Paleovegetation and marine paleoproductivity reconstructed using biomarkers and fossils of the Miocene Miri and Belait Formations, North Borneo, Brunei Darussalam

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The Miocene Miri and Belait Formations of North Borneo exposed in Brunei Darussalam, are characterised as muddy, fossil-rich offshore marine environments and sandy tidal-shoreface shallow marine environments, respectively. Both formations were deposited under progradational deltaic/shoreface sedimentary systems that developed due to rapid uplifting of the Borneo hinterland. Detailed studies on palaeoenvironments and palaeoecology of ancient North Borneo remains largely understudied in these formations. Hence, the objectives of this study are to reconstruct the hinterland paleovegetation changes and the paleoproductivity of ancient North Bornean waters by analyses of biomarkers, sedimentology and fossil assemblages.

The Miri Formation, exposed in Kampong Batong, Brunei Darussalam, consists of foraminifera-rich offshore muds containing deep-water formas such as *Reophax sp.* and *Globigerinoides ruber*. The Belait Formation, exposed in Kampong Meragang, Brunei Darussalam, consists of tide-dominated sandy upper shoreface sediments overlaying lower shoreface mud-rich mud and sandstone alternations. A total of 29 mudstone samples were collected and their biomarker compositions were analysed using GCMS. The fossil-rich mudstone samples were also analysed for microfossil assemblages using transmitted light microscopy.

Based on gymnosperm-derived diterpenoids and angiosperm-derived triterpenoids, an increase in diterpenoid biomarkers throughout the middle to late Miocene suggests an increase of conifers in the hinterland. Such increase, based on modern vegetation patterns (eg. Kitayama, 1992; Langner et al., 2015), may be linked to higher altitudes of the Bornean hinterland during the late Miocene compared to the middle Miocene. An increase in cadalene in the late Miocene sediments may also indicate radiance of certain species of angiosperms.

Using the gammacerane index, offshore waters were slightly more stratified than shoreface waters. A seawards increase in diatom-derived higher branched isoprenoid (HBI) alkanes compared to dinoflagellate-derived dinosterane suggests higher diatom productivity in offshore than in shallower waters. Apart from less sediment load and higher light penetration, cooler temperatures in offshore waters may have encouraged the growth of diatoms.

Keywords: biomarkers, vegetation, primary productivity

