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Late Holocene lowland fluvial archives and geoarchaeology: Utrecht's case study of Rhine river abandonment under Roman and Medieval settlement

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A B S T R A C T

Fluvial lowlands have become attractive human settling areas all around the world over the last few millennia. Because rivers kept changing their course and networks due to avulsion, the sedimentary sequences in these areas are archives of both fluvial geomorphological and archaeological development. We integrated geological and archaeological datasets to demonstrate the concurrence of the gradual abandonment of a major Rhine channel (Utrecht, The Netherlands), the development of human habitation in the area, and the interactions between them.

The Utrecht case study highlights the stage-wise abandonment of a natural river channel, due to avulsion, coincident with intensifying human occupation in Roman and Early Medieval times (1st millennium AD). The analyses make maximum use of very rich data sets available for the study area and the tight age control that the geo-archaeological dataset facilitates, offering extra means of time-control to document the pacing of the abandonment process. This allows us to quantify change in river dimensions and meander style and to provide discharge estimates for successive stages of the abandonment phase over a 1000-year period of abandonment succession, from mature river to eventual Late Medieval overbuilt canal when the Rhine branch had lost even more discharge.

Continued geomorphic development during this period - which includes the 'Dark Ages' (450-1000 AD) - appears to have been crucial in the development of Utrecht from Roman army fortress to Medieval ecclesial centre. The settlement dynamics in and around the city of Utrecht changed during the various phases of abandonment. In the bifurcating network of river branches forming the Rhine-Meuse delta, the main Rhine branch hosted the Roman limes military border and transport route. The Rhine- Vecht bifurcation at Utrecht provided an excellent location to raise a Roman fort. Continued geomorphic activity during abandonment in Early Medieval times was characterised by enhanced overbank sedimentation and shifts in the position of bifurcations. River flooding became more incidental in this stage, and alluvial-ridge occupancy became sensitive to flooding events for several centuries. We conclude by demonstrating that similar human-river interactions during Roman times occurred in several other deltas within the former Roman empire, with differences depending on the position of a settlement within the delta, the overall hydrological situation, and the ability of societies to control the changing environment.

1. Introduction

Rivers provide fresh water, open landscapes and transport routes for humans and as such have been repeatedly occupied

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environments through all archaeological periods (Hill, 2014). The relations between fluvial archives and their archaeological content have shown major changes over time (e.g. Ferring, 1986; Brown, 1997). Important differences on the Eurasian continent occurred between the eras of and preceding the Neanderthals (Early and Middle Paleolithic of the Pleistocene interglacials and glacials; e.g. Roebroeks, 2001; McNabb, 2007; Cohen et al., 2012a; Bridgland and White, 2015), the times of Home Sapiens hunter-gatherer subsistence (Late Paleolithic and Mesolithic of the Lateglacial and Early Holocene; e.g. Kelly, 1983; Louwe Kooijmans et al., 2005), the subsequent Neolithic revolution towards agricultural subsistence which enhanced permanent settlements (Middle Holocene; e.g. Butzer, 1970; Van Andel and Runnels, 1995; Bonsall et al., 2002; Turney and Brown, 2007), and the Late Holocene with increasingly developed catchment deforestation, growing population and urbanization, expanding trade and accelerating cultural exchange (e.g. Kaplan et al., 2009; Gates, 2011). With growing human presence and its impact in the catchments and rivers in the hinterland, especially in the last few millennia river discharge regimes changed as well, with larger fluxes of sediment supplied to the lowlands (e.g. Hoffmann et al., 2007). Further river-engineering changes such as the construction of dikes downstream and dams upstream caused the sedimentation regimes to change once more (e.g. Hesselink et al., 2003; Hudson et al., 2008; Syvitski et al., 2005, 2009).

Rivers are notoriously effective at reworking their past fluvial archives, eroding and redepositing their alluvium including the archaeological materials contained here (e.g. Brown, 1997). This is particularly true for valley reaches that over longer time intervals produce terrace sequences and for deposition in active channels. These processes create surfaces on which archaeology can accumulate afterwards and in such cases fluvial geomorphological patterns are informative for archaeological site distribution, especially on neighbouring terrace edges (e.g. Howard and Macklin, 1999; Bettis et al., 2008). In the lower delta-plain reaches of rivers, however, the downstream control of post-glacial sea-level rise and wide glacial-inherited valleys have caused extensive Late-Holocene records to have become preserved and accessible for geological and archaeological research. These areas can be especially rich in well-preserved archaeological finds (e.g. Edelman, 1950; Willems, 1986; Ferring, 1992). These finds are located in overbank deposits, in the tops of bars and not in the least, in deposits from abandonment and post-abandonment stages. In the latter case the alluvial ridges provide subtle high grounds in an otherwise regularly flooded plain.

In most deltas worldwide, including those of classic civilization centres such as Mesopotamia (e.g. Jacobsen, 1995; Wilkinson, 2000), the Egyptian Nile Delta (e.g. Coutellier and Stanley, 1987; Trampier et al., 2013; Pennington et al., 2016; Macklin et al., 2015; Pennington and Thomas, 2016), the Maya lowlands (e.g. Von Nagy, 1997; Liendo et al., 2014; Gunn and Folan, 2000; Liendo et al., 2014; Nooren et al., 2014) and the Indus (e.g. McIntosh, 2008; Giosan et al., 2012; Syvitski et al., 2013), besides the modern active river branches multiple former river branches of Late-Holocene age have been identified. These are the parts of fluvial reaches where long-sustained coeval geomorphological and human activity has taken place, creating spatially extensive and continuous fluvial archives of alluvial ridges with a very rich embedded archaeological record. In these areas rivers continuously changed their course and networks due to avulsion, creating new and abandoning older channels. In addition in these areas cultures changed, and distinct cultural periods emerged and succeeded. The dating of such periods is often very precise, sometimes with an uncertainty of a few years only, and outperforms that of sites dated exclusively with geological dating methods. Both from an archaeological and geomorphological perspective deltaic lowlands therefore provide rich archives for the study of the interaction between river processes and human occupation.

The study of human-fluvial landscape interactions requires an interdisciplinary approach integrating geological and archaeological datasets derived from fluvial archives. In the present study we exemplify this for the case of The Netherlands, where the rise of the Roman/Medieval city of Utrecht coincided with a shifting bifurcation and changing channel dimensions and meander lengths during a 1000-yr abandonment phase of the main river in the Lower Rhine Delta.

Avulsion is a principal process in the creation of new channels and the abandonment of existing channels in deltas and fluvial plains. It is a process that is seldom observed on a human time scale since it usually takes several human generations for the new channel to fully capture the water discharge (Jones and Hajek, 2007). Over the last 30 years research on avulsions in lowland settings mainly has focused on newly formed channels and related sedimentary products such as crevasse splays and avulsion belts (e.g. Smith et al., 1989; Smith and Perez-Arlucea, 1994; Stouthamer, 2001; Slingerland and Smith, 2004; Makaske et al., 2007), and on the quantification of avulsion frequencies, which most frequently is based on dating abandoned channels in order to identify channel relocation events (e.g. Törnqvist, 1994; Stouthamer and Berendsen, 2000; Makaske et al., 2002; Stouthamer, 2005; Fontana et al., 2008).

The pace of avulsion processes strongly varies depending on constraints such as basin configuration, local and regional gradients, and dynamics of bends and in-channel bars (e.g. Mackey and Bridge, 1995; Jones and Schumm, 1999; Slingerland and Smith, 2004; Stouthamer, 2005; Kleinhans et al., 2013). Studies of the Dutch Rhine-Meuse delta, an exceptional region because of its complete coverage of the Holocene avulsion history including avulsion duration (e.g. Berendsen and Stouthamer, 2001; Stouthamer and Berendsen, 2000; Gouw and Erkens, 2007; Stouthamer et al., 2011; Toonen et al., 2012), show that new and old channels often co-functioned for a few hundred years (Stouthamer and Berendsen, 2001).

Younger secondary channels developed ‘relatively rapidly’ (Jones and Schumm, 1999), but the majority of the discharge remained routed through the older course. The larger channels were the longest-lived courses which functioned as relatively conservative trunk channels (Stouthamer et al., 2011). In the few cases that a major avulsion led to full abandonment of a trunk channel in the Rhine-Meuse delta, the process took a long time to complete (Stouthamer and Berendsen, 2000; Toonen et al., 2012). One reason that large and old main channels did not easily become completely abandoned, is that fully plugging a former trunk channel demands considerable amounts of bed sediment to be trapped at its entrance. This not only takes time, but also requires sustained delivery of this sediment by the flow of water that is diverted over a bifurcation at the avulsion node. The instable morphodynamics of a bifurcating river causes the quantities of water and sediment delivered to the competing branches to oscillate (Kleinhans et al., 2008, 2011; 2013). This causes alternating phases of deposition (plugging, narrowing) and erosion (deepening, re-widening) of the channel, never closing either of the two branches, a situation that can persist for many hundreds to a few thousands of years. During this time interval the sedimentary signals of discharge loss and branch abandonment become visible over many meander wave lengths downstream in the abandoned branch, i.e. over reaches of tens of kilometres. The combined down- and upstream feedback effects of multiple bifurcations of different age occurring concurrently in the delta cause further complexity of the abandonment mechanisms of main branches.

The Utrecht case study demonstrates the slow pacing and