

*Short communication*

## **Discussion: Late Pleistocene sedimentation and landform development in western Kalimantan (Indonesian Borneo). Reply by the Authors**

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### **Abstract**

Quaternary alluvia in Sundaland, as elsewhere, give a simplified picture of the complexity of eustatic, tectonic and bioclimatically driven episodes of erosion and sedimentation during the Quaternary Era. It is premature, therefore, to propose the Batchelor model of the off shore Upper Cainozoic Sundaland sedimentary sequence as a standard for the region. The W Malaysian 'Old Alluvium' includes discrete sedimentary bodies with confirmed upper Pleistocene dates making them co-eval with W Kalimantan alluvial fan terraces whose late Pleistocene age we uphold. We caution the use of humicretes and ferricretes as inter-regional chrono-stratigraphic markers.

The authors are grateful for Dr. Batchelor's comments (1993, *Geologie en Mijnbouw* 71: 281–286), on the discussion of regional correlation of onshore and offshore palaeo-alluvial sediments in the Sundaland region of SE Asia which formed an addendum to our paper on the Quaternary alluvial sediments which occur on the coastal margins of W Kalimantan. His criticisms raise some interesting questions of both general and specific importance.

### **Correlations and dating of 'Sundaland' Quaternary alluvial deposits**

Batchelor contests our suggestion (Thorp et al. 1990: 148) that the Old Alluvium (OA) could correlate with the offshore Alluvial Complex (AC), rather than with the Older Sedimentary Cover (OSC). Our suggestion was made because (a) the Late Pleistocene Alluvial bodies (LPA) of W Kalimantan possess sedimentary and stratigraphic characteristics similar to some descriptions of the OA de-

posits from W Malaysia and Singapore (e.g. Gupta et al. 1987), (b) LPA morpho-stratigraphy invites connection and correlation with the offshore Alluvial Complex (AC) (Aleva 1973, 1985, Aleva et al. 1973, Batchelor 1979a, b) and (c) our initial dating of the LPA deposits suggests a Late Pleistocene age that could correspond not only with the AC deposits but also with published upper Pleistocene <sup>14</sup>C dates obtained for some members of the OA, but not with the OSC.

Batchelor chides us for dependence on published sources, but it is not clear that his 'new data' clarify the problems focussed by our suggestion. When problems of correlation and genetic interpretation occur in respect of age, stratigraphy and facies types, more questions are likely to be raised than are answered by any proposed scheme. In 1979 Batchelor described his innovative proposals as a 'tentative time framework for the depositional history of Sundaland'; this has now become 'the standard Upper Cainozoic offshore sequence' in his comments. One major problem with this assertion

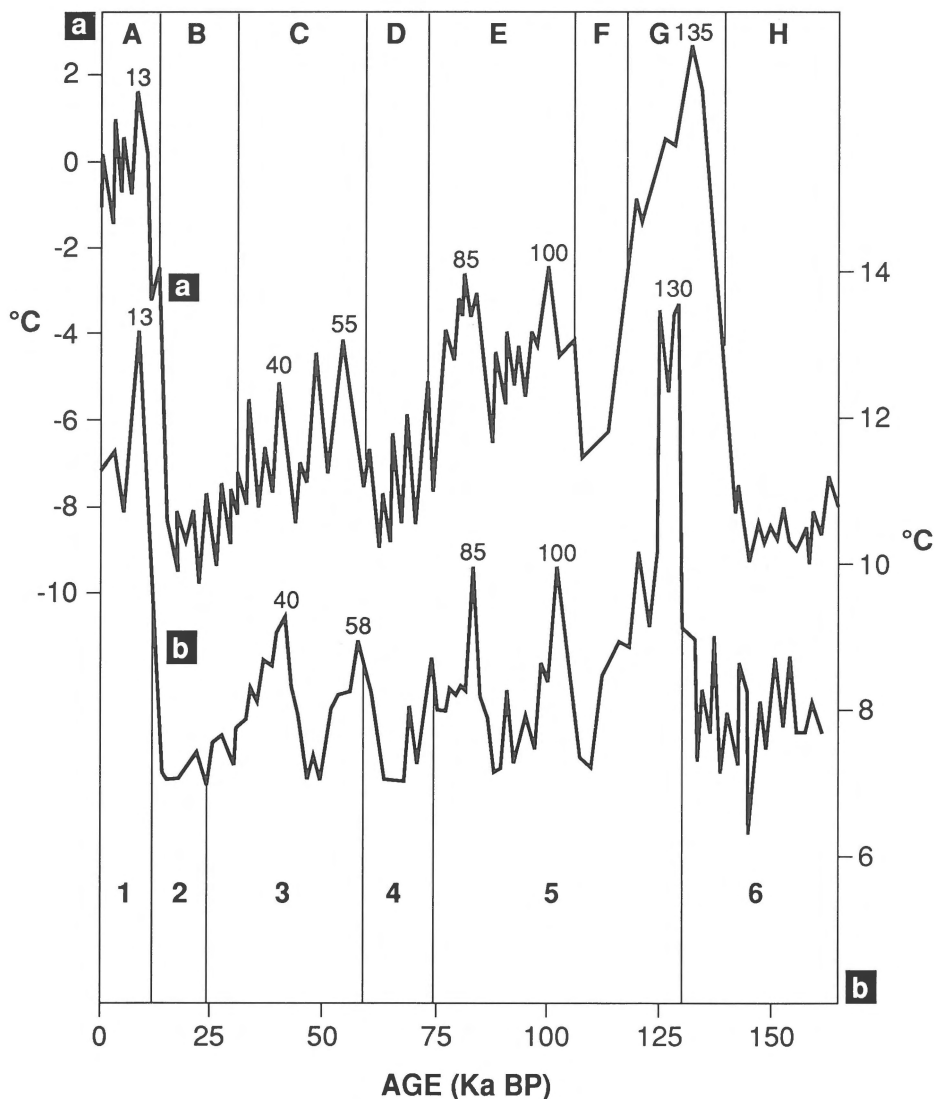


Fig. 1. (from Thomas & Thorp 1993, in press). Curves of palaeo-temperature for the last glacial cycle, based on the Vostok isotope temperature record (a), and (b) estimated Indian Ocean sub-polar sea-surface temperature (RC11-120), simplified after Jouzel et al. (1987). Figures superimposed on temperature peaks are intended to denote expected timing of major erosion/sedimentation pulses affecting world river systems in the last glacial cycle.

is that connections between the offshore stratigraphies and onshore sedimentary histories are at best tentative. This is a classic problem in geomorphology and sedimentology and it arises because of the fragmentary nature of the sedimentary record on land and the frequent discontinuity of borehole records whose sedimentological data is often limited. In the present instance the problem is compounded by uncertainties regarding the dating of the Quaternary deposits on land and especially offshore de-

spite the otherwise invaluable published sonograms (Aleva *op.cit.*, Aleva et al. *op.cit.*, Batchelor 1979a, Lericolais et al. 1987, Van Overeem 1969). Furthermore, as data continue to accumulate stratigraphies will become increasingly complex and models will require continuous revision.

We must also point out that in Batchelor's original Sundaland stratigraphic diagram (1979a: Fig. 7), reproduced in his comments as Figure 1, the AC deposits appear as time-transgressive into the upper

members of the lower Pleistocene OSC. If this is not intended, and we note that the diagram is shown partly amended in Figure 2 of Batchelor's comments, then some confusion has existed between time-stratigraphic and morpho-stratigraphic representations of the sequence.

Batchelor also complains we have wrongly interpreted descriptions of the AC as containing 'alluvial fan facies towards its landward margins', but in the Lumut-Dindings offshore stratigraphy as shown in Batchelor 1979a, Fig. 6 (and 1979b: Fig. 2), a 'piedmont fan margin' is clearly labelled as part of the AC, though this is not discussed.

An important issue for the geomorphologist working on land is to consider how the present landscape has evolved during periods of erosion and sedimentation, and this is a particularly acute problem for Quaternary geomorphology in the Sundaland area of SE Asia. If the LPA terraces identified in W Kalimantan (Thorp et al. 1990) equate to the OA and date back to the early Pleistocene, how then do we explain their survival, and the lack of any morphological evidence for the impact of five major global climatic cycles and many significant sub-cycles in-between? This problem must also apply to interpretations of the W Malaysian OA as being pre-Brunhes Chron. The terraces which we have identified in W Kalimantan as LPA have been slightly modified by surface erosion and dissected by the present day rivers, but the sediments from beneath the adjacent Holocene floodplains date from around 10 000 yr BP. Even during the last global glacial cycle, several episodes of climatic warming have occurred, and we might expect a geomorphic response from the most important of these (Fig. 1, from Thomas & Thorp 1993, in press). Similar problems arise if the LPA were to be correlated with the Transitional Unit (TU). The comments in our paper about the terraced alluvia to be seen further inland in W Kalimantan and which are sedimentologically quite different from the LPA, and which Batchelor wrongly thought to be contradictory, are pertinent in this regard for they are the results of episodes of erosion and sedimentation earlier in the Pleistocene.

Whilst the evidence of ages is, so far, fragmentary and perhaps unconvincing, the literature on the OA

suggests considerable spatial, stratigraphic and genetic variability within a complex group of discrete sedimentary bodies. Accurate dating is therefore required to resolve many of the issues of correlation and interpretation. Our paper did not attempt to address this issue of dating the OA but several points require mention.

We think that Batchelor dismisses too easily the various published  $^{14}\text{C}$  age determinations of 36 000–42 000 yr BP for sediments regarded as OA, or TU, including the data of 42 000 + 1600/–1400 yr BP for the upper clay member of the Simpang Formation (= OA) by Suntharalingam (1984: Fig. 7). Is the degree of contamination and stratigraphic complexity so great as to make these organic samples as old as the Matuyama Chron? Notwithstanding the problems of reliability of 'old'  $^{14}\text{C}$  dates we believe there is a strong case to be made for placing some of the strata hitherto regarded as OA into the last global cold cycle and thus into the stratigraphic position accorded the AC.

In the case of the two dates of 54 000 and 51 000 yr BP we published for our LPA, we have been assured by the CIO laboratory at Groningen that these are finite dates for uncontaminated samples (wood cut from large logs). We note with interest the confidence placed by Van der Hammen et al. (1992) in finite  $^{14}\text{C}$  dates of 56 000–30 000 yr BP (also determined at Groningen) for alluvial sediments in Colombian Amazonia formed, they argue, during the same middle Pleniglacial climatic perturbation. We would have liked to present results from thermal luminescence dating of these alluvia but preliminary attempts on quartz grains were not successful.

In this context we are indebted to Prof. C. Woodroffe for allowing us a prepublication view of a paper by Kamaludin et al. (1993, in press) which describes the dating by thermoluminescence and AMS  $^{14}\text{C}$  methods of Old Alluvium Simpang Formation strata as exposed in two mines in Perak, West Malaysia. For the top 15 metres of the sections, which here descend below M.S.L. and whose bases were not seen in the exposures, a Late Pleistocene age is indicated with absolute dates ranging from 28,000 to >67,000 yr B.P.

We remain convinced, therefore, that the W Kali-

mantan LPAs were built during a period of enhanced erosion and sedimentation dating to the onset of the oxygen isotope stage 3 during the last global cold cycle (Fig. 1). We correlate our LPA with Aleva and Batchelor's AC, the fluvial dissection and podzolic leaching of the LPA with Aleva's phases of upper planation, soil formation and shallow valley formation, and the Holocene alluviation and transgression with the Younger Sedimentary Cover (YSC).

We do not feel able to comment authoritatively on the reliability of the 0.70–2.41 Ma Matuyama Chron palaeomagnetic dating of the OA, though one might wish to know something of the statistical basis of the work, the comparability of the dated sediments to OA sediments elsewhere and especially to those not over limestone bedrock, solution of which may let down or introduce deformation of overlying sediments, the mineralogy of the dated material, the extent of its inheritance from older sources and any possible post-depositional diagenetic effects on the magnetic properties of the sediments and minerals.

Some of the problems of correlation and dating stem from the use of the terms Young Alluvium and Old Alluvium to embrace several formations and bodies. We are particularly worried by Batchelor's grouping together under the name YA sedimentary bodies clearly produced during the last global cold cycle (120 000–13 500 yr BP) with those laid down during the Holocene. Such a grouping obscures what, for geomorphologists, is one of the most clearly pronounced and well known changes in upper Quaternary stratigraphy and morphogenesis.

Given the uncertainties surrounding the nomenclature and ages of alluvial sediments on land and in the context of the Aleva and Batchelor versions of the Sundaland sequence, the correlation of the LPA sediments of W Kalimantan with the AC is logical, and even if different occurrences of onshore deposits known as OA from W Malaysia range from ca 36 000 yr BP to early Pleistocene in age, they also could correspond in part with the AC. What this reasoning suggests is that a series of deposits occur, the OA, that may include representatives of the OSC, the TU and the AC and which form a fragmentary and so far sparsely dated record of the

Quaternary denudation and sedimentation history of this part of SE Asia.

In short, we are not satisfied either with existing age criteria or with available regional correlations, and we see our own discussion as perhaps a timely opportunity to raise a number of doubts and questions concerning the 'accepted wisdom' regarding the age relationships amongst largely Pleistocene sediments in this part of SE Asia. Perhaps it may be time to take a new approach to the Pleistocene stratigraphy of Sundaland.

### **Geomorphic history and sedimentation in Kalimantan**

Regarding our own work on the W Kalimantan LPA and the 'new data' presented by Batchelor, we did not state that 'the late Pleistocene alluvial terraces are giant podzols'. We made it quite clear (p. 138) that it is the *soils* developed on these sedimentary bodies that are 'giant' podzols. As we explained, there is a considerable literature on the subject of podzolisation under hydromorphic conditions on permeable substrates often containing abundant free quartz in the humid tropics. It is quite clear that the humicrete ( $B_h$ ), subjacent mottling ( $B_{ox}$ ) and clay-rich layers ( $B_t$ ), frequently observed beneath the surficial podzolised white sands, are all integral parts of highly leached podzolic soils, brought about by the throughput of 2–3 m yr<sup>-1</sup> of rainfall over a period probably exceeding 30 000 yr and which has been sufficient to bring about the biochemical leaching and eluviation of fines that have led to the formation of the upper white sandy layer (1–5 m thick) and the subjacent illuvial  $B_h$  humicrete horizon (Brabant 1989, Siefferman 1988). Such podzols have also been observed to develop subsequently in ferrallitic weathering profiles and soils (Lucas et al. 1989). This is not to deny that colluviation may have played a part in the production of surface layers which are now podzolised, nor that some alluvial sedimentary bodies, generally white and light grey in colour, overly ferrallitic weathering profiles in Kalimantan.

Consequently we find it difficult to accept Batchelor's interpretation of colluvial white sands over-

lying humicretes and ferricretes in Central Kalimantan as having been spread over a planation surface of regional extent correlatable with the lateritisation of the OA in W Malaysia and dated there as early mid Pleistocene. Our field data and that of associates indicate that the Neogene stratigraphy in C Kalimantan is far more complex than shown in his Fig. 2.

## Conclusion

1. It is premature to describe the existing model of sedimentation and stratigraphies developed in the W Malaysian and Indonesian offshore tin islands areas as 'the standard Upper Cainozoic Sundaland sequence', let alone extend it to C Kalimantan as Batchelor proposes. There is much regional diversity in 'Sundaland' and correlation tables attempted by different workers point to anomalies and uncertainties. Although global cycles of climatic change will have affected the whole area during the Neogene, their geomorphological impacts will have varied qualitatively and quantitatively. Individual stratigraphic sequences will reflect this and also the effects of any vertical tectonic movements and the complex response of the landscape and the rivers that drain it.

2. Difficulties in matching onshore and offshore sedimentary records will always exist because denudation history on land is fragmentary and partially destroyed by later erosion while the interaction of terrestrial and marine sedimentation systems in coastal areas and beneath shallow epicontinental seas must be complex. There are yet too few reliable dates upon which to scale a regional stratigraphy, and research will be impeded by the premature acceptance of tentative time frameworks for application outside their type locations.

3. In our present state of knowledge we see no reason to retract either our proposal that the LPA terraces in W Kalimantan correspond with the offshore AC deposits in the Aleva-Batchelor model or our suggestion that elements of the OA may correlate with the AC. But we do recognize that these constructs like all others must be rigorously tested.

Despite the foregoing remarks, we recognize the

invaluable contribution made by the pioneering work of Aleva and Batchelor in respect of the offshore stratigraphy of western Sundaland and W Malaysia. As local studies increase so also will the spatial complexity of the sedimentary record. It is to be hoped that our work in Kalimantan can contribute to the emergence of a clearer picture in the future.

## Addendum

Since submitting this response the authors have had the opportunity to read a paper by Kamaludin et al. (1993, in pres). These authors describe the dating by thermoluminescence and AMS  $^{14}\text{C}$  methods of Alluvium Simpang Formation strata as exposed in two mines in Perak, West Malaysia. A Late Pleistocene age, with dates ranging from 28,000 to >67,000 years B.P., is indicated for the top 15 metres of the sections which here descend below M.S.L. and whose bases were not seen in the exposures. These results confirm and add further weight to our comments and we express our gratitude to one of the authors, Prof. C. Woodroffe, for allowing us a pre-publication view of this paper.

## References

- Aleva, G.J.J. 1973 Aspects of the historical and physical geology of the Sunda shelf essential to the exploration of submarine tin placers – *Geol. Mijnbouw* 52: 79–91
- Aleva, G.J.J. 1985 Indonesian fluvial cassiterite placers and their genetic environments – *Geol. Soc. London J.* 142: 815–836
- Aleva, G.J.J., E.H. Bon, J.J. Nossin & W.J. Sluiter 1973 A contribution to the geology of part of the Indonesian tin belt: the sea areas between Singkep, Bangka and around the Karimata Islands – *Geol. Soc. Malaysia Bull.* 62: 257–291
- Batchelor, B.C. 1979a Geological characteristics of certain coastal and offshore placers as essential guides for tin exploration in Sundaland, south east Asia – *Geol. Soc. Malaysia Bull.* 11: 283–313
- Batchelor, B.C. 1979b Discontinuously rising late Cainozoic eustatic sea levels, with special reference to Sundaland, South-east Asia. *Geol. Mijnbouw* 58: 1–20
- Batchelor, D.A.F. 1988 Dating of Malaysian fluvial tin placers – *J. Southeast Asian Earth Sciences* 2: 3–14
- Brabant, P. 1989 La Répartition des Podzols à Kalimantan (Ile de Borneo). In: D. Righi & A. Chauvel (eds.): *Podzols et Pod-*

- zolisation: 13–24. *Comptes Rendus de la Table Ronde Internationale, Assoc. franç. pour l'Etude du Sol, ORSTOM/INRA*
- Gupta, A., A. Rahman, W. Poh Poh & J. Witts 1987 The Old Alluvium of Singapore and the extinct drainage system to the South China Sea – *Earth Surface Processes and Landforms* 12: 259–275
- Jouzel, J., C. Lorius, J.R. Petit, C. Genthon, N.I. Barkov, V.M. Kotlyakov & V.M. Petrov 1987 Vostok ice core: a continuous isotope temperature record over the last climatic cycle (160,000 years) – *Nature* 329: 403–408
- Kamaludin, B.H., T. Nakamura, D.M. Price, C.D. Woodroffe and S. Fuji 1993 Radiocarbon and thermoluminescence dating of the Old Alluvium from a coastal site in Perak, Malaysia. In: C.D. Woodroffe (Editor), *Late Quaternary Evolution of Coastal and Lowland Riverine Plains of Southeast Asia and Northern Australia. Sediment. Geol.*, 83 (in press).
- Lericolais G., A. Berne, Y. Hamzah, S. Lallier, W. Mulyadi, F. Robach & S. Sujitno 1987 High-resolution seismic and magnetic exploration for tin deposits in Bangka, Indonesia – *Marine Mining* 6: 9–21.
- Lucas, Y., R. Boulet, A. Chauvel & L. Veillon 1989 Systèmes sols ferrallitiques-podzols en région amazonienne. In: D. Righi & A. Chauvel (eds.): *Podzols et Podzolisation, Comptes Rendus de la Table Ronde Internationale, Assoc. franç. pour l'Etude du Sol, ORSTOM/INRA*: 53–68
- Sieffermann, R.G. 1988 Le système des grandes tourbières équatoriales – *Ann. de Geogr.* 544: 642–666
- Suntharalingam, T. 1984 Quaternary stratigraphy and prospects for placer tin in the Taiping-Lumut area, Perak. – *Geol. Surv. Malaysia Bull.* 17: 9–32
- Thomas, M.F. & M.B. Thorp 1993 in press: The Geomorphology of some Quaternary Placer Deposits – *Z. Geomorph. N.F. Suppl.-Bd.* 87: 1983–194
- Thorp, M.B., M.F. Thomas, T. Martin & W.B. Whalley 1990 Late Pleistocene sedimentation and landform development in western Kalimantan (Indonesian Borneo) – *Geol. Mijnbouw* 69: 133–150
- Van der Hammen, T., T.J.F. Duivenvoorden, J.M. Lips, L.E. Urrego & N. Espejo 1992 Late Quaternary of the middle Caqueta River area (Colombian Amazonia) – *Journal Quaternary Science* 7: 45–55
- Van Overeem, A.J.A. 1969 Sonia Continuous Profiler – Offshore Technology Conference, Houston, Texas: 213–216