APPARENT NON-COINCIDENT COUPLING OF THE MISSOURI RIVER TRUNK SYSTEM DUE TO MID-CONTINENT CLIMATE CHANGE

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Abstract

Paleochannel research on the Missouri River Floodplain is funded through the USGS EDMAP program (2001- Present) and the National Science Foundation (2008-2010), with individual Quadrangle maps published through the University of South Dakota and Missouri River Institute. Maps include reaches from South Dakota to central Missouri, with current mapping being conducted on the northwestern Missouri reach. Morphologies between the Iowa/South Dakota reach and the Central Missouri reach indicate an overall transition from a meandering to braided river over the last 3,000 years. Within the upper reaches in Iowa and South Dakota, the meandering to braided transition occurs abruptly at 1.6 kbp. However, the southern reach within central Missouri includes transitional morphologies between meander and braided beginning at 3 kbp and completing at 1.5 kbp.. Current mapping between these two reaches in Northwestern Missouri includes some of the transitional morphologies absent to the north, but not to the same extent as farther south. In addition to transitional forms, distinct reverse meanders are found in the Iowa/South Dakota reach and northwestern Missouri reach, created by the accretion of successive braid bars on the cut-bank side of the loop rather than the traditional accretion on the loop interior. Reverse meanders are rare in the downstream reaches. This suggests the overall pattern of meandering to braided was spatially transitional on not just the local scale but also on the scale of the full trunk river system. OSL dating of the braid transition in northwestern Missouri is pending to assess if the trunk systems are temporally transitional as well.

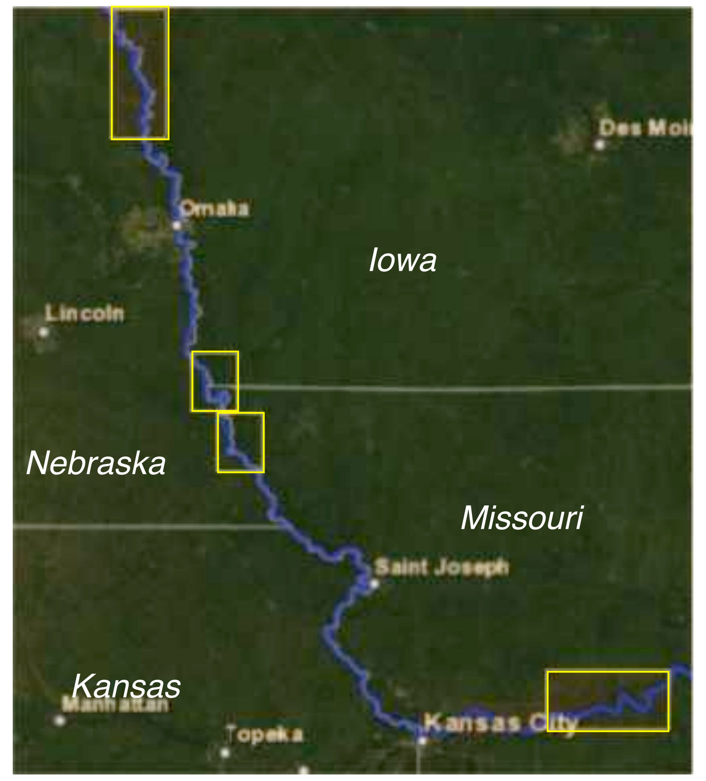


Figure 1: Locations of figures. The upper reach displayed in Figure 2 is located north of Omaha Nebraska along the Nebraska/Iowa border. The lower reach, Figure 3, is located east of Kansas City, Kansas, within the state of Missouri. The middle reach, Figure 5, is located at and just south of the borders of Nebraska, Iowa and Missouri.

River Morphology

Associating shifts in channel morphology with shifts in climate change requires an understanding of the "coupling rate", or lag time, between upstream changes and the rivers response (EDMAP, 2012). Coupling is typically understood to propagate downstream, except in the case of base-level change caused by eustatic, tectonic, or local events(Bridge, 2003). Generally coupling is assumed to be very rapid, but this is only valid within small drainages or within the upstream parts of larger drainages (Harvey, 2002). Coupling is far less understood in large drainages, where climate response has been extended over a long distance down the trunk of the river system (EDMAP). Lag time between the measured response and associated climate change remains largely untested, yet is critical in order to use channel processes in these types of rivers as a paleoclimate proxy, and to understand predictive river response and the response rate to both climate- and human-induced changes upstream (Harvey, 2002, EDMAP proposal, 2012). Two interesting morphologies are seen within the mapped reach that might further the understanding of the response rate of the Missouri river to climate change.

Transitional Morphology

The transitional morphology represents an alluvial reach that lies midway between traditional braided and meandering channel definitions. In this instance, transitional morphologies are 3-4 meters deep, and often include mid-channel bars, although not to the extent of braided channels in the area. However, the transitional morphologies do not represent a clear-cut gradual transition from meandering to braided, with constant shifts between meander, transitional, and braided occurring over a 1.5 kbp time span. These morphologies are present within the lower reach, but absent within the upper reach (Figure 2, Figure 3).

Reverse Meanders

Reverse meanders represent a distinct morphology where the accretion of successive braid bars occurs not on the traditional loop interior, but on the cut-bank side of the loop. While common within the Iowa/South Dakota and Northwest Missouri reaches (Figure 2), reverse meanders are very rare within the downstream reach east of Kansas City.

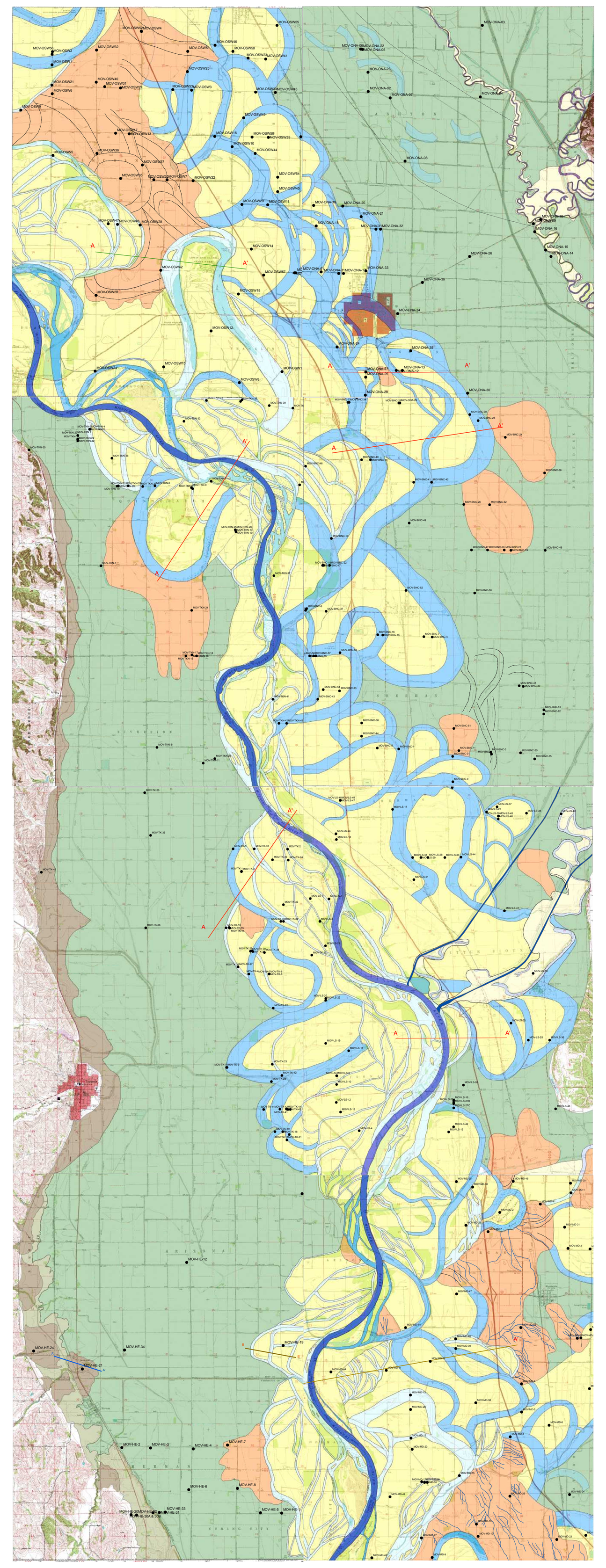


Figure 2: Section of upper reach of mapped Missouri River. The upper reach displays an abrupt transition from meandering to braided morphologies within the Missouri River, with a lack of transitional forms common within the lower reach. Reverse meanders are relatively common within the upper reach of the Missouri River. (University of South Dakota Missouri River Institute, 2011)

Problem

Previous studies through the EDMAP program have revealed somewhat counterintuitive results regarding the current understanding of coupling (EDMAP proposal, 2012). The current presumption in regard to the coupling processes within the EDMAP area would be that a climate-induced shift in pattern would propagate downship, resulting in a shift from meander to braided to occur at a later date in the downdip east of Kansas City reach then the updip Iowa/South Dakota reach (Harvey, 2002). However, EDMAP data seems to imply the opposite, with the transition appearing to occur at least 1000 years earlier in the downdip reach then in the updip reach (EDMAP proposal, 2012). Three possibilities exist to explain this. First, the downdip area could simply be influenced by climate change within two major tributaries of the Missouri, the Kansas and the Platte. If this is the case, mapping between the two tributaries should indicate if these tributaries influenced the early shifts in the downdip area, with these maps either mimicking the downdip Missouri condition (if the Platte is the influence), or mimicking the updip Missouri condition (if the Kansas is the influence). Eight maps within this reach were completed in May of 2013 and are awaiting publication, with three more maps currently in production from field work during the summer of 2013. If these maps reveal some sort of transitional area that does not resemble either the updip or downdip conditions of the Missouri, our presumptions over the standard propagation of coupling could be wrong, and river pattern changes due to climate change could propagate updip. In addition, the null hypothesis whereas none of these conditions are observed and a new condition appears is also possible.

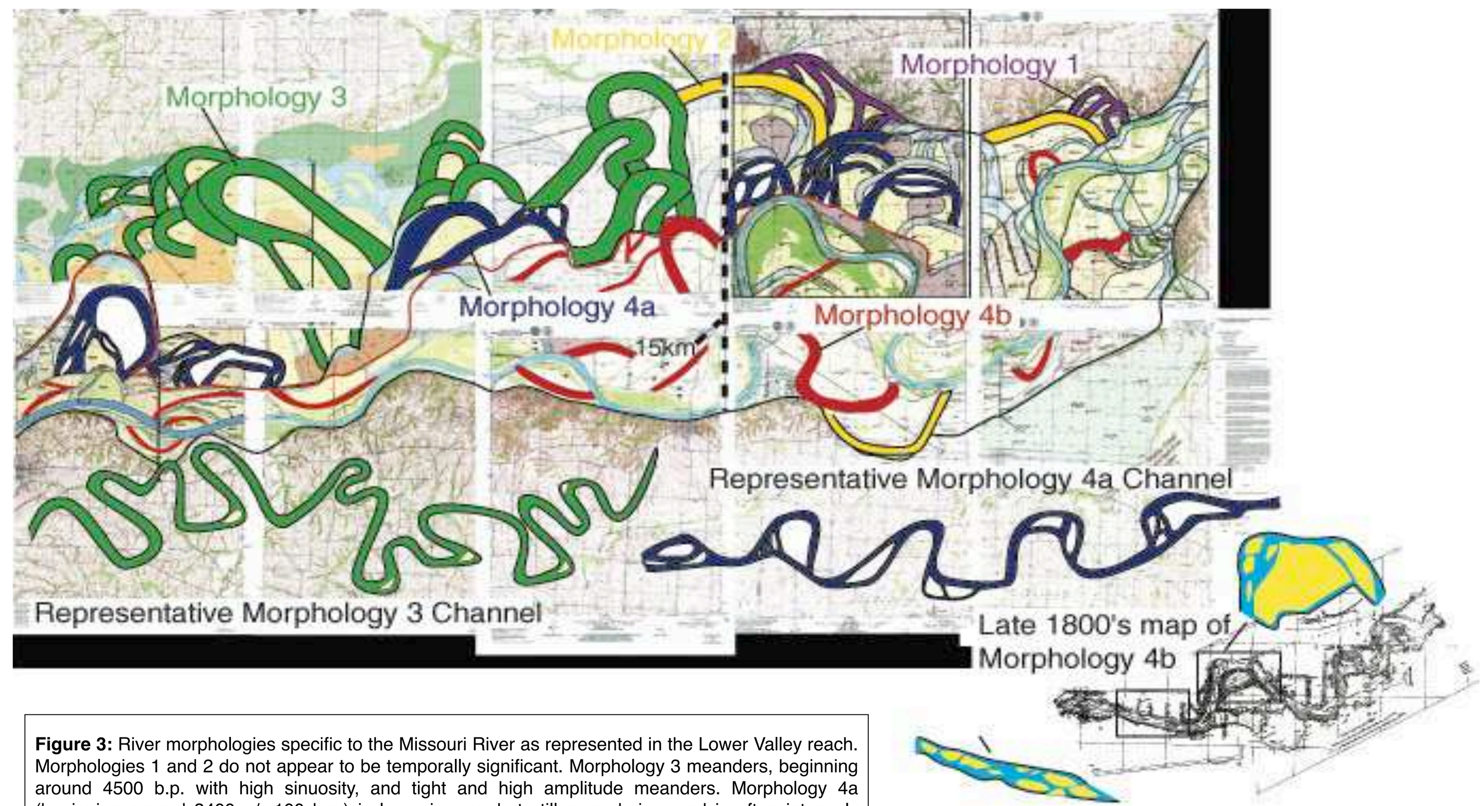
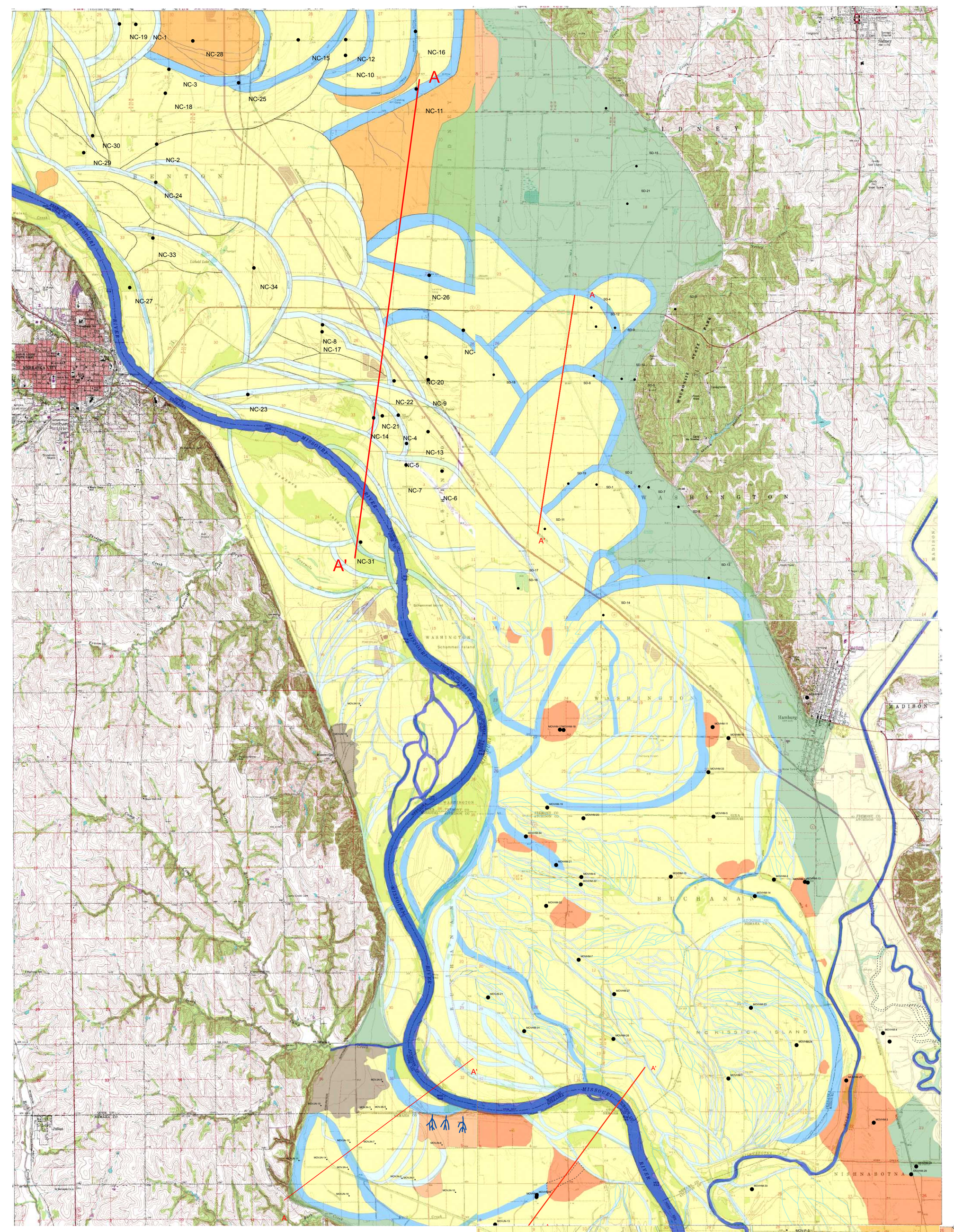


Figure 3: River morphologies specific to the Missouri River as represented in the Lower Valley reach. Morphologies 1 and 2 do not appear to be temporally significant. Morphology 3 meanders, beginning around 4500 b.p. with high sinuosity, and tight and high amplitude meanders. Morphology 4a (beginning around 3400 +/- 100 b.p.) is less sinuous, but still meandering, and is often intensely populated with mid-channel bars. Morphology 4b begins around 3000 b.p. and records complex "island braid" systems. By 1200 b.p. only the braided 4b morphology remains and the transition is complete (EDMAP proposal, 2012).

Methodology

Allostratigraphic map units are defined based on the recognition and delineation of their bounding discontinuities (NACSN, 1983). These maps units can include a variety of sedimentary bodies, such as: ox-bow lake/channel fills, incised valley deposits, individual channel belts, etc. The first step in mapping these units involves the examination of topographic maps, aerial photos, digital elevation models, satellite imagery, and existing soil maps for landforms characteristic of likely depositional units and trends. Likely depositional units are identified and tested through drilling, where as troughs that resemble channel fill should contain muddy strata, while raised areas that resemble bars should contain sandy strata. Of the channels, muddy strata ranging from 1-2 meters are considered braided, from about 4-6 meters are considered meandering, and over 6 meters are considered floodplain deposits. Splay morphologies are also seen on aerial photos, and are drilled to verify these area represent splay, and to determine any morphologies hidden underneath the splays, such as channel or bar. Drilling is conducted in teams of 2-3 with a hand auger, using the Dutch-auger method (Figure 4). The field data is collected and entered into the ArcGIS program, utilizing aerial photos, topographic maps and digital elevation models for map production. In addition, optically stimulated luminescence (OSL) samples are taken to determine the absolute age of depositional units throughout the EDMAP study area, and confirmthe temporal significance of such units.

Figure 4: Typical field site, channel, with Daniel Woodworth and Megan Dubose



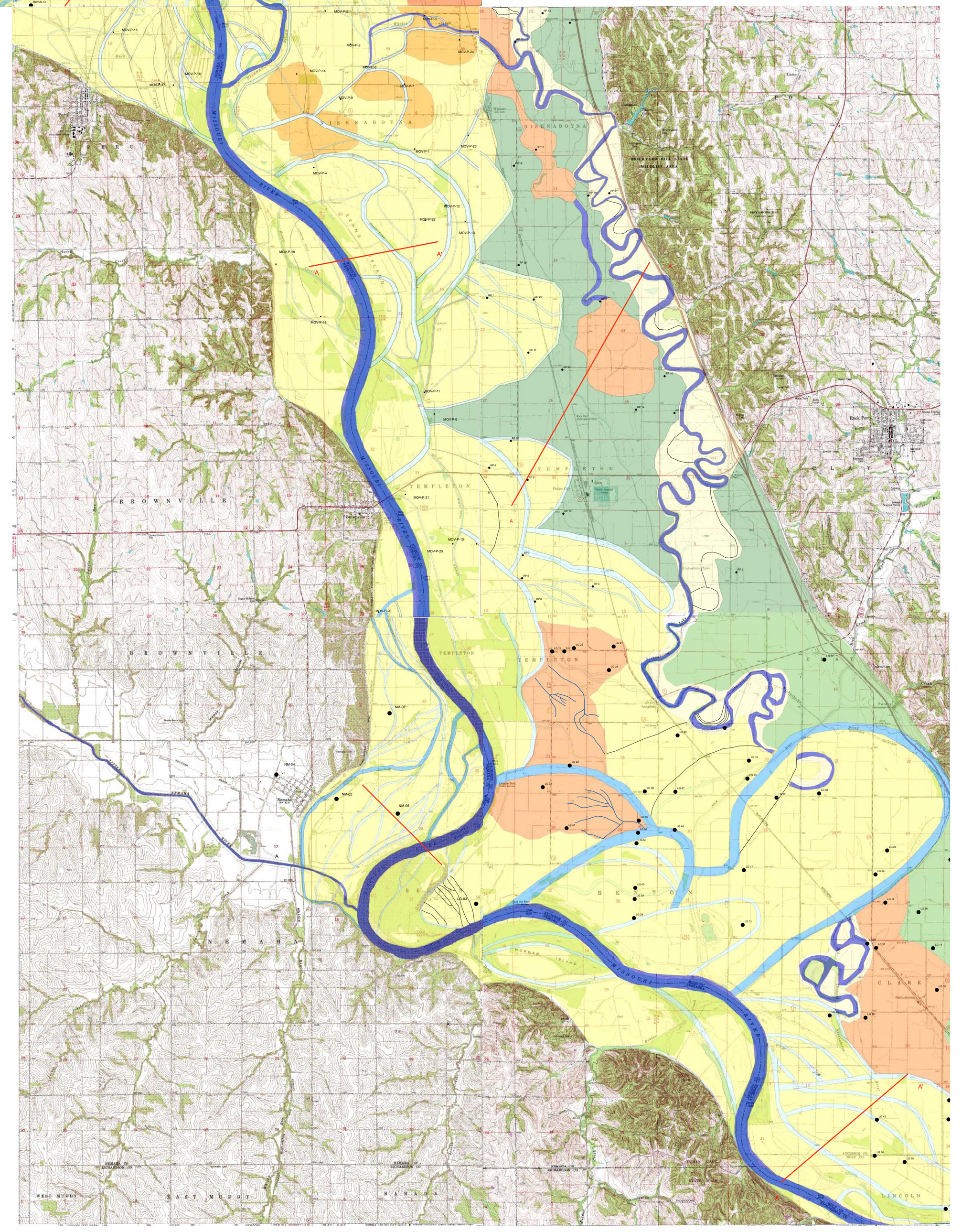


Figure 5: Middle reach of the Missouri River from the 2012 field season, including quads Hamburg, Sidney, Julian, Langdon, Rockport, Nebraska City, Nemaha and Peru. Reverse meanders are present within the middle reach, although not quite as common as in the upper reach. While no transitional forms are evident within the 2012 field season maps, transitional forms are present in maps currently in production from the 2013 field season, located just south of the 2012 field season maps in quads Corning and Big Lake. OSL samples were taken throughout the 8 quads to determine the ages of the meandering and braided channels, and compare them to the data already collected for the upper and lower reaches. Confirmation of these dates is still pending, but these dates will determine if this section of the lower reach most resembles the upper reach, which lacks a transitional phase and jumps from meandering to braided within a relatively short time span, or most resembles the lower reach, which includes a long transitional period lasting about 1500 years. (University of South Dakota Missouri River Institute, 2011)

Current Results

Current mapping in the midway reach between the updip and downdip sections includes Eight maps from the 2012 field season (to be published) and three maps from the 2013 field season (in production). Transitional forms were found within a few of the quads from the 2013 field season, including Big Lake and Corning (currently in production). However, transitional forms were not found in the eight maps produced from the 2012 season (Figure 5), and the transitional forms are not nearly as abundant as they appear to be downdip. Reverse meanders are present within the 2012 field maps (Figure 5) and 2013 maps, but not nearly at the same abundance as within the upper reach. Nevertheless, the 2013 maps represent the first mpas in the area to contain both transitional forms and reverse meanders. Dating in the area is currently in the process, but initial observation indicates that the transition in this reach is somewhat intermediate between the updip and downdip reaches. Confirmation of the absolute dates through OSL dating is currently underway.

Conclusions

The EDMAP program and its research of the Missouri River has revealed a number of interesting features, not the least of which is represented by its odd coupling behavior. A gradual transition from meandering to braided starting around 3000 years ago in the downdip reach coupled with a rapid transition around 1600 years ago in the updip reach seems to indicate updip propagation of change due to climatic influence, a stark contrast to the traditional view of downdip propagation. Initial mapping of a midway reach between the two also seems to support this updip propagation, with no clear evidence of heavy tributary influence. In addition, a reverse meander morphology is observed and described, another morphology that seems to break the traditional view of meander formation. Further research within this midway reach needs to be conducted in order to better confirm these initial observations, as well as analysis of OSL sample data to confirm the absolute date of many of these forms. However, with this research, we can gain a greater understanding of complex river systems, which will directly influence how we plan to utilize such rivers for our own economic gains, while balancing the ecological impact of such actions.

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