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Thrust in the Semanggol Formation, Kuala Ketil, Kedah

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Abstract— An excavation of a small hill, Bukit Kukus in the vicinity of Kuala Ketil town exposed the chert unit of the Semanggol Formation which comprises black mudstone, sandstone, tuffaceous sandstone, tuff, paraconglomerate, siliceous shale and chert. The chert contains radiolarians indicating late Early Permian to Middle Triassic of age. These rocks are generally thrusted northward. The thrust and the normal faults occupy the same orientation of fault planes. The dextral faults also occupy the same orientation as the Bok Bak fault which is of sinistral. As the result of transpressional deformation northward thrusts occupy fault planes which were formally the normal faults. The normal faults are the extensional faults resulting from the sinistral movement of the Bok Bak fault. The northward thrust is generated from the dextral movements along the northwest and west-northwestern faults, and is interpreted to be the youngest fault movement onshore.

Keywords: thrust faults, chert unit, Semanggol Formation, mylonite

Abstrak— Tarahan Bukit Kukus berhampiran dengan pekan Kuala Ketil mendedahkan unit rijang Formasi Semanggol yang terdiri daripada batu lumpur hitam, batu pasir, batu pasir bertuf, tuf, parakonglomerat, syal bersilika dan rijang. Rijang mengandungi radiolarian yang berusia akhir Perm Awal hingga Trias Tengah. Batuan tersebut secara umum tersungkup ke utara. Sesar sungkup dan sesar normal mempunyai orientasi yang serupa. Sesar dekstral pula juga menunjukkan orientasi yang serupa dengan sesar Bok Bak iaitu sesar sinistral. Sungkupan ke utara berupa hasil daripada keadaan transpresi yang dialami oleh satah sesar yang sebelumnya ialah sesar normal. Sesar-sesar normal tersebut ialah sesar ekstensi hasil daripada pergerakan sinistral sesar Bok Bak. Sungkupan ke utara terjana oleh pergerakan dekstral sesar-sesar berjurus baratlaut dan barat-baratlaut, dan ini berupa pergerakan yang terakhir dapat dikesan.

INTRODUCTION

The Kuala Ketil area is an undulated terrain consisting of hills and ridges of upper and lower Paleozoic rocks that has been mapped as the Semanggol Formation and the Mahang Formation (Burton, 1970, 1988). Burton (1965, 1970, 1988) proposed the occurrence of a major strike slip fault in Peninsular Malaysia, which cuts the rocks in the area of Baling and Kuala Ketil. This fault is oriented northwest and named after the Bok Bak River, with which the lineament is partly aligned. The fault was inferred based on the morphology and displacement of geological units adjacent to the lineaments. The southwards and the northwards extension of the fault has been discussed and agreed by several workers (Burton, 1965; Raj, 1982; Syed Sheikh Almashoor, 1996). Due to poor exposure there has been not much information on structures that affected the rocks in the area.

Recently, a fieldwork has been carried out at Kuala Ketil. We discovered an extensive outcrop at approximately 4½ km from Kuala Ketil town along the old road to Baling (Figure 1). This paper is to highlight thrust faults, which developed from the latest fault movement observed within the Semanggol Formation in Kuala Ketil. The presence of thrust fault in the Semanggol Formation from south Kedah has never been reported before.

GEOLOGY OF THE AREA

Burton (1973) divided the siliceous and clastic rocks of the Semanggol Formation into three members or unit (Teoh, 1992). Previously the chert unit was thought to be the oldest part, overlain by rhythmic unit in the middle and conglomerate unit as the upper part of the formation. Intertongueing relation among the units is proven by the discovery of fossils from the chert unit from various locations (Sashida *et al*., 1995; Basir Jasin, 1997). In study area at Kuala Ketil, seven lithofacies that may represent the chert unit have been identified in ascending order, laminated black mudstone, interbedded sandstone and mudstone, interbedded tuffaceous sandstone and tuff with a paraconglomerate bed, interbedded tuffaceous sandstone, siliceous shale and chert, bedded chert, tuffaceous mudstone and interbedded chert and siliceous mudstone (Basir Jasin & Zaiton Harun, 2007). Almost the whole sequence of chert that contains nearly the whole range of radiolarians representing the age of the Semanggol Formation is also exposed. The chert sequence from this location contains radiolarians of late Early Permian to Middle Triassic (Basir Jasin *et al*., 2005a, 2005b). However, an Early Triassic chert sequence is still missing. Previously, based on the occurrence of Triassic fossils such as *Posidonia* sp, *Halobia* sp.and *Daonella* sp. in shale beds indicate middle to late Triassic (Burton, 1970;

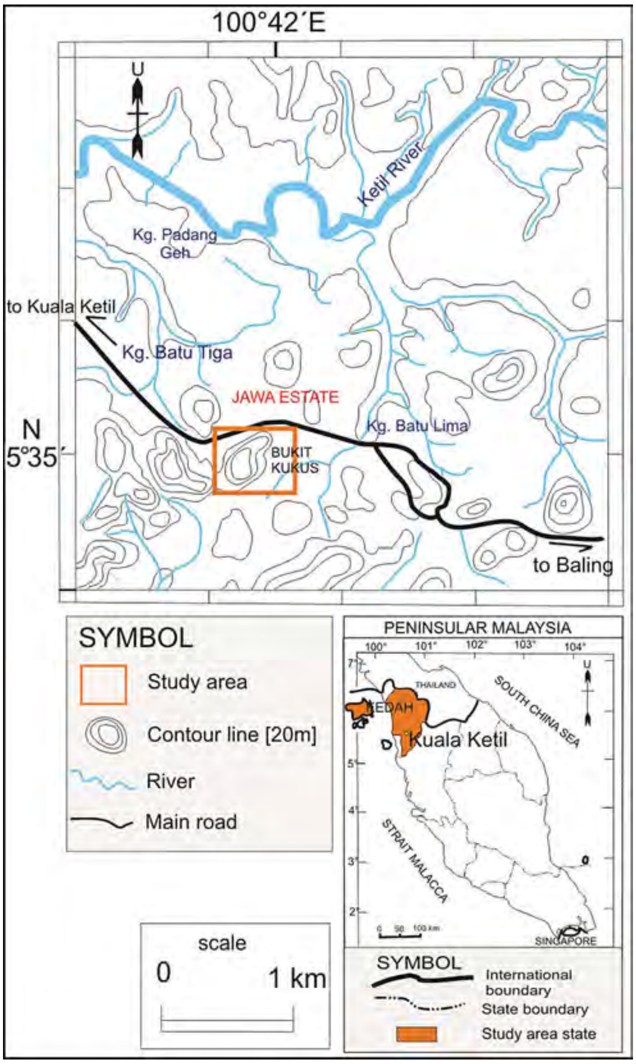

Figure 1: Topographic map of the study area in Kuala Ketil, Kedah.

Teoh, 1992) age for the Semanggol Formation. Generally the age of the Semanggol Formation is late Early Permian to late Triassic, however based on the radiolarians the age is late Early Permian to Middle Triassic. The sequence of the chert unit at Bukit Kukus was deposited in the deep open marine under the influence of different conditions (Basir Jasin & Zaiton Harun, 2007).

In north Kedah, the deep-water sediments of the lower Paleozoic Mahang Formation is overlain by the upper Paleozoic Kubang Pasu Formation of the deep-water environment. The boundary between the former and the latter is unconformable (Burton, 1988). However several quarries in Pokok Sena exposed thrust faults as boundary between these formations mostly exhibiting the Mahang Formation on top of the Kubang Pasu Formation (Zaiton Harun & Basir Jasin, 1999a, 1999b). The boundary between the Semanggol Formation and the Early Carboniferous to Early Permian Kubang Pasu Formation has not yet been exposed. In north Kedah, based on the biostratigraphic relation, the two formations is interpreted to be conformable. In south Kedah, particularly in Kuala Ketil, contact between the Semanggol Formation and the Ordovician to Devonian Mahang Formation is fault bounded (Burton, 1988; Courtier, 1974). The Kubang Pasu Formation is yet to be discovered here.

Burton (1970, 1988) identified two sets of lateral faults, truncating the rocks in the area of Kuala Ketil and Baling. In Kuala Ketil, Kampong Tembak Fault and Bukit Buloh Fault are parallel to the northwest trending Bok Bak Fault, which is sinistral. Sungai Jemerli and Kuala Ketil Faults are the northeast trending dextral faults. He also noticed the presence of dextral movement along the northwestern fault. He described that boundary of the Mahang and the Semanggol Formation has been displaced by 3.2 km along the Kampong Tembak Fault. In his geological map of the area, it is shown that the Sungai Jemerli Fault displaced the Kampong Tembak Fault and the chert ridges dextrally (Burton, 1988). He also inferred that the Semanggol Formation was deformed into a slightly overturned asymmetric fold with fold axes inclined southeastwards (Burton, 1970, 1988), whereas a section of the formation crossing from Kuala Ketil to Sungai Tawar has been interpreted to be a gentle open fold (Abdul Rahim Samsudin *et al.,* 1991).

GEOLOGICAL DESCRIPTION

In the Kuala Ketil area, isolated hills and ridges are oriented northeastwards. One of the isolated hills locally called Bukit Kukus (Figure 1) has been excavated and exposed a part of the Semanggol Formation. The orientation of the section is almost north-south direction. The northern part of the section is cut and leveled into one terrace whereas the southern part of the section mainly consists of two terraces. Generally both sections exposed moderate to highly weathered mudstone, sandstone, tuff, tuffaceous sandstone, paraconglomerate, siliceous shale and chert that represent the chert unit of the Semanggol Formation.

The most northern section of the outcrop exposed black mudstone representing the lowermost part of the chert unit of the Semanggol Formation in this area. The mudstone has been identified as the laminated black mudstone facies. The mudstone varies in colour from dark gray to reddish and whitish gray depending on the grade of weathering. The black mudstone contains parallel lamination and bioturbation. The mudstone is overlain by the other six lithofacies in ascending order; interbedded sandstone and mudstone, interbedded tuffaceous sandstone and mudstone with paraconglomerate, thinly bedded tuffaceous sandstone, siliceous shale and chert, bedded chert, tuffaceous mudstone and interbedded chert and siliceous shale (Figure 2). The paraconglomerate is rusty yellow, containing granule to cobble size clasts and fossils such as bryozoa and crinoid stems. Gradded bedding is clearly exhibited in turbiditic sandstone which gradually changing into mudstone towards the top of the bed. The sequence is younging towards the south.

The lower terrace of the south section exhibits about 30m wide of highly weathered mylonite separating the Late Permian bedded chert from tuffaceous mudstone and interbedded the late Late Permian chert and siliceous shale (Figures 2, 3 and 4). The weathered mylonite exhibits only structural relict. The upper terrace of the south section exposed approximately 80m wide of thrust fault and bedded chert of the Middle Triassic. The thrust fault consist of weathered mylonite enclosing blocks of bedded rocks such as bedded cherts, bedded mudstone, bedded sandstone and mudstone, bedded tuffaceous sandstone and mudstone (Figure 2). These rocks were cut and displaced by the thrust, strike slip faults and normal faults.

Generally the rocks strike ranging from ENE to ESE and gently to steeply (20° to 78°) dipping towards south. The attitude of the beds varies due to effect of fault displacements and folds. Bedded cherts are complicate by fractures, faults and folds i.e. reverse, thrust and normal faults, isoclinal and tight folds. The process of slumping and tectonic movements may contribute to the occurrence of folds in the bedded chert. In the case of Bukit Kukus, the processes that generate the folds in the bedded chert cannot be differentiated. This needs to be further study in future. The sense of fault movements within the bedded chert and siliceous shale is obviously indicated by highly fractured, brecciated and deflected adjacent beds. However in this section, fault surfaces are rarely exposed and fault striation is hardly observed.

There are two groups of the thrust and the reverse faults. The first group of the thrust faults strikes ranging from ENE to ESE and shallow to moderately steep (04°-60°) dip towards south. The mylonites belong to the first group. The second group of the thrust faults strikes either northward, dip gently to moderately steep towards east or strikes SSE and dip gently to moderately steep (24°- 45°) towards west. The first group is dominant here.

The thrust is commonly branched off, either running parallel with the main fault or disappearing into the bedding, and reappeared at another junction, joining the main fault again. This thrust fault changes its orientation and sense of movement from reversal into normal. The faults of ENE and ESE indicate thrusting towards north until the orientation of the faults change into SSW and WNW, in which the sense of movement appears to be normal. The WNW normal faults dip gently (04°- 30°) to north or moderately steep towards south (50°S). The normal SSW fault dips gently towards west. The normal sense of movement is also indicated along NNW fault planes which dip towards east.

Several lateral faults have been observed on the floor of the north terrace. Sinistral sense of movement is indicated by deflection of bedded sandstone and mudstone adjacent to almost vertical fault striking SE. At other location on the floor, the ESE fault and bedded sandstone and mudstone are cut and displaced dextrally for about 1 meter along an almost vertical fault striking 140°. The ESE fault dips moderately steep (50°-60°) towards south. The fault is approximately two and a half meter wide comprising gray colored weathered fault breccia. The dextral sense of movement along this fault is indicated by the drag of bedded sandstone and mudstone along the margin of the fault. This fault can also be traced towards the section wall where it cuts sequence of bedded tuffaceous sandstone and siliceous mudstone. The fault is about one and a half meter wide comprising weathered fault breccia. Deflection of the beds adjacent to the fault shows the evidence of normal component that has also taken place during the dextral movement of the fault (Figure 2). Other examples of normal movement along the ESE faults by deflection of adjacent beds exposed at several locations on the section wall. Lateral movement cannot be determined at this section.

DISCUSSION

At Bukit Kukus, there are three issues that need to be considered here:

(i) Occurrence of the dextral sense of movement along the WNW and NW faults within the zone of the Bok Bak Fault which is of the sinistral type.

(ii) Occurrence of the ENE to ESE thrust with the tectonic transport towards north.

(iii) The thrust and the normal faults occupy similar orientation.

Structures like thrust and fold may form at a restraining bend of strike-slip fault which is under transpressional tectonic setting (e.g. Sylvester, 1988). At Bukit Kukus, the thrusts of ENE to ESE are to be related to the dextral movement of the NW fault system (or any segments) of the Bok Bak fault. The movement has caused the extension occurred in the direction about east-west that led to the formation of normal fault along NNW to NNE (or SSW) fractures and faults. These structures are dominantly observed along those orientations at Bukit Kukus. However there are also the reverse faults and thrusts along NNW to NNE (or SSW), and normal faults along ENE to ESE faults that may belong to the sinistral movement along the NW fault system. The range of orientations of thrusts and normal faults indicate that the structures may have been subjected to rotations during prolonged deformations.

In north Kedah, thrust faults which related to the sinistral movement along the Bok Bak Fault generally strike northward and dip either eastward or westward are exposed at many locations(e.g. Zaiton Harun & Basir Jasin, 1999, 2000). Thrusting towards either one direction or both directions eastward and westward form a positive flower structure (a palm structure) resulting from transpressional condition which occurred in the area of Pokok Sena and Tunjang. This has caused the slate of the Mahang Formation thrusted eastward and westward onto the Kubang Pasu Formation. At Bukit Kukus, the reverse faults and thrusts along NNW to NNE (or SSW) and the northwestern trend of sinistral faults are present but not as a major structure

Burton (1970, 1988) described northwesterly faults showing both sinistral and dextral displacements at several parts of Baling and Bedong area. Since the main movement along the Bok Bak faults is sinistral, it has been interpreted to be the youngest displacement. The dextral sense of movement along the northwestern fault was thought due to

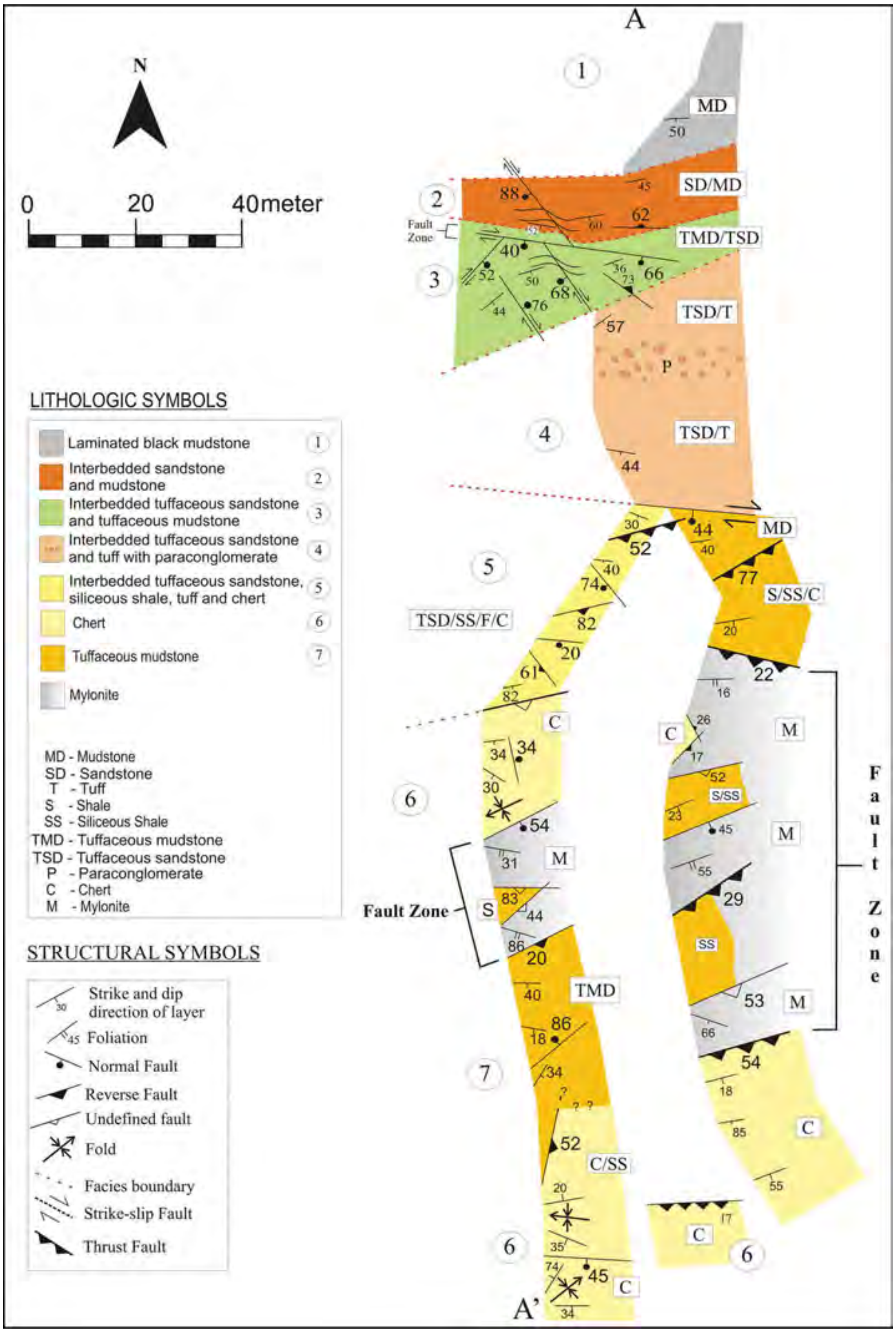

Figure 2: Geological map showing major thrusts and oblique dextral in the chert unit of the Semanggol Formation at Bukit Kukus, Kuala Ketil.

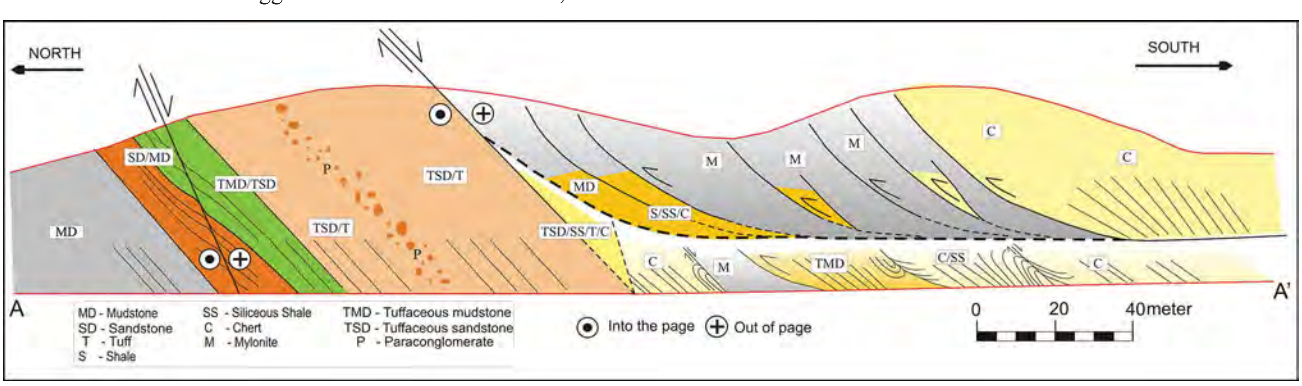

Figure 3: A cross section of the map showing northward thrusts and dextral normal faults in the chert unit of the Semanggol Formation.

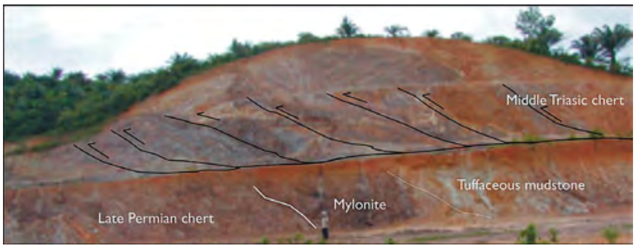

Figure 4: The north-south section of the outcrop showing northwards thrusting faults.

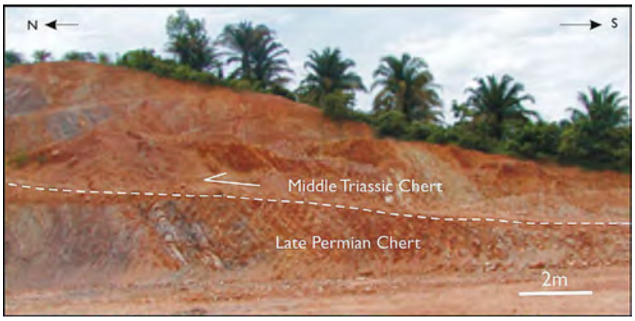

Figure 5: The Middle Triassic chert overlies the Late Permian chert and is separated by thrust fault at the southern end of the section.

the older tectonic movement. However recurring movement along the northwestern faults in this area may have caused the former extension planes (ENE to ESE) reactivated to be the thrust faults. The dextral movement along the northwestern fault segment caused northward thrusting and uplifting. An oblique dextral with reversal components has uplifted the chert unit of the Semanggol Formation at Bukit Kukus. However normal sense of movement along the NW and WNW dextral faults reflects prolonged deformation, rotations and adjustment of the former structures.

At Bukit Kukus, the chert unit of the Semanggol Formation is mainly thrusted towards north along the ENE to ESE thrust faults. The thrust is important because it has brought up sequence of The Middle Triassic of bedded chert lying 2-4 m on top of the late Late Permian chert (Figure 5). This is an example of the young sequence lying on top of the old sequence and the boundary is fault. Another similar example is in Bukit Tinggi, north of Alor Setar, Kedah where Kubang Pasu Formation lying on top of red slate of the Mahang Formation, the boundary is half a metre of mylonite (Mohamad Zamri Abdul Wahab, 2002).

The dextral movement along the northwestern faults and related ENE to ESE thrusts and NNW and SSW normal faults signify transpressional setting created at Bukit Kukus during the latest fault movement in this area. This may also represent the youngest fault movement onshore Peninsular Malaysia. The dextral sense of movement occurring along WNW and NW faults has been discovered at several locations in the Peninsular Malaysia (Tjia, 1986; Zaiton Harun, 1993) within the olistostrome at Genting Sempah, along mylonite of the Kisap Fault at Teluk Sudu, Pulau Dayang Bunting (Zaiton Harun, 1996) and within the Bukit Berapit Fault (Zaiton, 1994). The youngest fault movement onshore Peninsular Malaysia has been dated as Early Eocene and Middle Eocene (Zaiton Harun, 2002), which also signify the opening of some Tertiary basins in Peninsular Malaysia. This interpretation corresponds to the findings of Late Eocene palynomorph assemblage from Tertiary sediments (Yap & Uyop Said, 2002).

CONCLUSIONS

The occurrence of the dextral sense of movement along the WNW and NW faults within the Bok Bak fault zone which regionally is of the sinistral type were observed in the chert unit of the Semanggol Formation at Bukit Kukus. The movement explains the northward thrust across the ENE to ESE fault planes which were formally the extensional normal faults. These normal faults developed due to the extension in response to the previous sinistral movement along the northwestern faults. The northward thrusts at Bukit Kukus characterize localised transpressional deformation that occurred during the latest fault movement. The thrust has brought the Middle Triassic chert on top of the Late Permian bedded chert of the Semanggol Formation. The dextral movements along the WNW and NW faults are interpreted to be the youngest lateral fault movement onshore in Peninsular Malaysia. Prolonged deformation and rotation may have caused the adjustment of the former structures that finally resulting normal sense of movement along the NW and WNW dextral faults.

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