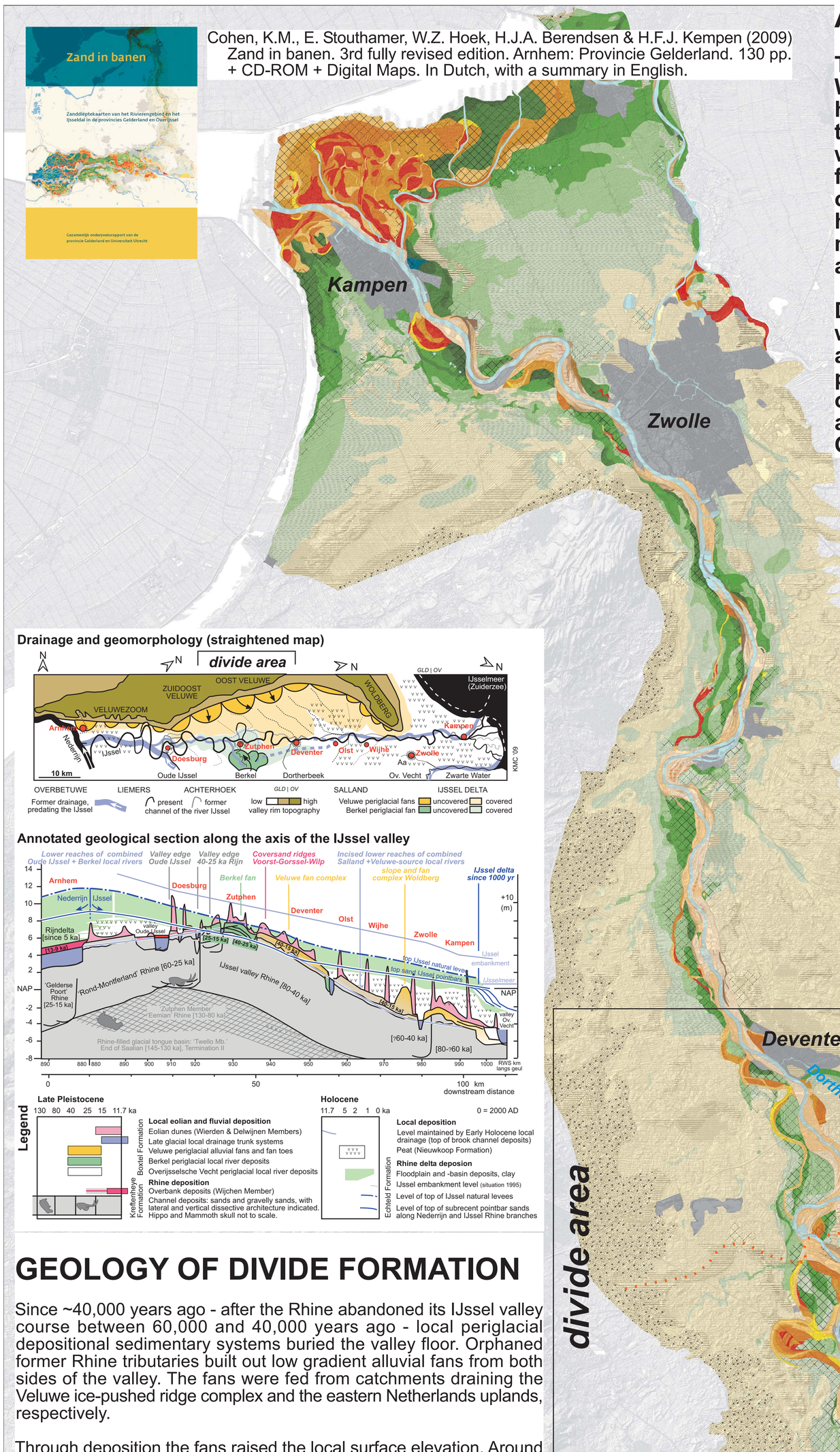
Rhine-Meuse delta studies

Universiteit Utrecht

Holocene Rhine reoccupation of the IJssel valley by divide dissection north of Zutphen

K.M. Cohen k.cohen@geo.uu.nl Dept. Physical Geography, Fac. Geosciences, Utrecht University POBox 80.115 3508 TC Utrecht, Netherlands



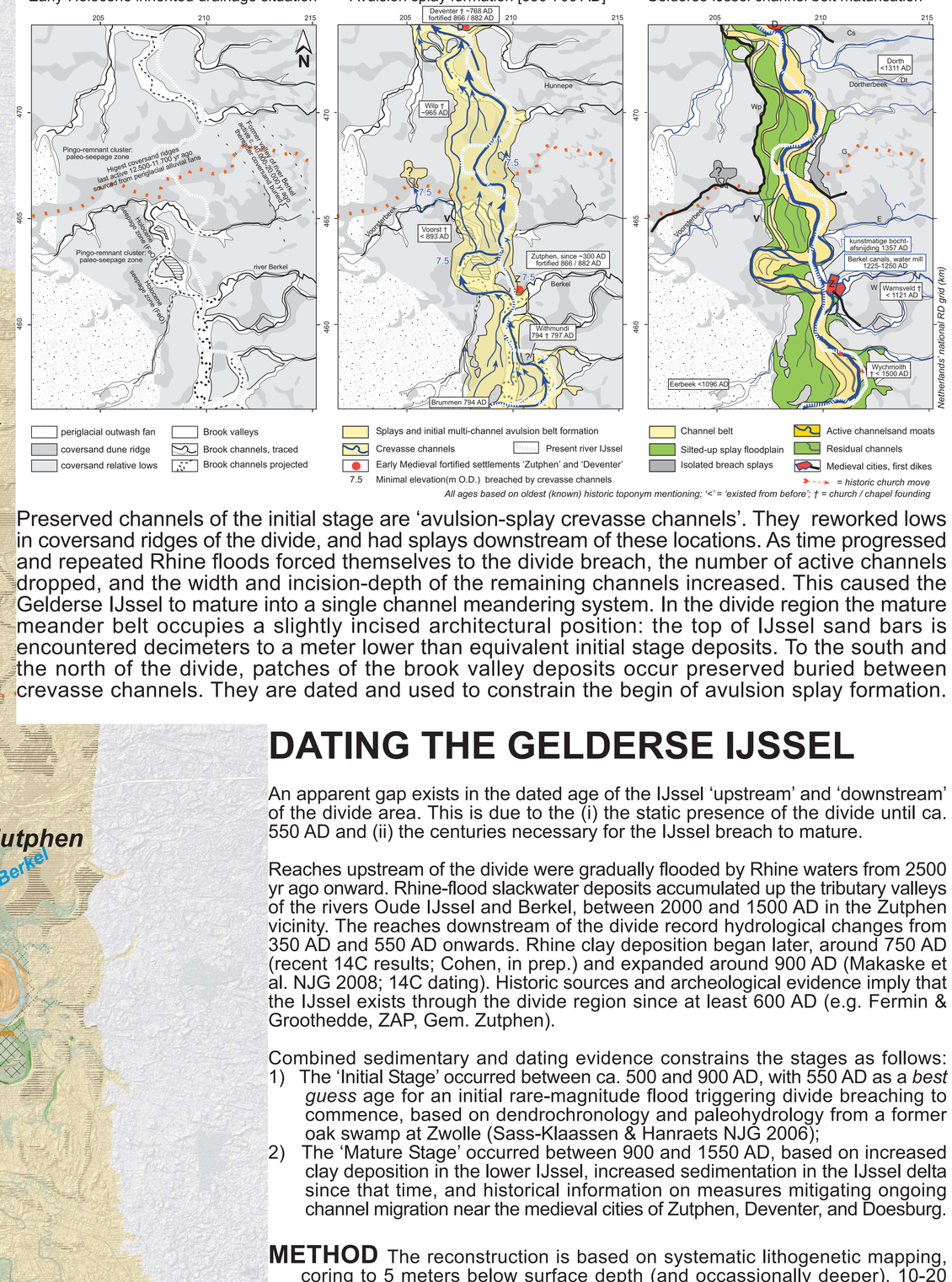
ABSTRACT

The Gelderse IJssel is the youngest natural distributary of the Rhine delta. When it came into existence between 300 and 700 AD, it annexed a valley that had not previously been part of the Holocene delta plain before. Understanding the drainage configuration of the valley and the position of the main divide, which separated 'Rhine tributaries' from 'drainage going north' prior to the formation of the IJssel, is key when reconstructing the timing and mechanics of the annexation process. The initiation of the IJssel is of archeological-historical interest, and the features from the initial stage - preserved some meters above deposits from later stages - offer a great opportunity to quantify a major flood of the Rhine.

During 5 years of field campaign covering the full river valley length and width, we mapped and dated landscape features related to the IJssel diversion and the area's many dissected older elements. This allowed us to position the paleodivide between Zutphen and Deventer, and to explain how it formed. The outcomes of this research falsify former paleodrainage reconstructions that assume the divide lay further south and that showed the rivers Berkel and Oude IJssel draining northward, instead of heading west towards the Rhine.

DIVIDE CONTROL ON REOCCUPATION

The channel deposits of the Gelderse IJssel show a two-staged division. The oldest stage ('initial stage') saw multiple shallow channels and occupied a relatively wide belt within the valley. The younger stage ('mature stage') occupies a relatively narrow channel belt of greater thickness, and showed all the phenomena of a meandering river. The river was embanked in the 14th century, continued to meander for two more centuries (still 'mature stage'), and then lost most of its discharge due to discharge redistribution events at the upstream delta apex.



Preserved channels of the initial stage are 'avulsion-splay crevasse channels'. They reworked lows in coversand ridges of the divide, and had splays downstream of these locations. As time progressed and repeated Rhine floods forced themselves to the divide breach, the number of active channels dropped, and the width and incision-depth of the remaining channels increased. This caused the Gelderse IJssel to mature into a single channel meandering system. In the divide region the mature meander belt occupies a slightly incised architectural position: the top of IJssel sand bars is encountered decimeters to a meter lower than equivalent initial stage deposits. To the south and the north of the divide, patches of the brook valley deposits occur preserved buried between crevasse channels. They are dated and used to constrain the begin of avulsion splay formation.

GEOLOGY OF DIVIDE FORMATION

Since ~40,000 years ago - after the Rhine abandoned its IJssel valley course between 60,000 and 40,000 years ago - local periglacial depositional sedimentary systems buried the valley floor. Orphaned former Rhine tributaries built out low gradient alluvial fans from both sides of the valley. The fans were fed from catchments draining the Veluwe ice-pushed ridge complex and the eastern Netherlands uplands, respectively.

Through deposition the fans raised the local surface elevation. Around 20,000 years ago, the largest two fans grew so large that they met in the axis of the abandoned valley. At this time lobe avulsions of the Berkel fan redirected this river to a position south of the most extensive Veluwe-sourced fan. As a result, the orphaned Berkel tributary once again became a Rhine tributary. Coversand ridges formed on top of the abandoned part of the fans, sourced from the ephimeral streams on the active parts. This caused further raising of the surface at a local level.

In sequence, these periglacial developments (from ~40,000 to ~11,000 years ago) created the saddle topography that became the drainage divide. The associated drainage network stayed active until late in the Holocene, until the Gelderse IJssel branch reoccupied the area as part of a deltaic avulsion-by-annexation event (in early medieval times).

DATING THE GELDERSE IJSSEL

An apparent gap exists in the dated age of the IJssel 'upstream' and 'downstream' of the divide area. This is due to the (i) the static presence of the divide until ca. 550 AD and (ii) the centuries necessary for the IJssel breach to mature.

Reaches upstream of the divide were gradually flooded by Rhine waters from 2500 yr ago onward. Rhine-flood slackwater deposits accumulated up the tributary valleys of the rivers Oude IJssel and Berkel, between 2000 and 1500 AD in the Zutphen vicinity. The reaches downstream of the divide record hydrological changes from 350 AD and 550 AD onwards. Rhine clay deposition began later, around 750 AD (recent 14C results; Cohen, in prep.) and expanded around 900 AD (Makaske et al. NJG 2008; 14C dating). Historic sources and archeological evidence imply that the IJssel exists through the divide region since at least 600 AD (e.g. Fermin & Groothedde, ZAP, Gem. Zutphen).

Combined sedimentary and dating evidence constrains the stages as follows:

1) The 'Initial Stage' occurred between ca. 500 and 900 AD, with 550 AD as a *best guess* age for an initial rare-magnitude flood triggering divide breaching to commence, based on dendrochronology and paleohydrology from a former oak swamp at Zwolle (Sass-Klaassen & Hanraets NJG 2006);
2) The 'Mature Stage' occurred between 900 and 1550 AD, based on increased clay deposition in the lower IJssel, increased sedimentation in the IJssel delta since that time, and historical information on measures mitigating ongoing channel migration near the medieval cities of Zutphen, Deventer, and Doesburg.

METHOD The reconstruction is based on systematic lithogenetic mapping, coring to 5 meters below surface depth (and occassionally deeper). 10-20 boreholes / km2 were strategically placed based on high resolution digital elevation data (AHN 1 5x5m; RWS-AGI, 2005). The geomorphological analysis and dating methods included: separation of *in-situ* Rhine deposits from locally reworked units on architectural and sedimentological grounds; palaeohydrological indications from periglacial and interglacial times; OSL dating of Rhine and local periglacial strata; 14C and pollen-biozone dating of Late Glacial, Early Holocene and later Holocene brook valleys buried below IJssel overbank deposits; separation of mature-stage meandering IJssel channel deposits from initial-stage crevasse deposits on architectural and sedimentological grounds; 14C, pollen-biozone and archeology-based dating of younger brook deposits and IJssel deposits, and application of established coversand stratigraphy and climate-hydrology-discharge-sediment yield morpho-stratigraphical schemes for the time period for the Netherlands.

Thanks to Wim Hoek, Esther Stouthamer, Henk Berendsen, Henny Kempen, Freek Busschers, Michel Groothedde, Nico Willemse, Maarten Kleinhans Annelies van Hoesel, Rens Quak, Marieka Brouwer and many others. Thanks to ~100 BSc and 10 MSc students since 2005.