Geologie en Mijnbouw **74:** 187–190, 1995.

Short communication

Discussion: Alluvial architecture of the Quaternary Rhine-Meuse river system in the Netherlands. Reply by the Author

Gerard H.J. Ruegg
Present address: Bos en Duinplein 5, 2061 VS Bloemendaal, the Netherlands

Received 14 February 1995; accepted in revised form 8 March 1995

Key words: hinge line, terrace intersection

In his contribution, Törnqvist (1995) questions the significance of initial lateral accretion near the top of the 'terrace gravels' in the Belvédère pit (Ruegg 1994: fig. 7b). In his opinion this deposit is inconsistent with my statement that, upstream of the terrace intersection point, deposits of meandering rivers are found underneath those of braided rivers. What I stated was, however, that the deposits near and on top of the braided-river deposits represent an incipient and immature meandering channel, which lost the competition with a rival incipient meandering channel. The meandering phase is represented by a laterally accreted setting in the uppermost 0.5 m of the gravelly deposit, overlain by 0.5 to 1.50 m of sand which locally exhibits levee characteristics. These deposits were laid down by a small meandering stream, quite incomparable in size with the meandering Meuse. The abrupt decrease in grain size points to an abrupt decrease in discharge. Vandenberghe (1993) also emphasizes the small scale of this fluvial phase. In other words, considering which shallow channel eventually became the one and only meandering channel: many were called but only one was chosen; and it was not the channel in the Belvédère area. Only deposits laid down during this competitive initial meandering phase are known to occur on top of terrace gravels. The later and much larger part of the deposits of prolonged meandering river activity was formed at a much lower topographic level, and was covered by subsequent braided-river deposits.

The main problem discussed by Törnqvist concerns the nature of the terrace intersection. He points out that in my paper (Ruegg 1994) two definitions are given of the terrace intersection point (TIP). In his opinion, my definition 'the location where the fluvial terrace landscape (exhibiting net incision) changes downstream into a non-terraced landscape (characterized by net aggradation)' corresponds with the definition of a hinge line (a term not mentioned by me). My second definition: 'upstream of the intersection the depth of a river's incision exceeds the thickness of its own previous deposits, whereas downstream of the intersection the reverse applies', is, according to Törnqvist, related to the view of Pons (1957). However, my TIP concept is based on Zonneveld (1963), see Fig. 1; a comparable picture is published by Brunnacker (1974), see Fig. 2. I stress that both definitions apply to the TIP concept of Zonneveld. Pons (1957) used the term terrace intersection point for intersections of slope lines, which is something quite different. In this reply, the term TIP is used in Zonneveld's sense. A TIP can only be identified as such once a complete climatic cycle with the corresponding fluvial process cycle has been completed.

The essence of my paper was, that the Quaternary Rhine-Meuse river system and its deposits are formed under the combined influence of major tectonic movements and major climatic cycles. Sea-level movements reflecting climatologic and eustatic causes did not affect TIP development, and had only a limited effect on its location. In general terms I related the different development on either side of the TIP to the rise of the Rhenish Shield on the one side and the subsidence of the North Sea Basin on the other.

The location of the TIP is determined initially by the end of a meandering, and thus incising phase, i.e. at the end of an interglacial (subsequently the system changes back to braiding, and thus also to aggrading).

During the Quaternary, the TIPs of both Rhine and Meuse shifted about 100 km downstream (M.W. van

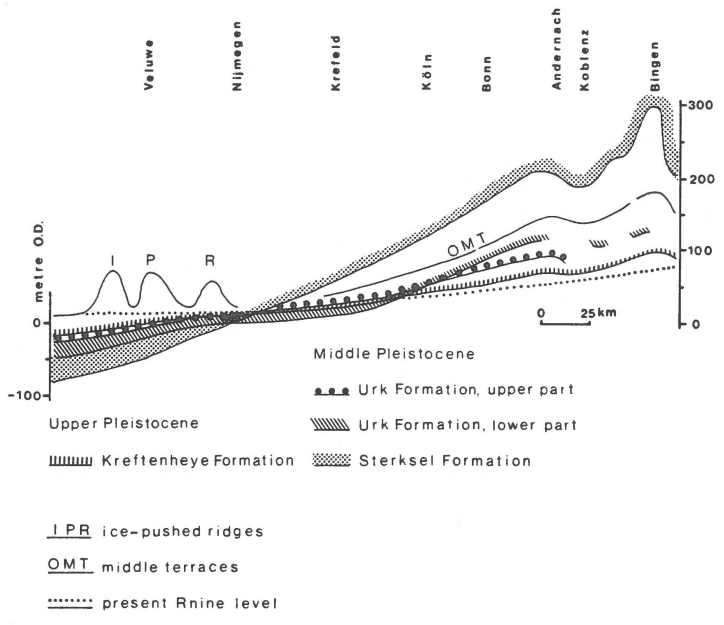

Fig. 1. The terrace intersection along the Rhine (after Zonneveld 1963; simplified). OMT: upper middle terrace (Obere Mittelterrasse); IPR: ice-pushed ridges; dotted line: present-day longitudinal valley profile of the Rhine.

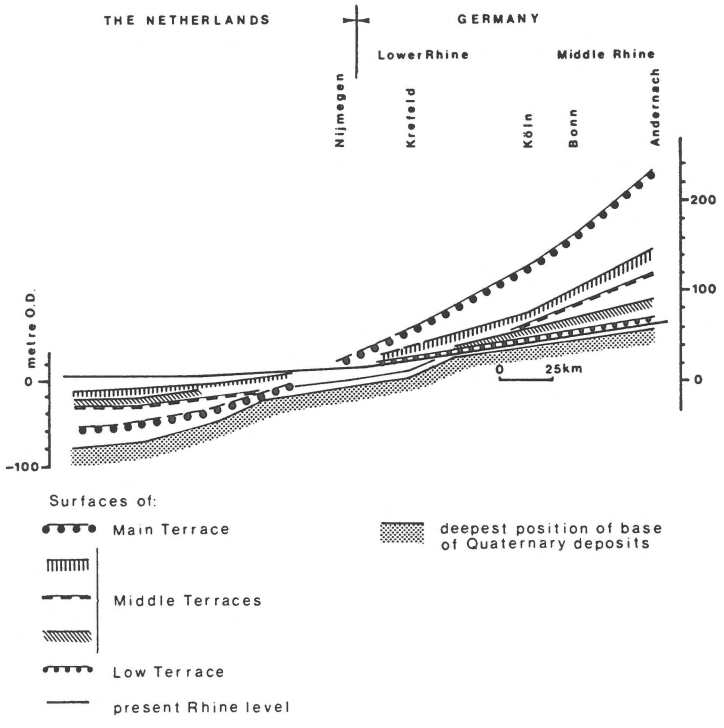

Fig. 2. Cross-section through the drainage area of the Rhine (after Brunnacker 1974).

den Berg, pers. comm.). Basically, this phenomenon can be attributed only to shifting of the hinge line.

Subordinate shifts of the TIP location are determined by the magnitude of the transgression, the thickness of the river deposits laid down during the preceding glacial time, the duration of the interglacial, and the erosive force of the meandering river.

In my paper (p. 327) I assumed an upstream shift of the future TIP during an interglacial time. On second thoughts this statement is not right: boundary points that determine a future TIP location will move downstream during a period dominated by a meandering river system.

The Rhine-Meuse system has two transition points in its course. One of them is the upstream limit of the anastomosing zone; during an interglacial, this point marks the transition from anastomosing to meandering, here abbreviated as MAP. The TIP is located further upstream. During the warming-up phase of an interglacial, the MAP shifts upstream for hundreds of kilometres, whereas the position of the TIP remains relatively unchanged. Consequently, the distance between MAP and TIP decreases considerably; during the Holocene it amounted to only a few dozen kilometres. During cold times the MAP shifts towards the edge of the present-day North Sea shelf; the distance between MAP and TIP eventually increases to several hundreds of kilometres.

On the basis of the above considerations,Törnqvist's statement 'the hinge line is likely to have a relatively fixed position over relatively long periods, like the entire Quaternary' is not justified. Where Törnqvist states 'the terrace intersection was located near Rotterdam by 8000 yr B.P., and presumably much further to the (south)west around the Pleistocene-Holocene transition', a different, and not generally accepted, sense of this term is used, viz. that of Pons. It seems, that Törnqvist uses this unconventional meaning also with respect to the discussion of Sangamonian (= Eemian) deposits of the Mississippi, for instance in the discussion of 'the climatically and/or eustatically controlled terrace intersection'. Törnqvist mentions the Sangamonian 'fluvial and deltaic highstand deposits' as terrace remnants. It is conceivable, that a river incises its previously formed anastomosing-zone deposits during the cooling phase of an interglacial, when sea level drops. However, a terrace formed in this way will have no morphological preservation potential on the flank of a subsiding basin, as is the case for the Rhine-Meuse system in the Netherlands.

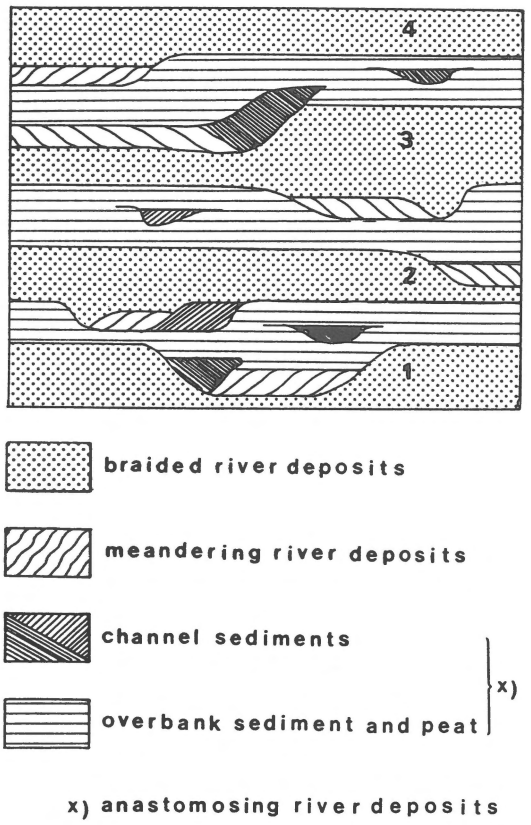

Fig. 3. Schematic diagram of the relation between braided, meandering and anastomosing river deposits in the coastal zone, such as formed during a period comprising four cold stages (cf. Ruegg 1994: fig. 11).

In my opinion, Fig. 3 shows a more realistic schematic picture of the stratigraphy of an area, where a river repeatedly acquired an anastomosing character during successive interglacials as a result of a rise in sea level, compared to fig. 2B of Törnqvist.

Törnqvist argues: '..it is clear that meandering (or anastomosing) rivers downstream of the hinge line were predominantly aggrading'. I refer to the footnote on p. 323 (Ruegg 1994). I still believe that meandering rivers incise and that anastomosing rivers aggrade. Channels in anastomosing zones may meander for some time and over some distance. Considered over a longer time, these rivers are dominated by avulsion processes; meandering is only a subordinate process in this (sub)environment; the net result here is aggradation. Thickness versus time comparisons between deposits (without considering *in-situ* formed peat deposits) laid down either during a braided-river phase or during a (partly) anastomosing phase, considered over only a

small area such as the western Alblasserwaard mentioned by Törnqvist, do not provide much information on the total sedimentation balance of the fluvial deposits for the period concerned.

In this discussion we are dealing with two basically independent processes in river reaches, both taking place because of large climatological cycles. One of them is concerned with the influence of sealevel movements in a river plain; the other has to do with deposition and erosion on both sides of a hinge-induced terrace intersection. The first-mentioned process is likely to occur in a river setting without such a terrace intersection; the latter process may occur in a river flowing into an inland sea which is not influenced by global sealevel movements.

In the Rhine-Meuse system we have to do with a situation in which during some interglacials, the anastomosing river zone approaches the TIP area so closely, that a certain influence upon the latter may be possible, as described above. In other river systems in the midlatitudes, the MAP and TIP may remain far apart and without such influence at all. The moving up of an anastomosing zone over a TIP area is another possibility.

Acknowledgements

Meindert van den Berg (Geological Survey of the Netherlands) is thanked for critical reading and valuable remarks. Ad Walkeuter took care of the figures. Mrs. T. van de Graaff-Trouwborst corrected an earlier English translation.

References

Brunnacker, K. 1974 Results of Quaternary stratigraphy on the middle and lower courses of the Rhine. — IUGS-UNESCO International Geological Correlation Programme. Proj. 73/1/24: Quaternary Glaciations in the Northern Hemisphere. Report No 1: 17–33.

Pons, L.J. 1957 De geologie, de bodemvorming en de waterstaatkundige ontwikkeling van het Land van Maas en Waal en een gedeelte van het Rijk van Nijmegen. — Versl. Landbouwk. Onderz. 63.11: 1–156.

Ruegg, G.H.J. 1994 Alluvial architecture of the Quaternary Rhine-Meuse river system in the Netherlands. – Geol. en Mijnbouw 72: 321–330.

Törnqvist, T.E. 1995 Discussion: Alluvial architecture of the Quaternary Rhine-Meuse river system in the Netherlands. — Geol. Mijnbouw: this issue.

Vandenberghe, J. 1993 River terrace development and its relation to climate: the Saalian Caberg terrace of the Maas river near Maastricht (The Netherlands). — In: J. Vandenberghe, W. Roebroeks & T. van Kolfschoten (eds): Maastricht-Belvédère: stratigraphy, palaeoenvironment and archaeology of the Middle and Late Pleistocene deposits; Part II – Meded. Rijks Geol. Dienst 47: 19–24.

Zonneveld, J.I.S. 1963 Accumulation and erosion in the lower Rhine area. — (INQUA) Report VIth Int. Congress on Quaternary (Warsaw 1961), Lódź, Vol. III: 403–410.