Geometric trends for floodplain lakes in high accommodation floodplains

STONER, Scott and HOLBROOK, John: The University of Texas at Arlington

UT ARLINGTON GEOSCIENCES

Abstract

Fluvial systems are prolific hydrocarbon reservoirs. Accordingly numerous studies have addressed architectural styles and aspect ratios aimed at the "net" channel-belt reservoirs. Floodplain lake deposits are known to typically constitute the majority of the "gross" sections of fluvial systems in high-accommodation settings. Virtually no comparable studies have been done to quantify lake geometry and evolution. Partly this reflects the few examples of high-aggradational fluvial systems in the modern. We made a first attempt to measure trends in floodplain lakes by examining four lake-rich fluvial sites where lakes were in early developmental stages. These included two systems located on the Mexican Gulf Coast, one deltaic system in Alaska, and one interior fluvial section in the Magdalena River Basin, Columbia. We defined lakes as forming on the floodplains next to and between channel belt levees. Sediment fill is mainly delivered here by smaller secondary channels that feed crevasse splay deltas and deliver plumes of mud. We measured the area of each lake and interfluve satellite images obtained from Landsat 5 and Google Earth.

The lakes in the study areas ranged widely in area from fractions of a kilometer width to over one hundred kilometers, with shape and area of the lakes being highly variable as well. Much of the variability stemmed from the tendency of large lakes to undergo partitioning into multiple smaller lakes as they became dissected by avulsive small channels during filling creating complex relationships between lakes, small feeder channels and splay deltas (**very** few lobate splay deltas were observed**)**. Consequently the relationship between trunk channel/channel belt size and lake size was weak. Channel belt density however appears to be the primary controlling factor in lake size. The lakes maximum size is limited by the distance between the channel belts or the distance between a channel belt and floodplain termination.

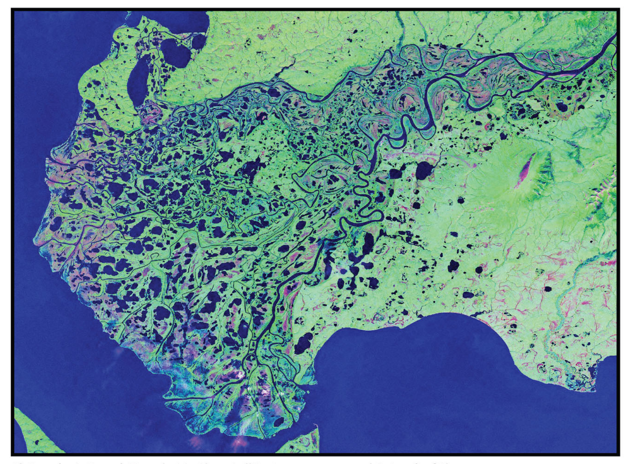
Purpose

Floodplain lakes are observed in scattered modern systems (e.g. Rhine, Berendsen and Stouthamer, 2001; Amazon, Latrubesse and Franzinelli, 1999; Saskatchewan, Morozova and Smith, 2000; Mississippi, Tye and Coleman, 1989; etc.) but are considered an important and common part of the geologic record of high-accommodation fluvial settings (e.g. Browne and Plint, 1994; Plint and Browne, 1994; Glover and O'Beirne 1994). Although progress has been made to understand lake processes (e.g. Morozova and Smith, 2000; Hill et al., 2001; etc.) and the role of lakes in avulsions (Smith et al., 1989; Smith et al., 1998; Smith and Perez-Arlucea, 1994) little has been said about lake dimensions and how the scale to the fluvial system in which they formed.

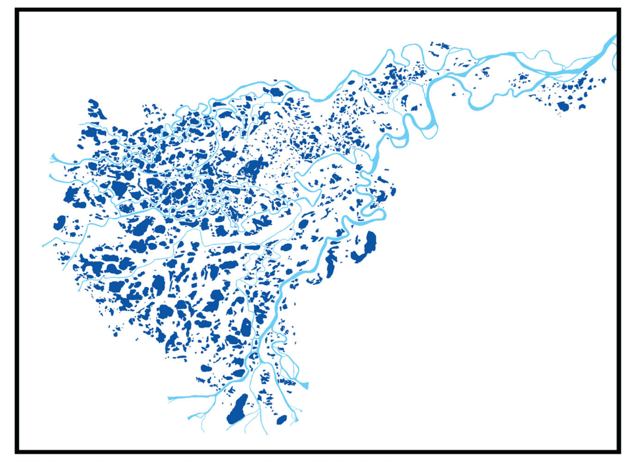
This is a first look geomorphic study using Landsat 5 and Google Earth images to look for generalized relationships between floodplain lakes and their fluvial systems in a range of settings including delta (Kobuk River Delta, Alaska), inland (Magdalena River Basin, Columbia) and coastal settings (Grijalva and Usamucinta Rivers, Mexico). These sites chosen record some of the few high aggradation fluvial floodplains preserved during this relative sea level highstand.

These areas are analogs for fluvial response to base level rise in the transgressive phase of sequence stratigraphic models.

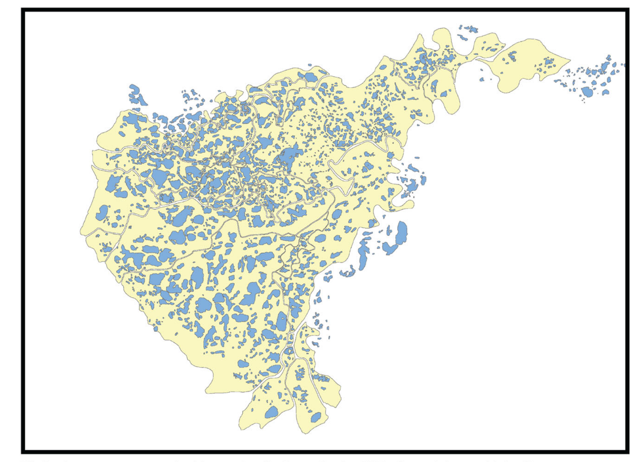
Methods



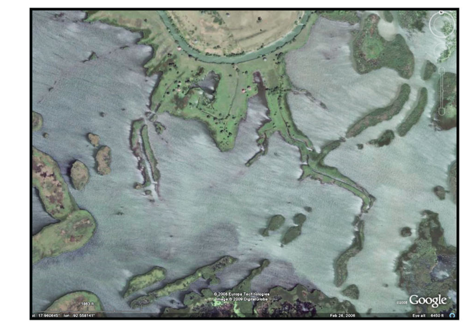
1) Landsat 5 and Google Earth satellite images were obtained of the areas.

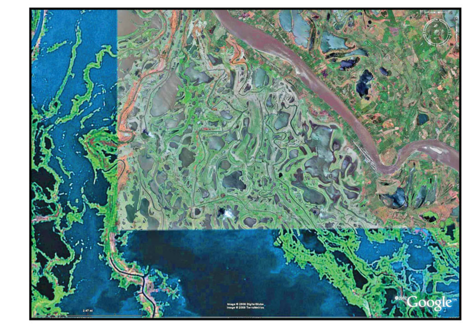


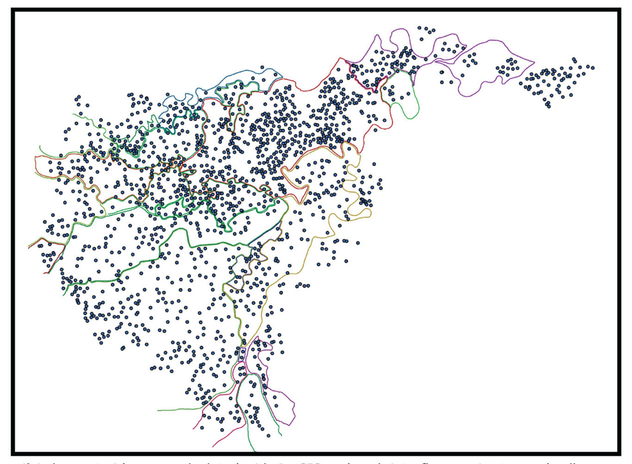
2) Lakes and rivers were drawn as rasters in Adobe Photoshop.



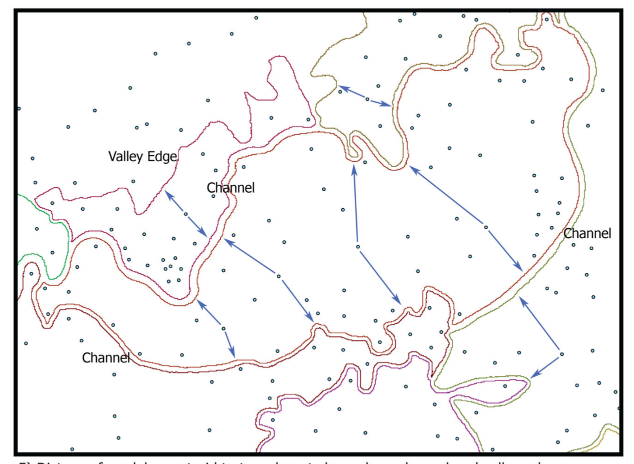
3) Rasters were converted to vector features in ArcGIS where lake and interfluve areas were calculated.



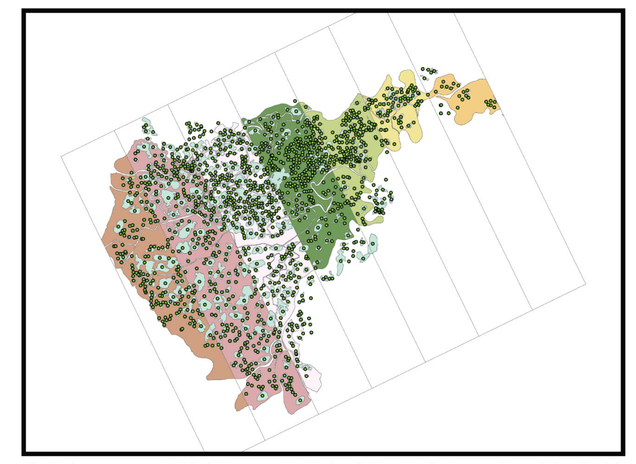




4) Lake centroids were calculated with ArcGIS and each interfluve perimeter and valley edge were drawn as a seperate vector.



5) Distance from lake centroid to two closest channels or channel and valley edge was calculated and the results were added together to find the width between the channels (or channel and valley edge) at the lakes location. Results were exported to Excel and lake area was plotted against distance between channels (or channel and valley edge). Best fit line was drawn and R2 calculated to determine strength of the relationship.

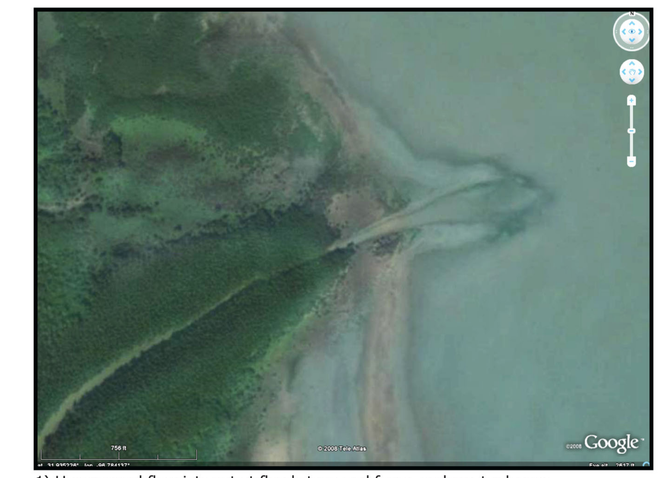


6) Study areas were divided into zones to study relationships between channel density, lake density, lake area and interfluve area.

7) High resolution Google Earth images were acquired, where available, to observe the processes in better detail.

Hypothesis on formation of dissecting splay channels

From observation of satellite photos it appears that the floodplain lake dissecting channels are formed by a combination of hyperpycnal flow, seasonal changes in water level and vegetation. Very similar channels form in the man made accommodation created by daming rivers to form water reservoirs where the river enters the lake. These examples are from lakes in North Texas, USA.



1) Hyperpycnal flow jets out at flood stage and forms underwater levees.

2) More hyperpycnal flow.

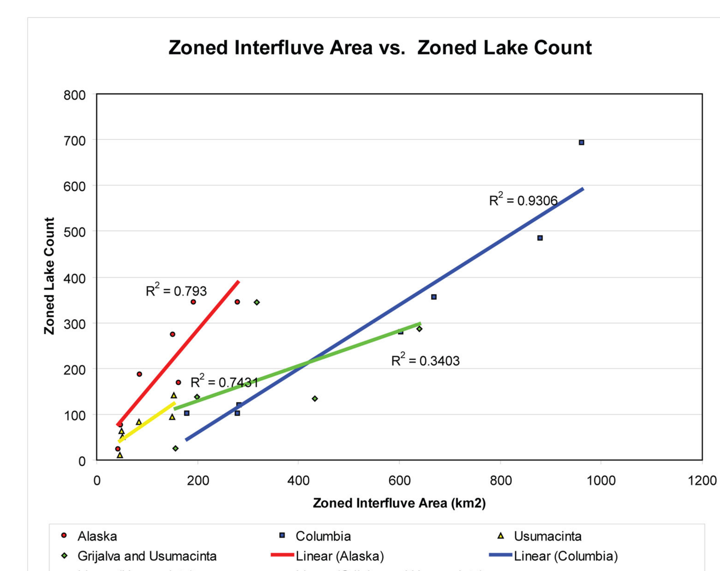
3) During low water level intervals vegetation grows preferentially on the higher, well drained, levee thus reinforcing it and providing an extension for the hyperpynal flow during the next flood stage.

4) This process continues until long dissecting channels are formed.

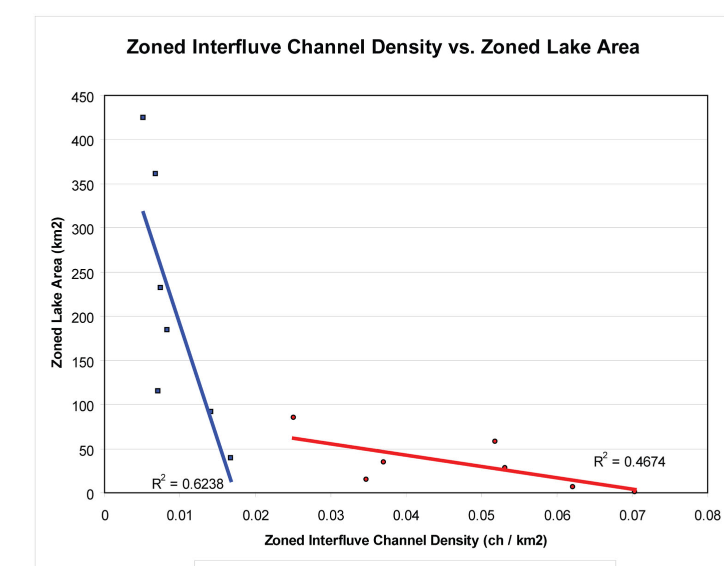
5) Lake Weatherford January, 1995.

6) Lake Weatherford December, 2002.

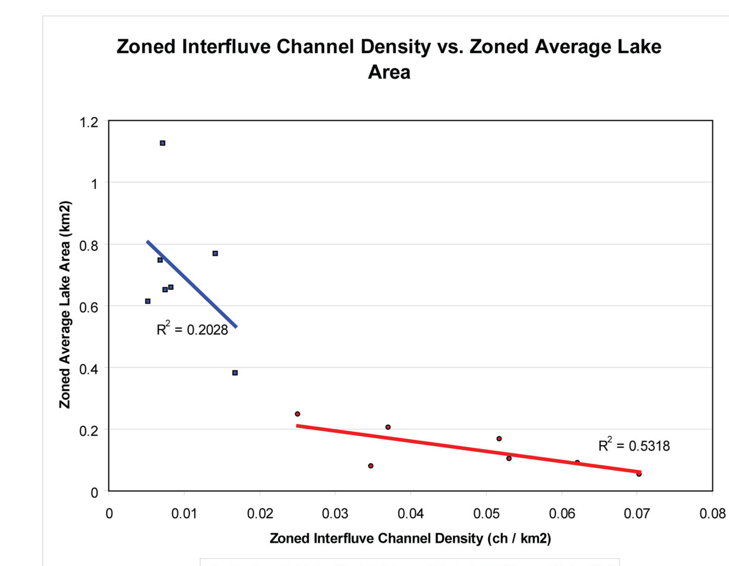
Attribute Comparison



Larger interfluve area means more lakes (and more total lake area).
The is a basic characteristic of high accomodation settings.
Bigger interfluve = more lakes and lake area.



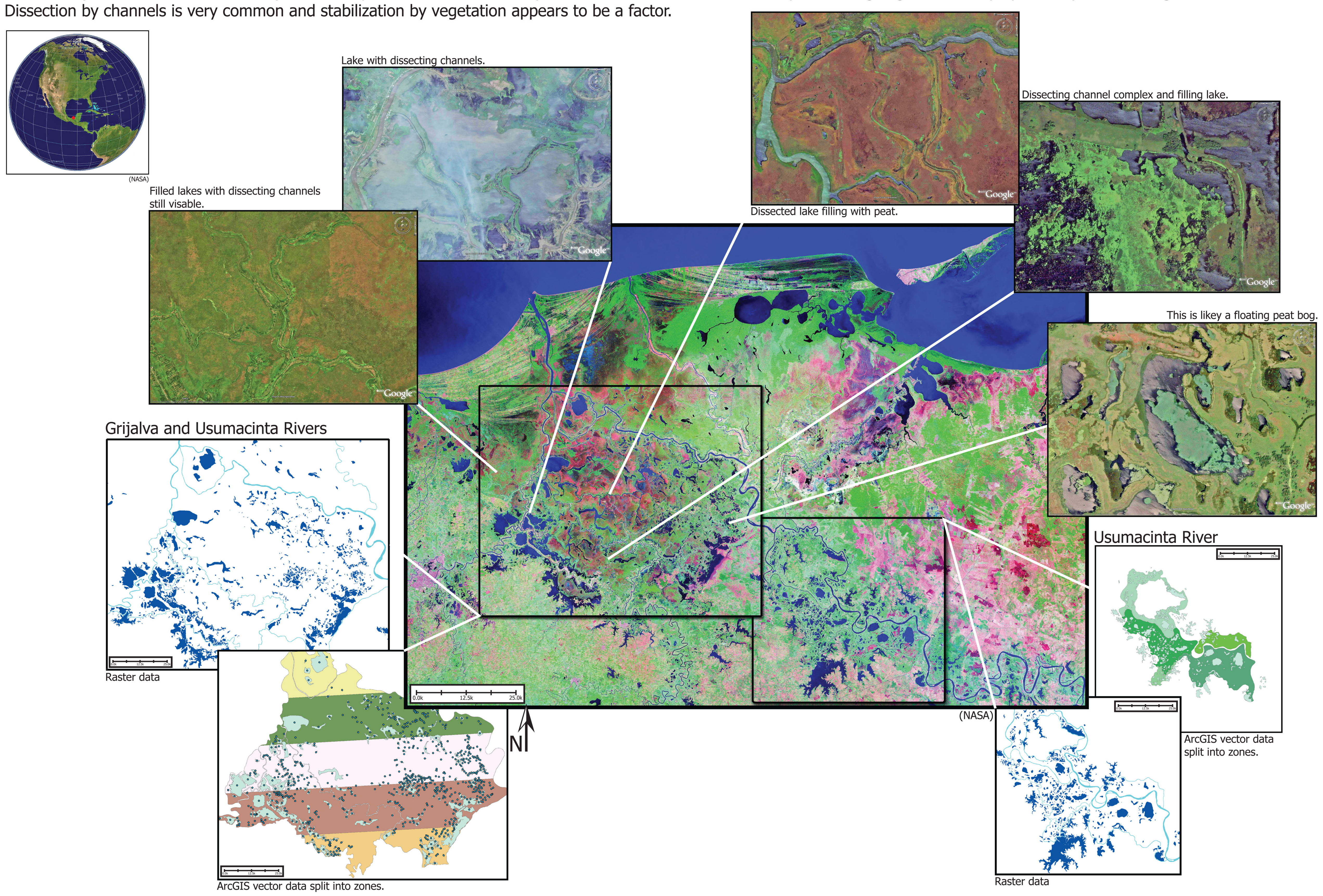
The more channels that cut an interfluve zone the less total lake area is in that zone.
Higher channel density = less total lake area.



The more channels that cut an interfluve zone the smaller the average lake size in that zone.
Higher channel density = smaller lake size.

Grijalva and Usumacinta Rivers, Mexico

Characteristics - An extensional basin has formed in this area due to the Yucatan moving in the southeastward direction in sympathy to the right-lateral displacement along the Orizaba fault zone (Burkart and Scotese, 1990). This floodplain is mature and many of the lakes have filled. In this tropical setting vegetation has played a key role in filling the lakes. Dissection by channels is very common and stabilization by vegetation appears to be a factor.



General Observations

Maximum lake size is constrained by the distance between major channel levees or major channel levee and valley wall.

Maximum size is rarely obtained because of filling by splays and dissection of larger lakes by channels into smaller lakes. These minor chan nels are probably built by splay extension (as described by Hill, et al., 2001) and are known to evolve in to full channel avulsions (Smith et al., 1989; Smith et al., 1998; Smith and Perez-Arlucea, 1994).

Lakes may fill with peat in areas distal to sediment influx; this occurs more rapidly in warmer climates.

Dissecting nature of such channels is probably related to support by vegetation and is much more common in tropical and temperate climates.

Lakes shrink and swell seasonally causing a complex interrelationship between lake and emergent floodplain environments.

Splays into standing water form elongate channels rather than splay deltas most of the time.

Conclusions

Interfluve areas in high accommodation settings are a complex mosaic of lakes, splay deltas, dissecting channels, swamps and emergent floodplain ever evolving and shifting at high frequencies dependent on fluxuations in climate, sediment supply and aggradation rate. Rather than constraining dimension of temporal lakes to constrain dimension of lake –derived facies it is probably better to consider a lake complex comprising the interfluve area with a facies assemblage reflective of the mosaic of environments.

Implications for Petroleum

Dissecting channels may form good conduits between reservoir channel belts for petroleum through floodplain lake complexesand may play an important role if the reservoir is self sourced. Interfluve lake areas may not thus model well as continuous seals.

Ideas for future research

Obtain time lapse high resolution satellite photos and get photos from both rainy and dry seasons to refine the study.

Look for possible missed relationships between floodplain lakes and their related fluvial system.

Do a ground study of one of the floodplain lake areas to obtain bathymetry data from lakes/channels and take core samples from filled lakes and channels to map and describe the sediments left behind.

References

BERENDSEN, H.J.A. and STOUTHAMER, E., 2001, Palaeogeographic development of the Rhine-Meuse delta, The Netherlands: Koninklijke Van Gorcum, The Netherlands, 268p.

BROWNE, G.H., AND PLINT, A.G., 1994, Alternating braidplain and lacustrine deposition in a strike-slip setting: the Pennsylvanian Boss Point Formation of the Cumberland Basin, Maritime Canada: Journal of Sedimentary Research, v. 64, p. 40–59.

BURKART, B. and SCOTESE, C. R., 1990, The Orizaba fault zone: link between the Mexican Volcanic Belt and strike-slip faults of northern Central America: Trans American Geophysical Union, 71, p.1559.

GLOVER, B.W. & O'BEIRNE, A.M. 1994. Anatomy. hydrodynamics and depositional setting of a Westphalian C lacustrine delta complex, West Midlands, England. Sedimentology, 41, 115-132.

HILL, P.R.; LEWIS, C.P.; LEWIS, C.P.; DESMARAIS, S.; KAUPPAYMUTHOO, V., and RAIS, H., 2001. The Mackenzie Delta: sedimentary processes and facies of a high-latitude, fine-grained delta. Sedimentology, 48, 1047-1078.

LATRUBESSE, E.M. and FRANZINELLI, E., 1999, The Holocene alluvial plain of the middle Amazon River, Brazil: Geomorphology, v.44, no.3-4, pp.241-257.

MACKAY, J.R. (1963) The Mackenzie Delta Area, N.W.T. Miscellaneous Publication no. 8. Geological Survey of Canada, Ottawa.

MOROZOVA, G.S. and SMITH, N.D., 2000, Holocene avulsion styles and sedimentation patterns of the Saskatchewan River, Cumberland Marshes, Canada: Sedimentary Geology, v.130, no.1-2, pp.81-105.

PLINT, A.G., AND BROWNE, G.H., 1994, Tectonic event stratigraphy in a fluviolacustrine, strike-slip setting: the Boss Point Formation (Westphalian A), Cumberland Basin, Maritime Canada: Journal of Sedimentary Research, v. 64, p. 341–364.

SMITH ND, CROSS TA, DUFFICY JP, CLOUGH SR. 1989. Anatomy of an avulsion. Sedimentology 36:1–23.

SMITH ND, SLINGERLAND RL, PEREZ-ARLUCEA M, MOROZOVA GS. 1998. The 1870s avulsion of the Saskatchewan River. Can. J. Earth Sci. 35:453–66.

SMITH ND, PEREZ-ARLUCEA M. 1994. Finegrained splay deposition in the avulsion belt of the lower Saskatchewan River, Canada. J. Sediment. Res. B64:159–68.

TYE, R.S. and COLEMAN, J.M., 1989, Depositional processes and stratigraphy of fluvially dominated lacustrine deltas: Mississippi delta plain: Journal of Sedimentary Research, v.59, no.6, p.973-996.