboniferous Kubang Pasu Formation which consists mainly of shales, siltstones and mudstones (Jones, 1978). It is highly probable that this outcrop in Perlis, together with the similar one around Bukit Kayu Hitam a few kilometres to the east in Kedah, are subbasins or southern extensions of the main Sadao basin in Thailand. There the Tertiary beds have also been found to lie unconformably on a Carboniferous basement. They were deposited in fluvial to lacustrine environments with pronounced changes in facies (Chaodumrong *et al.*, 1983).

Due to the marked similarities in the characteristics of the coal seams and the general lithology between the Bukit Arang deposits and the Batu Arang Coal Beds in Selangor, they have been assumed to be stratigraphically correlated. A Late Miocene age was suggested by Roe (1953). Mahendran *et al.* (1991) reported that palynological studies give a Late Oligocene to Early Miocene age for the lower coal seam and a Late Miocene age for the upper coal seam in Batu Arang. Correlation with other very similar basins in the peninsula (Stauffer, 1973 and Suntharalingam, 1983) and in Thailand (Gibling and Ratanasthien, 1980 and Chaodumrong *et al.*, 1983) also suggests a Middle to Late Tertiary age.

GEOPHYSICAL INVESTIGATIONS

Gravity data (Fig. 2) show that the width of the basin is at least 6 km, twice the original width inferred by Jones (1978). The long axis of the basin is approximately north-south rather than NE-SW as originally mapped. Two-dimensional modelling of the gravity data indicates depths of up to 800 m (Fig. 3). The basement appears to be uneven, deepening slightly towards the east and abruptly to the south. A basement ridge (Figs. 2 and 4) with a north-south strike runs down the middle of the northern half of the basin (Arafin *et al.*, 1987).

A relook at the two-dimensional models (Fig. 3) reveals that the boundaries of the basin consist of rather steep and abrupt margins. This suggests that they are very likely to be fault-controlled.

Upon closer examination of the Bouguer gravity contour map (Fig. 2) it becomes obvious that the basin extends a considerable distance beyond the southernmost gravity profile (Profile 6). This makes the length of the basin, in the north-south direction,

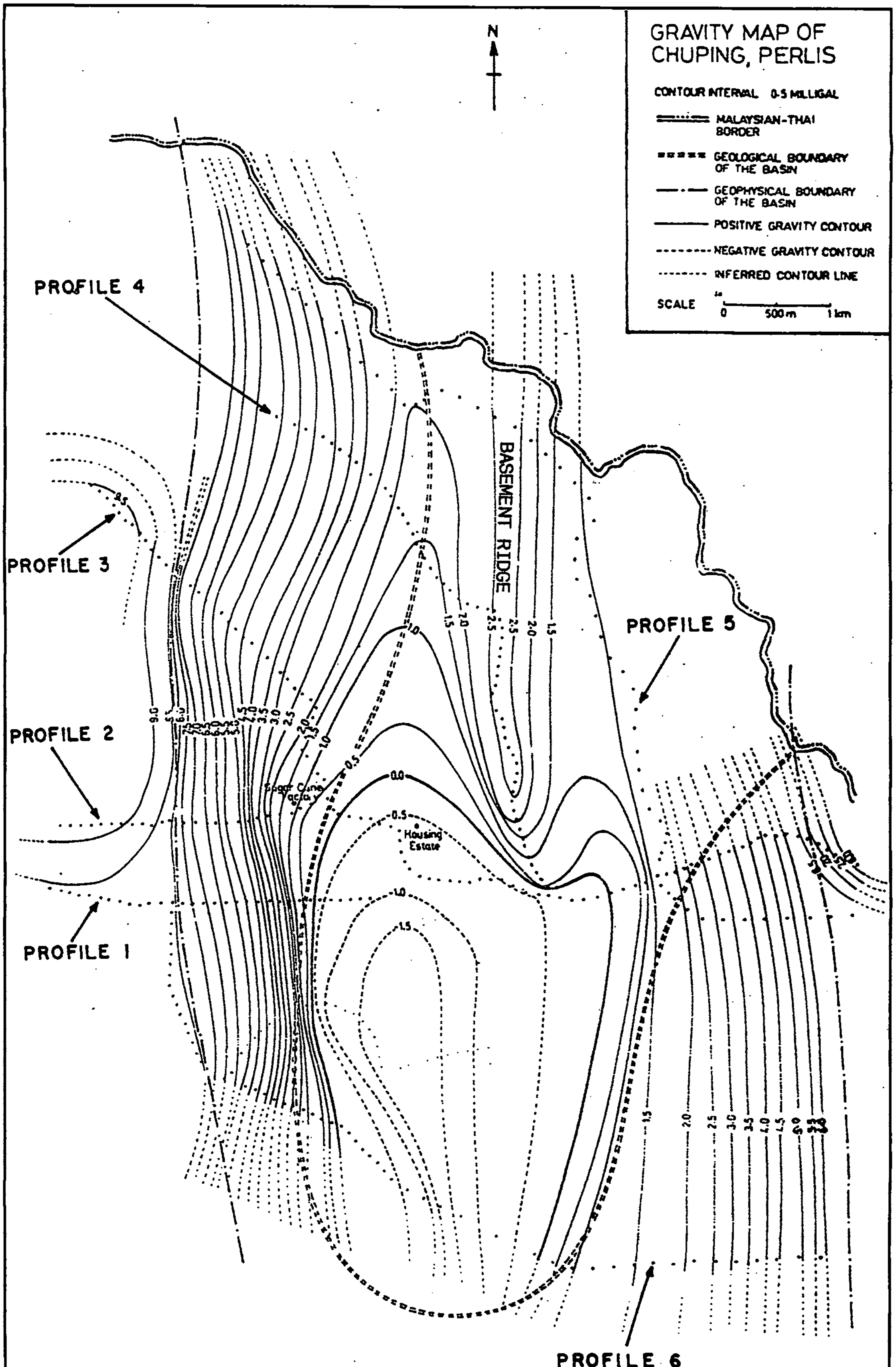

Figure 2. Bouguer Gravity Contour Map of the Bukit Arang Tertiary Basin (after Arafin *et al.*, 1987).

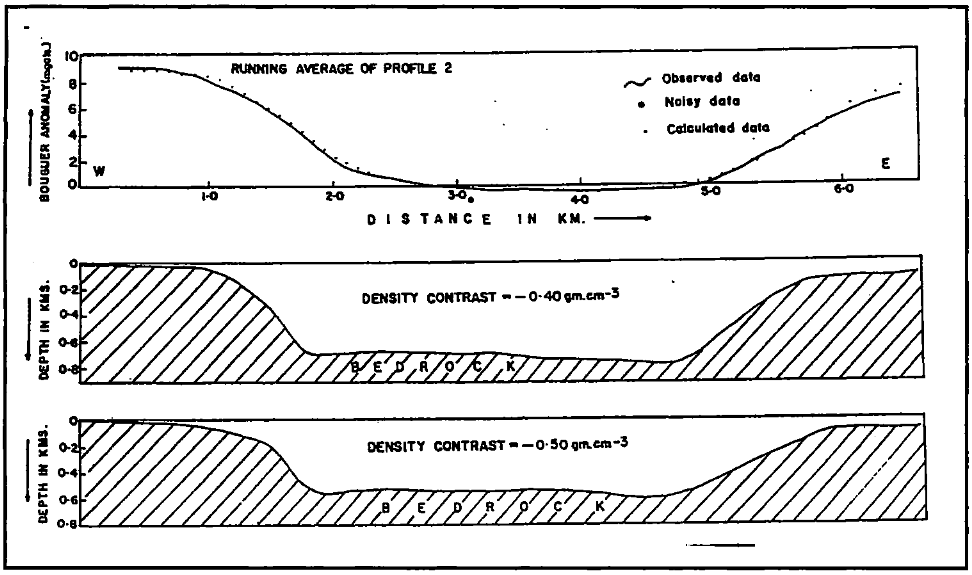

Figure 3. Two-dimensional Gravity Models along Profile 2, Showing Deep Steep-sided Basin (after Arafin *et al.*, 1987).

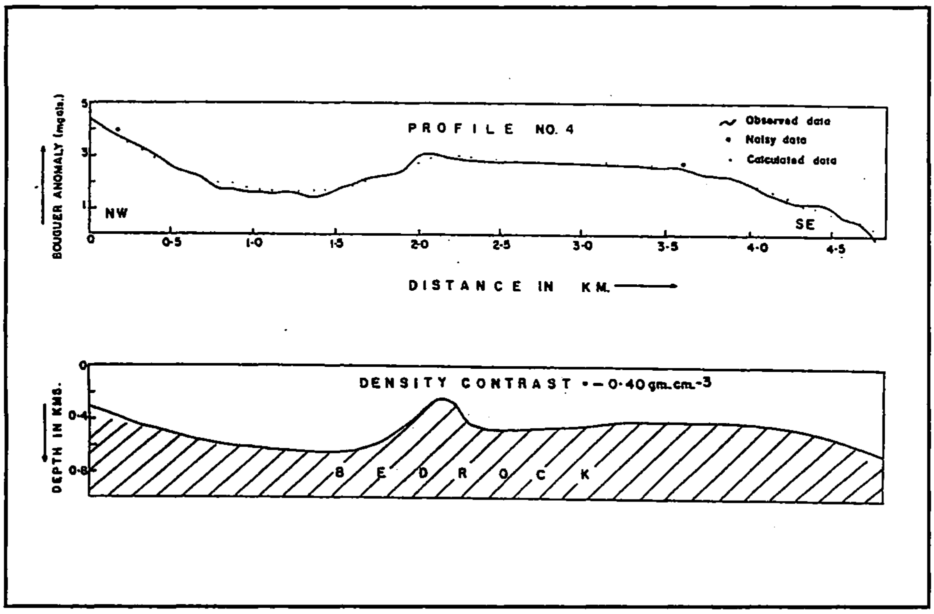

Figure 4. Two-dimensional Gravity Model along Profile 4, Showing Basement Ridge (after Arafin *et al.*, 1987).

at least 10 km. The general shape of the contours is confirmed by a subsequent gravity survey on a more regional scale (Burley and Jamaludin Othman, 1990) which indicates that the length of this basin exceeds 10 km.

The rather peculiar shape of the contours around the middle of basin strongly suggests a major fault with a WNW-ESE strike (Fig. 5). In the next section it is shown that its orientation and location are entirely consistent with lineaments in the area. The north-south basement ridge is probably bounded by faults as well, which makes it a horst. The broad gravity low in the southern half of the Bouguer gravity map suggests dip slip faults in an approximately north-south direction, forming a half-graben structure.

Resistivity sounding data in the area reveal the presence of at least four electrically distinct layers. Aquifers were detected at various depths. Confined aquifers in sand and gravel beds overlain by, or sandwiched between, thick layers of impermeable clay exist from depths of around 8 m downwards to 100 m and beyond (Arafin, 1988). This information is consistent with reports of artesian water struck at a depth of 110 m (Alexander, 1947).

Self-potential surveys in Chuping near the western edge of the basin demonstrated the presence of vertical streaming potentials. This has been interpreted as probably due to the near-vertical flow of groundwater at the steep contact between the Kubang Pasu Formation and the Tertiary Beds or along steep faults in the bedrock (Arafin, 1988).

STRUCTURE

Jones (1978) described a system of NW-SE trending faults in west Perlis consistent with east-west compressional forces. Fold axes in central Perlis also trend approximately north-south.

Geophysical evidence suggests that the Bukit Arang Tertiary Basin is bounded by normal faults striking approximately north-south. This is further supported by the fact that about 4 km to the west, Lai (1994) postulated two parallel dip slip faults with approximately the same strike. The idea of fault control of this Tertiary basin advanced in this paper is entirely consistent with similar structural frameworks proposed for other Tertiary basins in Peninsular Malaysia such as at Batu Arang (Mahendran *et al.*, 1991), Lawin (Syed Sheikh Almashoor and Mat Arifin Ismail, 1987) and Layang-Layang (Vijayan, 1990). Similar structural control has been suggested for the Tertiary basins in Thailand (Gibling and Ratanasthien, 1980 and Chaodumrong *et al.*, 1983).

Within the Bukit Arang Tertiary Basin itself a few approximately north-south basement faults have been postulated here, together with one striking WNW-ESE, on the basis of gravity data (Fig. 5). Faulting with similar orientations probably continued after deposition of the Tertiary Beds. This is clearly shown by the lineaments, based mainly on drainage patterns, in the area (Fig. 5). A comparison of these lineaments with the postulated faults based on gravity data shows rather striking similarities in orientation.

ECONOMIC POTENTIAL

While low-grade coal (lignite) is present it is not of any economic importance. Seams are no more than 15 to 30 cm thick. However, its quality is comparable to the coal at Batu Arang in Selangor which has been mined (Scrivenor, 1913).

Clay of various colours in layers up to 8 m thick have been recorded from pits and boreholes (Willbourn, 1926). Samples have been test-fired and found to be of good quality and possible commercial value (Alexander, 1947).

Traces of oil have been found in the shales but this is of no commercial consequence. Some alluvial cassiterite has been reported from the gravel beds. However, the amounts are far too small to be of any economic interest.

The layers of sands and gravels within these Tertiary deposits serve as important aquifers, both confined and unconfined. From geophysical data and various other considerations, Arafin (1988) estimated that the average porosity of the basin fills is about 0.25, the volume of groundwater that can be extracted is approximately 6.2×10^8 cubic metres and the volume of water in storage is about 6×10^9 cubic metres. These sedimentary deposits are in fact one of the more important sources of groundwater in water-deficient Perlis. The other significant sources are the karstic aquifers in the Chuping Limestone (Arafin and Lee, 1985).

A large part of the Tertiary basin is now covered by sugarcane plantations. Many wells have been drilled to extract the groundwater for this agricultural use. Resistivity sounding in the area revealed anomalously low resistivity values at some localities. This suggests that the groundwater has already been contaminated by the widespread use of fertilizers and other agricultural chemicals in the plantations (Arafin and Lee, 1988). Nevertheless, groundwater is currently the most valuable economic resource in the Bukit Arang Tertiary Beds.

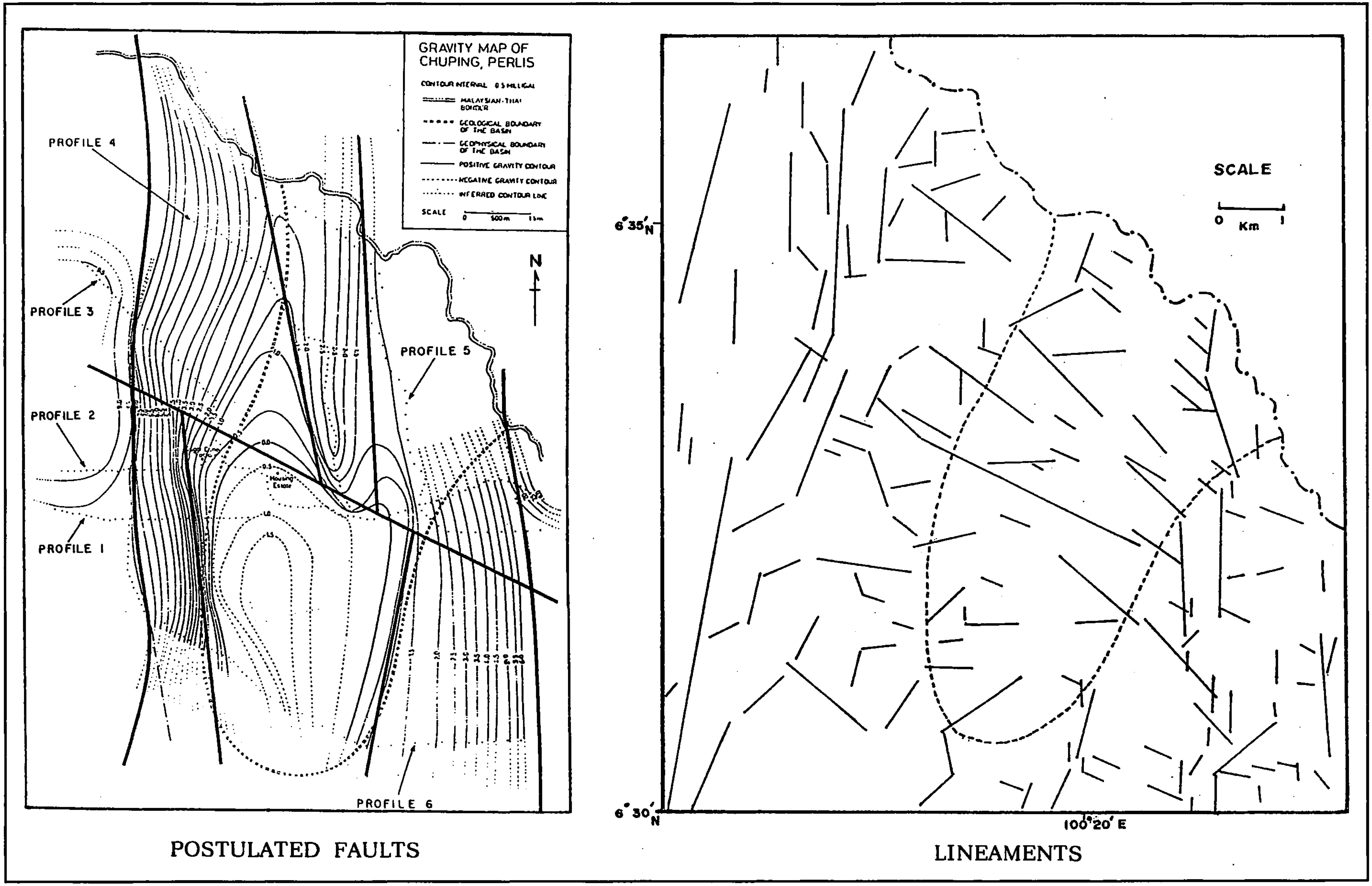

Figure 5. Comparison of Postulated Faults with Lineaments in the Bukit Arang Tertiary Basin.

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