Correlating Borneo Outcrop To Offshore Geology; A Regional Perspective

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A review of outcrop and offshore geological data over a wide area from East Natuna to Sarawak, Kalimantan, Sabah and Palawan encountered numerous mis-matches at national boundaries and study areas, but here we try to link them into a common stratigraphic framework.
Over sixty years of studies have seen evolving usage of both age terminology and formation definitions. Care is required in comparing stratigraphies during the gradual adoption of modern standards. Assigning ages to formations, and especially the correlation and dating of unconformities, remains at the heart of stratigraphy, and is a challenge across such a large range of facies. Historical problems also hamper integration of environmental analyses. The authors have researched historical usage of foraminifera in determining environments of deposition in archived reports. The arenaceous foraminifera that dominate brackish water facies (called "Kakus Faunas" in coaly beds onlapping the eroded Rajang Highlands during the Late Oligocene) and calcite-poor bathyal conditions (large areas of the outcropping Crocker Fan) were initially confused because of similarity in morphologically very simple fossils. An unpublished Shell report by A.J. Keij (1966, supported by dredge samples taken by Shell) has become a "Rosetta Stone" for converting archived taxonomy into a more modern form. Sadly basic mistakes in faunal and environmental interpretation have continued to occur in literature, mainly because faunas in the deep marine, rapidly deposited, sediments are so sparse.

Walther's Law is used to reconcile mismatches in data; so stratigraphic sections in adjacent areas must reflect a history composed of rational palaeogeographies. In the example of environmental determination above, it would not be possible to have both very shallow brackish faunas outcropping close to very deep marine facies without some record of the highly micro-fossiliferous shelf facies somewhere in between, - yet such relationships have been inadvertently proposed in the past. More widespread cross-checking of balanced palaeogeographies has been hampered by data access issues over national or contract-area boundaries, as well as the problems integrating small outcrops containing good samples with continuous, but poor quality, well cuttings samples. Walther's Law is also applied to unconformities as it is inevitable that the geologic factors involved in rapid changes in sedimentation must also balance in space and time. The review here has looked at onshore and offshore data regarding major unconformable events, such as the Base Miocene or Base Meligan Unconformity – or the Top Crocker Unconformity [TCU] as it has become widely known. The also poorly named Mid Miocene Unconformity [MMU] is reviewed, and distinguished from the younger Deep Regional Unconformity [DRU] (Levell, 1987)

The stratigraphic reconstruction presented here appears to fit the plate break-up history of the South China Sea as proposed by Barckhausen et al. (2014). Our new model implies a three-phase, stepped (not diachronous), MMU. Dating of the end of the "Break-up" type unconformity from NE to SW, and the subsequent deposition of carbonates on highs during the following subsidence, supports the three stages of break-up. The oldest event was Early Oligocene and this initiated the Nido Limestone offshore Palawan, the second phase was almost on the Oligo-Miocene boundary and initiated a widespread carbonate and marine flood (the Subis Limestone in Sarawak). The third phase, and the one the MMU was first named after, was seen on seismic by Shell in deep water Luconia (Doust, 1981 and internal reports before then - see it on the figures for the original Sarawak “Cycles” paper of Ho Kiam Fui in 1978). This event seems to peak within NN4, at the end of what we now consider the Early Miocene, rather than Middle Miocene.

The Top Crocker Unconformity [TCU] is also dated as about the Oligo-Miocene boundary, but it is the end of a period of deformation and reworking in north Sabah. Variations in facies seen onshore (Tongkul, 1991, 1994), and nearshore Sabah wells, suggests this deformation was due to southward drift of Palawan into the Sabah area, driven by the first, intra Oligocene, phase of drift in the NE South China Sea. As the plate drift suddenly jumped to SW South China Sea the Sabah compression stopped, and both parts of the southern plate were pulled equally towards the southeast.

The DRU compressional unconformity in western Sabah and Palawan was dated as early to mid Middle Miocene by Levell (1987), and the original data has been re-examined. This was a major event, but the actual compression had begun about latest Early Miocene times, but suddenly paused in mid Middle Miocene times, and this pause left a highly angular contact on seismic once sedimentation (and compression) renewed. This tectonic pause may have been due to the sudden end of subduction off eastern Sabah. Volcanic activity of the Sulu Arc stopped, and it subsided rapidly. A series of reefs fringing or above this arc, onshore called the Tabin Limestone, were terminated in mid Mid Middle Miocene times. They subsided so rapidly that they were being on-lapped and covered by fully bathyal clastics (notably lacking any volcaniclastic heavy minerals) before the end of the Middle Miocene.

At present the best way to accommodate this new interpretation is to change the plate tectonic model. The commonly used reconstruction, of southward subduction of Mesozoic oceanic crust under Sabah and the Sulu Sea, linked to the drift movement in the SCS, and giving rise to the Cagayan volcanic arc, no longer seems the best solution. Preliminary mapping of Early Miocene beds (Stage III clastics in offshore Sabah wells, Meligan Formation and Tanjong Formation in south and central Sabah respectively) does not fit any model of a trench and accretionary wedge during that time. There is also a space problem of how to accommodate a trench and a wedge between Palawan continental crust off northeast Palawan and the extension of the Cagayan Arc into Panay Island.

An old tectonic model is preferred, of northwestwards subduction with a trench on the east side of Sabah (e.g. Rangin, 1989). Oceanic crust roll-back from this subduction created the tension that drove plate drift, at times obliquely, creating compression, as seen between Palawan and northern Sabah during the Late Oligocene. This model fits well with a review of the ages of the extensional mélanges in eastern Sabah, which appear to be the same time as the drift ceased in the SW South China Sea (c. 20.5 Ma; Barckhausen et al., 2014). The rifting onshore and offshore, into what would become the Sandakan Basin, changing to drift at this time would have released the SW South China Sea area from tensional stress.

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