*Geological Society of Malaysia, Bulletin 48*
*June 2004, p. 97 – 102*

# Periglacial involutions, large folded recumbent folds and tectonic overprints at Putrajaya

H.D. TJIA

Institute for Environment and Development (LESTARI)
Universiti Kebangsaan Malaysia
43600 Bangi, Selangor Darul Ehsan

**Abstract:** The development of Putrajaya and Cyberjaya brought to light many new outcrops of black pelite, buff to reddish brown psammite and subordinate bands of light-coloured tuffaceous or loessic material. Most of the outcrops are in advanced weathered states. The nature of the fresh rock was identified in drill cores acquired for foundation designs. These rocks are geochemically similar to the Upper Palaeozoic Kenny Hill Formation, although the dominant dark colour is rarely found among the Kenny Hill strata in the type area of Kuala Lumpur. At Salak Tinggi, Kenny Hill-like strata is marked by an *Agathiceras* sp. fossil (Early Permian) and also contains a pebbly horizon of interpreted glacigenic origin. The Putrajaya-Cyberjaya rock assemblage is therefore interpreted as being of Gondwanan origin. At "Cyberjaya Hill", bands of light-coloured tuff(?) or loess(?) were irregularly deformed into crinkles of varied wave lengths and shapes that contrast with the more systematically folded larger structures. The disharmonic character of the crinkles suggests these to represent periglacial involute structures. The larger folds are tectonic and developed as recumbent structures that became refolded into open warps. These two tectonic fold sets are coaxial about a north-southerly trend. Indications of tectonic transport of the recumbent folds include to the west, southeast and east.

**Abstrak:** Pembukaan tanah meluas bagi penubuhan Putrajaya dan Cyberjaya telah mengungkap banyak singkapan baru yang terdiri daripada batuan pelit hitam, psamit berwarna perang-karat serta sejumlah kecil lapisan berbahan tuf atau loes yang berwarna cerah. Pada singkapan kebanyakan batuan didapati dalam keadaan terluluhawa; batuan segar dikenali dalam inti gerudi. Sifat geokimia batuan sama dengan formasi Kenny Hill (Bukit Tungku) walaupun warna gelapnya tidak am bagi formasi Kenny Hill. Fosil *Agathiceras* sp. dalam batuan serupa Kenny Hill di Salak Tinggi menunjukkan usia Perm Awal. Suatu lapisan berpebel serta canggaan-dalam- keadaan-lembut di singkapan yang sama ditafsirkan sebagai hasil aktiviti berkaitan pergerakan glasier atau "iceberg". Berdasarkan hujah di atas, persekutuan batuan Putrajaya-Cyberjaya telahpun dianggap berasalmula di benua Gondwana. Pada "Bukit Cyberjaya", didapati lapisan nipis berwarna cerah yang mungkin mewakili tuf atau loes. Lapisan tersebut telah tercangga kepada lipatan berpanjang gelombang dan berbentuk kurang menentu dan oleh kerananya menampakkan lipatan tak-harmoni. Bentuk lipatan tak-harmoni jelas bertentangan dengan bentuk bersistem daripada lipatan tektonik bersaiz lebih besar. Perlipatan dalam-keadaan-lembut dianggap telah mewujudkan lipatan tak harmoni itu yang boleh dikelaskan sebagai involusi periglasial. Lipatan tektonik berbentuk rebah yang telah dicangga sekali lagi kepada lipatan terbuka. Kedua-dua struktur tektonik tercangga mengikut paksi lebih kurang utara-selatan. Angkutan tektonik yang boleh dikesan ialah ke barat, ke tengara dan ke arah timur.

## INTRODUCTION

The new federal capital Putrajaya and neighbouring Cyberjaya are located in the southern part of Selangor State. The region once comprised rubber and oil palm plantations centred about Perang Besar (Figure 1). Large-scale construction activities and ongoing development have exposed geological outcrops of dark gray and buff coloured bands of foliated pelites, plus some psammites. Originally the buff-coloured bands were perhaps tuff or loess. At least at one location in Putrajaya crops out a very dark coloured, mafic metamorphic rock (rhyolite or amphibolite). In surface outcrops of Putrajaya-Cyberjaya (abbreviated as PC) rock associations show up in partially to advanced weathered states. Only quartzites and the dark coloured crystalline rock present fresh outcrops. Drill cores for foundation design show calc-silicate hornfels, granite, carbonaceous schist and quartz-mica schist (Lim, 2001). However, no recognisable granite outcrop has been encountered.

Several colleagues have examined and interpreted the geology of the region. Rohayu Omar (*2004, pers. comm.*) found geochemical correlation between the PC metapelites and those of the Kenny Hill formation. On the other hand, the geochemical signatures of the PC pelites are different from the Hawthornden Schist (The Hawthornden Schists were described by Gobbett (1965) from the northeasten part of Kuala Lumpur), although both rock groups bear some lithological similarities in terms of metamorphic rock types and dominant dark colours. Kenny Hill rocks commonly are granular, reddish brown to reddish yellow, pelites and psammites. Very fine grained, light-coloured strata are also common. The interpreted volcaniclastic constituents very much resemble those building the present volcanoes of island arcs. However, no glass could be seen under the microscope, possibly due to the advanced geological age of the deposits. Alternatively, these could be light-coloured loess.

At the District Office of Sepang, some 20 km to the south of Putrajaya-Cyberjaya, Kenny Hill-like bedded rocks contained a single *Agathiceras* sp. fossil that determined its age as Early Permian (Abdullah Sani, 1985) A pebbly psammite/pelite horizon and associated intraformational deformation in the Sepang outcrop were interpreted as glaciogenic features (Tjia & Anizan Isahak, 1989). Spores in the Kenny Hill beds of Kuala Lumpur were attributed to probable Carboniferous or Permian age (Chen *et al.*, 2002). The geological age and glacigenic features are consistent with the interpretation that the western zone of Peninsular Malaysia once belonged to the Gondwana continent (Stauffer & Lee, 1986). Based on Rohayu's finding, the PC rocks are considered as Kenny Hill formation.

Lim (2001) described and interpreted interesting structures of the region and already concluded that the Putrajaya-Cyberjaya rocks experienced several phases of deformation. A couple of years ago Lim also guided me to several of the outcrops. Two of these were of exceptional scientific value. For easy reference, one is named "Cyberjaya Hill" (WGS 84 map coordinates: 02° 56' 10" N, 101° 40' 07" E), the other "Putrajaya Hill" (02° 56' 16" N, 101° 40' 49" E.) was a deep cut across the western ridge of Putrajaya. Unfortunately, in 2003 both were partly destroyed. Over the past three years, repeated visits to these outcrops and other outcrops that meanwhile became available led to the interpretation as reflected in the title of this article. In addition to these two outcrops a few others will be described and interpreted.

## OBSERVATIONS AND INTERPRETATION

### "Cyberjaya Hill"

"Cyberjaya Hill" is located several hundred metres west of the Express Rail station of Putrajaya-Cyberjaya, approximately on the boundary of Putrajaya with Cyberjaya (Figure 1). Since 2003, this hill outcrop has decreased in size as the top and sides were quarried for landfill. It will probably disappear completely in the near future. The outcrop consists of a black main body with buff coloured, thin to metres wide stringers of possibly tuffaceous, or loessic material. Weathering is at an advanced stage; occasionally patches of black phyllite and schist showing foliation and cleavage indicate the original lithology. The top part is completely weathered to soil of rusty brown colours (Figure 2). The light-coloured stringers suggest a refolded recumbent fold. The stringers proper are irregularly deformed into crinkly folds. It was ascertained in the outcrop that the crinkly appearance was not caused by topographic irregularities but represented actual shapes. The disharmonic style of the folds is clearly shown in the photographs. These irregular folds cannot be of tectonic origin: their wave lengths and amplitudes vary; the deformation intensity ranges from non-existent to open fold types. In addition, the fold axial planes range from flat and upright to warped and recumbent without any systematic pattern.

Bearing in mind that the deposits could have been laid down during glacial Gondwanan time, the crinkly, disharmonic fold structures are interpreted as *soft-sediment features deformed by ice movements in a periglacial environment*. Such structures were described and interpreted by Sharp (1942) who named them periglacial involutions. At the south side of "Cyberjaya Hill", Rohayu Omar (*2004, pers. comm.*) recorded an unsorted breccia in dark coloured, muddy matrix. In spite of the chaotic appearance, inverse grading of larger fragments lying in the upper part is distinct. Further study is underway to determine if this is a glacial till.

The large structures in the outcrop are shown in Figure 3. The light-coloured bands of irregular thickness and deformation style strongly suggest a refolded recumbent fold of about 25 m wave length. Rare occurrences of reverse graded psammites were observed in the lower fold limb. The overall asymmetry of the fold in Figure 3 is consistent with east vergence. Late-phase east-vergence is also suggested by the moderately dipping reverse faults. The larger folds of the outcrop are interpreted as tectonic folds deformed about a SSE axis (Figure 4) and overfolded into recumbent state. Tectonic vergence was easterly. During a subsequent deformation stage the recumbent fold was deformed once more into an open folds. Small to large folds of the multiple deformation stages are coaxial. Minor isostatic adjustments are indicated by normal faulting with strikes roughly parallel to the strike of the earlier structures. No appreciable rotation about a vertical axis has taken place.

### "Cyberjaya Hill" - Equal-area plot of structures

The crenulation axes of black phyllite in this outcrop plunge at 5° to 10° towards the 140° - 190° sector. The most

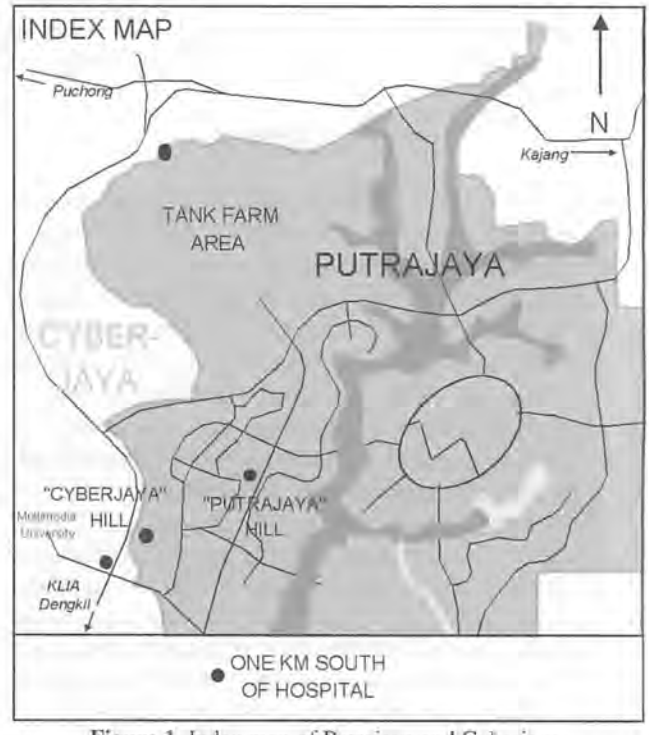


**Figure 1.** Index map of Putrajaya and Cyberjaya.

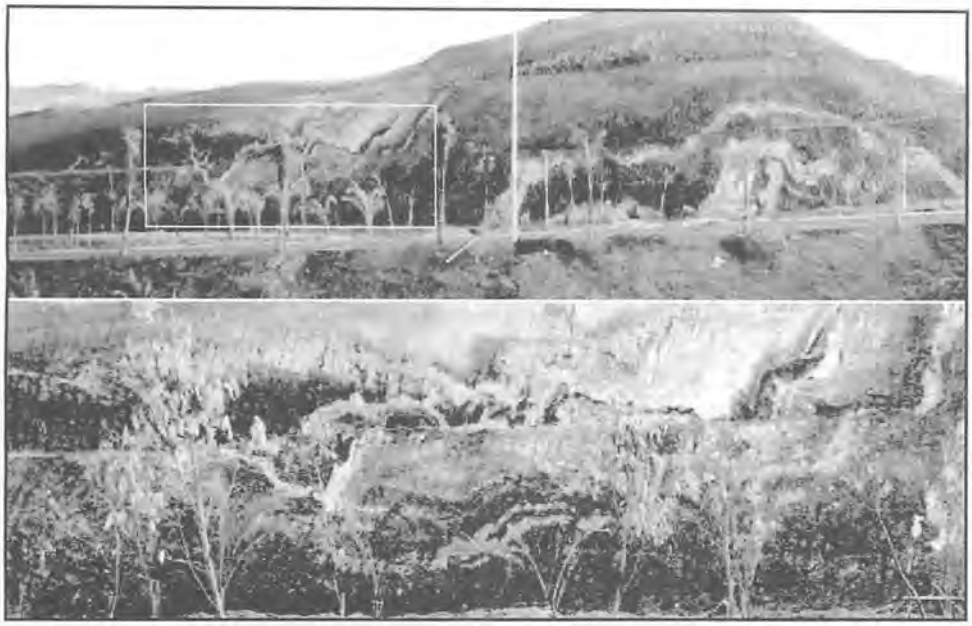

**Figure 2.** "Cyberjaya Hill" as seen in 2001. The lower photograph is a closer look at the left part of the hill. The light coloured bands indicate a large recumbent fold. Irregular crenulations are probably products of repeated freezing and thawing at the fringe of an ice sheet.

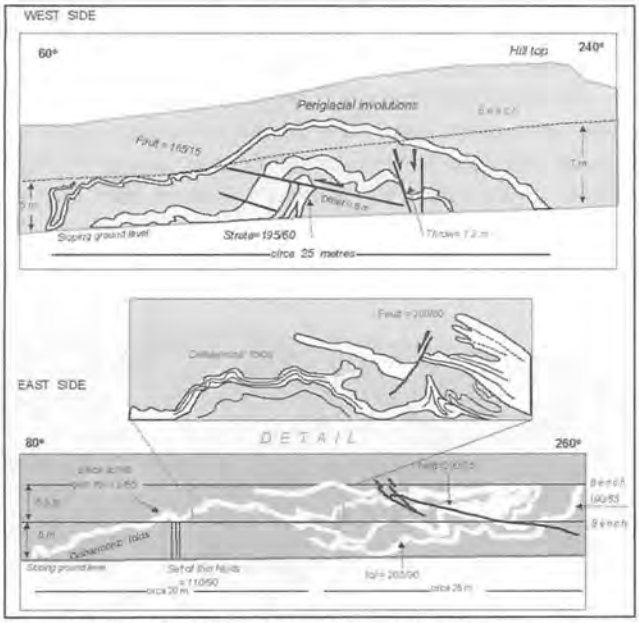


**Figure 3.** Field sketches of "Cyberjaya Hill". The upper sketch is the west side of the long hill cut. The lower two sketches shows the east portion of the outcrop. Thin bands display irregular crenulations. This disharmonic fold character is also appreciated in the detailed sketch (middle).

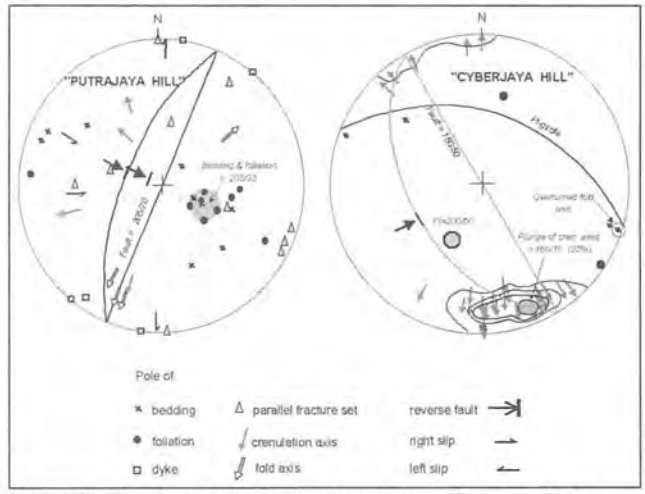


**Figure 4.** Lower hemisphere, equal-area plots of structural elements measured in the field at "Cyberjaya Hill" and "Putrajaya Hill".

frequent plunge (25% of the population) is towards 160° at 10 degrees. A few crenulation axes trend NW. A moderately dipping reverse fault has slickensides showing updip motion sense of the fault plane towards N50°E. Both reverse fault motion and plunge of most crenulation axes correspond with compression inside the sector 60° - 70°. Stratification, including the overturned bedding, and foliation correspond with a Pi-belt belonging to a fold structure plunging 50 degrees towards N200°E (Figure 4). The steeper plunge angle suggests that the Pi structure represents an older compression event.

## "Putrajaya Hill" - Western hill cut along 115° - 295°

The structural style of well-foliated, sometimes massive banded, pelite-psammite is shown on Figure 5. Within thick siliceous bands of schist are medium scale structures consisting of intricate isoclinal folds. Most fold axes plunge gently towards SSW, others toward NW and NE. A metres wide interval marked by a breccia zone and faults crops out in the eastern part of the outcrop. A bleached patch of rock associated with a fault zone suggests hydrothermal alteration. Drag folds indicate tectonic transport towards east. The large folds in the outcrop also verge eastward. The attitude of crenulation cleavage (detail inset) is consistent with the general structure. The folded structure is overlain with an angular unconformity by well-bedded reddish coloured unconsolidated clastics striking parallel with the older structures but having only a general inclination towards west devoid of folds. Near the base is

a black coloured interval that seems organically rich. Lithologically, these beds resemble weathered Jurassic-Cretaceous continental beds of the Tembeling equivalents cropping out in the Central Belt of Peninsular Malaysia. However, a Tertiary age for these overlying beds cannot be ruled out. A colleague has collected samples for palinological studies.

## Putrajaya Hill - Equal-area plot of structures

Medium-scale structures comprising bedding, foliation, fold and crenulation axes, parallel fractures, (weathered) igneous dykes through the pelites at "Putrajaya Hill" are plotted on an equal-area projection, lower hemisphere (Figure 4). Besides, sense of fault motions were interpreted in the field using now established fault-plane markings including bruise steps, pluck steps, accretion spalls, are also shown on the plot.

The medium-scale fold axes generally plunge between 5 and 15 degrees in SSW direction. A large reverse fault zone (strike 205°, dip 70°) trends parallel to the fold axes. Most bedding and foliation strike 205° and dip 35° west. Their representative frequency of orientation and attitude are consistent with overturned folds, as shown by the outcrop. The weathered igneous dykes are subvertical and strike perpendicular to the fold axes and thus may fill extensional cross fractures. Three sets of very steep, parallel fractures strike in the direction of the fold axes. The referred to fold axes, reverse fault zone, preferred bedding/foliation orientation, and three very steep sets of parallel fractures are interpreted as products of tectonic compression directed along 115° - 295°. The orientations of the dykes and moderately plunging folds towards various directions (WSW, NNW and NE) are inconsistent with this compression direction and most probably resulted from reorientation of an earlier deformation. The sense of fault slips are not explained by the interpreted ESE - WNW compression. The associated fault movements correspond with compression in NNE - SSW direction, which is roughly 90 degrees out-of-phase with the interpreted regional compression direction.

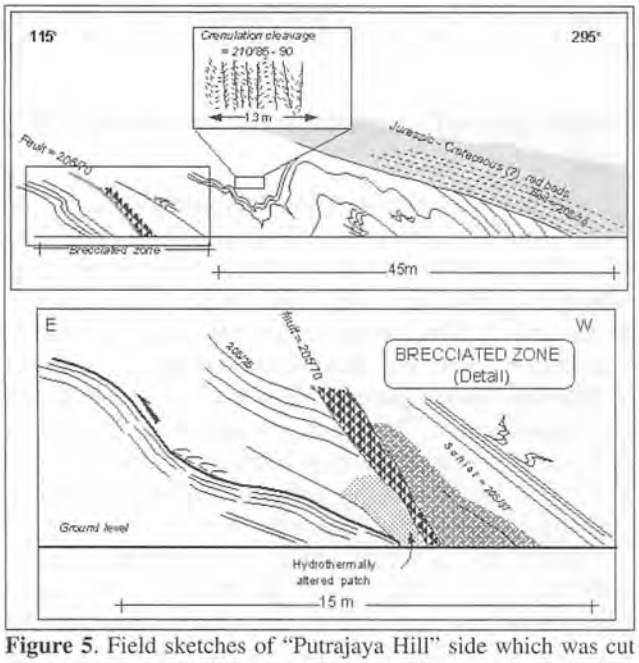


**Figure 5**. Field sketches of "Putrajaya Hill" side which was cut across the western hill of Putrajaya. Details of the breccia zone indicating east vergence.

## Putrajaya - Hill side near Tank Farm

This long hill-side outcrop consists mainly of pelite of dark gray, red-brown and buff colours located near the petroleum tank farm in the northwest corner of Putrajaya (Figures 1, 6 & 7). The pelite is deeply weathered except for small patches where foliation is still measurable. A dark rusty brown horizon of a few decimetres' thickness appears to separate an overlying structure that is parallel to the rusty brown horizon from an underlying packet that is disconformable (Figure 7). In the lower part, asymmetrical open folds mark an axis plunging 62 degrees towards north. In spite of the structural discordance, the asymmetrical open folds in the upper part have bedding attitudes similar to those in the lower part. The youngest structures are the 110°-striking, almost-vertical faults.

The dark rusty brown horizon is interpreted to represent a low-angle thrust zone. More advanced weathering of this horizon produced the distinct colouration. The asymmetry of the warps suggests SW vergence, without indication of


**Figure 6.** Photograph of weathered metaclastics exposed in a hill side near the Putrajaya tank farm. Note the reddish brown horizon separating rock packets of different structural appearance.

stratigraphic facing it is not possible to definitively determine the sense of thrusting.

## Dengkil Trunk Road, Cyberjaya

This outcrop is a roadcut along the west side of the Dengkil/KLIA (Kuala Lumpur International Airport) trunk road near the entrance of the road leading toward the Multimedia University of Cyberjaya (Figures 1 & 8). The sketch of Figure 8 covers a length of about 35 m. Thick to massive bands of medium to coarse-grained psammite show common west-east striking, gently north dipping undulating faults and fault zones (Figure 8). Dips of the faults are 22° and less. The gentle fault dips suggest low-angle thrusting. The sense of tectonic transport is equivocal, whether south or north.

## One Kilometre South of Putrajaya Hospital

Black schist, pelite of predominantly dark colours and subordinate bands of lighter coloured psammite and tuffaceous/loessic material formed a small and low hill group located due south of the Putrajaya Hospital. The outcrop of Figure 9 is now levelled and was at 210° from the dome of the Putrajaya Mosque. The folded fault planes and complex folds on the east side of the outcrop strongly suggest soft-sediment deformation. Being more systematically deformed, the remainder of the outcrop probably resulted from tectonics. The rather irregular folds below the low-angle reverse fault may be interpreted as tectonically overprinted involute folds. East-vergence is indicated by the reverse faults

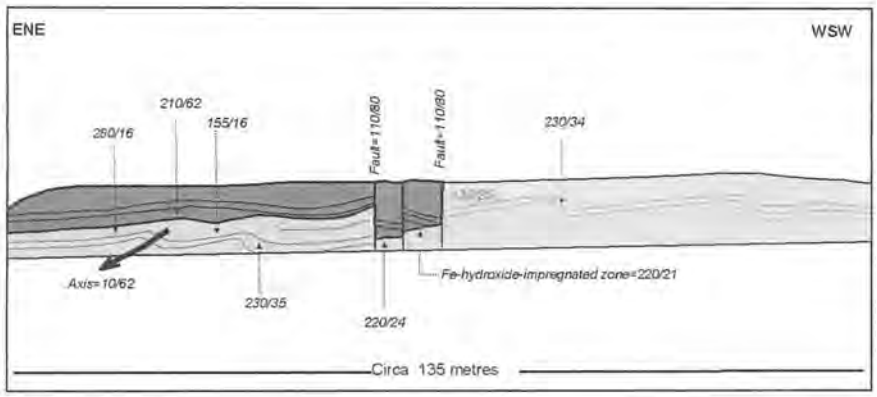


**Figure 7.** Field sketch of the hill side on Figure 6.

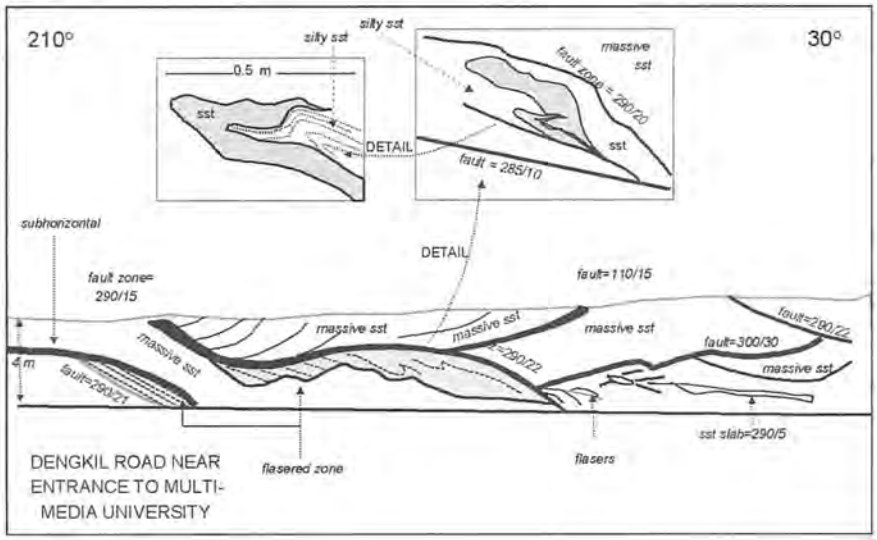


**Figure 8.** Low-angle thrust structures in psammitic bands showing north or south vergence. Roadcut on the Dengkil trunk road.

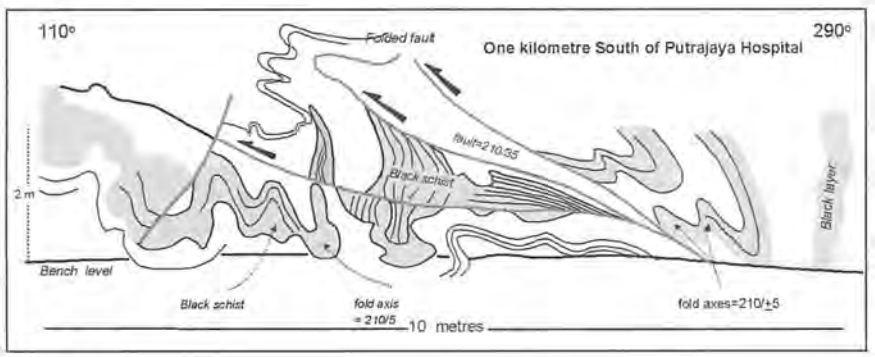


**Figure 9.** Complex soft-sediment folds and folded faults occurring together with more systematically deformed features of tectonic origin. Locality is 1 km south of the Putrajaya Hospital.

## DISCUSSION AND CONCLUSIONS

The geochemical signature of the metasedimentary rocks of Putrajaya and Cyberjaya correlates with that of the Upper Palaeozoic Kenny Hill formation (Rohayu Omar, *pers. comm.*). Lithologically similar rocks (psammitic) also crop out at Salak Tinggi. There an *Agathiceras* sp. fossil and the presence of an interpreted glacigenic pebbly horizon are consistent with the Western Domain of Peninsular Malaysia (including Putrajaya-Cyberjaya) having been part of Gondwana.

At "Cyberjaya Hill", disharmonic folds in the form of irregularly spaced crinkles exhibited by interbedded, light-coloured layers, clearly indicates soft-sediment deformation. In view of points raised in above, these soft-sediment structures are interpreted to have formed at shallow depth in response to moving ice masses with or without repeated freezing and thawing of the shallow subsurface material. Ice flow, possibly as glaciers or icebergs, dispersed from Gondwana. Such environment can be indicated as *periglacial*. Sharp (1942) called such structures *involutions*.

The larger structures in the studied area display consistent strikes and fold style. Fold wavelength, fold amplitude, relationship to microstructures (cleavage, crenulation cleavage) and vergence are systematic. These features are therefore tectonically deformed structures. Large and smaller folds, moderate to low-angle reverse faults and drag folds frequently indicate east vergence. However, south or north vergence is also indicated. The main tectonic deformation produced recumbent folds at "Cyberjaya Hill" and low-angle reverse faults in the outcrops near the Putrajaya Tank Farm, near the Multimedia University at Cyberjaya, and at a location about one kilometre south of the Putrajaya Hospital. The last mentioned locality was near the large steel bridge leading to the Convention Centre. The recumbent fold at "Cyberjaya Hill" is overprinted by open folds. The tectonic deformations were co-axial about a general North-South direction.

Among the outstanding issues is the nature of the light-coloured bands among the black schists; are these bands composed of volcanic tuff or of loess?

Tectonic vergence is the study area was within the sector W - S - E, while north vergence has not been seen. The Kenny Hill formation in the type area (Kuala Lumpur) commonly has west vergence. Southeast and east vergence are shown by outcrops in Bangi and Salak Tinggi and were considered results of an older, pre-Kenny Hill deformation phase (Tjia, 1986).

## REFERENCES


Abdullah Sani Hashim, 1985. Discovery of an ammonite in the Kenny Hill Formation and its significance. *Warta Geologi* 11: 205-211.

Chen, B., Mustaffa Kamal Shuib & Khoo, T.T., 2002. Dating the Kenny Hill Formation: spores to the fore. *Warta Geologi* 28 (5):189-191.

Gobbett, D.J., 1965. Lower Palaeozoic rocks of Kuala Lumpur. *Federal Museum Journal* 9:67-79.

Lim, Chee Kheong 2001. Structural style of Cyberjaya and Putrajaya, Selangor. *Annual Geological Geological Society of Malaysia Conference 2001 Proceedings*, p. 67-70.

Sharp, R.P., 1942, Periglacial involutions. *Journal of Geology* 50:113-133.

Stauffer, P.H. & Lee, C.P., 1986. Late Palaeozoic glacial marine facies in Southeast Asia. *Geological Society of Malaysia Bulletin* 20:363-397.

Tjia, H.D. 1986. Geological transport directions in Peninsular Malaysia. *Geological Society of Malaysia Bulletin* 20:149-177.

Tjia, H.D. & Anizan Isahak 1990. Permian glacigenic deposits at Salak Tinggi, Selangor. *Sains Malaysiana* 19 (1):45-64.


*Manuscript received 22 March 2004*