FORCE

DIPARTIMENTO DI GEOSCIENZE

19 - 20th October 2017, Stavanger

FLUVIAL MEANDERS: LINKING PLANFORM BEHAVIOR WITH POINT-BAR DEPOSITS

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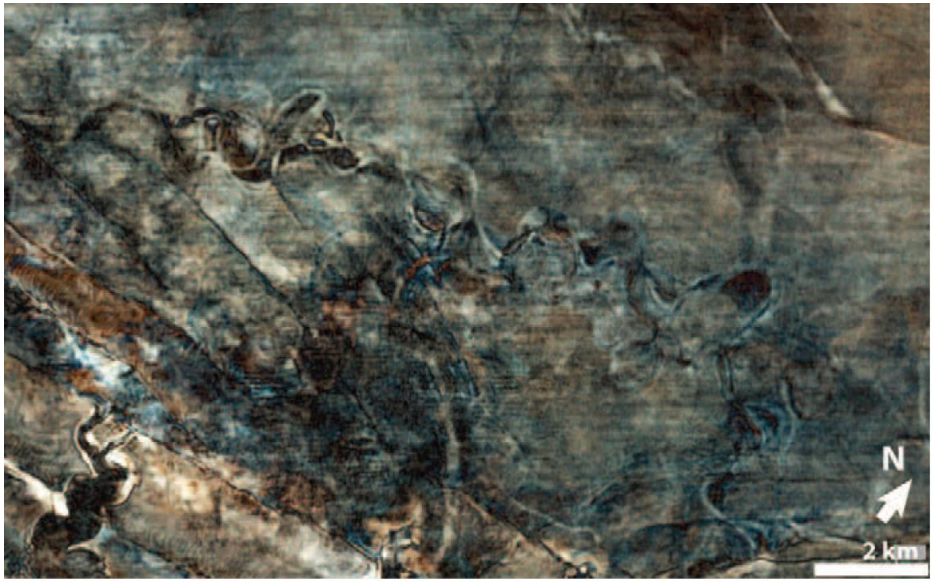
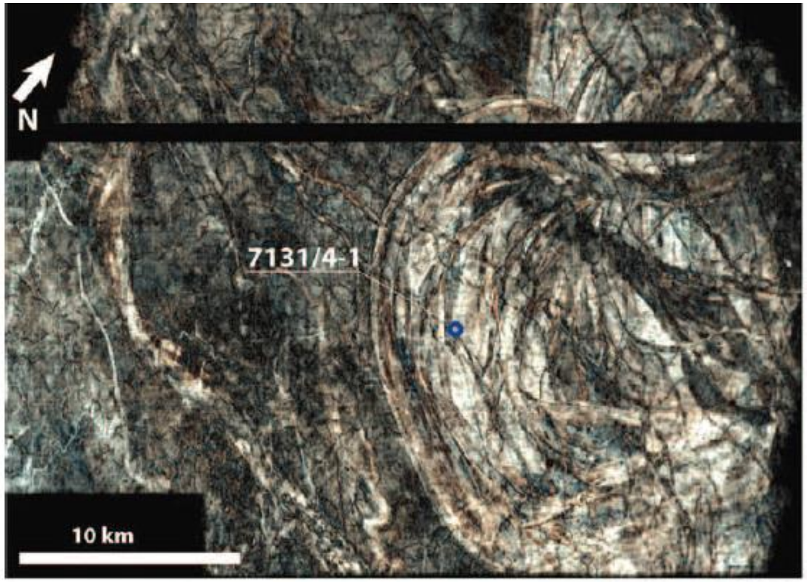
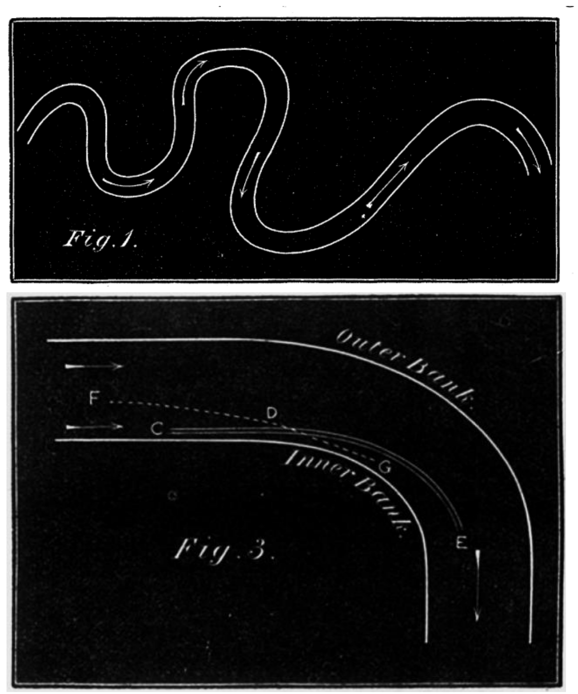
RIO NEGRO (ARGENTINA)





SNADD FM. (Klausen et al., 2014)

Leonardo da Vinci (Map of Imola)



Thomson, 1876

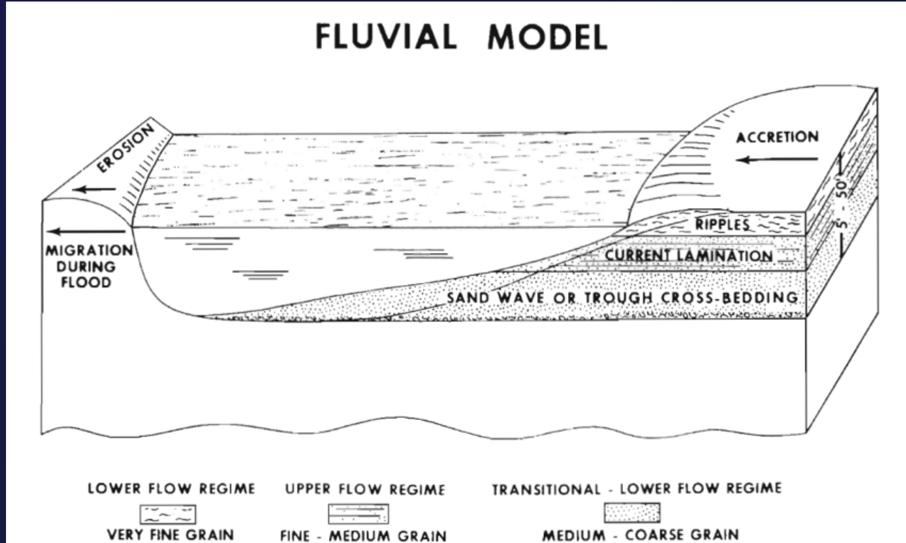
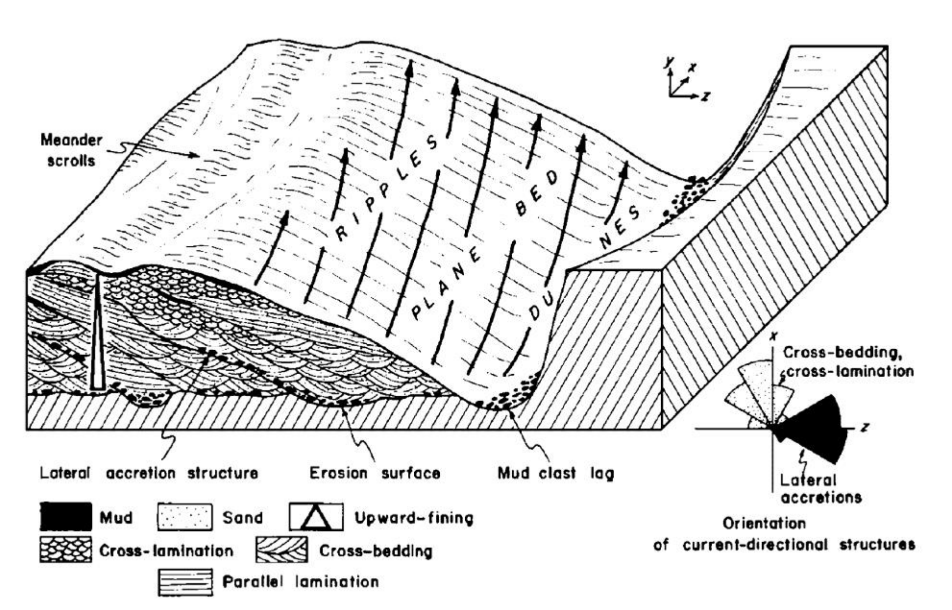
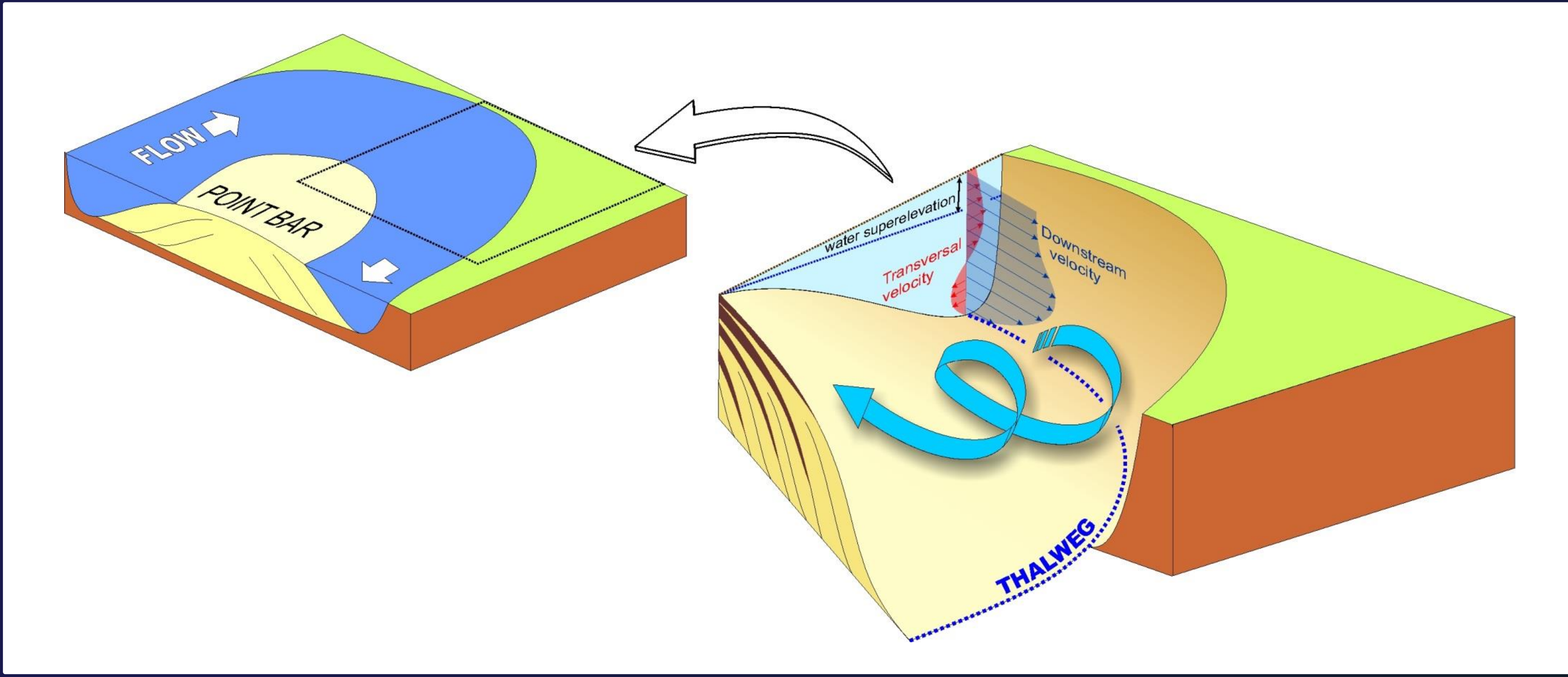


Fig. 13.—This represents an idealized version of the vertical distribution of sedimentary structures and grain size on a point bar.

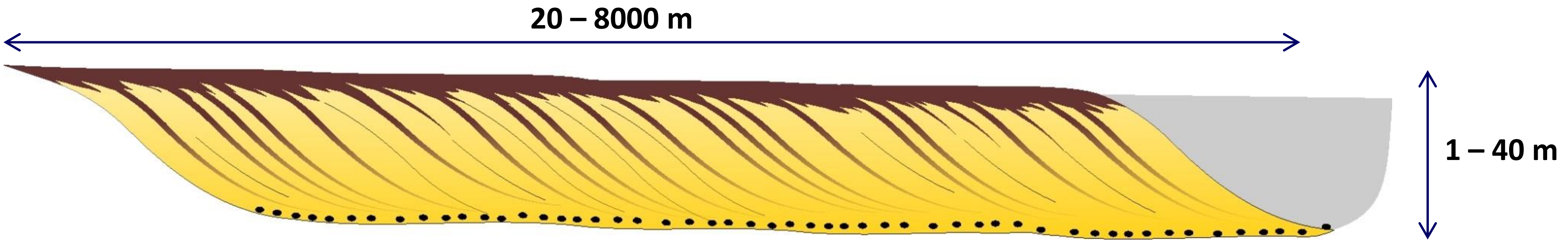
Visher, 1964



after Allen, 1970

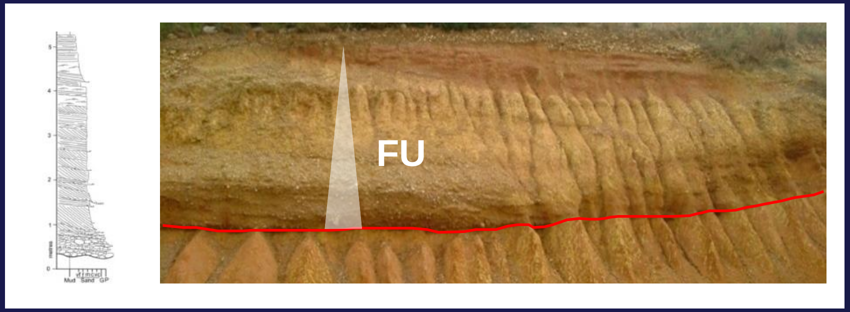

FLOW
POINT BAR
water superelevation
Transversal velocity
Downstream velocity
THALWEG

Point bar axial cross section

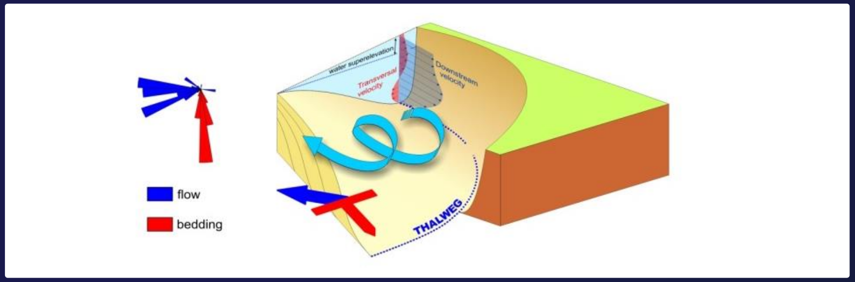


The "cornerstones" of fluvial point-bar sedimentology

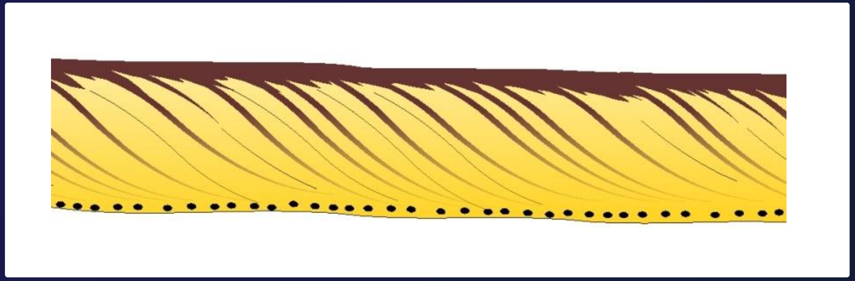
Progressive increase of bend sinuosity and neck cutoff



Fining upward vertical grain size trend



Paleoflow transverse to dip of beds (secondary circulation)



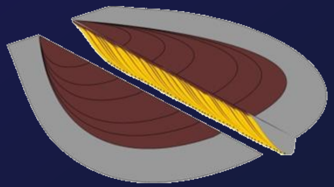
Heterogeneities in the middle-upper part of the bar

- Progressive increase of bend sinuosity and neck cutoff
- Fining upward vertical grain size trend
- Paleoflow transverse to dip of beds
- Heterogeneities in the middle-upper part of the bar

Reijenstein et al., 2011

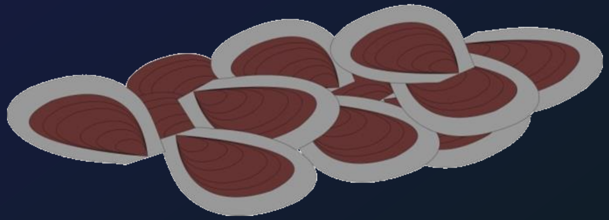
POINT BAR BODIES

- internal heterogeneities
- delimited by channel-fill mud

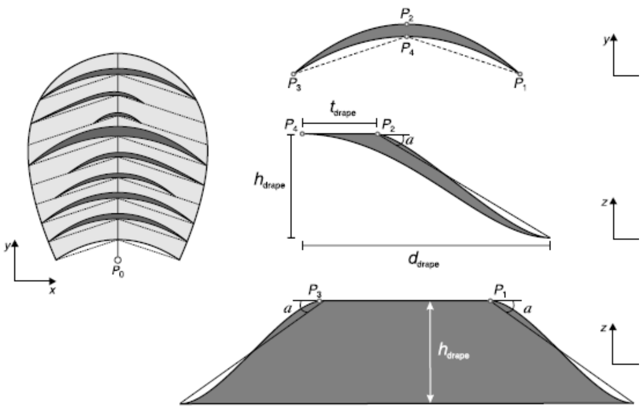


CHANNEL BELT BODIES

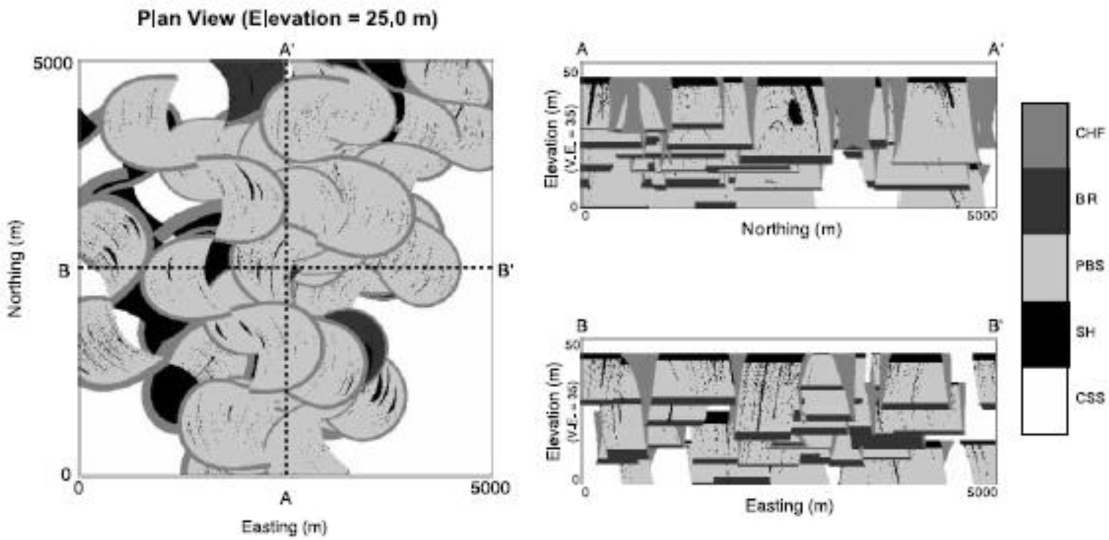
- includes several point bars bodies
- compartimentalized by channel-fill deposits



RESERVOIR MODELLING (BAR AND CHANNEL BELT SCALE)



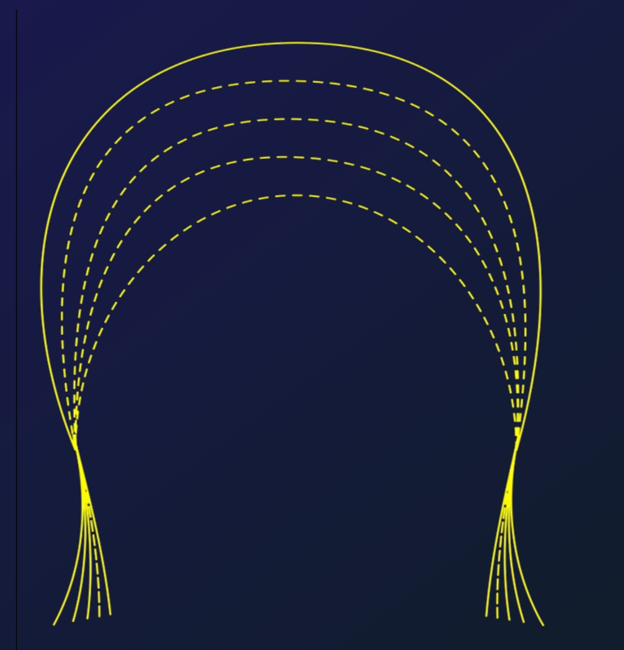
Hassanpour et al., 2013



CAN THE CLASSICAL FACIES MODELS ACCOUNT FOR THE VARIETY OF MEANDER BEND SHAPES AND RELATED FLUVIAL POINT-BAR DEPOSITS?

Fisk, 1944

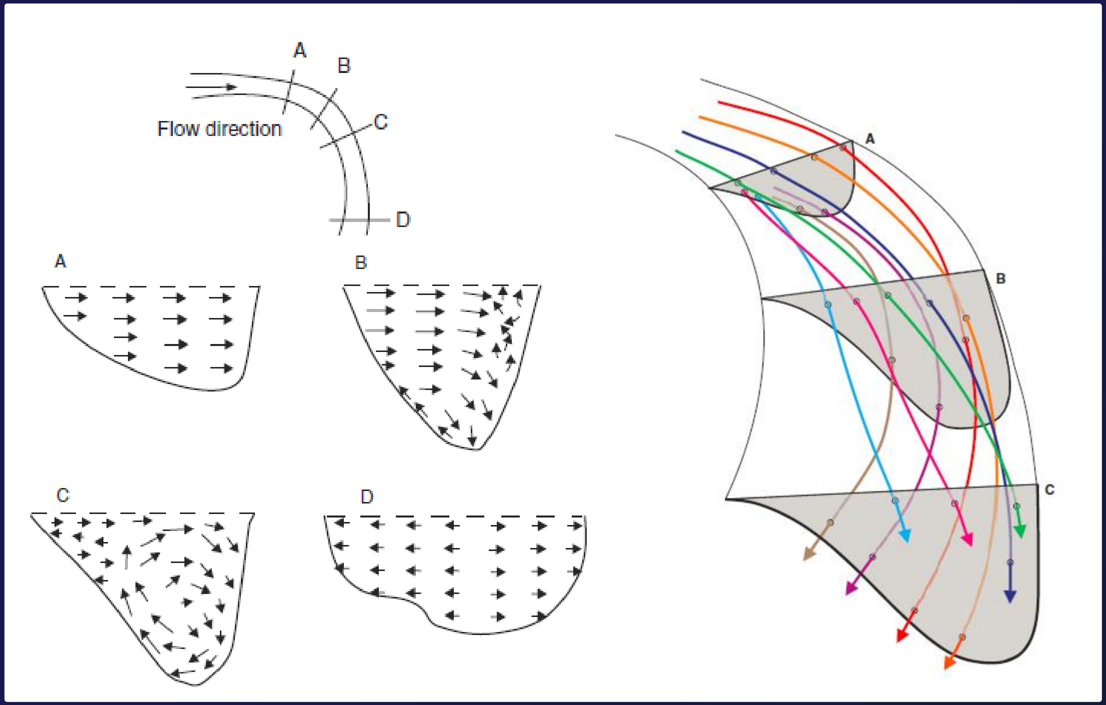
"Textbook-like" meander bend expansion is the exception…not the rule!



- **HYDRODYNAMICS OF FLUVIAL BENDS AND EFFECTIVE GRAIN-SIZE (e.g. HETEROGENEITIES) DISTRIBUTION IN POINT-BAR BODIES**
- **PLANFORM EVOLUTION OF MEANDER BENDS AND RELATED POINT-BAR DEPOSITS**
- **PLANFORM EVOLUTION OF MEANDER BENDS AND CHANNEL BELT GEOMETRIES**

HYDRODYNAMICS OF FLUVIAL BENDS AND EFFECTIVE GRAIN-SIZE (E.G. HETEROGENEITIES) DISTRIBUTION IN POINT-BAR BODIES

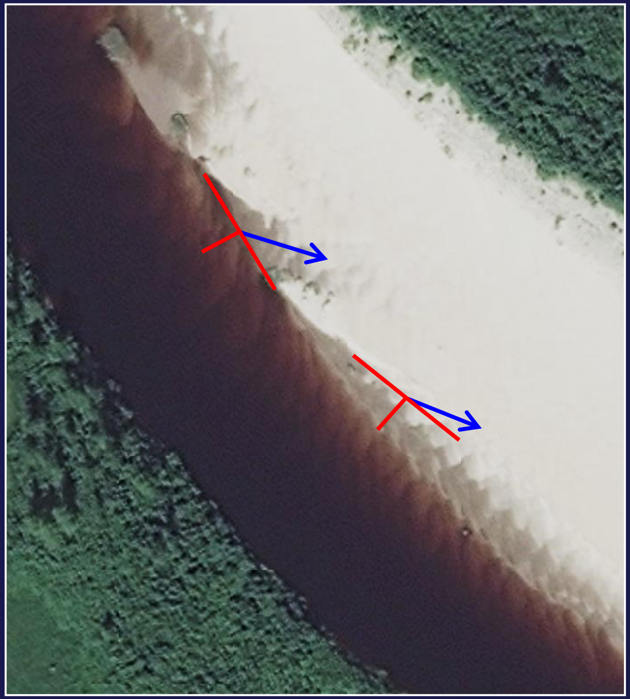
FLOW PATTERN ALONG AN OPEN BEND



Frothingham & Rhoads, 2003
Embarras River, Illinois, US

FLOW PATTERN ALONG AN OPEN BEND

UPSTREAM



Ob River, Russia

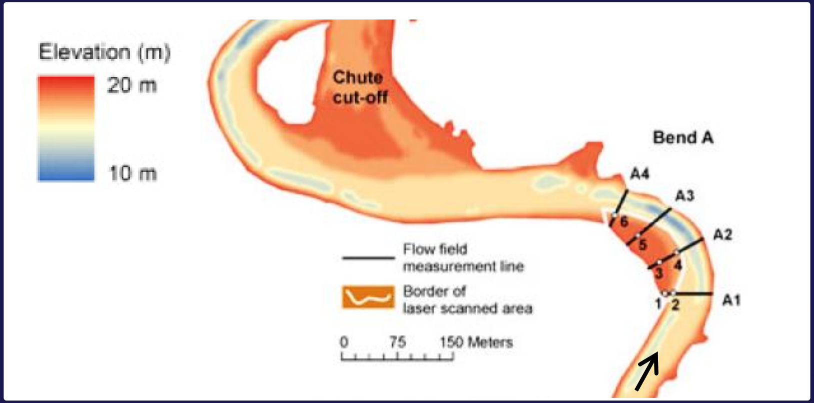
DOWNSTREAM

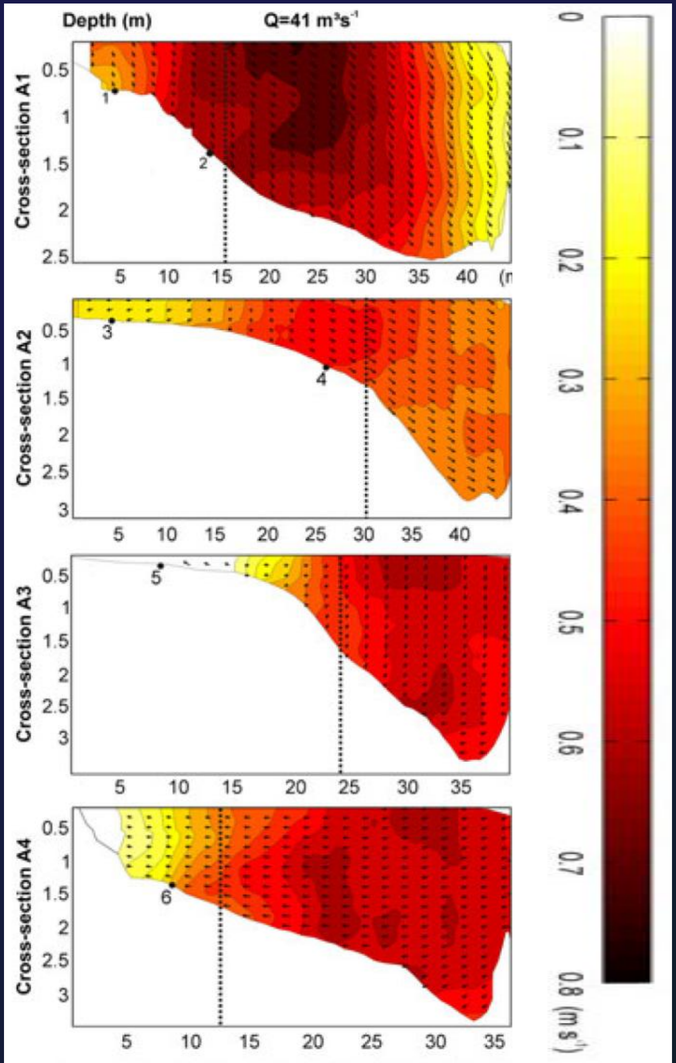
Dunes (crests) parallel to bar slope ⇨ **NO HELICAL FLOW**

Dunes (crests) highly oblique/transverse to bar slope ⇨ **HELICAL FLOW**

FLOW PATTERN ALONG AN OPEN BEND

Streamwise flow velocity

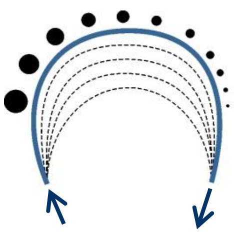




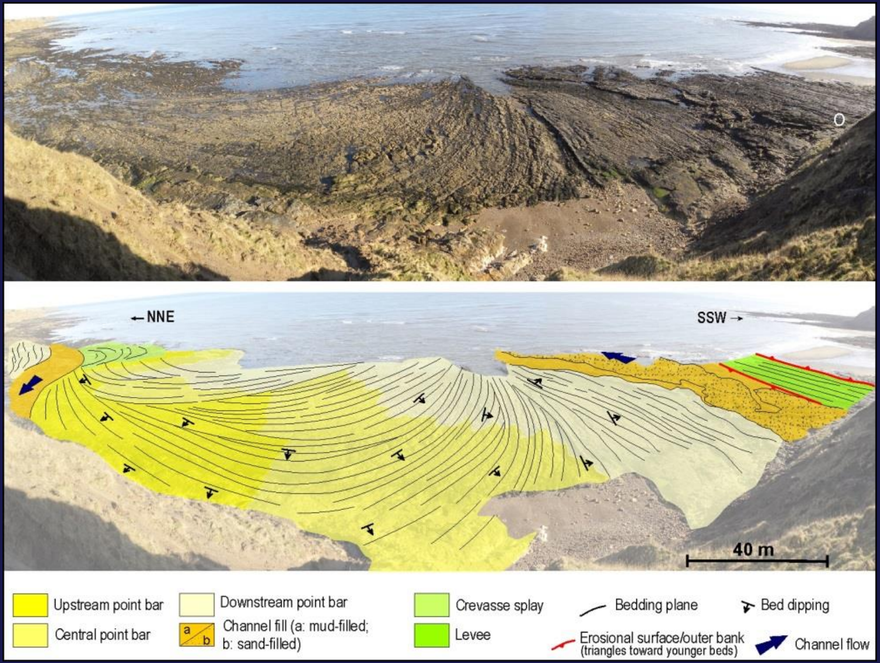
Kasvi et al., 2013
Pulmanki River, Finland

Highest velocities:

- upstream side
- close to the inner bank



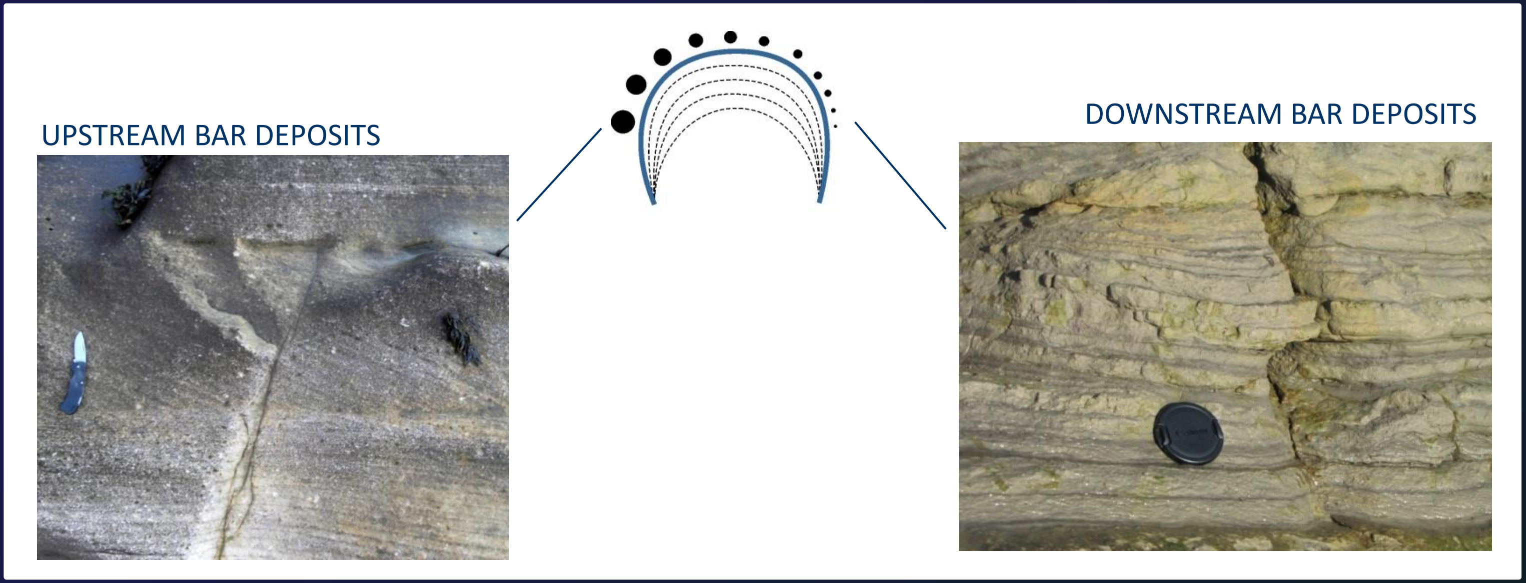
Coarser deposits occur in the upstream side of point bars

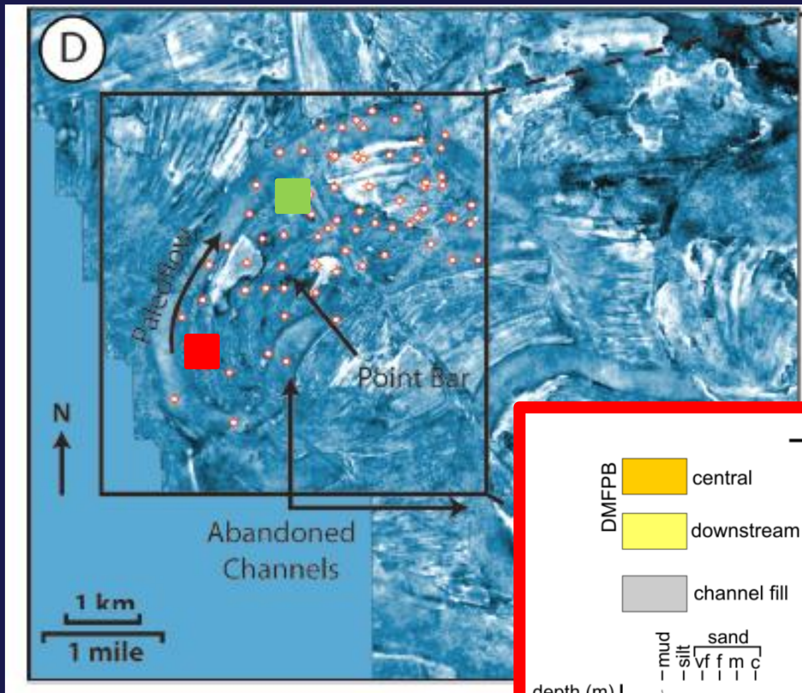


Ielpi & Ghinassi, 2014

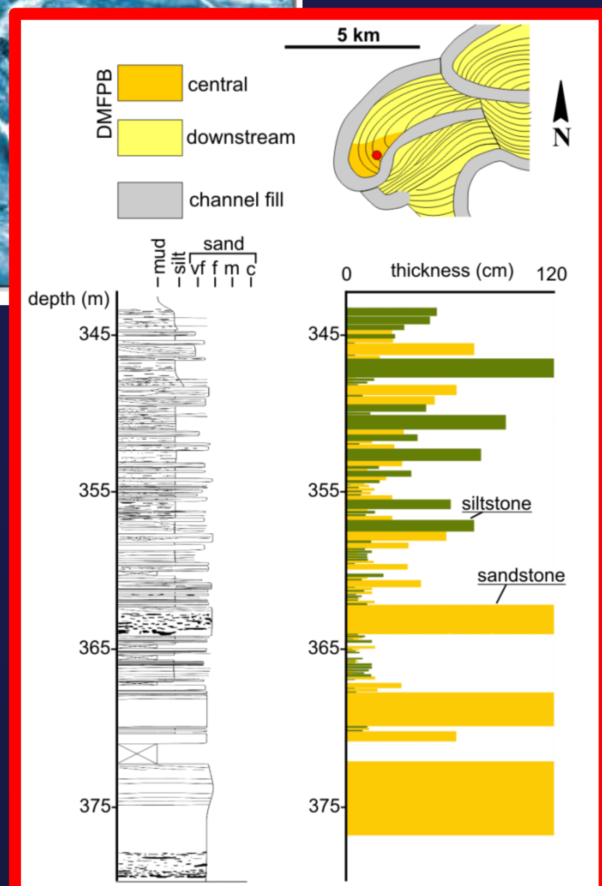
GRAIN SIZE DISTRIBUTION ALONG POINT BAR BODIES

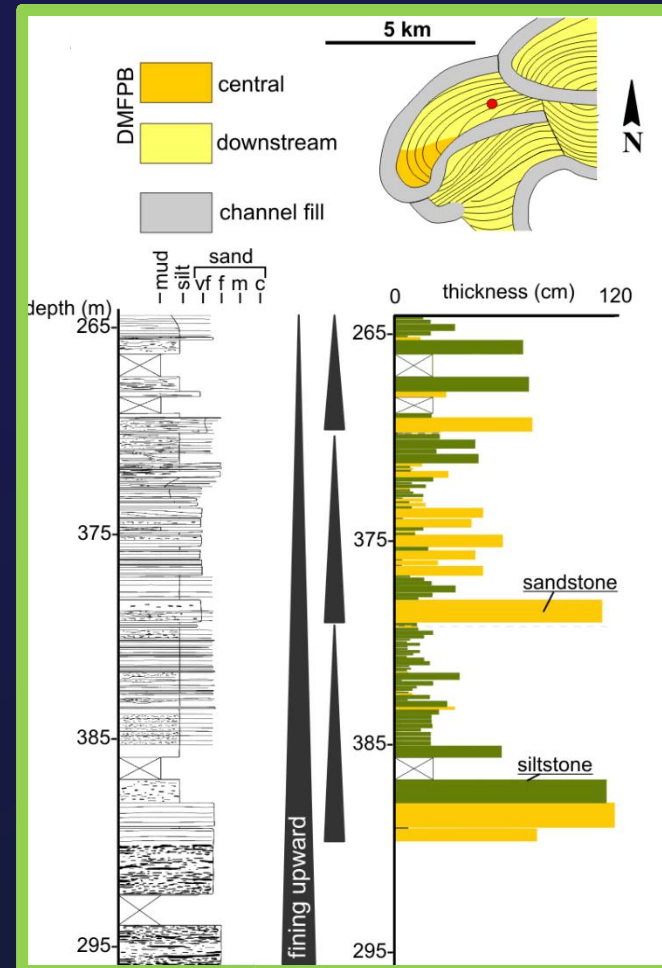
- downstream fining
- downstream increase in heterogeneities

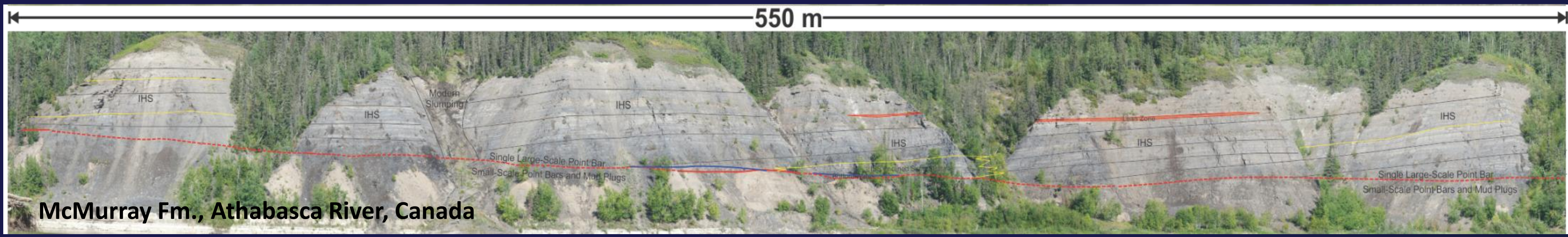


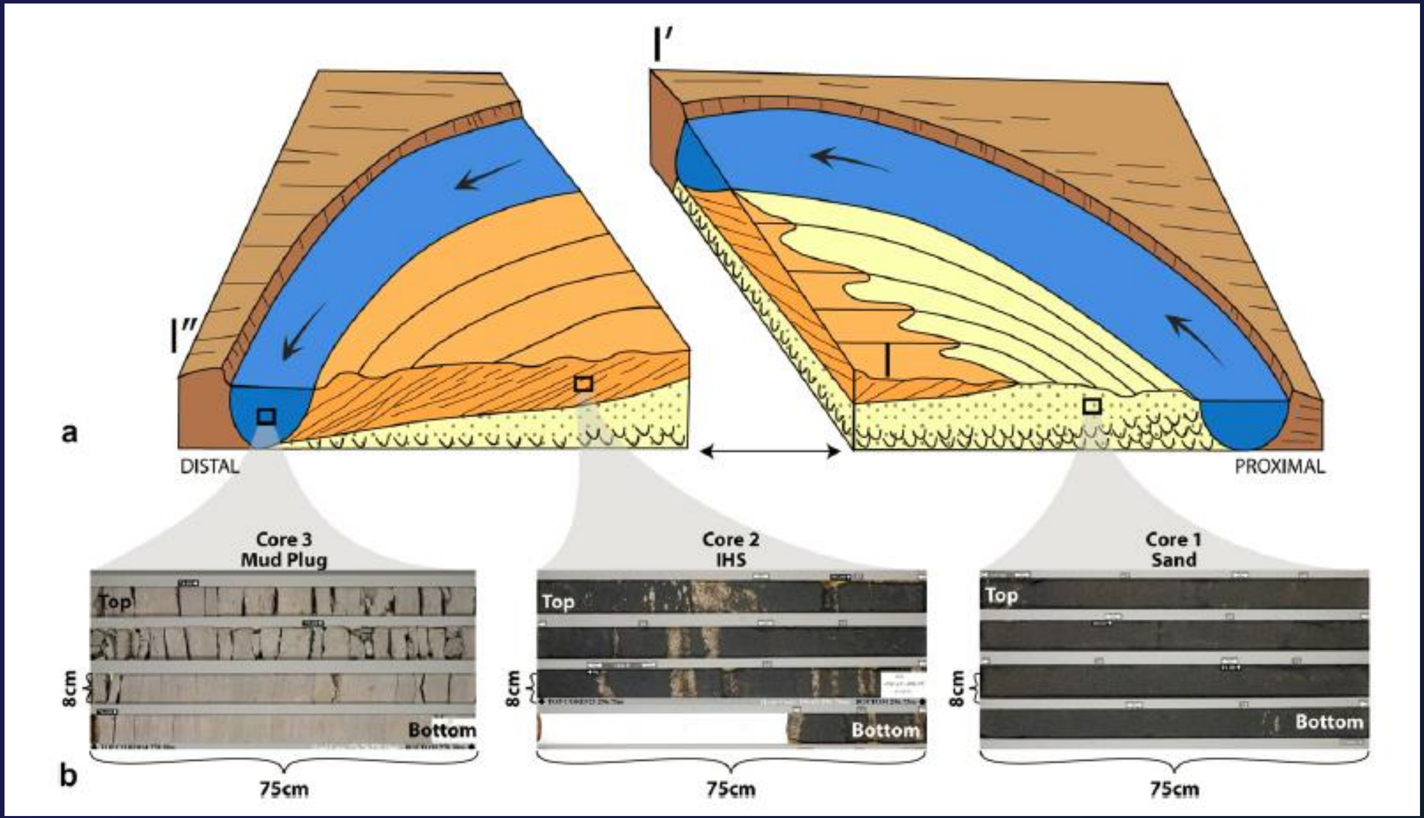


Labrecque et al., 2011









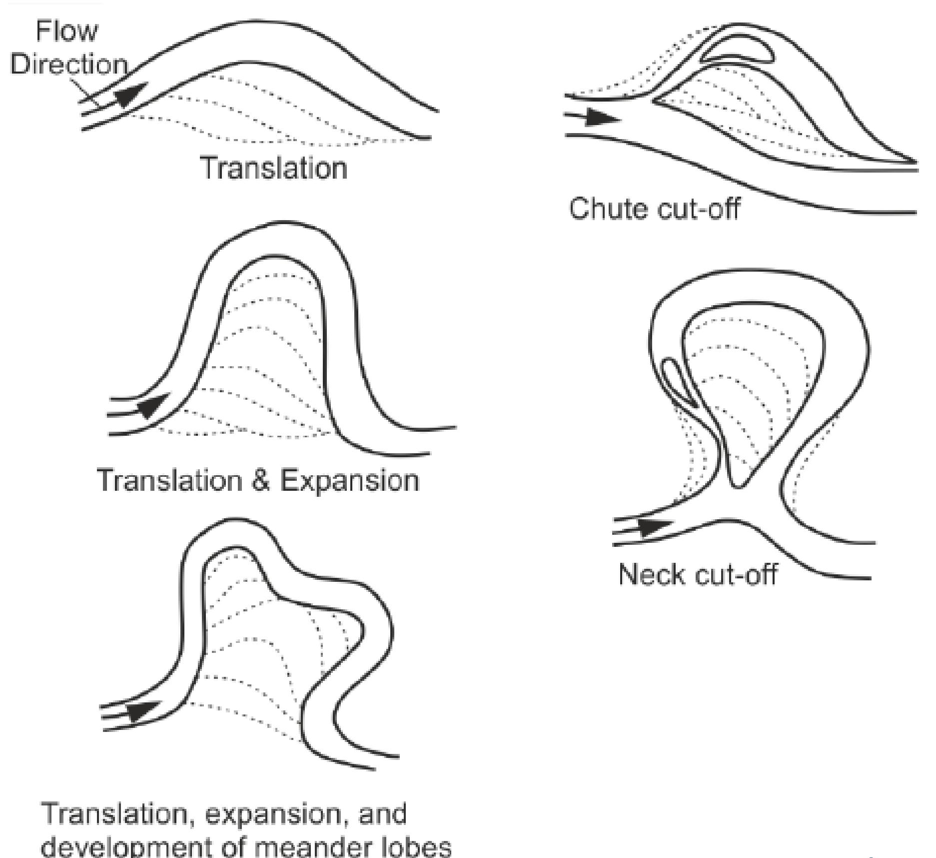
Fustic et al., 2012

TAKE HOME MESSAGE #1:

- *Grain size (heterogeneities) is not equally distributed along point bar bodies*
- *The upstream side of point bar is coarser grained than the dowstream one, where heterogeneities are more common*

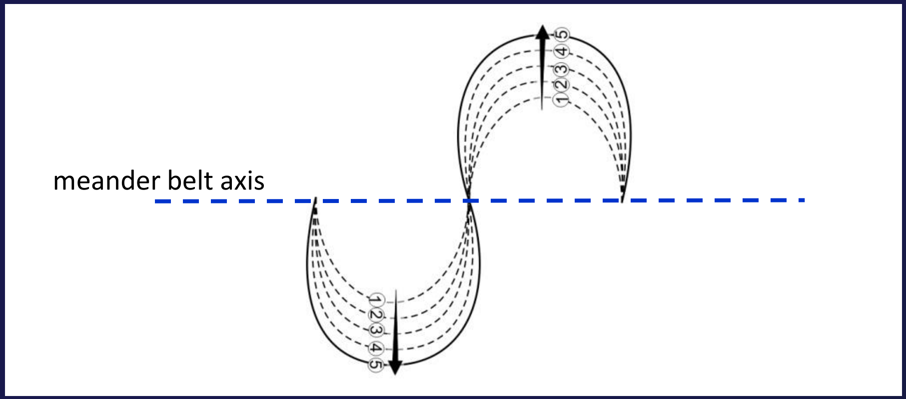
PLANFORM EVOLUTION OF MEANDER BENDS AND RELATED POINT-BAR DEPOSITS

PLANFORM EVOLUTION



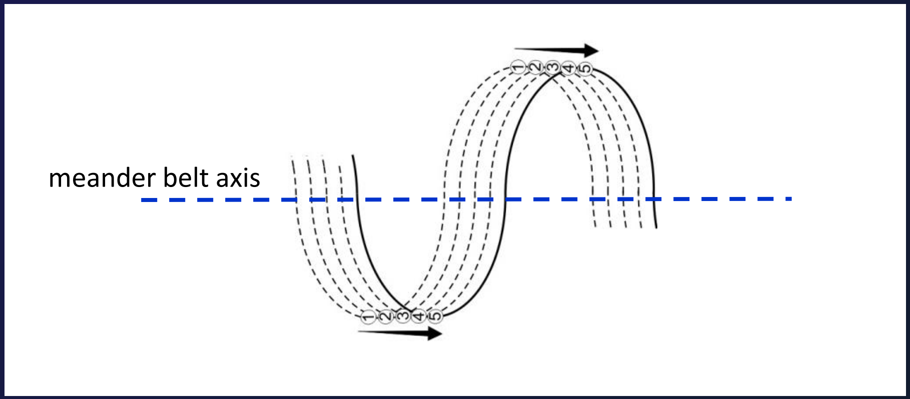
Bridge, 2003

EXPANSION



- low gradient
- sediment discharge
- sand to silt

DOWNSTREAM MIGRATION



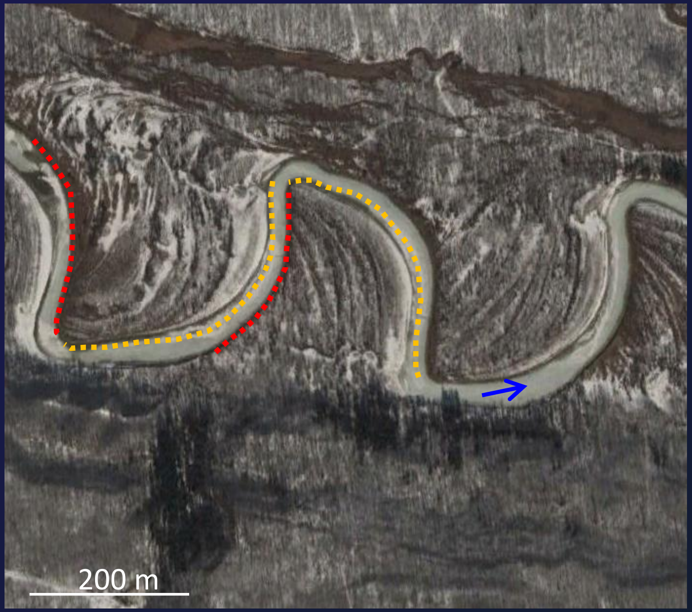
- low gradient
- sediment discharge
- sand to silt
- erosion-resistant banks
- confinement (tectonic/morphologic)

UPSTREAM vs. DOWNSTREAM BAR ZONE

EXPANSION

Powder River, Montana, US

DOWNSTREAM MIGRATION



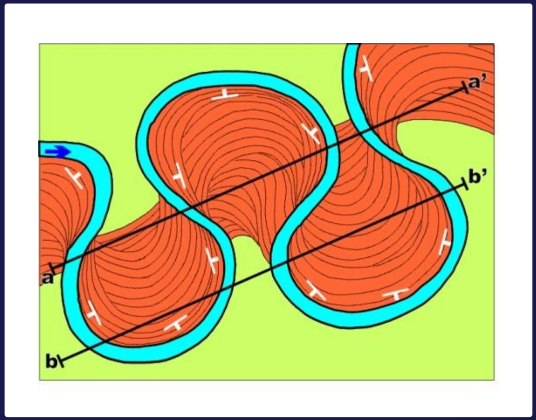
Beaver River, Canada

deposition

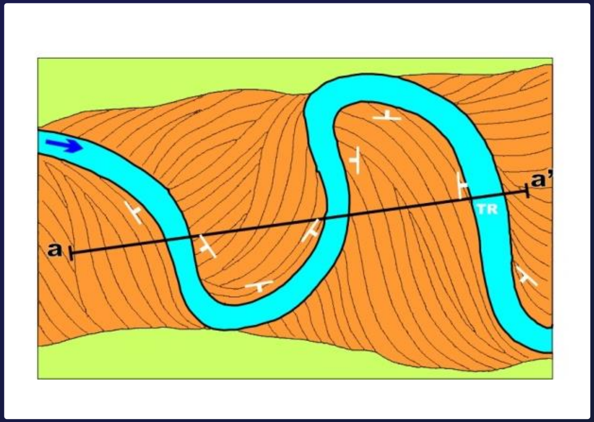
erosion

LONGITUDINAL OUTCROP SECTIONS

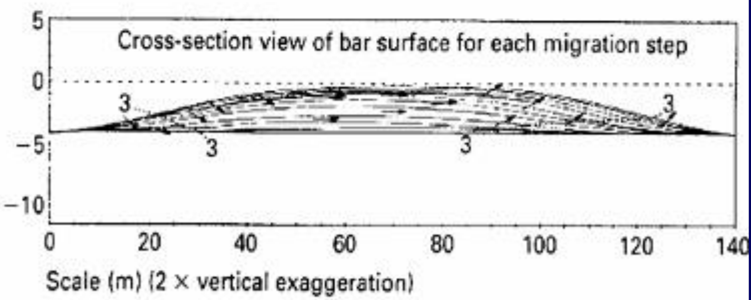
EXPANSION

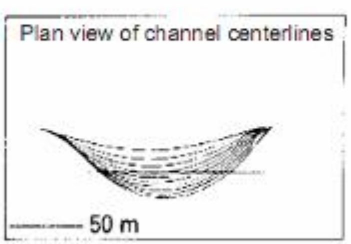


DOWNSTREAM MIGRATION



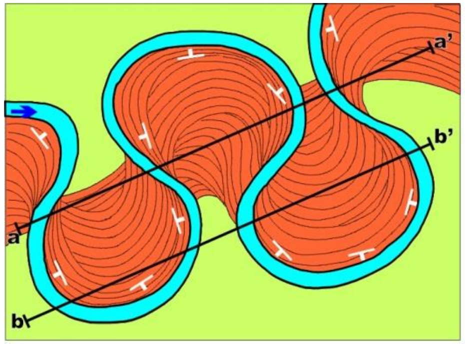
LONGITUDINAL OUTCROP SECTIONS





Willis, 1993
modified by
Bridge, 2006

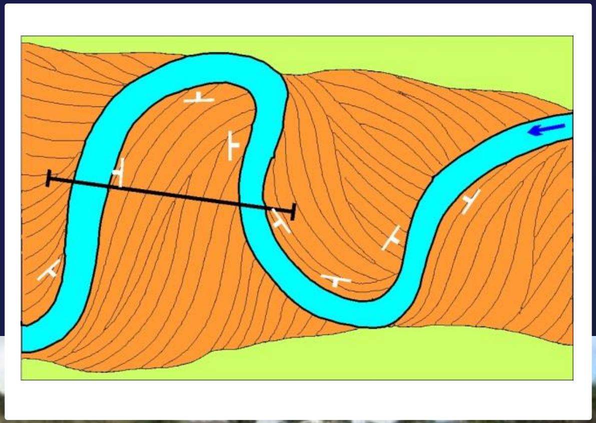
EXPANSION

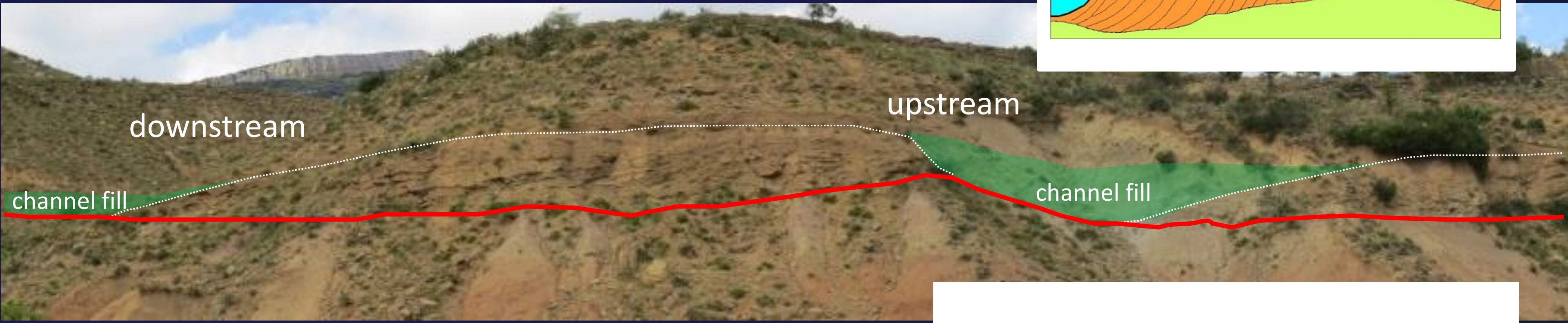


LONGITUDINAL OUTCROP SECTIONS

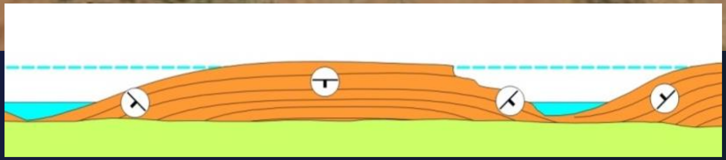
LONGITUDINAL OUTCROP SECTIONS

DOWNSTREAM MIGRATION





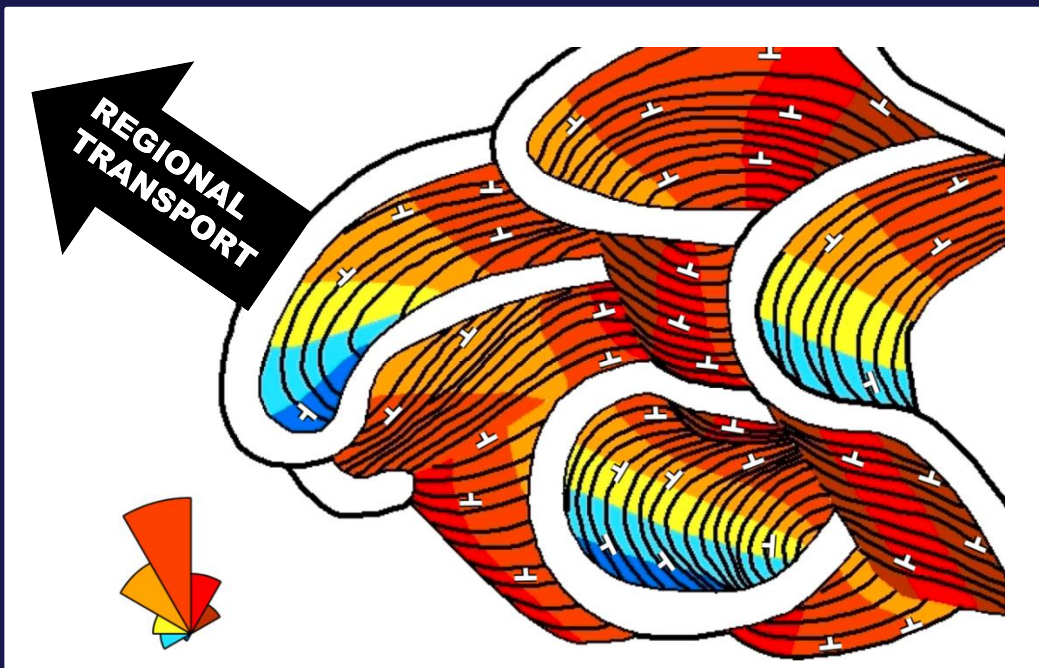
Tremp. Fm., Spain



McMurray Fm. (Alberta, Canada)

regional transport: toward North

~ 90% of beds dip toward North

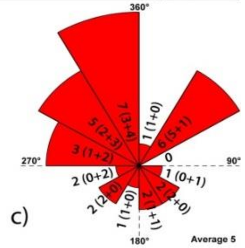


Fustic et al., 2012

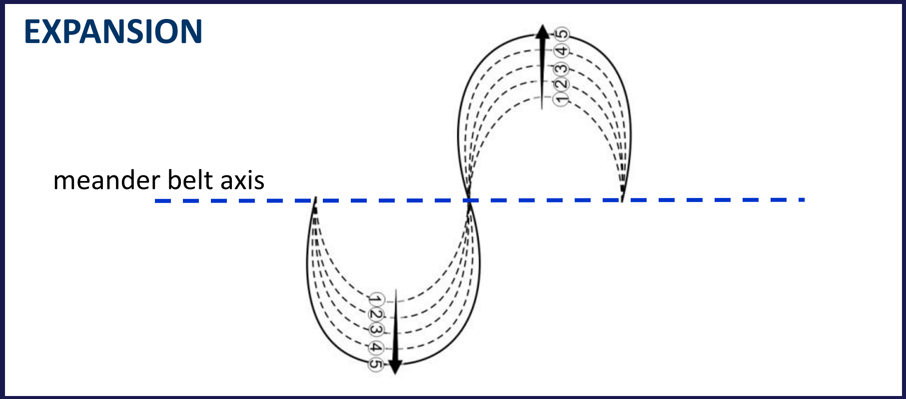
Outcrop	Elevation Interval		Thickness	Type of Fill	Azimuth	
	Top	Bottom			Azimuth	Ave. Az.
McKay River Outcrop 1	23.5	25.5	2.0	IHS	354	354
Ells River 99-01	11.0	14.0	3.0	IHS	225	198
					170	
					345	345
Ells River 99-04	7.3	14.5	7.2	IHS	50	50
Ells River 99-10	0.5	8.0	7.5	IHS	52	52
	aa	aa		IHS	222	214
	aa	aa		IHS	205	
Ells River 99-11	1.0	4.8	3.8	IHS	10	15
	aa	aa		IHS	20	
Horse River 2	12.5	16.0	3.5	IHS	0	36
Horse River Roadcut 4	29.2	35.5	6.3	IHS	135	135
Athabasca - Crooked Rapids	12.0	27.0	15.0	IHS	315	315
Athabasca - Type Section 2	30.0	51.0	21.0	IHS	325	325
Athabasca - Type Section 3	21.0	41.0	20.0	IHS	180	180
	52.5	56.0	3.5	IHS	45	45
Daphne Island East 1	0.3	4.3	4.0	IHS	120	124
	8.3	9.6	1.3	IHS	134	
Daphne Island East 3	0.4	4.6	4.2	IHS	120	
Daphne Island East 4	0.5	4.3	3.8	IHS	60	60
Steepbank 3-1	26.0	23.8	2.2	IHS	20	39
	15.0	12.5	2.5	IHS	50	
	11.0	5.0	6.0	IHS	50	
Steepbank 3-2	22.0	12.0	10.0	IHS	20	
	aa	aa		IHS	40	
	aa	aa		IHS	15	
	aa	aa		IHS	25	
	12.0	8.2	3.8	IHS	30	
	aa	aa		IHS	50	
	aa	aa		IHS	35	
Steepbank 3-3 - lower channel	20.5	8.5	12.0	IHS	65	
	aa	aa		IHS	10	
	aa	aa		IHS	5	
Steepbank 4-1 - lower channel	28.0	19.0	9.0	IHS	50	
	aa	aa		IHS	50	
	aa	aa		IHS	55	
	aa	aa		IHS	90	
Steepbank 3-3 - upper channel	29.0	23.0	6.0	IHS	350	294
	aa	aa		IHS	330	
	aa	aa		IHS	325	
Steepbank 4-1 - upper channel	39.5	34.0	5.5	IHS	265	
	aa	aa		IHS	280	
	aa	aa		IHS	250	
Steepbank 4-2	50.5	47.5	3.0	IHS	275	
	aa	aa		IHS	275	
Steepbank 7						36
Steepbank 9-1	28.0	23.0	5.0	IHS	220	220
Average						348

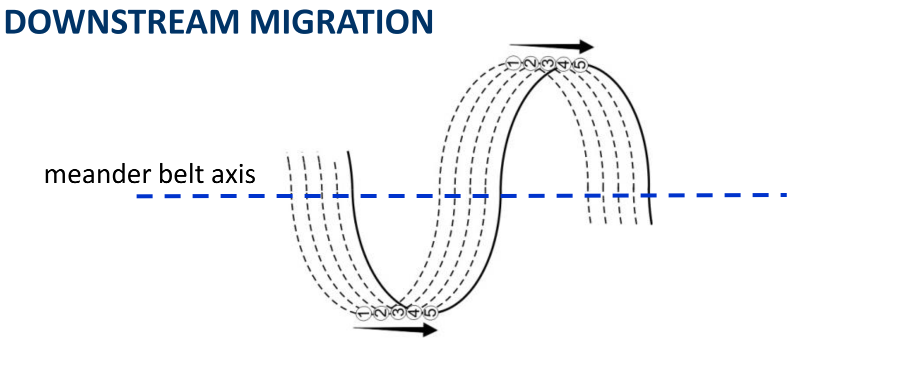
Subsurface Studies		
Cuddy and Muwais, 1989	Syncrude	315
Strobl et al, 1997	UTF	45
Brekke and Evoy, 2004	Meadow Creek	180
Leduc et al, 2003	Surmont	0
Fustic, 2007	Albian	110
		290
		300
Druesne et al, 2007	Surmont	0
		315
		270
Smith et al, 2009	Long Lake South	0
		315
		270
Average		323

c)



TAKE HOME MESSAGE #2



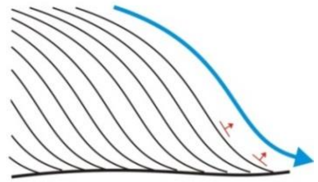


- *" Classical" expansional point bars includes: i) coarse-grained, upstream-dipping beds (i.e. no/scarce heterogeneities) and ii) fine-grained (i.e. heterogeneities), downstream-dipping beds*

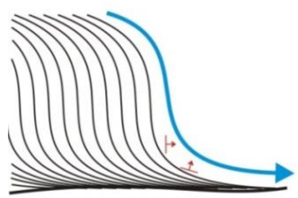
- *Downstream-migrating fluvial point bars do not preserve upstream-dipping deposits, and entirely consists of fine-grained, downstream-dipping beds (i.e. heterogeneities)*

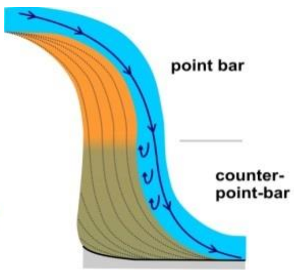
BAR TAIL ZONE IN DOWNSTREAM MIGRATING FLUVIAL POINT BARS

CONVEX OF GENTLY CONCAVE SCROLL PATTERN
(expasion and downstream migration)

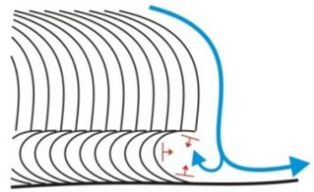


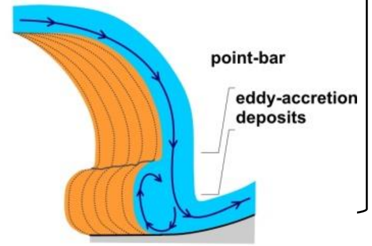
CONCAVE SCROLL PATTERN
(downstream migration)





CONCAVE SCROLL PATTERN
(downstream migration)



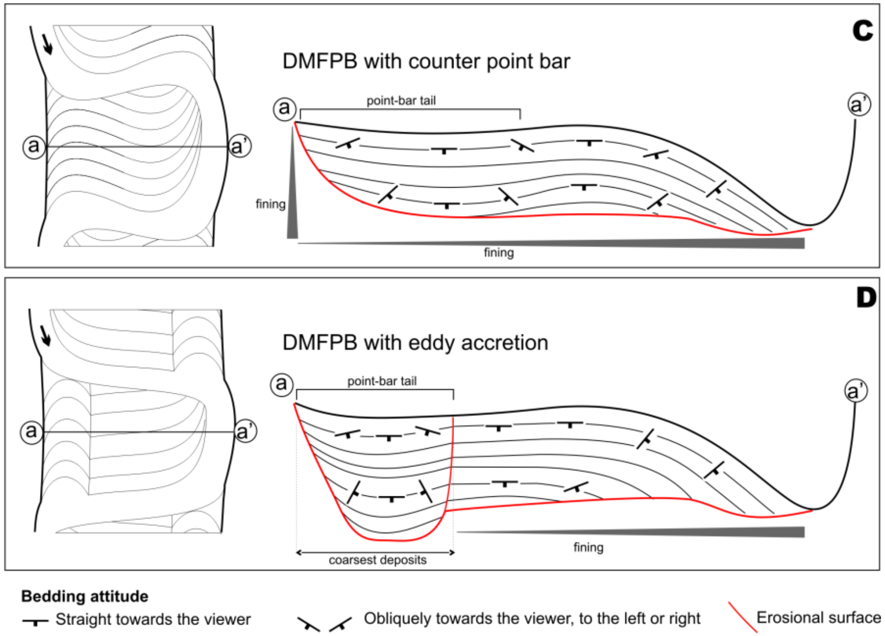


Burge & Smith, 1999
Smith et al., 2009; 2011

Ghinassi et al., 2016

BAR TAIL ZONE IN DOWNSTREAM MIGRATING FLUVIAL POINT BARS

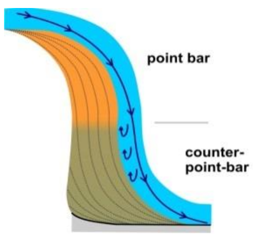
BAR TAIL ZONE IN DOWNSTREAM MIGRATING FLUVIAL POINT BARS

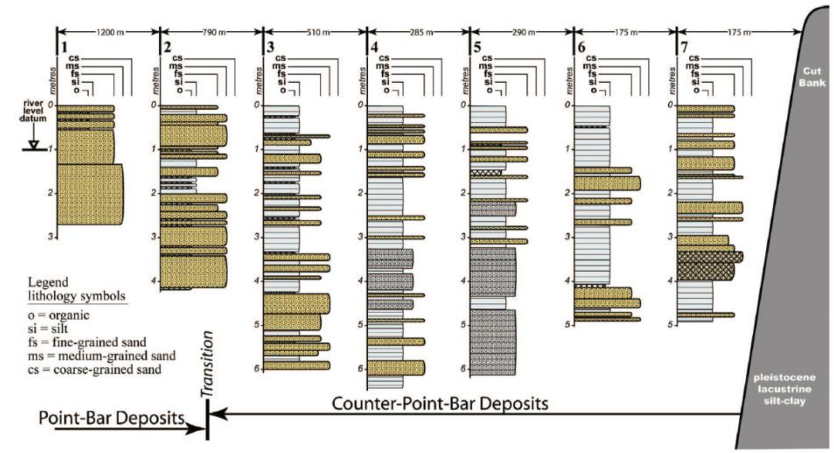


Ghinassi et al., 2016

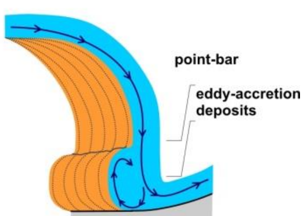
BAR TAIL ZONE IN DOWNSTREAM MIGRATING FLUVIAL POINT BARS

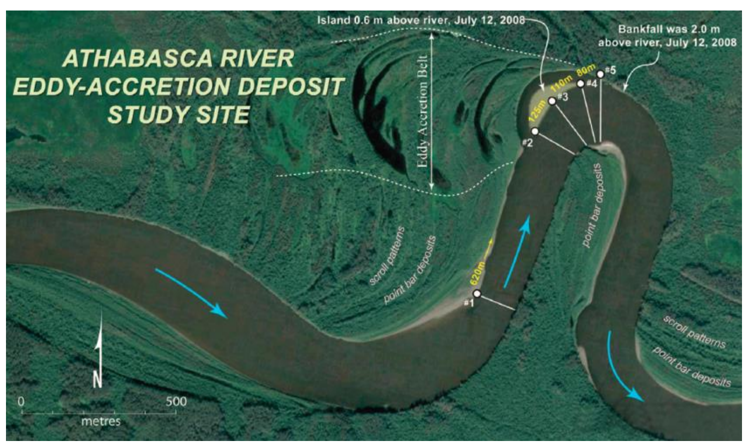
counter pointbar deposits

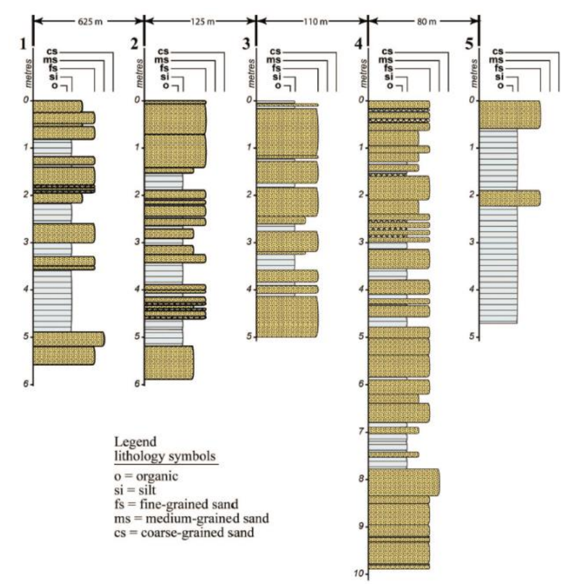




eddie-accretion deposits

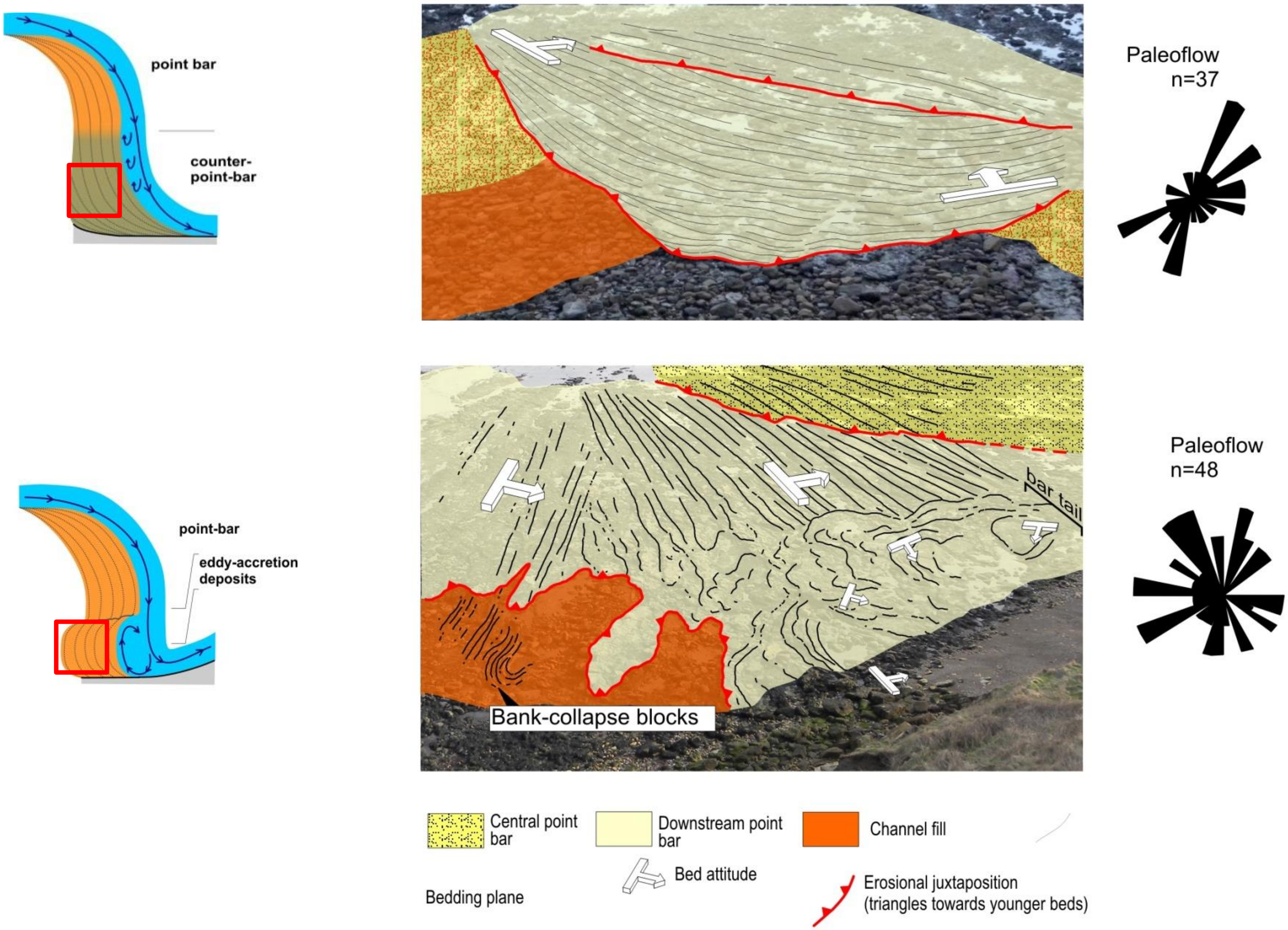






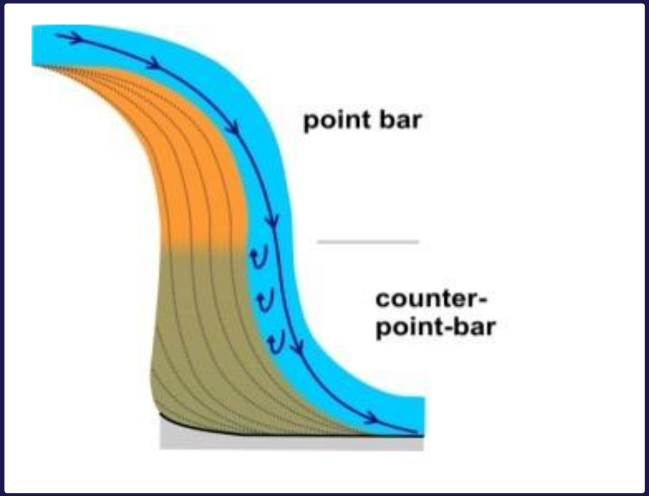
Smith et al., 2011

BAR TAIL DEPOSITS IN DMFPB

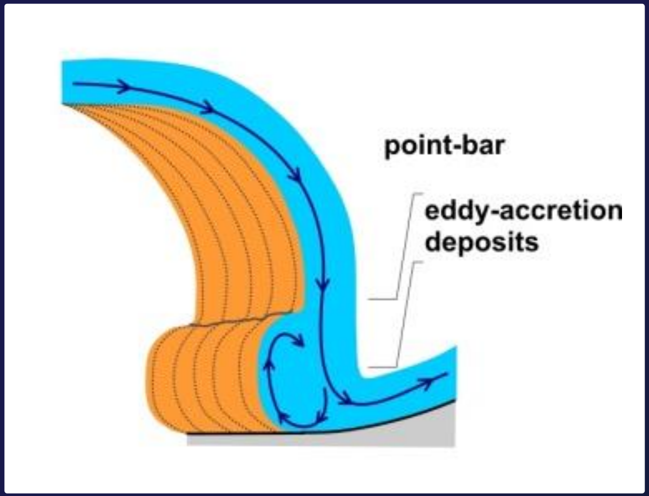


Ghinassi & Ielpi, 2015

TAKE HOME MESSAGE #3



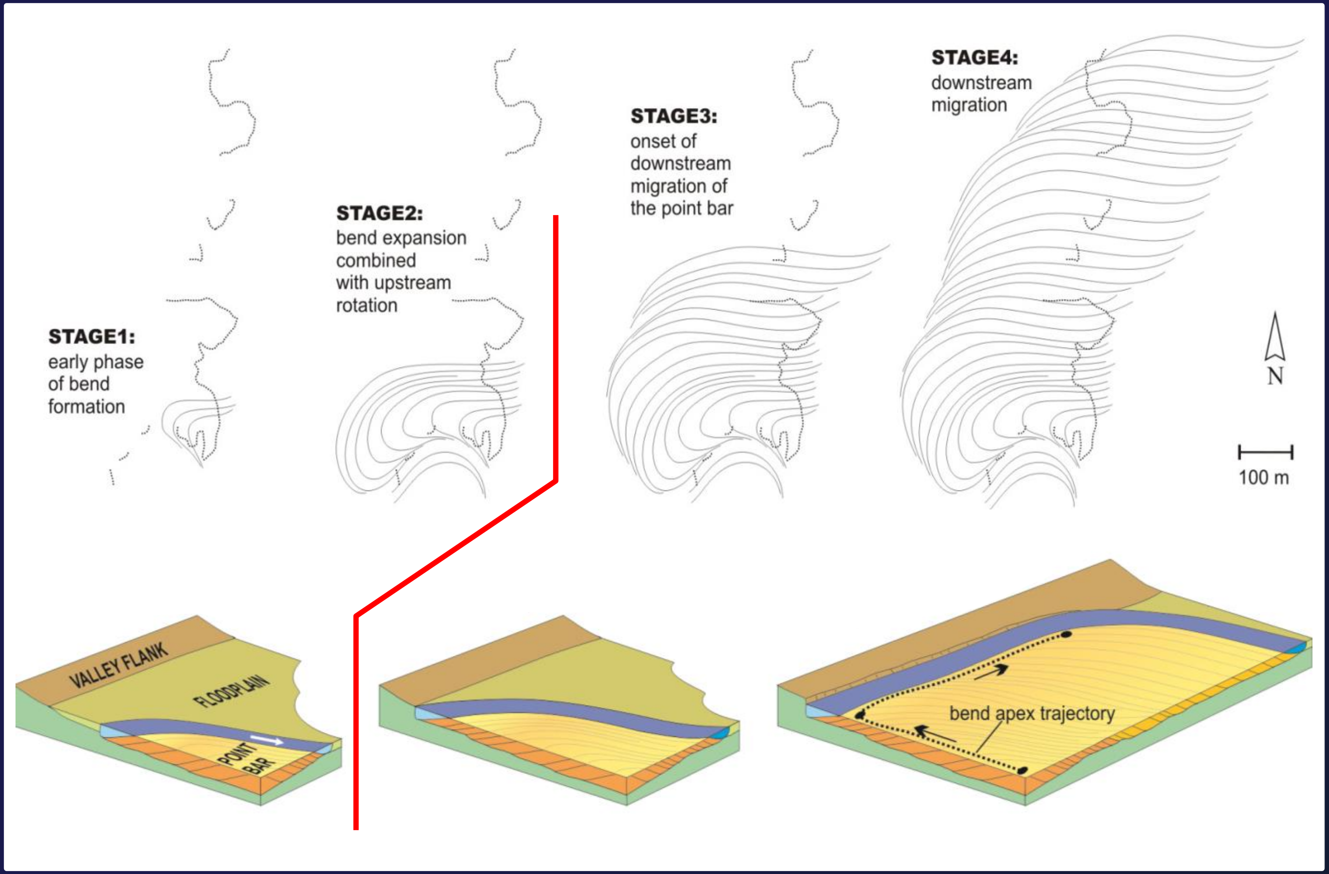
Counter point bar geometries:
fine-grained deposits form the downstream part of point bars



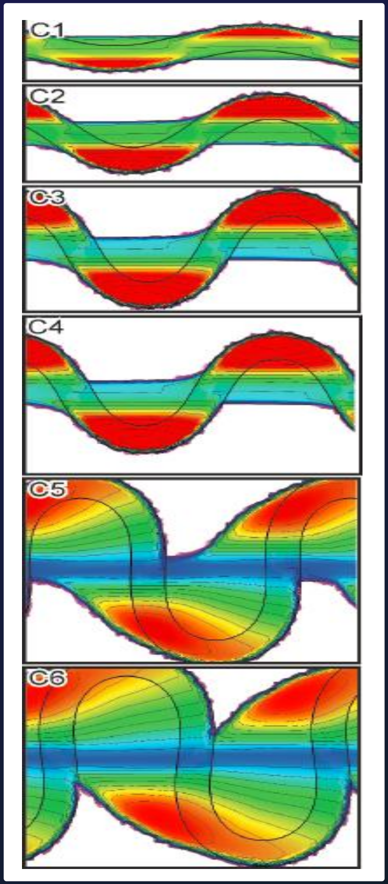
Eddy-accretion geometries:
coarse-grained deposits form
the downstream part of point bars
(i.e. no/scarce heterogenieities)

PLANFORM EVOLUTION OF MEANDER BENDS AND CHANNEL BELT GEOMETRIES

CHANNEL BELT BASAL SURFACE

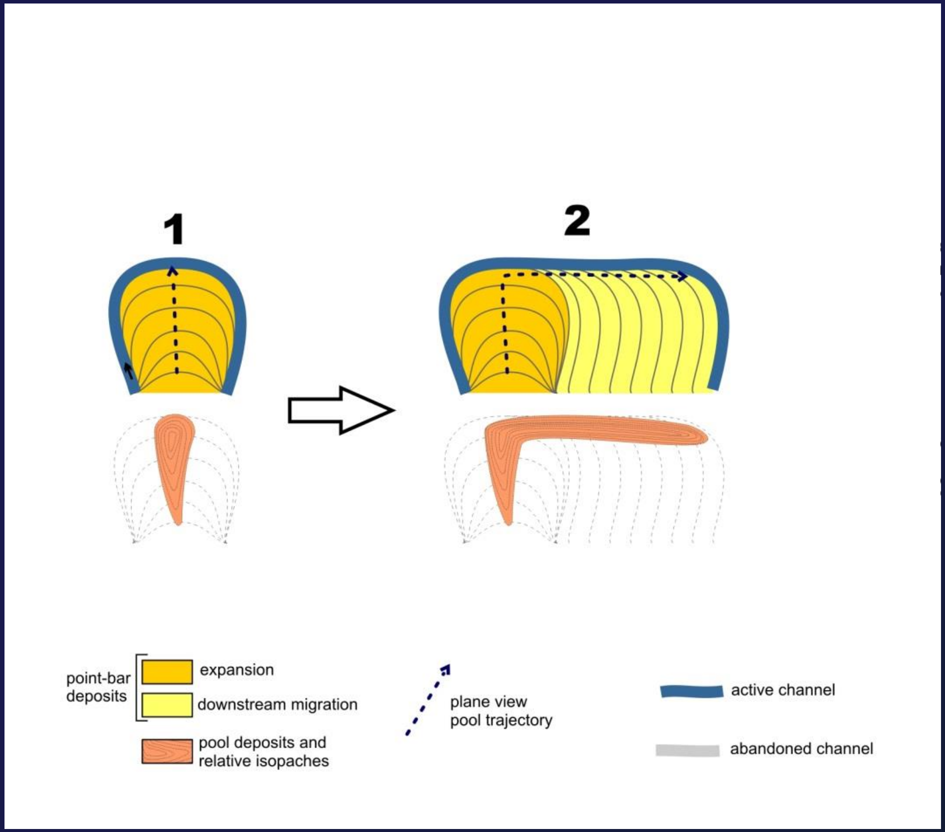


Ghinassi et al., 2013



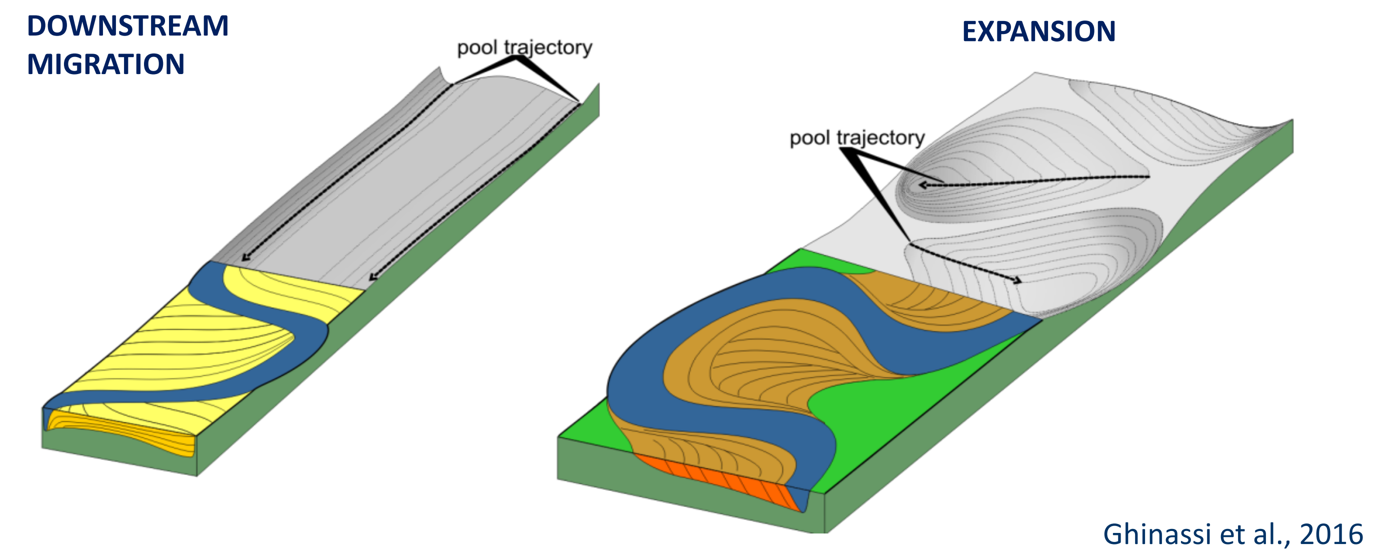
Willis & Tang, 2011

CHANNEL BELT BASAL SURFACE

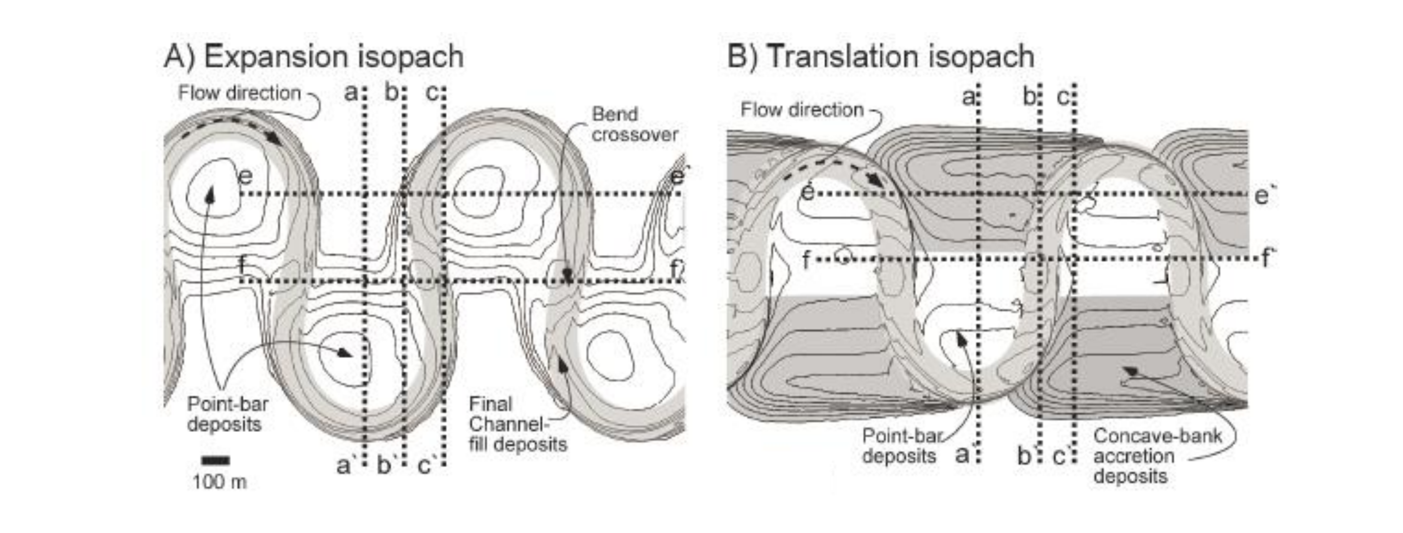


Ghinassi et al., 2016

CHANNEL BELT BASAL SURFACE



Ghinassi et al., 2016



Willis & Tang, 2011

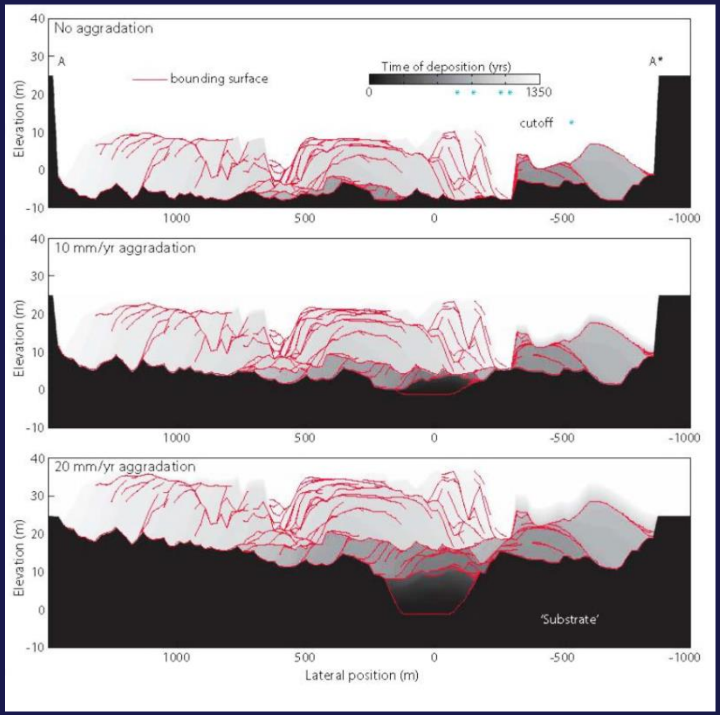
TAKE HOME MESSAGE #4

Meander bends with different styles of planform evolution can shape the basal surface of related channel-belt in different manners

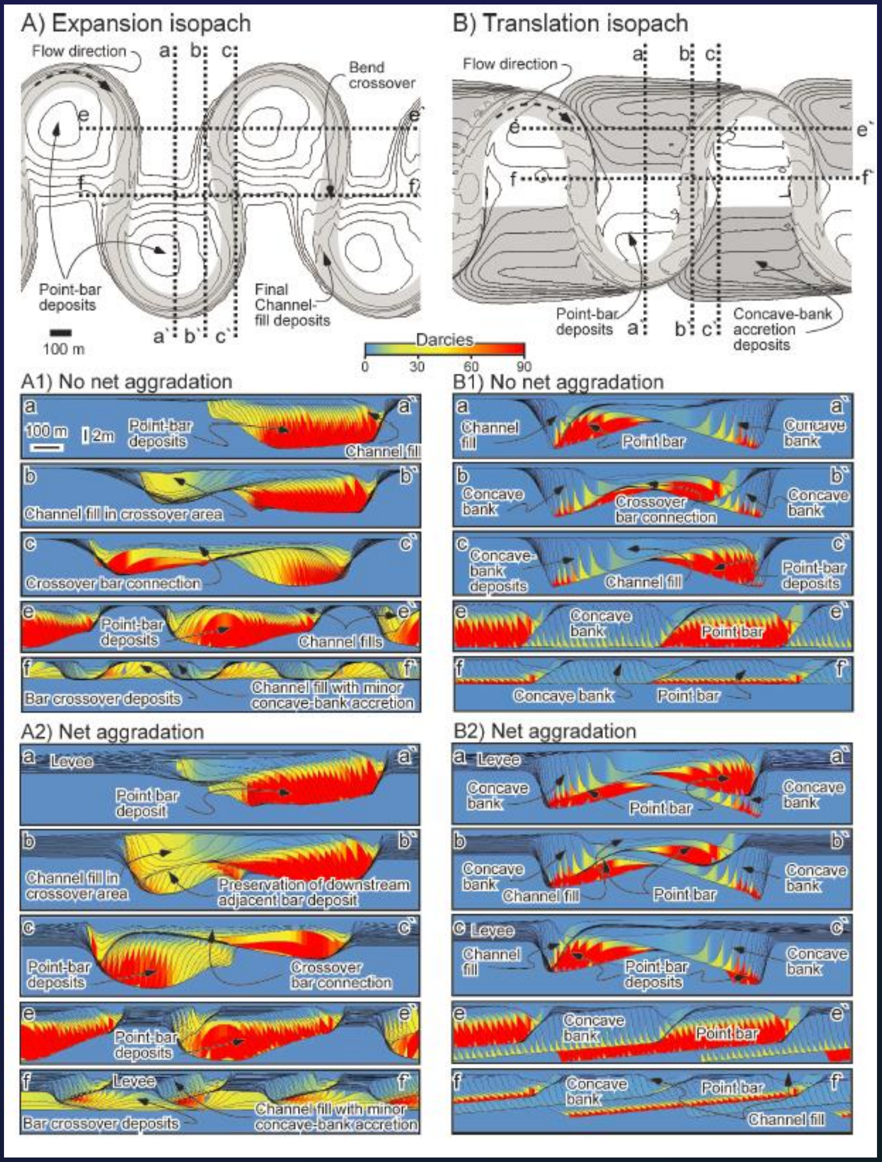
Downstream migrating systems will produce surfaces characterized by two main elongated depocenters located at the belt sides.

Expansional systems will produce surfaces with elongate d scoures oriented transverse to the belt axis

CHANNEL BELT ARCHITECTURE VS. AGGRADATION RATE

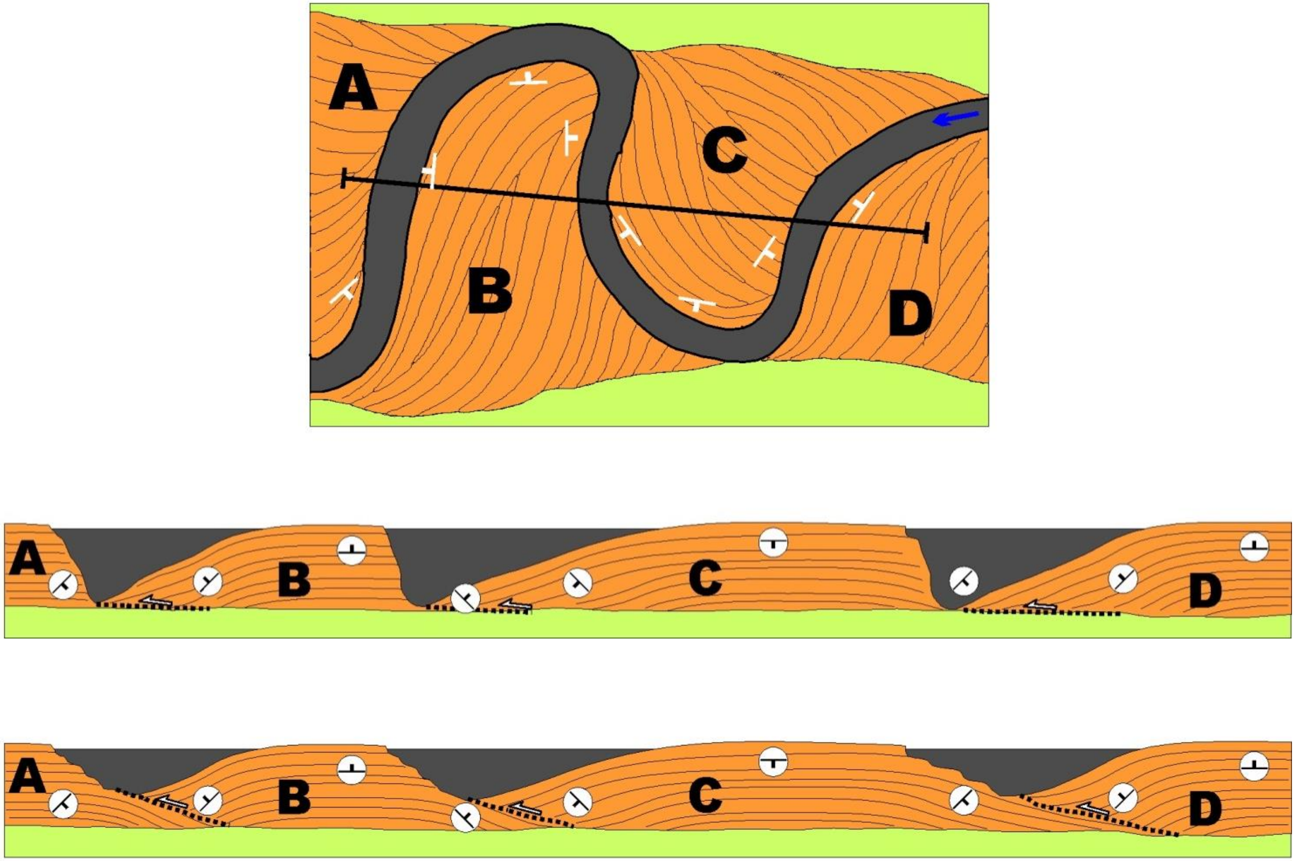


Van de Lageweg et al., 2015

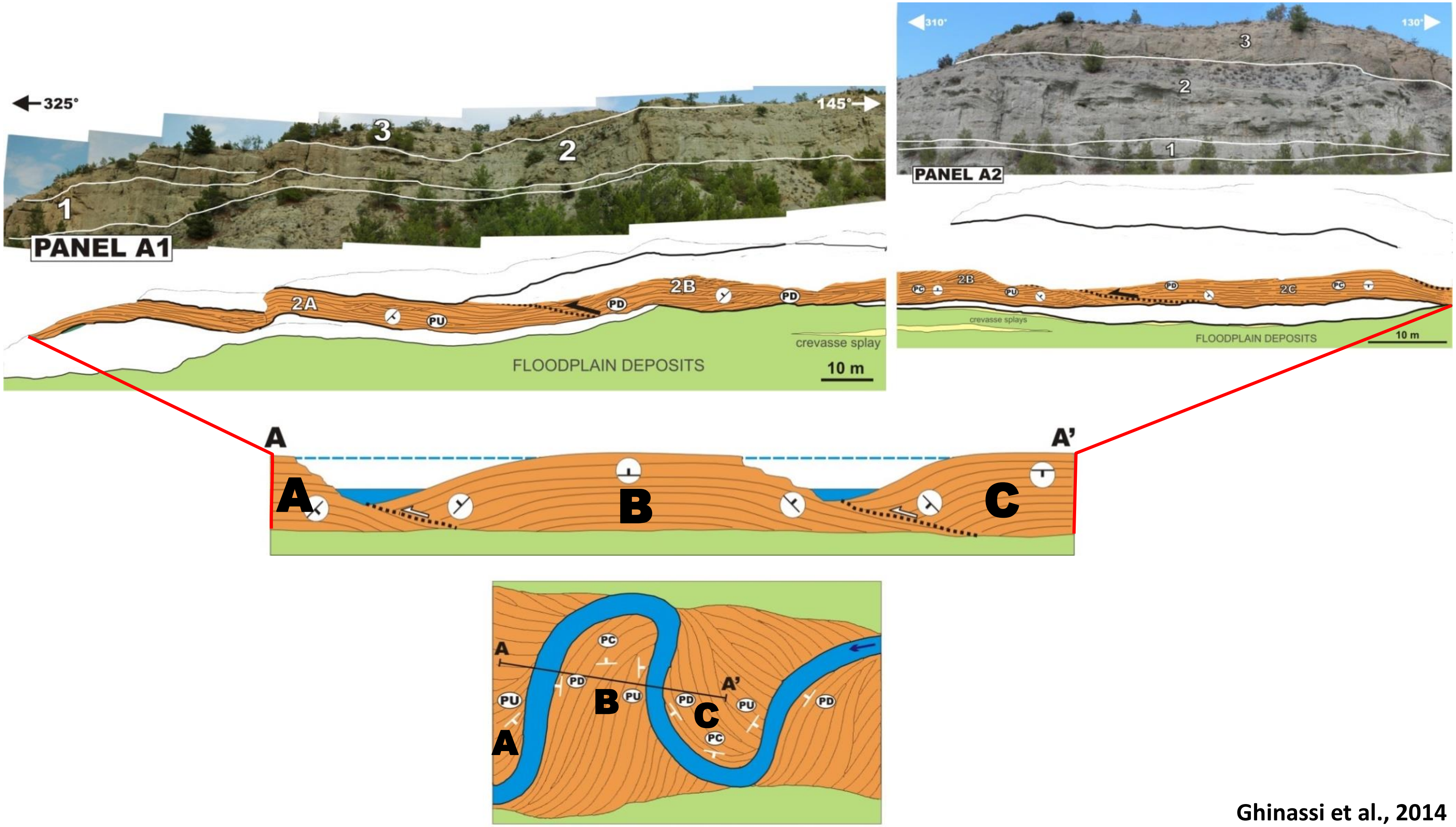


Willis & Tang, 2011

CHANNEL BELT ARCHITECTURE VS. AGGRADATION RATE

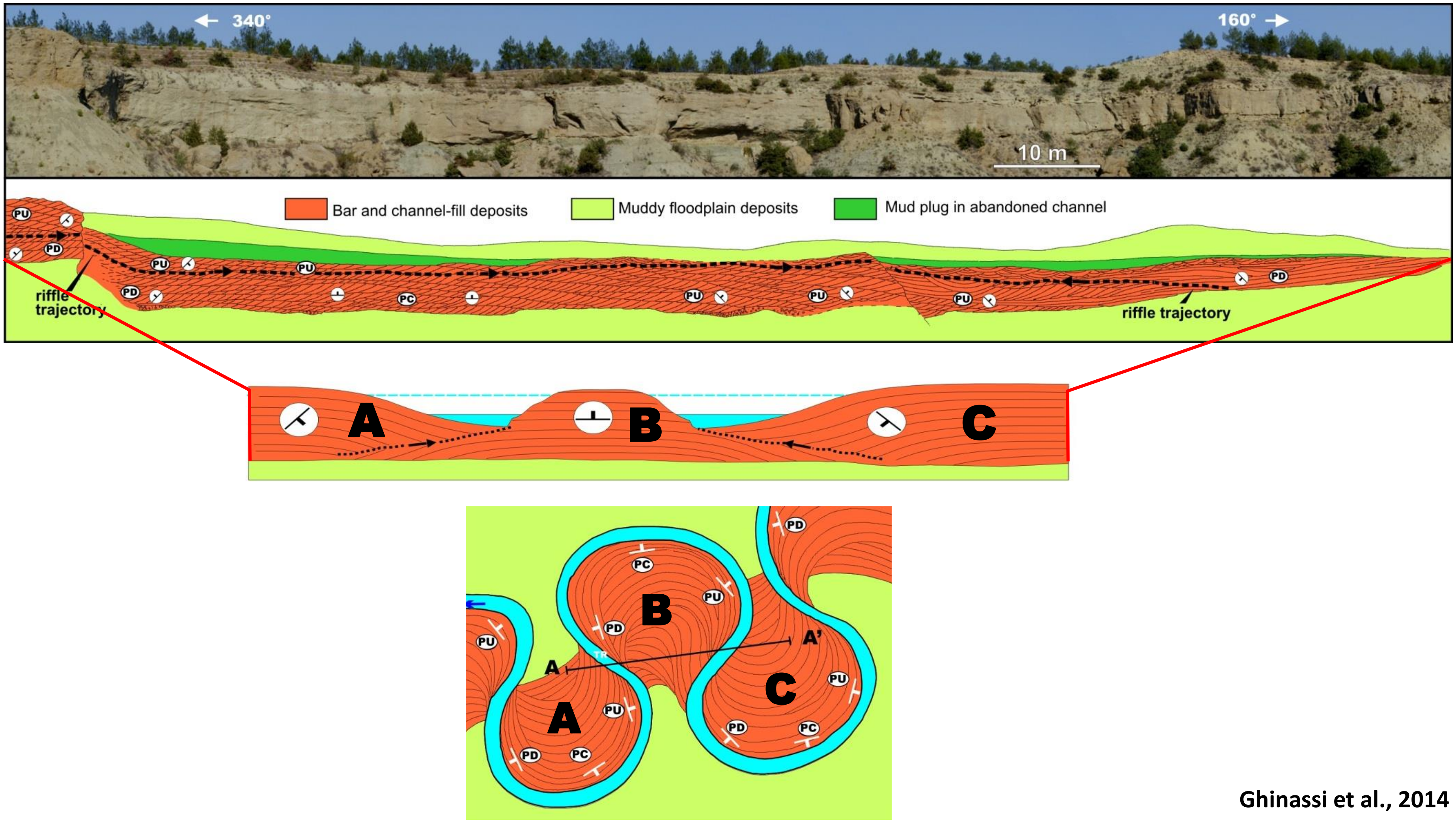


CHANNEL BELT ARCHITECTURE VS. AGGRADATION RATE



Ghinassi et al., 2014

CHANNEL BELT ARCHITECTURE VS. AGGRADATION RATE



Ghinassi et al., 2014

TAKE HOME MESSAGE #5

Planform transformation occurring under low aggradational conditions mainly causes cannibalizationof differents sectors of point bars, which will be separated by channel-fill deposits. This will lead to compartimentalization of channel belt units

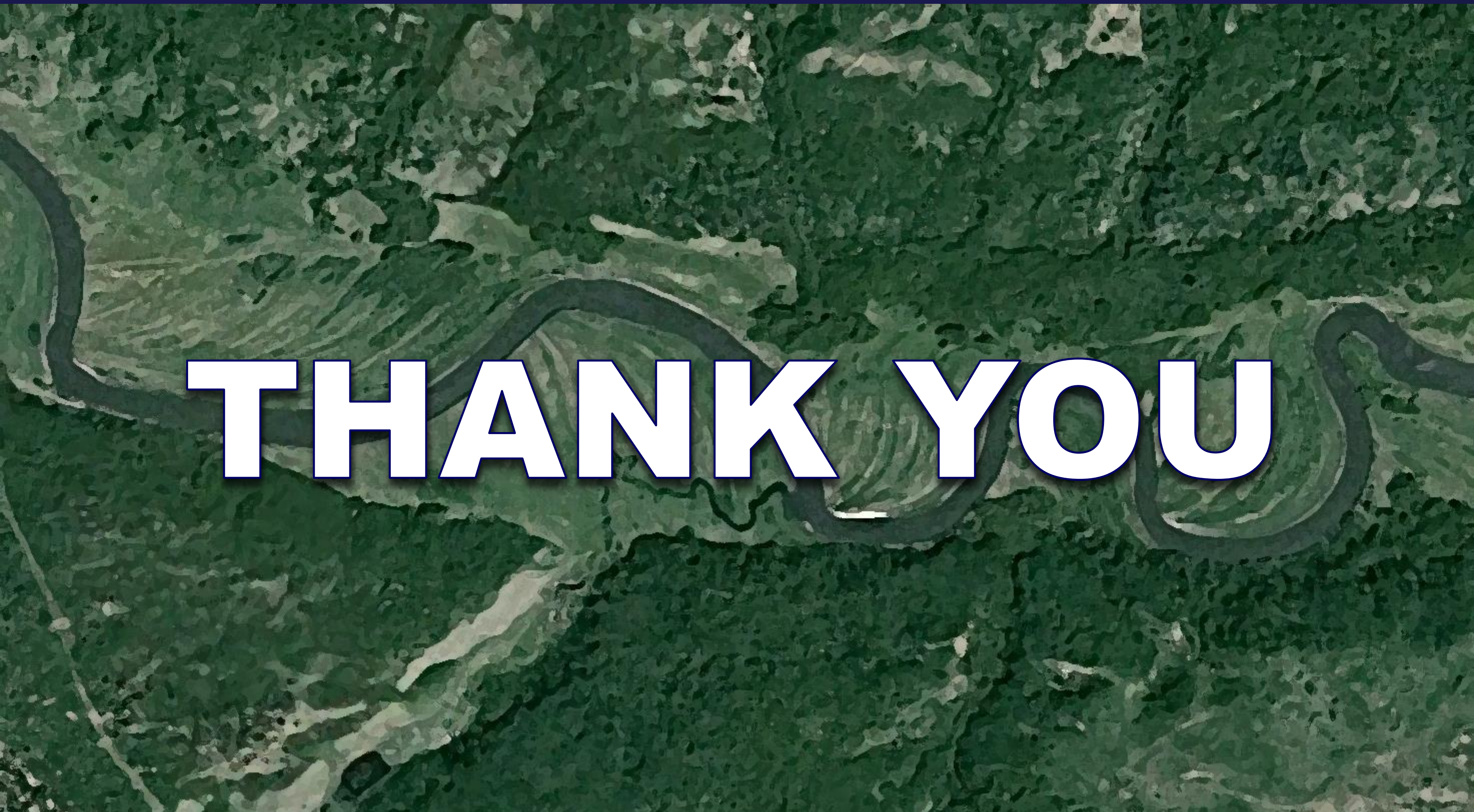
Planform transformations evolving under high aggradational conditions will lead to overlap of bar units, with consequent decrease of channel-belt compartimentalization.

CONCLUSIONS

Most of the facies models used to predict/modelling sedimentary facies distribution within point bar deposits do not reflect the effective complexity of these sedimentary bodies .

A new generation of fluvial facies models needs to be developed on the base of quantitative and 3D data deriving from integration among outcrop, subsurface and laboratory analyses.

A properly planned reservoir modelling and development needs to be constrained by the application of these facies models


THANK YOU