Temburong and Setap in Northwestern Borneo: Equivalent or Different Formations?

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BACKGROUND

The predominantly argillaceous lithostratigraphic units of the Setap and Temburong Formations crop out extensively in northern Sarawak, Brunei Darussalam and southwestern Sabah (Figure 1). Only a single Setap Shale Formation was recognized of Late Oligocene-Miocene (Te + Tf) age by Liechti et al. (1960) before Brondijk (1962) distinguished a Te1-4 (Late Oligocene) Temburong Formation separated by an unconformity from a younger Setap Formation (Te5 - lowermost Tf; mainly Early Miocene).

The type area of the Temburong unit is in the headwaters of the Temburong River in the Brunei district of similar name. Paleocene to Lower Eocene foraminifera among the Miocene fossils in the Setap unit were classified as "reworked" (see e.g. Kamaludin Hassan, 2004). The Setap Formation was deposited in neritic to littoral environment. The formation is mainly argillaceous with thinner (<10cm) interbeds of siltstone and fine-grained sandstone. Liechti et al. (1960) reported a maximum thickness of 18,500 feet (>5500 m), probably including the yet unrecognized Temburong Formation, in the Sungai Tutoh and Belait Syncline areas. To a field geologist, without the benefit of immediately available fossil recognition, the argillaceous parts of Setap Formation are usually exposed as grey to yellowish brown shales. In places thin silty layers predominate (Figure 2).

In contrast, the Temburong is exposed as dark grey to blackish shale that occasionally encases meter to several meters thick fine to medium-grained

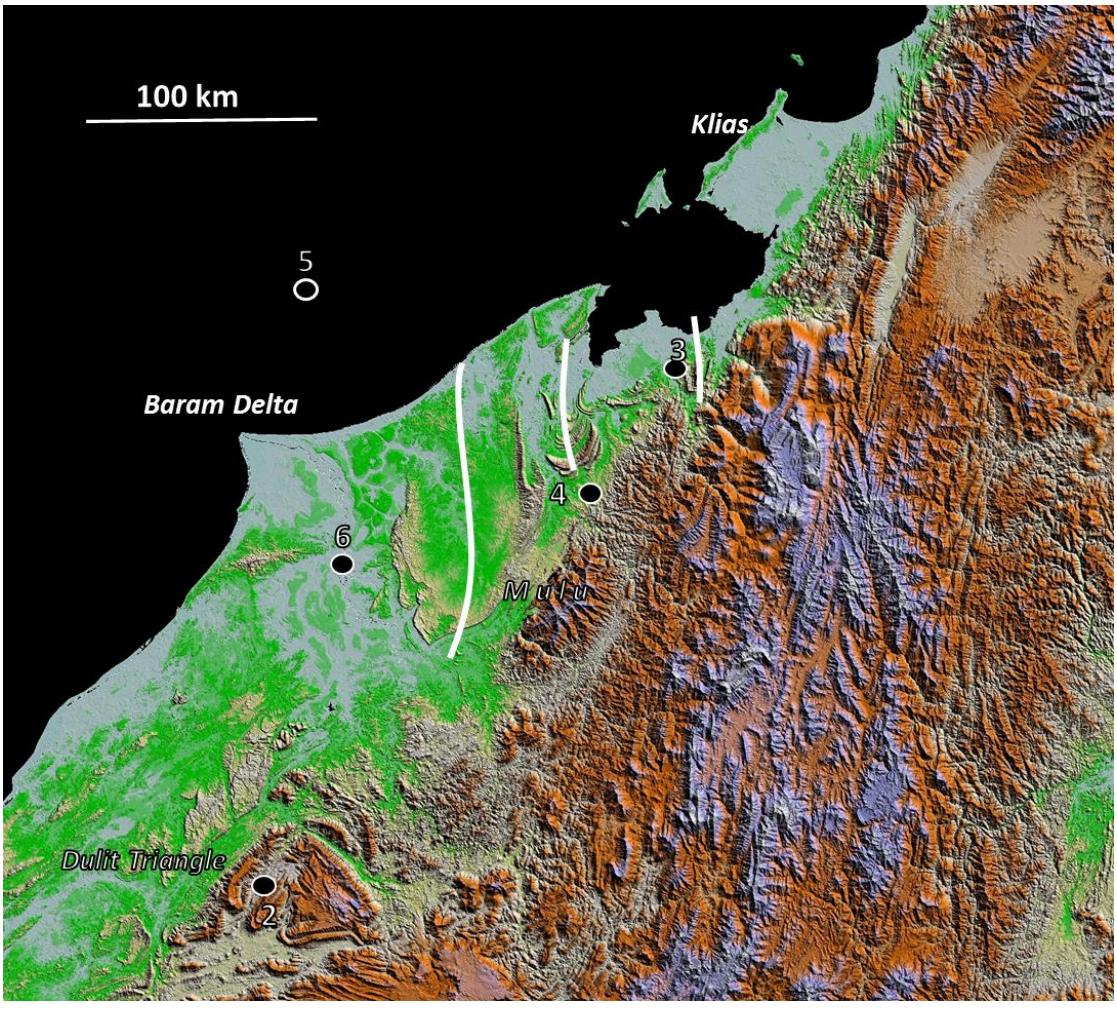


Figure 1.
Index map of part of northwestern Borneo, consisting from lower left to upper right of northern Sarawak, Brunei Darussalam and southwestern Sabah. Numbers refer to figures in this article. Bold white lines from left to right are Belait, Limbang and East Limbang synclinal axes.
Note the Dulit Triangle whose plan resulted from gravity tectonics in an area confined on all sides by major faults (Map from JMG, Sabah - Geological Survey of Malaysia).

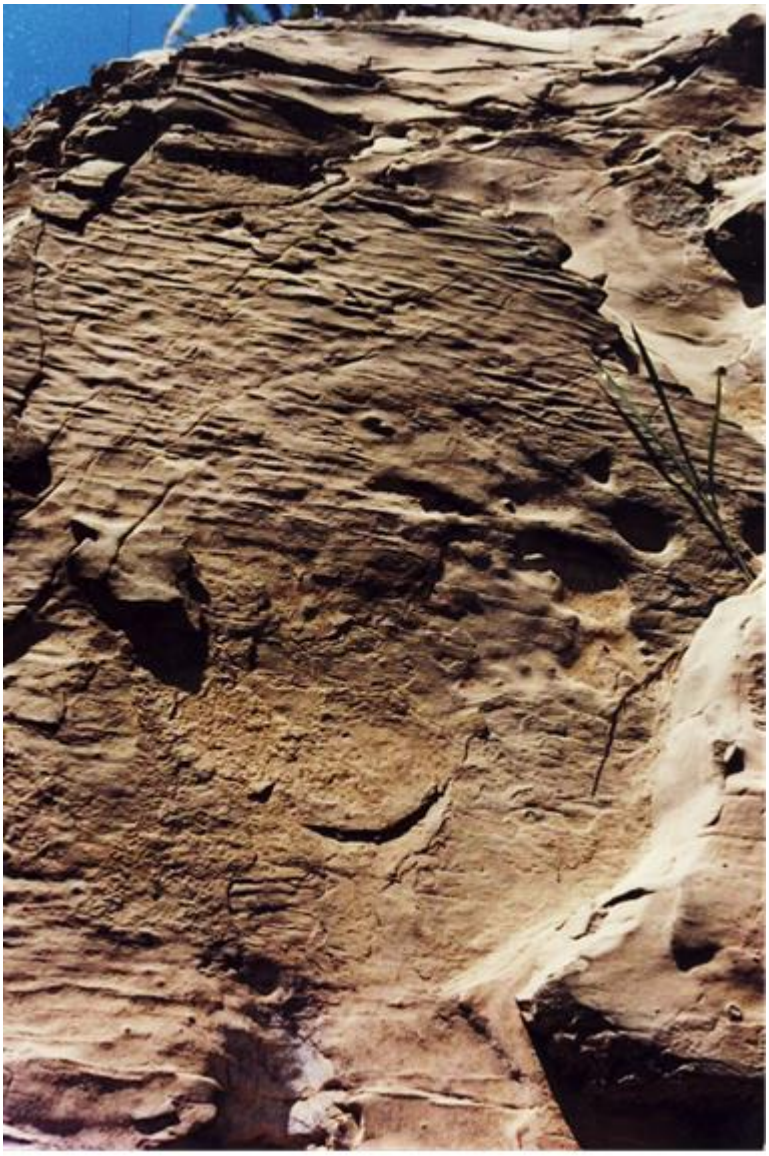


Figure 2.
Bedding surface of steeply inclined shale-siltstone-dominant Setap Formation in the Dulit Triangle. Subparallel ridges on the bedding surface are somewhat deformed current ripples produced by paleocurrent moving towards the observer. The unusual triangular landform plan exhibited by the sandstone ridges of the younger Belait Formation resulted from gravity tectonics lubricated by the shales of the Setap Formation as described in Tjia (1998). Base of the photograph is 2.5 m wide. Bala Timber Camp, Tubau area.

sandstone (Figure 3). The Temburong Shale was deposited in a deep-water marine environment according to Brondijk (1962). The map distribution of these two formations appears to be geographically demarcated by the longitude separating the Limbang district of Sarawak and the Temburong district of Brunei. The text of the 1996 book on Brunei petroleum resources described the Temburong Formation, but its accompanying geological map shows only Setap Formation, even in the upper reaches of the Temburong River that has been referred to as the Temburong type area (Sandal, 1996).

There is a tendency among colleagues who have visited only parts of the areas where Malaysian Geological Survey geological maps clearly indicate the existence of Temburong (to the East of the above mentioned geographical boundary) and Setap (to its West) to lump the stratigraphic units as Setap/Temburong Formation in spite of the great age differences and the unusually great vertical extent that has been estimated to locally range from over 730 m up to 5600 meters or more (Liechti et al., 1960).

NEW EVIDENCE

Outcrop

Figure 4 shows a complex injection contact between dark coloured Temburong into yellowish brown Setap. The Temburong is internally convoluted and encloses fragments of the Setap. The Setap has more regular bedding (white subparallel lines). General stratification indicates dip of 36° obliquely away from the observer with dip azimuth 350°. The outcrop is near the northern tip of the Mulu complex at the Lubuk Lalang log pond (Locality 4 on Figure 1).

Geoseismic Section

Tall mud columns in the subsurface of the Baram Delta area are common and represent mud diapirism. Two of them are illustrated in Petronas (1999, Figures 13.8 and 13.46). Small mud eruptions at the surface, still erroneously called “mud volcanoes” by the general public and geologists alike are well known from Bulak Setap, Meritam (Limbang), Nosong (Klias) and Pulau Tiga. The latter island off the Klias Peninsula is composed of three, up to two hundred meters high cones

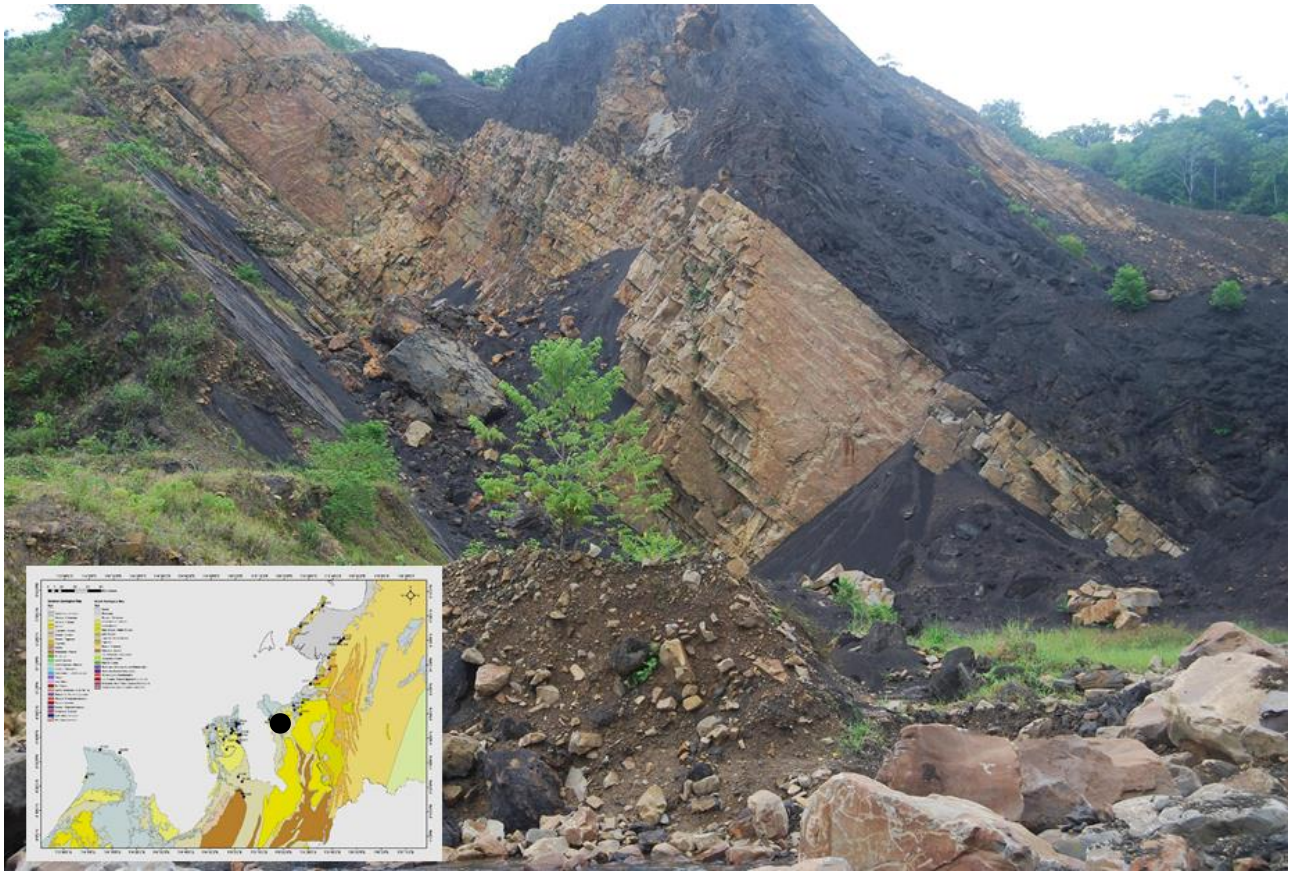


Figure 3. *Black argillaceous Temburong Formation encasing more than 12-meters thick sandstone at Siang Siang quarry in Lawas, Sarawak. The solid circle marks the locality.*



Figure 4. *Injection of black Temburong into yellow-brown Setap. Log pond Lubuk Lalang, Limbang. White lines represent discernible stratification within the formations.*

associated with chaotic assemblages of mega-breccia. Only the northern-most cone shows recent activity. Outside the area of current discussion, mud diapirism has been mapped and are on record

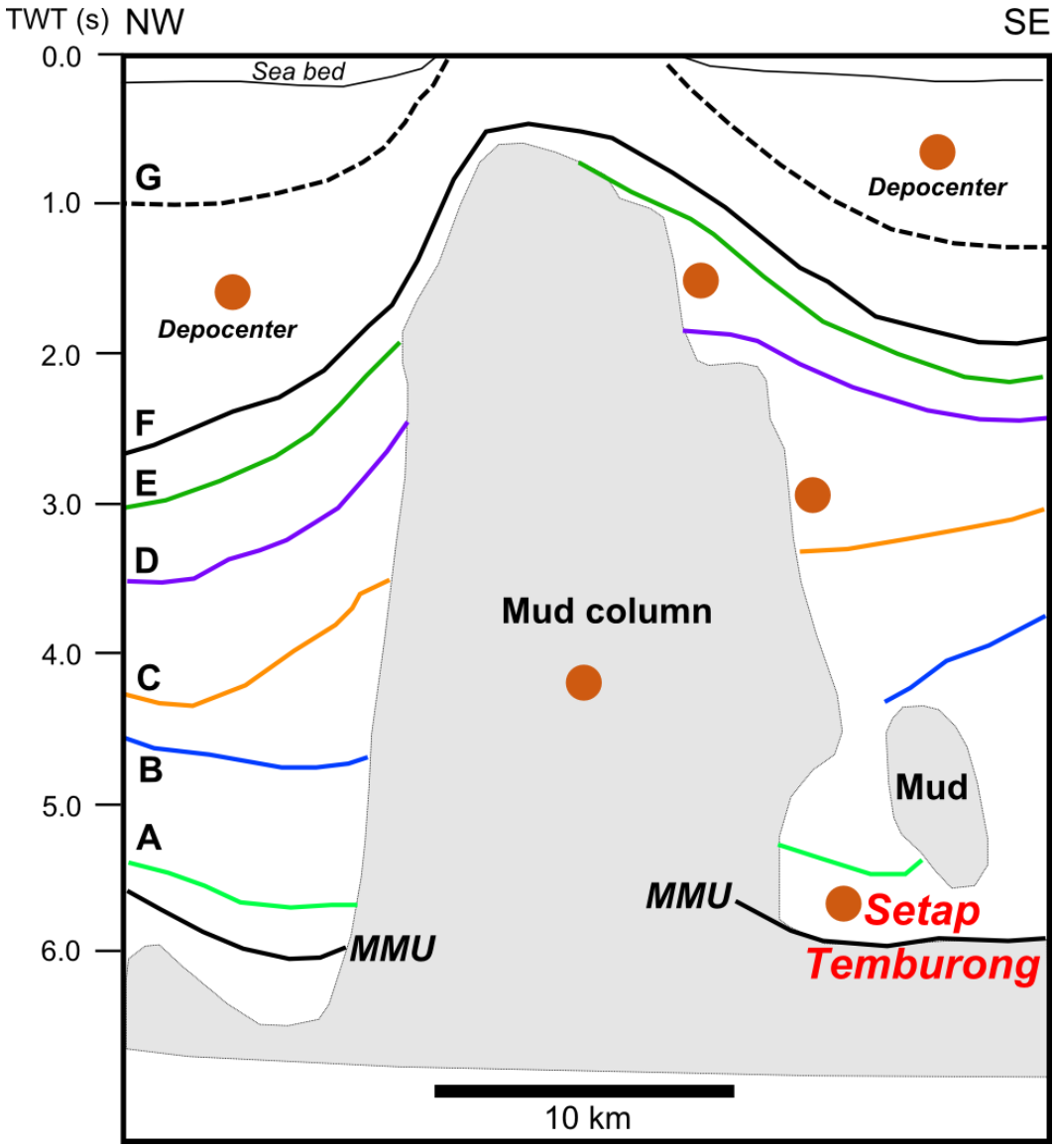


Figure 5. *Geoseismic section of a mud column in the offshore Baram Delta. Vertical scale is in seconds (TWT). In situ "Setap" probably includes the intervals from MMU to the B-event. The regional dip is towards NW and the positions of depocenters switching between updip to downdip sides of the column possibly correlates with pulses of upward injection of the main mud column. The lowest unconformity is interpreted to correlate with the Miocene Regional Unconformity that separates Temburong from Setap.*

by the Geological Survey of Malaysia from northern and eastern Sabah. Slightly over two decades ago suspected mud diapirism spectacularly raised the sea floor up to several meters above the sea to form Pulau Batu Hairan in the vicinity of Pulau Banggi (Lee, 1990).

The geoseismic section provided on Figure 5 is instructive. The NW-SE geoseismic section illustrates a 5.5 second TWT high mud diapir that has risen from an interval interpreted as representing the deep-seated Temburong below the Middle Miocene Unconformity (MMU = circa 16 Ma according to Petronas, 1999). The MMU to A surface is most probably Setap Formation, which is interpreted to extend at least up to the B-event. A to G are other unconformities shown by seismic reflectors. The brown solid dots mark depocenters of thickest interval between respective events/unconformities. The changing positions of these depocenters suggest the mud column to have injected in stages before finally "doming up" in a ductile fashion that impacted events F, G and the seabed. The positions of depocenters with respect to the main mud column suggest that initial injection of the Temburong mud began during the interval of B and C events. The crown of that mud column created a depocenter on the southeastern side of the section allowing a thicker C-D sequence to accumulate on that side. Further updoming maintained the position of the D-E depocenter. Renewed updoming during the F-G interval shifted the respective depocenter to the Northwest. The youngest phase of updoming again shifted the depocenter of the G-Seabed interval to the Southeast. The existence of a rootless mud blob between MMU and C suggests smaller mud injections had accompanied the main diapirism. The outcrop shown in Figure 4 may represent such a smaller mud injection. In this scenario of stage-wise diapirism the mud column beginning after the deposition of the B-C interval could well include small and larger, internally cohesive slabs of Setap that were broken through by the Temburong.

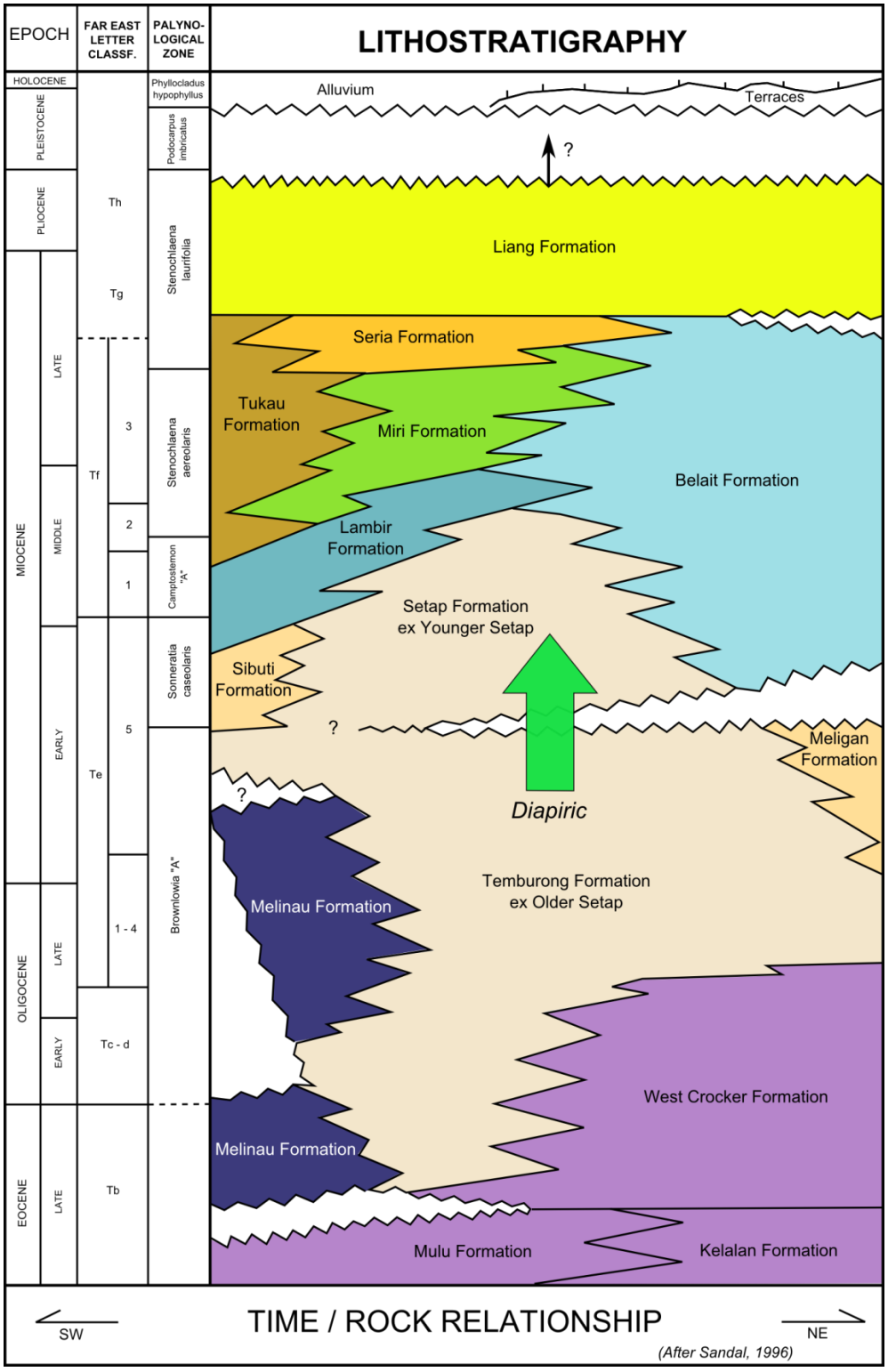


Figure 6. *Lithostratigraphy of northwestern Borneo by Sandal (1996). In places the Setap-Temburong contact is unconformable such as shown by Figure 4. The green arrow illustrates part of their diapiric character.*

Modern Biostratigraphy

Biostratigraphic information that has become available after the initial Brondijk work showed that the upper part of the Temburong Shale Formation actually ranges into the Early Miocene, and the basal part of the Setap Shale is close to the base of the Middle Miocene (zone N8; Basir Jasin et al. 1993 and Basir Jasin, 2002). However, as the mud diapiric structure may contain fragments, possibly of large sizes and reaching high stratigraphic levels, of both Setap as well as Temburong lithostratigraphic units, the author of the current article contends that the positions of Basir Jasin's and Basir et al. interpreted "Setap" may be incorrect.

DISCUSSION AND CONCLUSION

The stratigraphic scheme devised by Sandal (1996 and Figure 6) is supported by the new evidence. *In conclusion it is stated that there exists an Oligocene – Early Miocene Temburong Formation and a mainly late Early – Middle Miocene Setap Formation in*

northwestern Borneo. The diapiric character of the two argillaceous formations in northwestern Borneo is amplified by adding the green arrow.

Figure 6 also explains and confirms a number of significant observations: (a) a diachronous boundary between Setap and Belait Formations (Liechti et al., 1960, p.149), (b) injection contact between Temburong and Setap as in the outcrop of Figure 4, (c) slump structures in drill cores of the Setap in the Kalejau Valley of the lower Baram River (Liechti et al., 1960, p. 145), (d) the perceived extreme thickness of the argillaceous succession of the Setap, (e) the mainly Miocene fossil evidence of the Setap and Oligocene fossil content of the Temburong, and (f) internally coherent Setap masses at high stratigraphic levels, where portions were ripped off its original position immediately overlying Temburong Formation and were transported in stages by the upward moving diapir.

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