Distributive Fluvial Systems, Fluvial Megafans, Terminal Fans – Stratigrapher's Nightmare*

Piret Plink-Bjorklund1, Jianqiao Wang1, Matt Belobraydic1, Bryan McDowell1, Jessica Don1, Chayawan Jaikla1, and Gaochao Shi1

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1Colorado School of Mines, Golden, Colorado (plink@mines.edu)

Abstract

Recent work on distributive fluvial systems has greatly elevated our awareness on laterally extensive “unconfined” fluvial systems. Yet, this is a morphological classification that includes everything from alluvial fans to multiple fluvial fan systems, and is not necessarily distributive at all. To a stratigrapher, sedimentologist and petroleum geologist, there is a very distinct and significant difference between alluvial fans and any fluvial (river) system. Differences between the fluvial megafans and terminal fans are, however, less clear. Moreover, the facies and stratigraphic models presented within the distributive fluvial system’s concept are the same as those published on fluvial megafans in 1990s. Specifically, fluvial megafans were recognized for the fan shape, progradation across alluvial plains, building extensive sedimentary bodies that show lateral and vertical changes in net/gross ratio, channel amalgamation degree and channel size and type. This raises the question on how are distributive fluvial systems (excluding the alluvial fans) different from fluvial megafans or terminal fans. The aim of this presentation is to compare the different fluvial fan types, analyze their similarities and differences that concern facies, their distribution, stratigraphic and lateral trends, sediment delivery to the basin, and controls on deposition. Examples of detailed field and subsurface data are presented from Wasatch and Green River Formations, Uinta Basin, and Williams Fork Formation, Piceance Basin, and compared to literature.

Selected References


Presenter’s notes: Recent work on distributive fluvial systems has greatly elevated our awareness on laterally extensive “unconfined” fluvial systems and their significance in the geological record. This is a morphological classification that includes everything from alluvial fans to multiple fluvial fan systems.
Presenter’s notes: To a stratigrapher, sedimentologist, and petroleum geologist, there is a very distinct and significant difference between alluvial fans and any fluvial (river) system.
Presenter’s notes: Differences between the different large fluvial fans are, however, less clear.
Fluvial Distributary Systems

Nichols and Fisher 2007
Fluvial Megafans

Shukla et al. 2001
Losimean Fans

Stainistreet and McCarthy 1993
DFS: Distributive Fluvial Systems

Weissmann et al. 2010

Davidson et al. 2013
Presenter’s notes: Yet, this is a morphological classification that includes everything from alluvial fans to multiple fluvial fan systems, and is not necessarily distributive at all. To a stratigrapher, sedimentologist, and petroleum geologist, this is like having just one model for all shallow marine systems, independent if they are wave or tide dominated. The main difficulty I see is that, although the models seem distinct enough, the actual data and their modern analogues are not.

Objectives

What are the differences in large fluvial fans:
- facies
- lateral/vertical trends & architecture?

What are the differences in
- autogenic processes
- climatic and tectonic setting
- sediment delivery beyond the fans
Lateral vertical trends and architecture
Fluvial megafan lateral/vertical/architecture

Mountainous hinterland, large drainage, seasonal discharge, most common in foreland basins

Discharge, grain size, sediment flux decreases; Floodplain sediment increases; Most spays in anastomosing zone

Despite high aggradation, deliver sediment and water beyond the fan

Shukla et al. 2001
Fluvial megafan lateral/vertical/architecture

Radial paleochannel pattern due to avulsions, not bifurcations
Fluvial megafan

Builds its own topography:

Hinterland, not accommodation control
Fluvial megafan lateral/vertical/architecture

Wasatch and Green River Fm., Uinta basin:
Channels largest, braided, extremely amalgamated in proximal part
Fluvial megafan lateral/vertical changes

Wasatch and Green River Fm., Uinta basin:
Channels smaller, less amalgamated more basinward
Fluvial megafan lateral/vertical changes

Channels anastomosing, some meandering, less amalgamated,
large volume of splays; avulsion packages
Fluvial megafan lateral/vertical changes

Distal: small channels, not amalgamated, heterolithic channels fills, thin splays, lower splay volume, thinner succession

Runs out of coarse sediment
Predictable trends, correlatable across the basin
Fluvial megafan lateral/vertical/architecture

Williams Fork Fm., Piceance basin:
Predictable upward-coarsening packages

Predictable trends, correlatable across part of the basin
Fluvial megafans: Autogenic processes

- Build by avulsions: Nodal single channel avulsions and lobe avulsions
Highly aggradational systems: relatively small sediment volume reaches the basin – small deltas.
Terminal fans &

Kelly and Olsen 1993

bifurcations

Model:
Bifurcations:
increase in number of channels distally

Modern examples:
Avulsions rather than bifurcations

Fluvial distributary systems
Nichols and Fisher 2007

bifurcations, terminal lobes

North and Warwick 2007
Terminal fans & Fluvial distributary systems

Kelly and Olsen 1993

Nichols and Fisher 2007

Model:
Bifurcations: increase in number of channels distally
Terminal lobes = most lobes in distal part

Modern examples:
Avulsions rather than bifurcations
Not documented

Terminal:
no sediment delivery;
Runs out of sediment and water
Losimean fan lateral/vertical/architecture

Runs out of sediment and water; Avulsions? or bifurcations?; No terminal lobes

Stainistreet and McCarthy 1993
DFS: Distributive Fluvial Systems

Similar to fluvial megafans;

does not completely capture fluvial megafan facies distribution;

does not capture other fluvial or alluvial fans

Davidson et al. 2013
Lateral/vertical trends & architecture summary:

- Fluvial megafan models fit with modern and ancient examples

- Terminal Fan and Fluvial Distributary System models do not have convincing analogues

- DFS facies model looks very similar to fluvial megafan model, and does not capture e.g. Okavango system or alluvial fans or terminal fans etc. included in the morphological model, and is thus not a unifying stratigraphic model
Channel-fill facies
Fluvial megafan facies: Wasatch and Green River Fm., Uinta Basin

Planar laminations
- ripples
- planar
- dunes
- scour and fill

Gradational planar laminations
- climbing ripples
- climbing dunes
- gradational planar
- convex-up

High deposition rates

Convex-up low-angle laminations

Scour and fill

UFR deposition
More similar to flashflood or megaflood deposits than facies models for river systems...

Flashy rivers where most of deposition happened during high-magnitude floods

The Altai flood

Lake Missoula flood
Perennial channel fills

Geometry:
- complex, thin, lateral, downstream and upstream accretion sets

Sedimentary structures:
- dominantly cross-stratified sandstones
- plane-parallel-laminated sandstone
- ripple-laminated sandstones

Presenter’s notes: My task here is to explain what we made out of this complex.
**Fluvial megafan facies are highly variable**

*Wasatch and Green River Fm., Uinta Basin*

- ripples
- planar
- climbing ripples
- dunes
- scour and fill
- climbing dunes
- gradational planar
- convex-up

*Williams Fork Fm., Piceance Basin*

*Kosi megafan (Shukla et al. 2001; Singh et al. 2007)*

- Mottled mud
- Ripple cross-bedding
- Trough cross-bedding
- Planar cross-bedding

Dominated by cross strata
Terminal fan facies are highly variable

River Gash (Abdullatif 1989)

- Climbing ripples
- Climbing dunes
- Gradational planar dunes
- Convex-up dunes

Gun Point Fm (Sadler and Kelly 1993)

- Dominated by cross strata

Devonian (Kelly and Olsen 1993)
Fluvial distributary systems facies are highly variable

Kobo basin (Billi 2007)

- climbing ripples
- climbing dunes
- gradational planar
- convex-up
- rippled
- planar dunes
- scour and fill

Ebro basin (Nichols and Fisher 2007)

Dominated by cross strata
Facies summary:

- Facies are not unique

- Some indicate very flashy deposition during high magnitude floods

  Others indicate a mixture of high-, low-magnitude flood and non-flood discharge deposition

- 95% of examples indicate seasonally and yearly variable discharge and precipitation pattern

Facies indicate that fluvial fans occur preferentially in seasonal climates, as has been suggested for Fluvial Megafans and Terminal fans
Conclusion:

- Although the facies are not unique, their distribution and architecture are, thus
-a nightmare?

- we need to figure out what the specific fluvial fan types are, and their sedimentologic/stratigraphic differences and characteristics

- not least for understanding the autogenic and allogenic processes, sediment delivery, and stratigraphic/reservoir predictions and modeling

-I do not intend to diminish the DFS concept, as it works well as a morphological unifying model, and has raised awareness on the significance of fluvial fans,
we just need more specific stratigraphic models...
Piceance Basin Field data:

Questions?

Uinta Basin Field data:
Alluvial Depositional Models

Colorado School of Mines
Green River Collaborative Consortium

Anadarko
bhp Billiton
Bill Barrett Corporation
ConocoPhillips
devon
EOG Resources
NEWFIELD
Platte River
StatOil