

ePS Facies-Belt Pinch-Out Relationships in a Distal, Mixed-Influence Shallow-Marine Reservoir Analogue: Lower Sego Sandstone Member, Western Colorado, USA*

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Abstract

Lateral and proximal-to-distal facies relationships in mixed, wave- and tide-influenced shallow-marine deposits are poorly documented in both reservoirs and outcrop analogues. This study focuses on outcrops of the Lower Sego Sandstone Member, western Colorado, where tide-dominated sandstones interfinger with wave-dominated delta-front deposits within a series of stacked regressive-transgressive tongues. The stratigraphic relationships and facies-belt pinch-outs between tide- and wave-dominated deposits have been documented along continuous exposures over an area of 7 by 12 km.

Wave-dominated deposits are characterized by coarsening-upward successions with hummocky-cross stratified, very fine-grained sandstone in the upper parts. Tide-dominated facies are dominated by trough and herringbone cross-stratified, fine- to medium-grained sandstone, with intercalations of heterolithic sand-mudstone and inclined heterolithic strata. Tidal deposits are coarser grained and have a higher net-to-gross ratio, compared to wave-dominated facies, and hence have superior reservoir characteristics. Erosively based tidal deposits overlie wave-dominated lower shoreface deposits and form either (1) thick, amalgamated sand bodies, or (2) thinner sand bodies intercalated with wave-dominated deposits. Clear proximal-distal trends exist, which follow the established regional paleogeography. The proximal (western) area comprises tidal channels that erode into subtidal to upper intertidal deposits. Towards the distal (eastern) area, tide-dominated deposits form increasingly sheet-like sand bodies, which were exclusively formed in subtidal environments. Along the same proximal-to-distal trend, tidal sandstones decrease in thickness from 32 to 16 m over a distance of 8 km and pinch-out within another 4 km. Towards the pinch-out, tidal sandstones are increasingly reworked by waves due to successive flooding. Hence, sand-body geometry reflects a combination of original tidal deposition and subsequent modification by wave reworking.

This study quantifies the intertonguing and pinch-out relationships within this mixed-influenced shallow-marine setting, providing analogue data that could improve the understanding of reservoir architecture and potential production behavior of similar reservoirs. Future work will assess the impact of these complex facies relationships, and the detail with which they are represented, on flow patterns and estimated recoveries in reservoir-simulation models.

References

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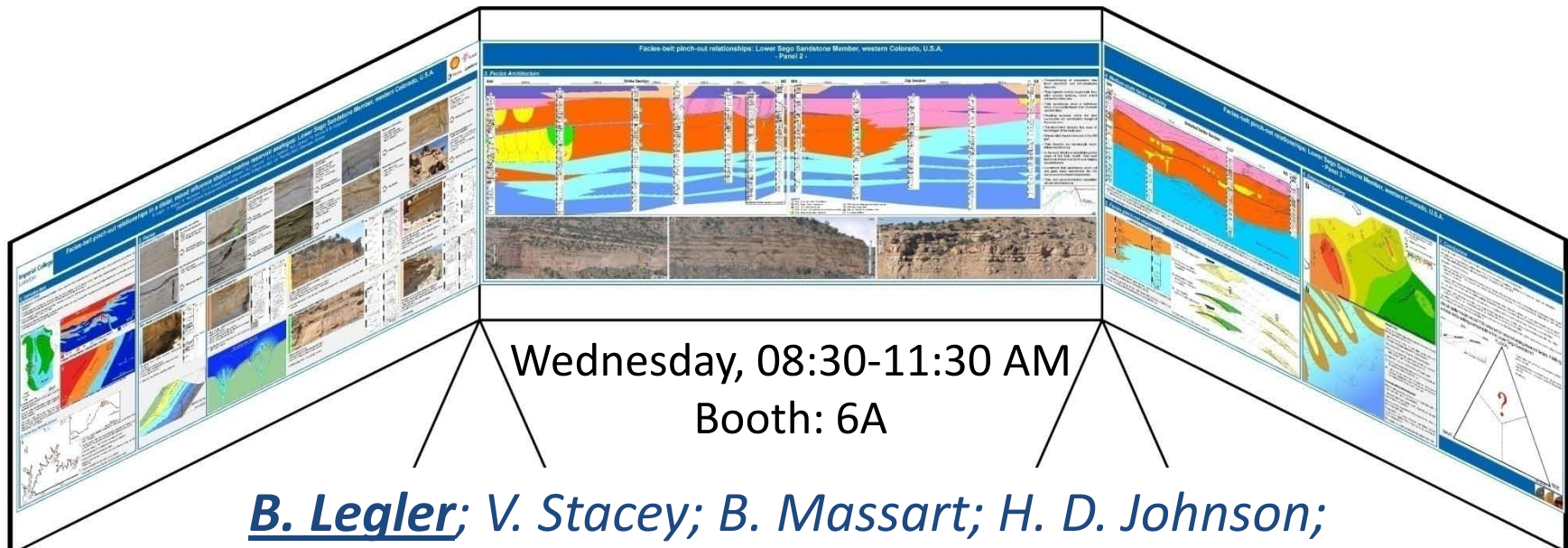
Kauffman, E.G., and W.G.E. Caldwell, 1993, The Western Interior Basin in Space and Time, *in* W.G.E. Caldwell, and E.G. Kauffman, (eds.), *Evolution of the Western Interior Basin: Geological Association of Canada Special Paper*, v. 39, p. 1-30.

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Wood, L.J., and S. Yoshida, 2004, Sequence Stratigraphy and Reservoir Architecture of Tide-Influenced Shoreline Systems in the Late Cretaceous (Campanian) Sego Sandstone Member of the Mancos Shale: *SEPM Field Trip Guidebook Day 2, SEPM Research Field Conference, Recent Advances in Shoreline-Shelf Stratigraphy*, Grand Junction, Colorado, unpaginated. Web accessed 16 May 2011, http://www.beg.utexas.edu/indassoc/dm2/qcl_pubs.htm



Facies-Belt Pinch-Out Relationships in a Distal, Mixed-Influence Shallow-Marine Reservoir Analogue: Lower Sego Sandstone Member, Western Colorado, USA

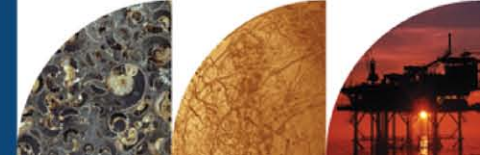


Wednesday, 08:30-11:30 AM
Booth: 6A

B. Legler; V. Stacey; B. Massart; H. D. Johnson;
G. J. Hampson; C. Jackson; M. D. Jackson;
R. Ravnas; M. Sarginson

Imperial College London, Norske Shell Stavanger

Panel 1: Introduction and Facies



Imperial College
London

Facies-belt pinch-out relationships in a distal, mixed influence shallow-marine reservoir analogue: Lower Sego Sandstone Member, western Colorado, U.S.A.

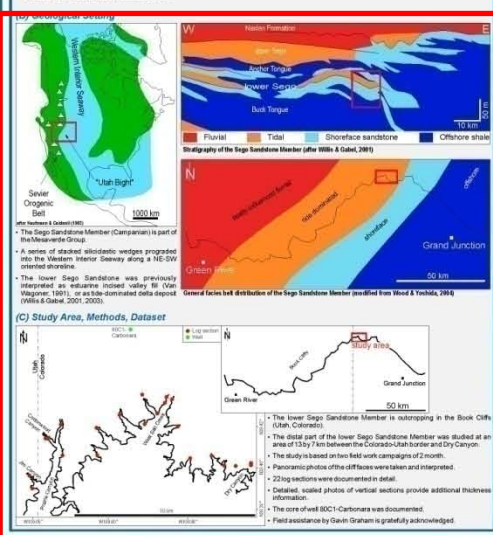
B. Legler¹, V. Stacey¹, R. McDonald¹, B.Y.G. Massart¹, H.D. Johnson¹, G.J. Hampson¹, C.A.L. Jackson¹, M.D. Jackson¹, R. Ravnsås² & M. Sarginson²
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1. Introduction

(A) Aims of Study

- Lateral and proximal to distal facies relationships in mixed, wave- and tide-influenced shallow-marine deposits are poorly documented in reservoirs and outcrop analogues.
- This study focuses on outcrops of the Lower Sego Sandstone Member, western Colorado, U.S.A., where tide-dominated sandstones interfinger with wave-dominated delta front deposits within a series of stacked regressive low-pressure troughs.
- The stratigraphic relationships and facies-belt pinch-outs between tide- and wave-dominated deposits have been documented in detail along continuous exposures that cover an area of 7 by 12 km.
- This study quantifies the interfingering and pinch-out relationships, providing analogue data that could improve the understanding of reservoir architecture and potential production behaviour of similar reservoirs.



2. Facies

(A) Shoreface Deposits



(B) Tide-influenced Deposits



(C) Active fluvio-tidal channel



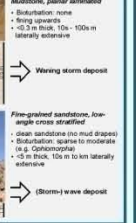
(D) Abandoned tidal channel



(E) Wave influenced tidal bar/channel



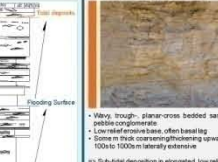
(F) Bayhead delta/lagoon



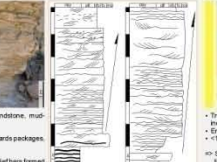
FA1: Distal to proximal lower shoreface



FA2: Tide-dominated bar



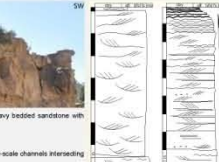
FA3: Active fluvio-tidal channel



FA4: Abandoned tidal channel



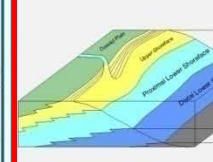
FA5: Wave influenced tidal bar/channel



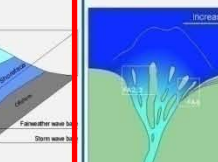
FA6: Bayhead delta/lagoon



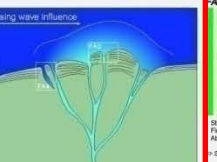
FA7: Distal to proximal lower shoreface



FA8: Tide-dominated bar



FA9: Active fluvio-tidal channel



FA10: Abandoned tidal channel



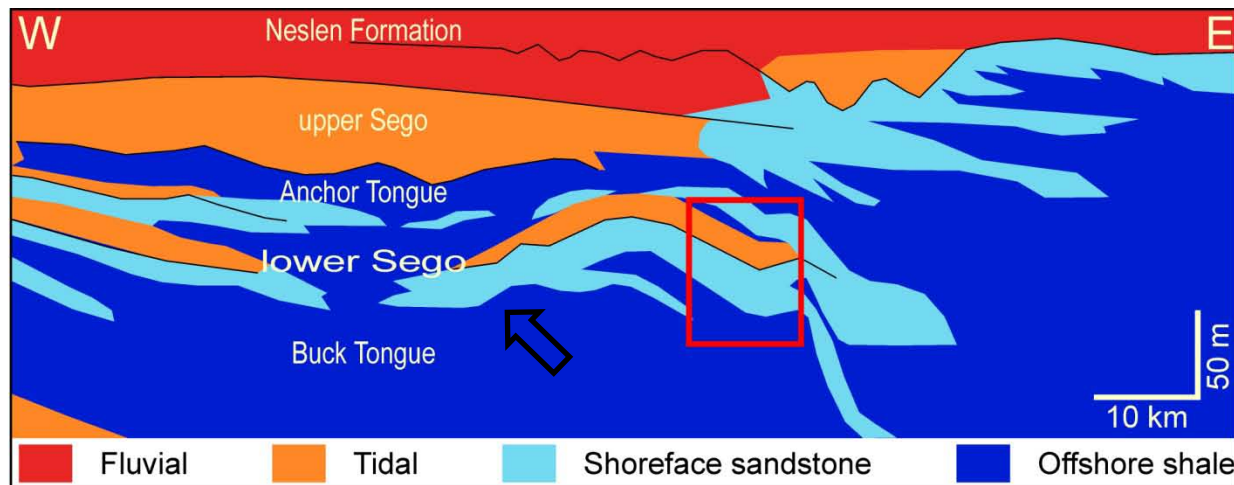
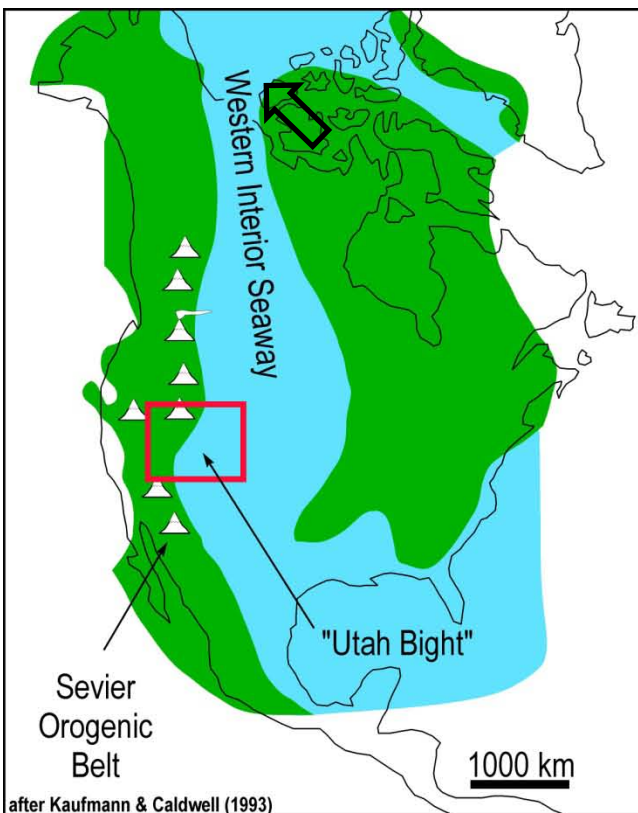
FA11: Wave influenced tidal bar/channel



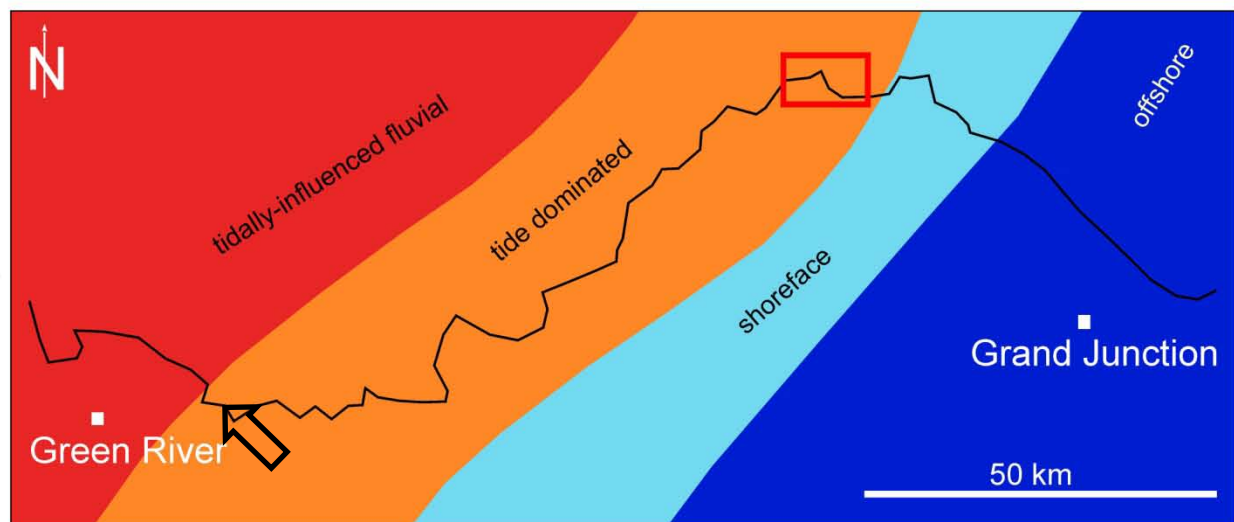
FA12: Bayhead delta/lagoon



Panel 1: Introduction



Stratigraphy of the Sego Sandstone Member (after Willis & Gabel, 2001)

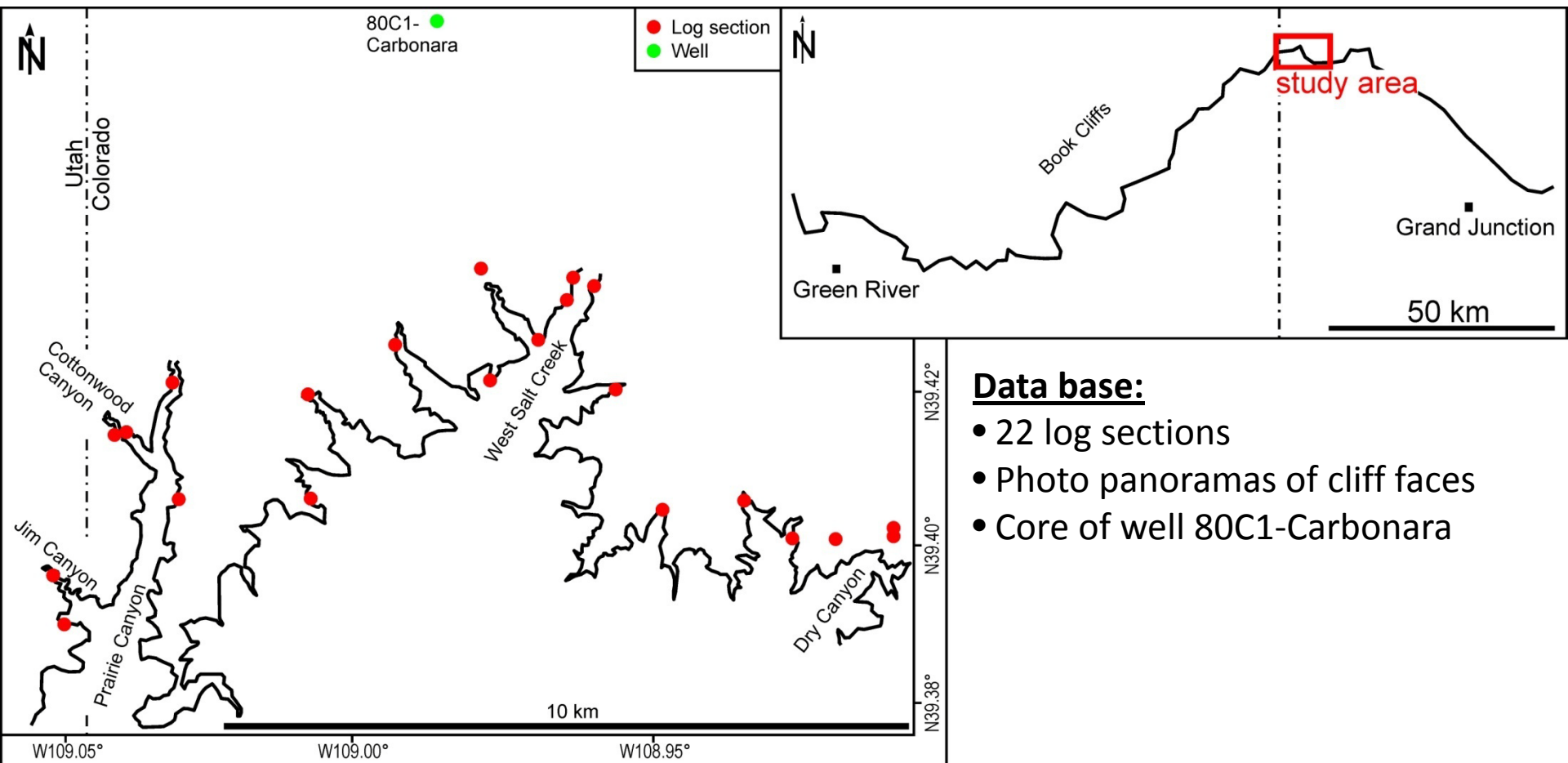


General facies belt distribution of the Sego Sandstone Member (modified from Wood & Yoshida, 2004)

Lower Sego Sandstone Member:

- Progradation in WIS
- Stacked siliciclastic wedges
- Study of distal part in western Colorado

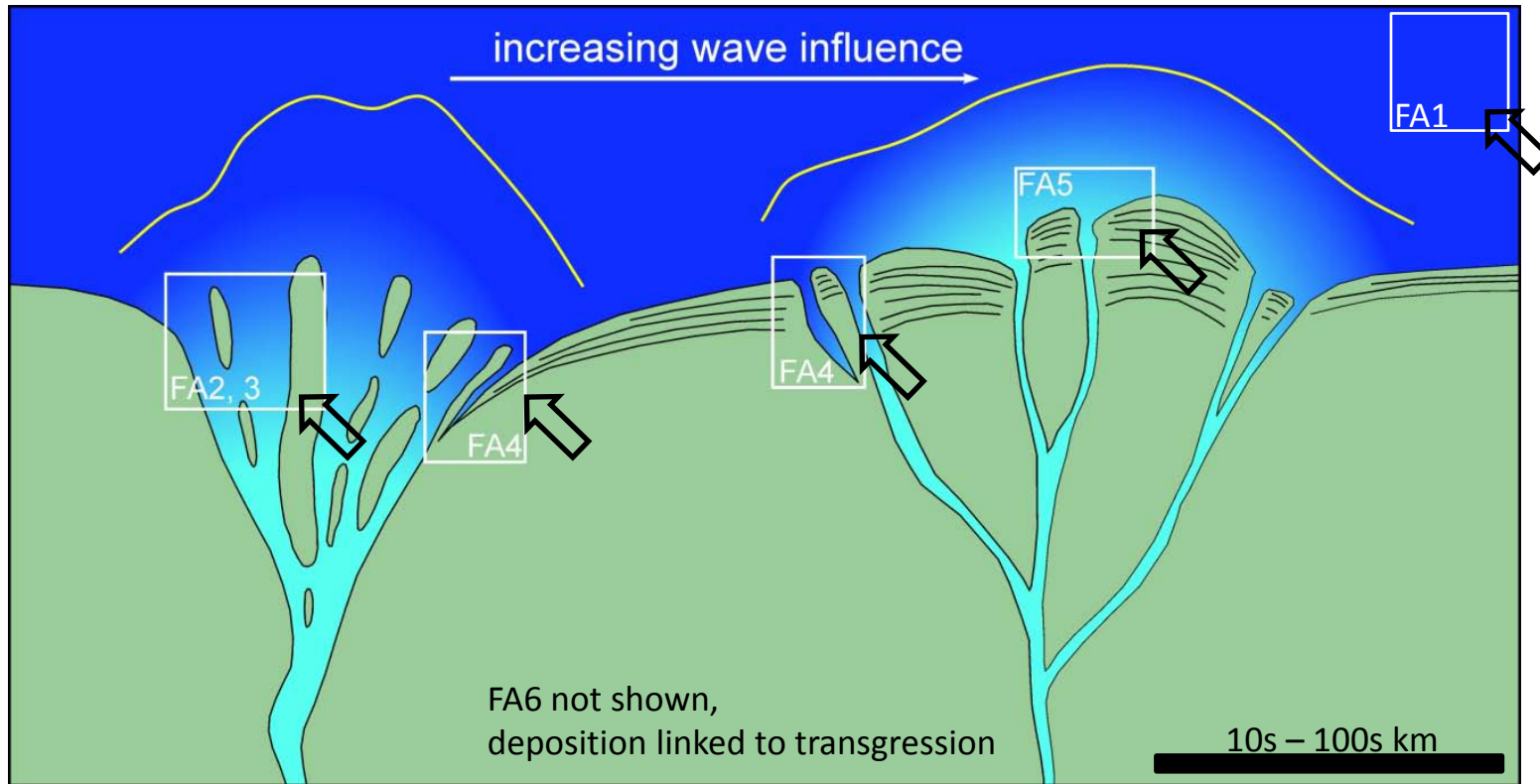
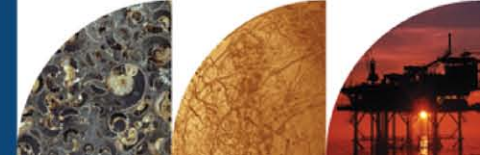
Panel 1: Introduction



Data base:

- 22 log sections
- Photo panoramas of cliff faces
- Core of well 80C1-Carbonara

Panel 1: Facies



Six facies associations:

FA1: Distal to proximal lower shoreface

FA2: Tide-dominated bar

FA3: Active fluvio-tidal channel

FA4: Abandoned tidal channel

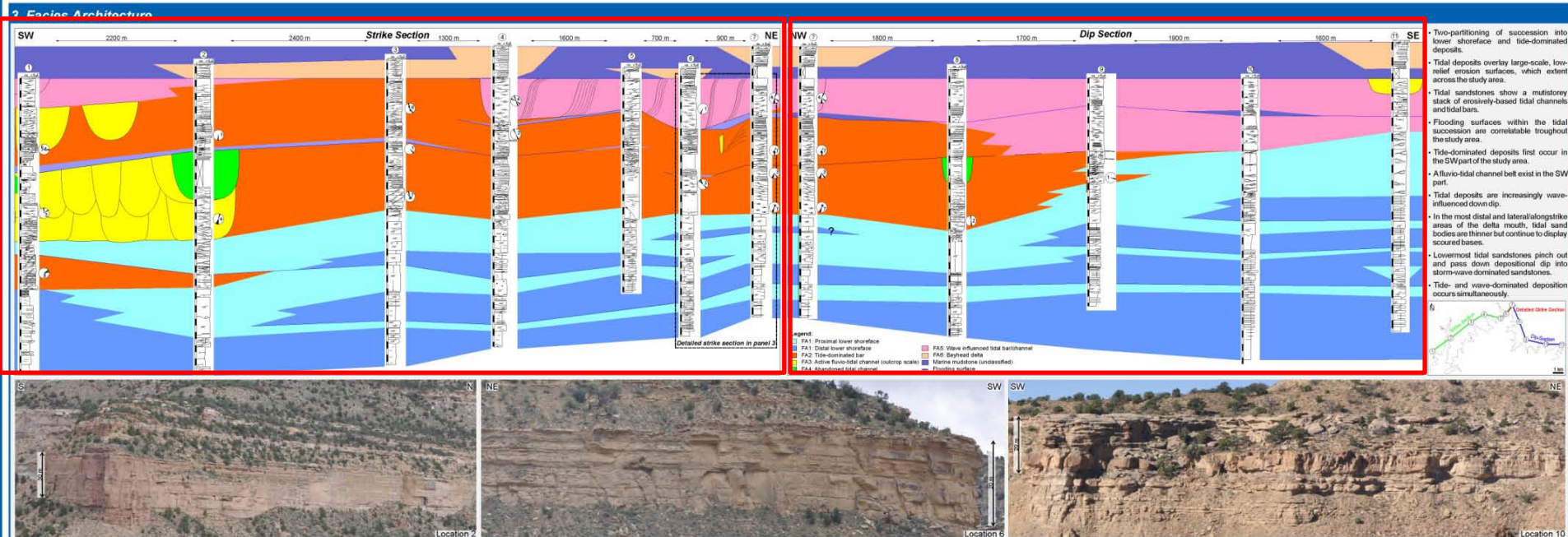
FA5: Wave-influenced tidal bar/channel

FA6: Bayhead Delta, Lagoon

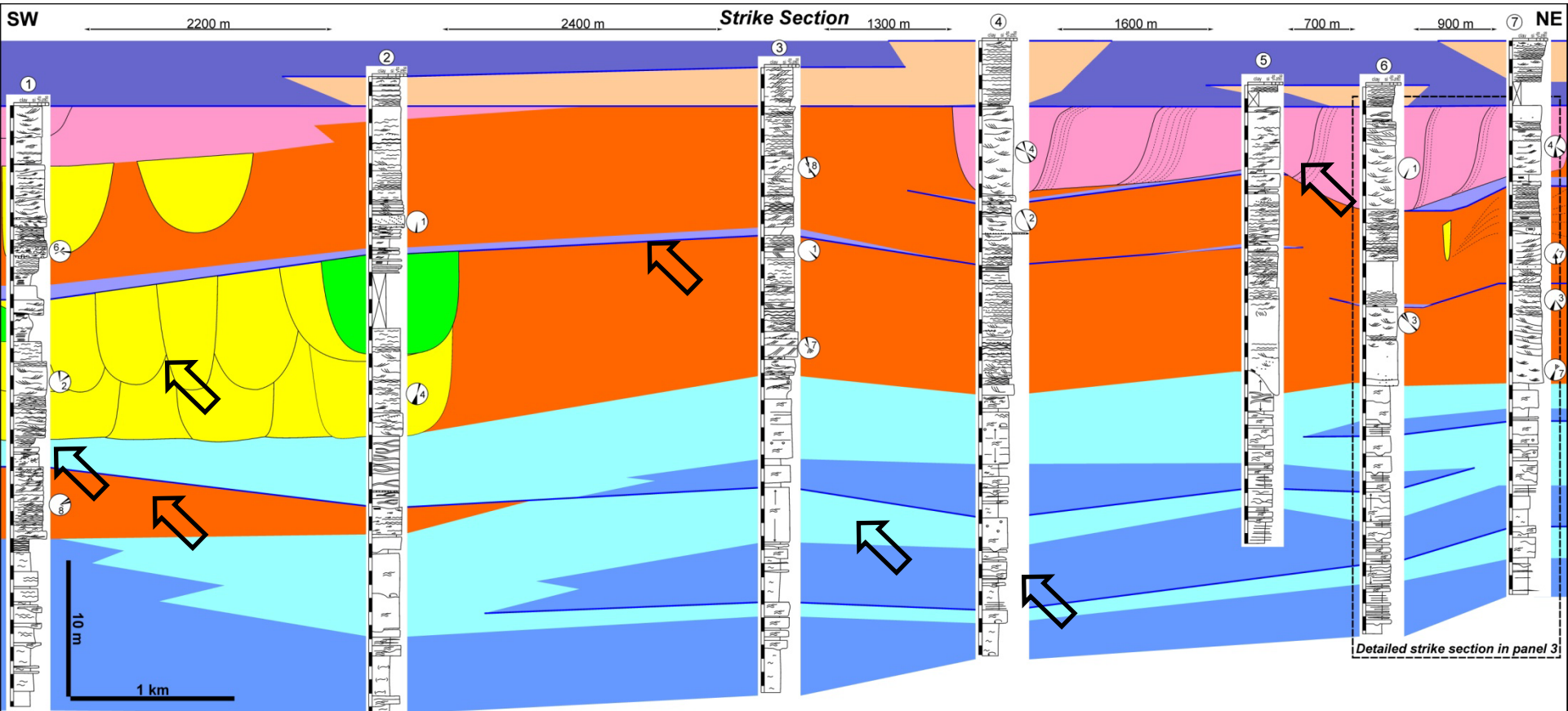
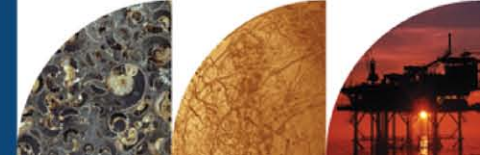
Panel 2: Facies Architecture



Facies-belt pinch-out relationships: Lower Sego Sandstone Member, western Colorado, U.S.A. - Panel 2 -

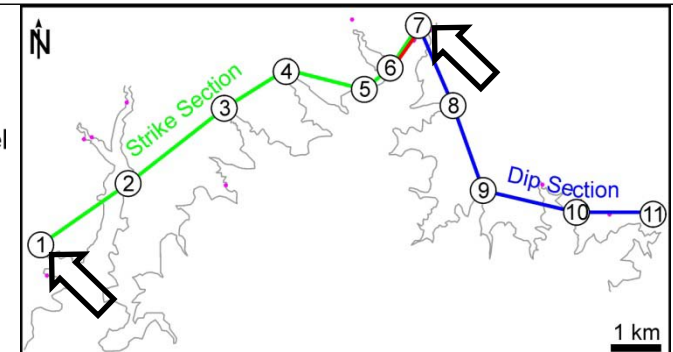


Panel 2: Strike Section

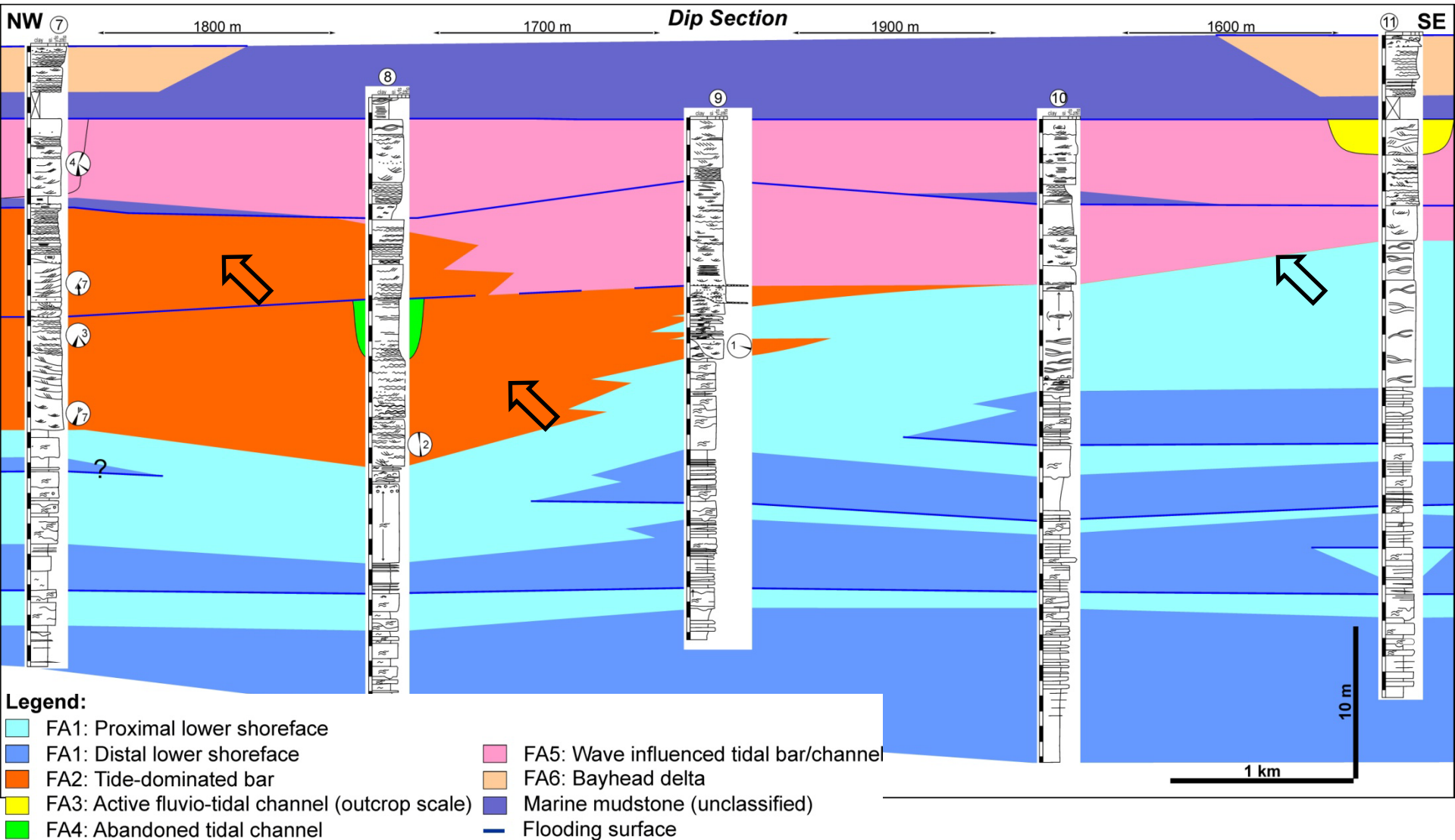
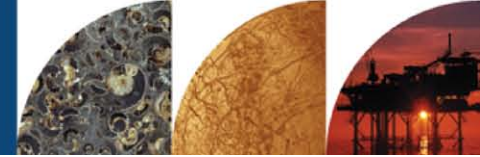


Legend:

- FA1: Proximal lower shoreface
- FA1: Distal lower shoreface
- FA2: Tide-dominated bar
- FA3: Active fluvio-tidal channel (outcrop scale)
- FA4: Abandoned tidal channel
- FA5: Wave influenced tidal bar/channel
- FA6: Bayhead delta
- Marine mudstone (unclassified)
- Flooding surface



Panel 2: Facies Architecture

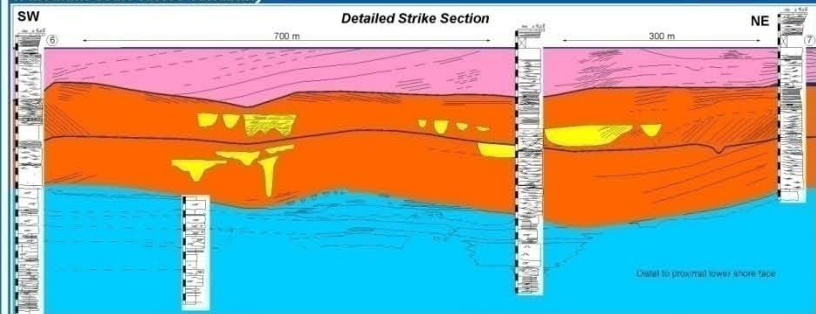


Panel 3: Interpretation & Conclusions



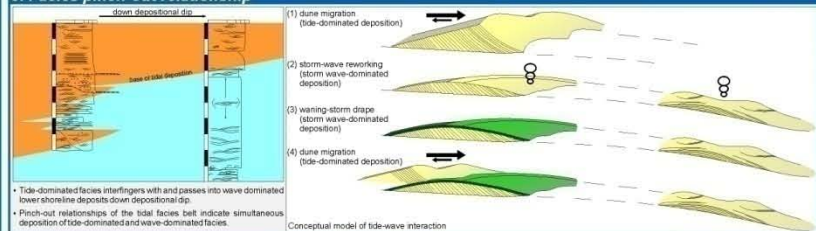
Facies-belt pinch-out relationships: Lower Sego Sandstone Member, western Colorado, U.S.A. - Panel 3 -

4. Medium-scale facies variability



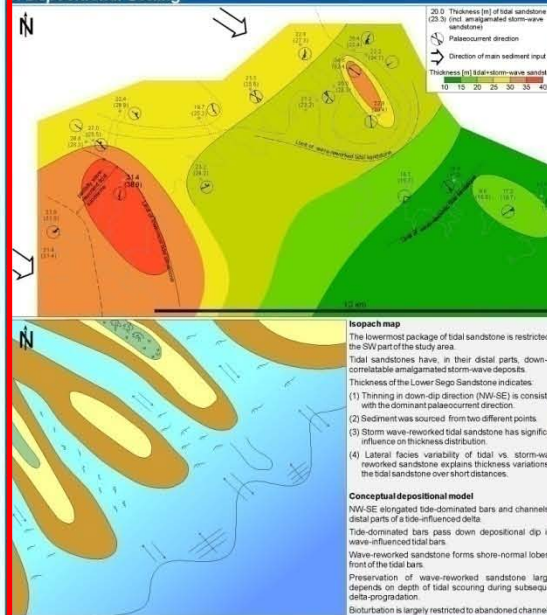
- The detailed strike section reveals internally variable facies architecture of tidal bars at m to 10s m scale. (1) cross-bedded sandstone pass vertically and laterally into heterolithic sandstone, reflecting decreasing current energy, and (2) small-scale channels intersecting tidal bars. Inclined bounding surfaces indicate lateral accretion of tidal bars. Within each erosive based package, several tidal bars might be stacked, showing differences in dip direction and dip angle of bounding surfaces.
- The upper package of tide dominated deposits is represented by laterally migrating wave-influenced tidal channels. The channels are dominated by cross-bedded sandstone, inclined heterolithic strata periodically occur.

5. Facies pinch-out relationship



- Tide-dominated facies interfingers with and passes into wave dominated lower shoreline deposits down depositional dip.
- Pinch-out relationships of the tidal facies belt indicate simultaneous deposition of tide-dominated and wave-dominated facies.

6. Depositional Setting

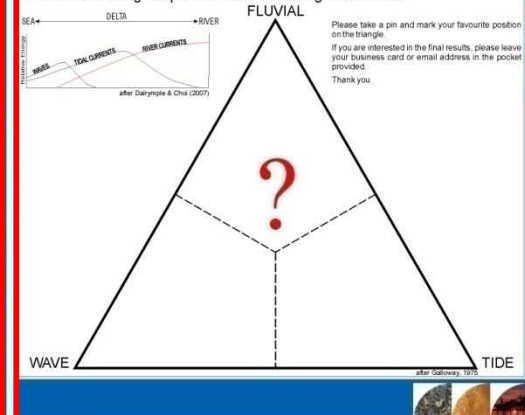


- Isopach map**
- The lowermost package of tidal sandstone is restricted to the SW part of the study area.
- Tidal sandstones have, in their distal parts, down-dip correlative amalgamated storm-wave deposits.
- Thicknesses of the Lower Sego Sandstone indicates:
- Thinning in down-dip direction (NW-SE) is consistent with the dominant paleocurrent direction.
 - Sediment was sourced from two different points.
 - Storm wave-reworked tidal sandstone has significant influence on thickness distribution.
 - Lateral facies variability of tidal vs. storm-wave reworked sandstone explains thickness variations of the tidal sandstone over short distances.
- Conceptual depositional model**
- NW-SE elongated tide-dominated bars and channels in distal parts of a tide-influenced delta.
- Tide-dominated bars pass down depositional dip into wave-influenced tidal bars.
- Wave-reworked sandstone forms shore-normal lobes in front of the tidal bars.
- Preservation of wave-reworked sandstone largely depends on depth of tidal scouring during subsequent delta progradation.
- Biocurbation is largely restricted to abandoned channels.

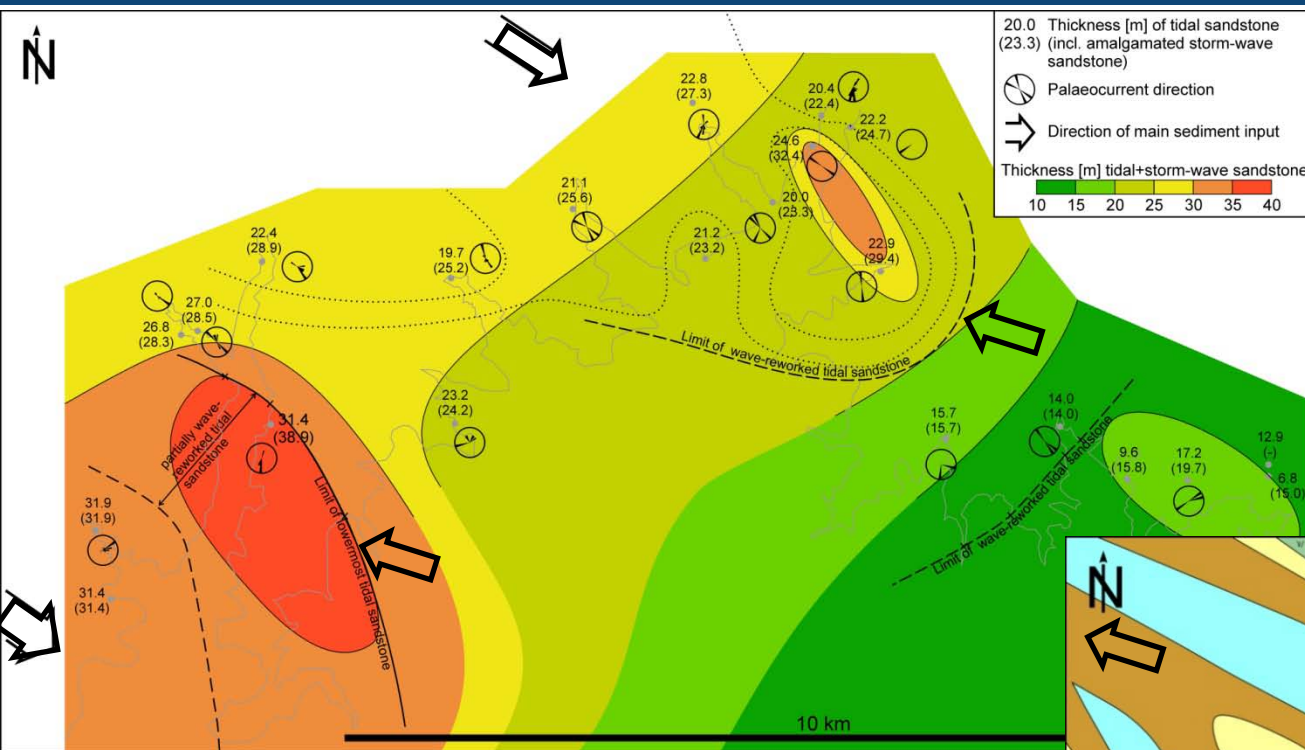
7. Conclusions

- Facies pinch-out relationships indicate simultaneous tide- and wave-influenced deposition.
- Although wave-overprinted deposition close to the pinch-out of tidal sandstone, tidal bars and channels largely tide-dominated.
- Strong partitioning between tidal and wave/storm processes at the delta front.
- Implication for reservoir facies:
- Waves resuspend mud, deposited during slack-water phases. This results in rare, thin and discontinuous mud drapes in tidal bar and channel sandstones. The reservoir sandstones are relatively homogeneous in comparison to those, deposited in tidal settings protected by waves.
 - Stacked storm-wave reworked tidal sandstones have generally better reservoir qualities than storm-wave sandstones deposited "normally" in proximal lower shoreface settings. Reworked sandstone is coarser grained (fine-grained vs. very fine-grained sand).
 - Tidal and storm-wave reworked tidal sandstones are potentially chlorite coated and not very intensively quartz-cemented.
 - Proximal lower shoreface sandstone and basal channel sandstone show partially intensive calcareous cementation at a length-scale of m to few 10s m. Calcareous cement is linked to abundant occurrence of shells.
- The influence of fluvial, tide, and wave energy varies down depositional dip (Dairymple & Choi, 2007), facies changes accordingly. One of the resulting questions for reservoir application is:

Which delta model would YOU choose for reconstructing reservoir facies, if drilling a distal delta setting comparable to the Lower Sego Sandstone?

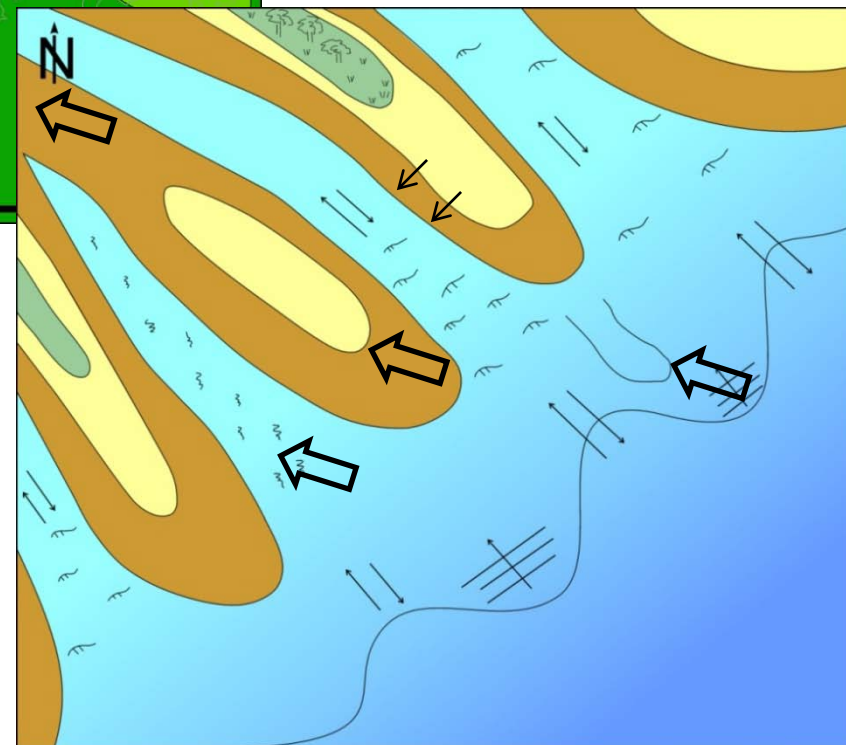


Panel 3: Depositional Setting



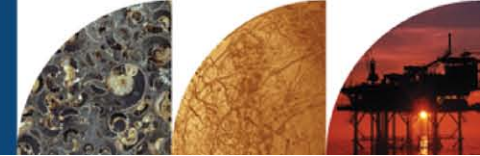
Isopach map:

- Two main sediment sources
- Storm-wave reworked sand significantly influences thickness
- Lateral facies variability – thickness variations over short distances



Conceptual depositional model:

- NW-SE oriented, elongated tide-dominated bars
- Down-dip transition into wave-influenced tidal bars
- Storm wave reworked sandstone forms shore-normal lobes
- Preservation of lobes depends on depth of tidal scour
- Bioturbation largely restricted to abandoned channels

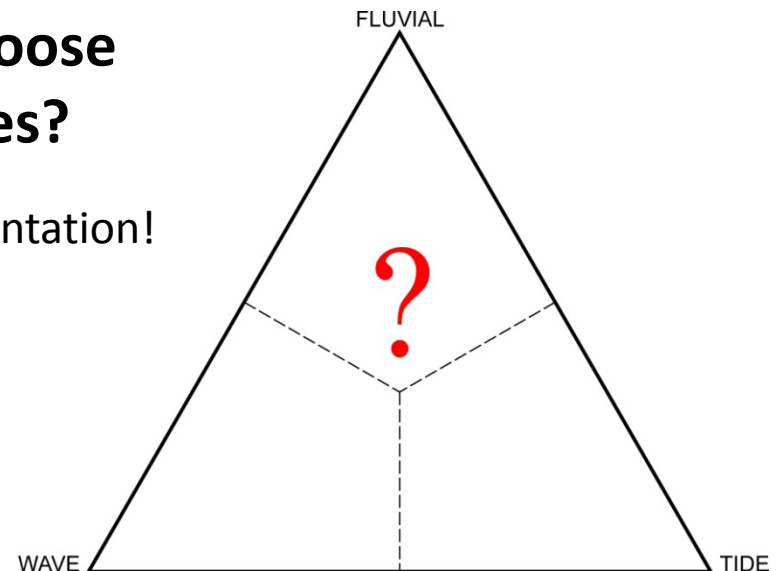


Implications for reservoir facies:

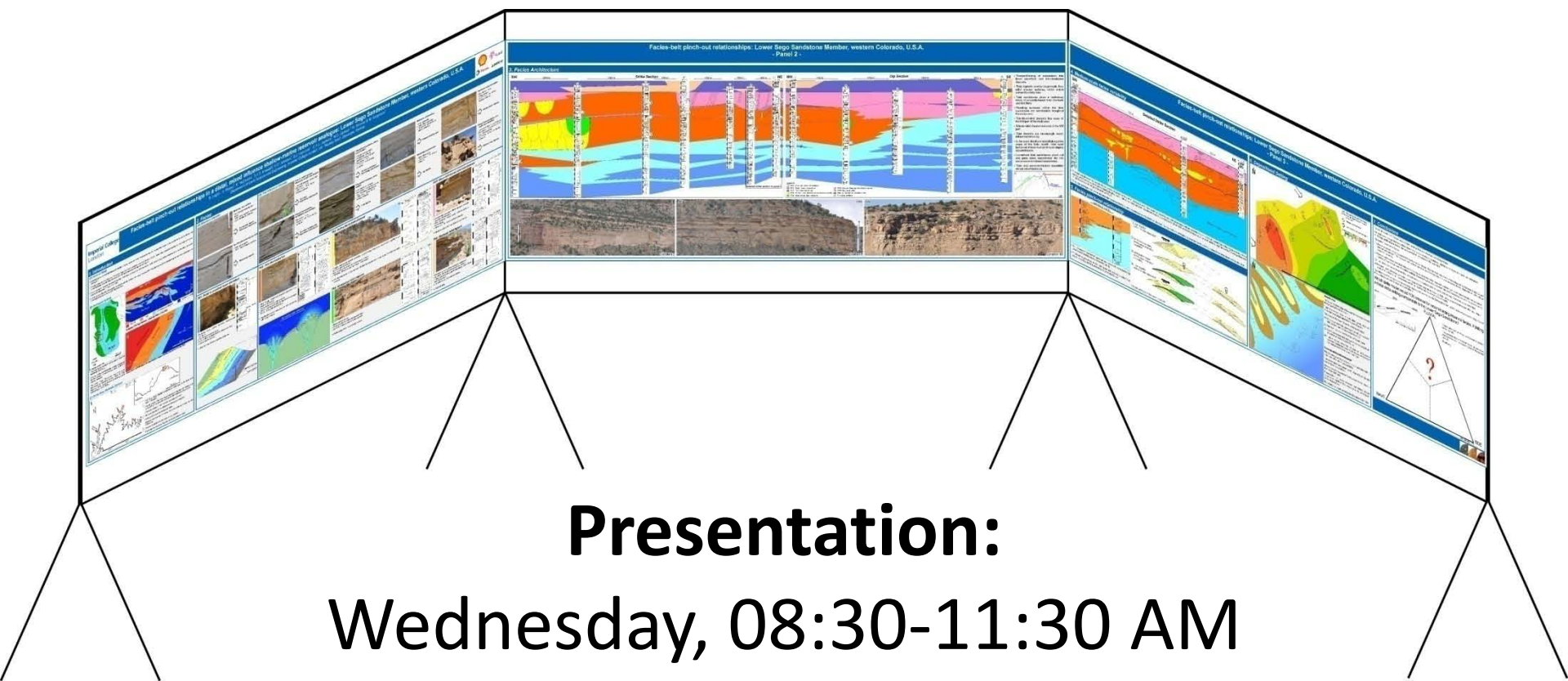
- (1) Rare, thin and discontinuous mud drapes due to wave action
- (2) Stacked storm-wave reworked tidal sandstones with better reservoir qualities than proximal lower shoreface sandstones (grain-size separation)
- (3) Tidal and storm-wave reworked tidal sandstones potentially decreased quartz cement
- (4) Partially carbonate concretions up to a few 10s m in length

**Which delta model would YOU choose
for reconstructing reservoir facies?**

=> Please take your pick during the poster presentation!



See you there...



Presentation:
Wednesday, 08:30-11:30 AM
Booth: 6A