Preservation of meander channel and scour features under aggradational and non-aggradational conditions

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1. Introduction

The internal architecture of channel belts commonly consists of channel-form bounding surfaces due to channel migration and scouring (e.g. Miall, 1985). These bounding surfaces are essential to our reconstructions of palaeochannel dimensions. It is therefore crucial to understand the suite of processes that form and transfer these surfaces into the fluvial rock record. Quantitative theoretical relations have been derived between fluvial surface processes and the formation of channel bounding surfaces in the subsurface (e.g. Paola & Borgman, 1991). These indicate that the balance between lateral channel migration and aggradation rate determines bounding surface formation. How large the aggradation rate needs to be to have a notable impact on bounding surface formation and how this affects preservation is currently not well understood. While these subsurface bounding surfaces are straightforward to measure from the sedimentary record and thus to characterize as a probability distribution, the conditions that formed these surfaces are unknown. The objective of this study is to quantify the relation between meander surface morphodynamics and the resulting meander belt internal architecture during aggradation in contrast to non-aggradational conditions.

2. Data and methodology

A morphologically-rich meandering river pattern and resulting alluvial architecture is simulated by the two-dimensional fluid dynamics and morphodynamics code NAYS, which is the first to produce meandering without presuming a fixed relation between bank erosion and bank accretion, contrary to one-dimensional meander simulation models. NAYS2D model parameters were chosen such that a dynamic and sustained free meandering river formed. Simulations started with an initial straight 200 m wide and 8 m deep channel (Fig. 1).

In our main run, the NAYS2D model was used to simulate the alluvial channel belt architecture formed by meandering river processes without aggradation. From this three-dimensional model output, virtual cores and transects were visualized and analyzed (Fig. 2). The analysis of these virtual cores included extraction of descriptive statistics on the number of and typical thicknesses between channel and scour bounding surfaces. We define stratigraphic sets as depositional bodies enclosed by two successive bounding surfaces (Fig. 2). To further quantify the resulting meander belt architecture, a vertical set preservation ratio (*VSPR*) was calculated. The *VSPR* quantifies which fraction of the channel preserves on average. For example, if the channel is on average 10 m deep and we find a mean set thickness of 5 m, the *VSPR* is 0.5.

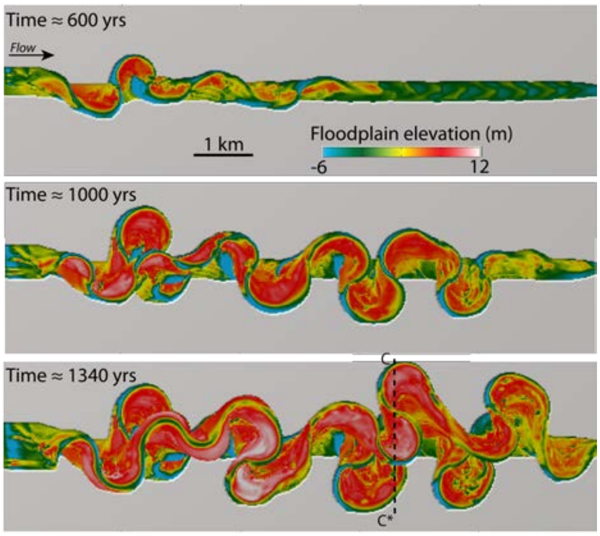

Figure 1: Floodplain evolution of the meandering river without aggradation (Schuurman & Kleinhans, this volume).

The influence of aggradation on the meander belt internal architecture was quantified by comparing the statistics extracted from the main model run (simulating zero-aggradation), to such results from the data with post-added excess sedimentation (simulating aggradation). Simple, linear aggradation rates were applied.

3. Meander morphodynamics

The initial straight channel developed into a highly sinuous meandering river pattern. The sinuous single-thread channel was on average 8 m deep but locally reached depths up to about 20 m. The deepest parts corresponded to outer bends whereas inner bends were notably shallower. Channel width also varied greatly with an average of 250 m but locally it was only 180 m wide. The meandering channel migrated laterally across the channel belt surface with an average rate of 2.5-5 m/yr. Due to differences in channel curvature also large differences in lateral channel migration were observed with rates up to 20 m/yr. Individual meanders had a typical length of 1000-1200 m with a maximum meander length of about 1500 m. Point bars formed in the inner meander bends and consisted of ridge and scroll topography. The channel was locally straightened again due to neck cutoff. In total, we observed four neck cutoffs. This shows that most of the morphological activity for this meandering river took place in the channel belt center as the original point bar deposits were reworked multiple times over there due to cutoffs.

Closer to the channel belt margins, reworking occurred less frequent.

4. Meander belt internal architecture

The deepest channels form the thickest sets, which are reworked and therefore decreased in thickness by shallower channels again (Fig. 2). The sequence of the migrating channels determines which part of the channel history is recorded.

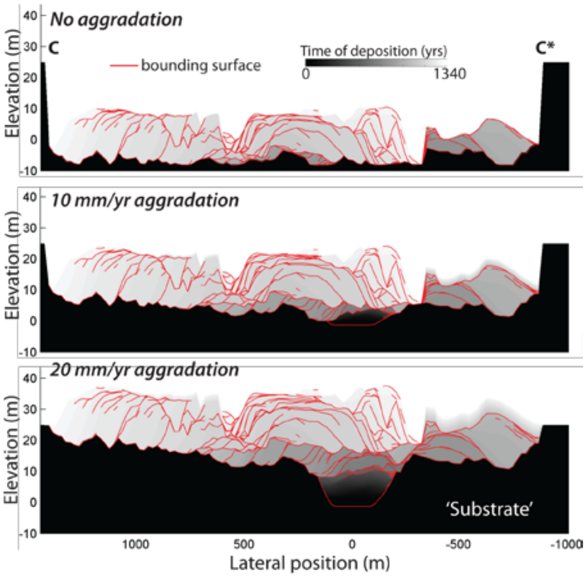

Figure 2: Synthetic stratigraphy (see Fig.1 for location). All slices were used to measure set thickness statistics and preservation.

4.1 Effect of aggradation on internal architecture

The general structure of non-aggradational and aggradational deposits are fairly similar, but the overall *variability* in channel belt architecture increases for higher aggradation rates. The *median* set thickness only increases from 2.02 m for the run without aggradation to 2.72 m for the run with an unusually high aggradation rate of 20 mm/yr, which indicates that even for the latter most of the deposit consisted of relatively thin sets. While sets were found with a thickness of up to three times the mean channel depth, the majority of the deposit was truncated..

4.2 Lateral trends in architecture due to aggradation

We find large spatial differences in channel belt architecture, even without aggradation (Fig. 3). The systematic quasi-cyclic behaviour of the meandering channel, i.e. point bar growth followed by neck cutoff, created lateral differences in alluvial architecture. We find relatively undisturbed sets close to channel belt margins and a more irregular stratigraphy with multiple stacked sets in the channel belt center (Fig. 3a). As a result, sets were, on average, thicker for the channel belt margins than for the center (Fig. 3b,c). Net-aggradation amplifies these zero-aggradation lateral differences in architecture within the meander belt. Due to frequent reworking in the channel belt center most of the aggradation signal is not recorded over there whereas it is preserved closer to the channel belt margins.

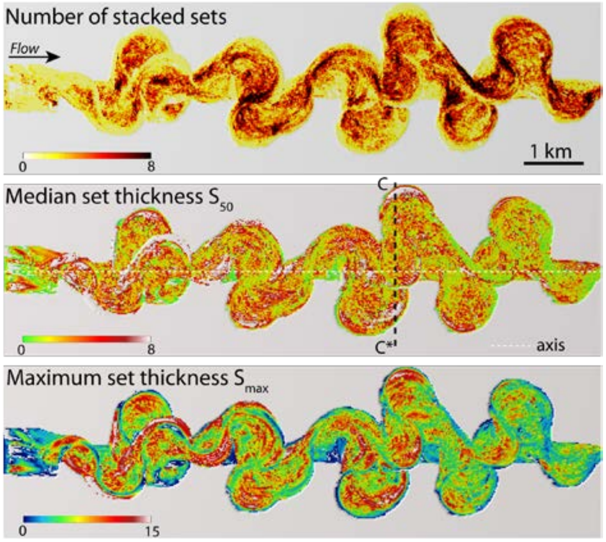

Figure 3: Map view of the meander belt architecture.

5. Conclusions

Numerical simulations of a meandering river that incorporates point bar formation and neck-cutoff demonstrate that the internal architecture of a channel belt that has been influenced by realistic aggradation rates is similar to the internal architecture of a non-aggrading channel belt. Results demonstrate that:

- Fluvial reservoir modelling frameworks can use the same architecture within the individual channel belts for aggrading conditions.
- Robust estimates of palaeochannel dimensions from stratigraphy can be made based on a *VSPR* between 30% (limited aggradation) and 50% (high aggradation).
- Meandering rivers favour preservation of more complete channel fills closer to the channel belt margins.

Acknowledgments

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