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Addressing mixed facies interpretation difficulties by coupling sedimentary data with ichnofacies and microfossil data: an example from several paralic deposits in Brunei Darussalam.

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The geology of a depositional system can mostly be described by looking at sedimentary structures and sedimentary composition. However, in areas of complex shoreline mixed-process system (influenced by fluvial-tides-marine processes), many factors should be put into consideration. In Brunei, the mixed-sediment types occur extensively. The geology is mainly characterized here by thick Neogene siliciclastic facies ranging from fluvial, tidal and marine sediments deposited during periods of deltaic to shelfal setting, affected also by tectonic events. Due to this, differentiating tide and wave dominated facies is often a major challenge in the region.

In this study, it is emphasized that in order to support interpretations on these transitional facies, specific factors such as ichnofacies and microfossil content can be considered. Pollen and spores are more expected and useful in rather terrestrial systems, whilst in marine environments dinoflagellates, foraminifera and nannofossils could be convenient if preserved. Foraminifera and ichnofossils have the merit to be great indicators of a variety of sub-environments within the complex shallow water system.

The methods involve standard outcrop logging of fluvial, tidal and shallow marine outcrops, identifying lithology and key sedimentary features including trace fossils. Clay-rich samples were checked for microfossil content. Laboratory work involved extracting organic (pollen, spores, dinoflagellates) and calcareous (foraminifera, nannofossils) microfossils and documented them with light microscope (LM), stereo microscope, and Scanning Electron Microscope (SEM).

The results revealed that the most common trace fossil assemblages are the *Ophiomorpha, Cruziana* and *Skolithos* ichnofacies, and they refer to proximal marine settings. Among the calcareous microfossils recovered were very few coccolithophorids (*Sphenolithus abies* and *Sphenolithus moriformis*), which indicate very rare holomarine conditions, while the following benthic foraminifera genera were identified: *Ammonia, Nonion, Elphdium, Elphidiella, Quinqueloculina, Ammobaculites,* and *Trochammina*. Each of these genera have specific environmental requirements concerning hydrodynamics, trophic resources, oxygen content, substrate-type and deltaic influence. Results on pollen and spores, mangrove vegetation is marked

by *Sonneratia* and *Rhizophora*-types, mixed-dipterocarp by *Shorea* spp., while peat swamp by *Verrucatosporites usmensis* and *Osmunda* sp.. Besides few dinoflagellate cysts (*Achomosphaera* sp., cf. *Exosphaeridium* sp., cf. *Operculodinium* sp., gen indet., *Lingulodinium? pycnospinosum* and *Tuberculodinium vancampoae*) and two acrtitarch taxa (*Cymatiosphaera* sp. and *Cymatiosphaera* cf. *nuda*) were found. These findings indicate incomplete sets of parasequences with palaeoenvironments of mixed shallow marine conditions. Mangrove pollen retrieved within tidal sediments indicates mangrove-dominated tide-influenced shoreline, while shoreline with diverse ichnofossils show coastal area connected to wave-dominated upper shoreface/ delta front. The calcareous foraminifera and nannofossil differentiate sediments belonging to lower shoreface to offshore/ prodelta deposits.