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How extreme floods can trigger river avulsion beyond delta plain limits

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Maturisation: >AD 730-890 Initiation: >AD 590-750 Kampen Floods: AD 300?, 550 Maturisation: AD 780-980 Zwolle

ABSTRACT

In lowland fluvial environments such as delta plains, rivers can create new branches through avulsion. This causes reorganizing of discharge diversion over the delta, in cases breaching former limits of floodplains to annexate new areas. Avulsions show a phased development, beginning with crevasse splay formation during floods, eventually maturing into a new single meandering river channel. This overall process can take several centuries and is affected by the flooding regime of the river. Periods of intensified flooding are thought to initiate avulsions, push ephemeral overflow routes to become permanent, and cause crevasse complexes to evolve into single channels. This means that studies of the pacing of geomorphological change can benefit from palaeohydrological studies focusing on the timing of larger flooding events.

Here we show the role of major flood events in fluvial morphology for the Gelderse IJssel case in the eastern Netherlands. This 100 km long river resulted from a major avulsion in the Rhine delta that occurred in the first millennium AD. It annexed a peat filled brook valley and debouched into the Central Netherlands lagoon. This downstream valley hosts a unique geological dataset to track the phasing of avulsion, while the upstream delta has a complete record of major flood events. These flood events have been independently identified in sedimentary and dendrological palaeohydrological records.

Triggering of the avulsion occurred while increased fine-sediment loads doubled due to deforested hinterland and when flooding intensified from the 6th to the 8th century AD. From the 7th century onwards a crevasse complex had permanently breached the rim of the former floodplain. A final extreme flood (c. AD 784/5) appears to have triggered maturation into a single meandering channel, that by 1000 AD was fully developed. These dates are in agreement with geological data upstream and with abundant archeological and historical evidence along the river, such as the rise of the cities of Deventer and Zutphen. This case highlights the importance of extreme flood events for fluvial morphology, delta-network evolution and the impact on people living in the delta.



Trees rings indicate stress: AD 300, AD 550

Drainage and geomorphology (straightened map)

Late Pleistocene



IJssel clays on peat sampling: AD 780-980

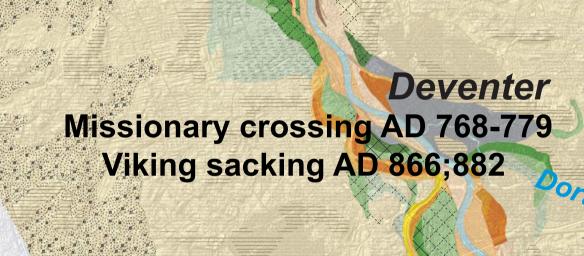
Veluwe periglacial fans uncovered covered covered

[?60-40 ka]

downstream distance

divide area

Annotated geological section along the axis of the IJssel valley

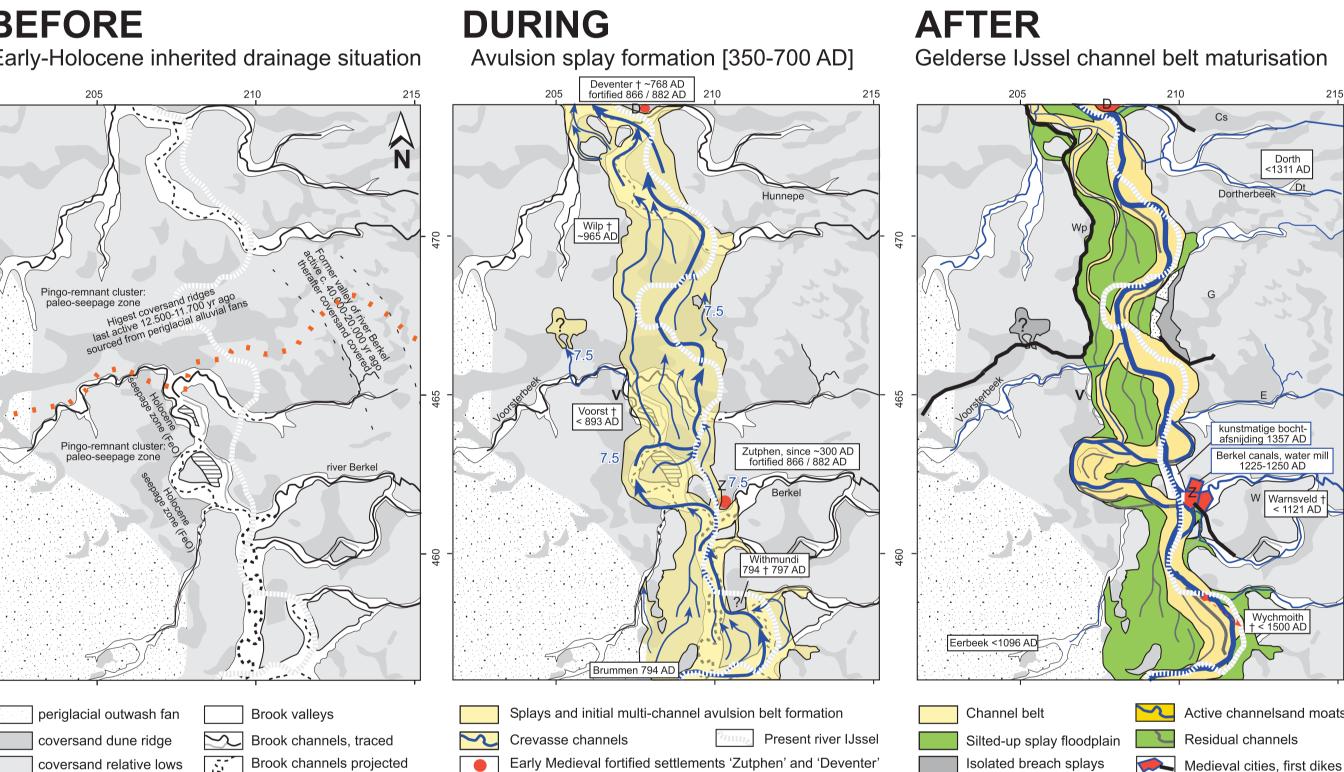


Splay initiation

AD 670-770

FORMER DRAINAGE DIVIDE: BEFORE Early-Holocene inherited drainage situation

Source: Zand in Banen - Cohen et al. 2009 report + digital map UU / Prov Geld.



7.5 Minimal elevation(m O.D.) breached by crevasse channels

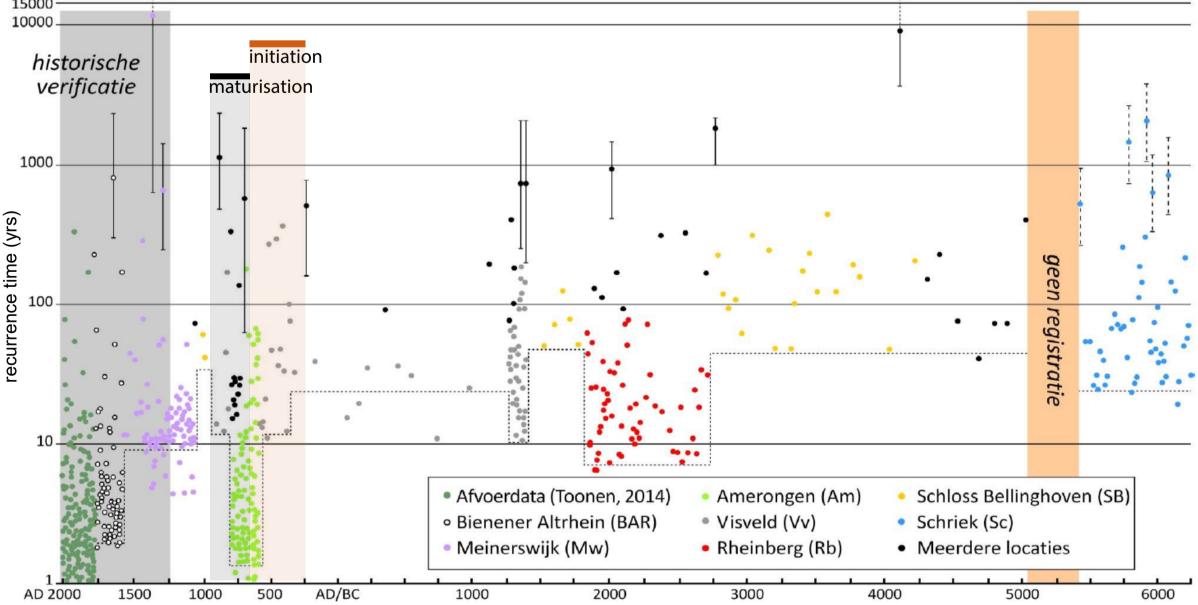


Zutphen Maturisation **AD 1000** Slack waters AD 500 Missionary crossing

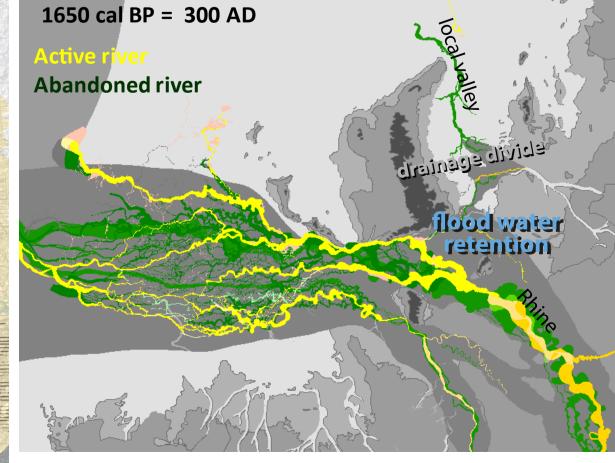
Doesburg

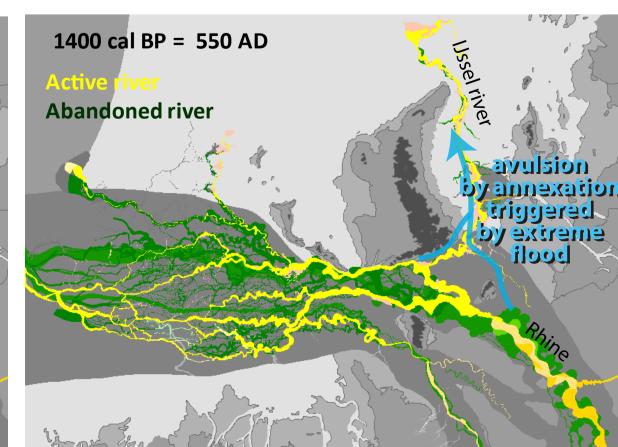
AD 794

PALAEOFLOOD HISTORY AND INTENSITY









Toonen et al. (2013, 2017); Cohen et al. (2016)

All ages based on oldest (known) historic topographic mention; '<' = 'existed from before'; † = church/chape

130 80 40 25 15 11.7 ka 11.7 5 2 1 0 ka 0 = 2000 ADLocal eolian and fluvial deposition **Local deposition** Eolian dunes (Wierden & Delwijnen Members) Level maintained by Early Holocene local drainage (top of brook channel deposits) Late glacial local drainage trunk systems Veluwe periglacial alluvial fans and fan toes Peat (Nieuwkoop Formation) Berkel periglacial local river deposits Rhine delta deposion Overijsselsche Vecht periglacial local river deposits Floodplain and -basin deposits, clay IJssel embankment level (situation 1995 Overstromingsleem (Wijchen Laagpakket) Level of top of IJssel natural levees Channel deposits: sands and gravelly sands, lateral and vertical dissective architecture indicated Level of top of subrecent pointbar sands lippo and Mammoth skull (not to scale)

Arnhem

Slack waters: AD 250-650 Mature levees: AD 650 - 1500

Missionary crossing: AD 726

Nederrijn trunk channel belt Inititiation: 700 - 200 BC Maturation: 200 BC - 1600 AD

CONCLUSION

- IJssel river is a Rhine branch that annexated a former local brook valley after tipping over a local drainage divide. - Initiation phase AD ca. 350-700, flood water retention upstream, occasional overtipping of the drainage divide, crevasse formation and floods downstream. Driven by delta apex aggradation, helped by floods. - Mature single channel development and permanent drainage ca. AD 700-1000, most likely triggered by large floods.