Paper 6

A geochemical evaluation of the West Crocker Formation — clues to deepwater source rock facies?

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Recent exploration activity in the present day deepwater areas of offshore northwest Sabah have resulted in varied successes in the targetted turbidite sands; results ranging from dry wells to considerable oil discoveries. These mixed results have raised some issues regarding the hydrocarbon charge in a turbidite setting, particularly concerning the source rock distribution, quality and maturity (Walker, 1978).

Almost all published geochemical studies to date have focussed on the shallow water (present day and ancient) areas of offshore Sabah and have discussed source facies dominated by dispersed terrigenous organic matter (Azlina Anuar, 1994; Leong *et al.*, 1999). However, are these source facies appropriate models for deepwater depositional settings? To try to address this issue, a field study and subsequent geochemical characterisation study, of an onshore deepwater analogue — the West Crocker Formation — were carried out. The West Crocker was selected by virtue of geographic and temporal proximity to the current exploration turbidite targets. In this way, source facies variations were minimised. Furthermore, the West Crocker has been well described sedimentologically, with several turbidite elements recognised and described in the field (Crevello, 1998; Crevello, 2001).

Warta Geologi (Newsletter of the Geological Society of Malaysia), Vol. 29, No. 6, November-December 2003

A total of 92 samples, predominantly shales, were collected from 6 localities around the Kota Kinabalu area, each of which represents one or more turbidite depositional elements: channel margins, channel levees, interchannel overbank, slumps, distal lobe, and basin plain. The collected samples were subjected to a detailed geochemical work programme. The sedimentological work (Crevello, 1998; Crevello, 2001) provided accurate positioning of the analysed samples within a sequence stratigraphic and depositional framework. This allowed comparisons to be made between shales having a predominantly reworked shelfal provenance, and shales of a pelagic, generally transgressive, origin. The geochemical analyses comprised basic source rock screening (TOC, Rock-Eval, and VR) with more advanced characterisation (visual kerogen typing and biomarker studies) of selected samples.

The intimate arrangement of shales and reservoir sands observed at the studied localities is very conducive for direct primary migration into carrier and/or reservoir beds.

The shales studied can be categorised into three main types: *pelagic basin plain shales*, as typified in the Seen Seen Section; *turbiditic shales*, representing either the fine tails of turbidity currents or levee/overbank shales, as observed at the Junkyard section; and *slumped shales/debris flows*, as strikingly displayed at the Papar–Beaufort highway quarry.

The basin floor shales are pelagic in nature and tend to be very thick, with a correspondingly very low sand to shale ratio. The organic richness of these shales tends to be very low, generally less than 0.50 wt%. The biomarker distributions of these shales have a predominantly marine signature, typified by an even C27, C28, C29 sterane distribution and the presence of C30 steranes, an absence of higher plant indicators such as 18a(H)-oleanane and bicadinanes, and low Tm/Ts and Pr/Ph ratios. The low organic richness of the basin floor shales suggests they do not represent a likely source rock facies.

The fine turbiditic shales represent either levee/overbank deposits or the fine tails of turbidity currents. The former consist of either thinly bedded levee system shales with a moderately high sand shale ratio, or of thicker overbank shales. The organic richness in these shales is very variable, ranging from as low as 0.11 wt% to as high as 2.52 wt% with shales separated by a single sandstone bed possessing very different organic richness. The organic richness of some of these turbiditic shales suggests that this is a promising source facies, although the variation in organic richness emphasises the need for close sampling when evaluating turbidite sequences as possible source facies. The biomarker distributions of these shales possess a predominantly marine signature, not too dissimilar from those of the basin plain shales: an even C27, C28, C29 sterane distribution and the presence of C30 steranes, an absence of higher plant indicators such as 18a(H)-oleanane and bicadinanes, and low Tm/Ts and Pr/Ph ratios.

The third type of shale studied are those associated with slumps and debris flows. These are observed at the Papar – Beaufort highway quarry which displays some excellent examples of slumps and a striking debris flow. The organic richness of the slump shales appears to be variable, ranging from a poor 0.42 wt% to a promising 2.75 wt%. The debris flows can be very carbonaceous, with TOC values of up to 68.62 wt% being observed. The biomarker distributions of the slumps and debris flows contrast markedly with those of the basin plain and levee/overbank shales. The slump/debris flow shales display a strong terrigenous, higher plant signature. They are characterised by a marked C29 sterane preference, a lack of C30 steranes, and can contain high amounts of higher plant derived compounds such as 18a(H)-oleanane. The organic rich nature of the slump/debris flow shales suggests that they are a promising source rock facies, although the key question is: *how common are they in a typical deep water sedimentary sequence?* At the Papar – Beaufort highway quarry they are very common and represent quite a prospective source. However, elsewhere they are more scarce, perhaps due to the distal depositional settings involved.

Vitrinite reflectance analysis has revealed considerable variation in the maturity of the West Crocker formation from locality to locality. This maturity variation is considered to be due to the thrusted nature of the formation, in which adjacent slices could have been thrusted up from very different depths. Vitrinite reflectance values range from as high as Ro 2.0% or higher to as low as Ro 0.65%. It is often assumed that the West Crocker is invariably overmature. This study has shown that this is not the case, the full implications for which are, as yet, unsure.