[PS]Characterization of a Seismic-Scale, Outcropping Channel-Levee Complex, Tres Pasos Formation, Southern Chile*

Sebastian A. Kaempfe[1], Brian W. Romans[1], Stephen M. Hubbard[2], Lisa Stright[3], Benjamin G. Daniels[2], Sarah Southern[2]

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Abstract

Seismic reflection datasets enable large-scale characterization of deep-water slope channel systems, whereas outcrop studies are essential for investigating stratigraphic details. Consideration of both scales is crucial for development of conceptual models to characterize these systems. However, seismic resolution limits bed- to geobody-scale interpretation, whereas most outcrops are limited by their scale or stratigraphic context. Linking these scales of observation is important for understanding slope channel systems and characterizing subsurface hydrocarbon reservoirs.

We describe a previously undocumented, 750 m long by 300 m thick exposure of a slope channel system from the Tres Pasos Formation that crops out 25 km north of Puerto Natales, Chile. This formation records the southward filling of the Magallanes Basin axially, through a prograding clinoform system (800-1000 m relief) that connects shelf deposits of the Dorotea Formation with deep-water units. The present-day outcrop belt extends for >100 km from north to south (along depositional dip), offering a rare opportunity to consider fine-scale facies and architectural details together with seismic-scale stratigraphic context. The studied section is interpreted to be located ~40 km down-dip from a coeval shelf edge, and it is characterized with more than 1300 m of measured stratigraphic section, approximately 500 paleocurrent measurements, and GPS mapping of 100s of stratal surfaces.

Analysis of stratigraphic data reveals several composite channel-form bodies, each up to 40 m thick and ~250 m wide. The lower units show evidence for lateral migration and low aggradation whereas the upper units are characterized by greater aggradation and a laterally offset stacking pattern. This suggests that vertical connectivity between channel fill sandstone is higher in the basal part of the succession and the preservation of fine-grained out-of-channel deposits is prominent in the upper part. A distinctive, tens of m thick siltstone-prone succession occurs lateral to channel fills and is dominated by thin (mostly <5 cm), fine-grained beds that rarely exhibit amalgamation. We propose that this unit represents an inner levee or terrace deposit. The discovery of an outcrop with this unique range of channel system components in the

Tres Pasos Formation provides key insight into the outcrop belt, as well as facies and stratigraphic architecture trends in petroliferous deep-water conduit deposits, worldwide.

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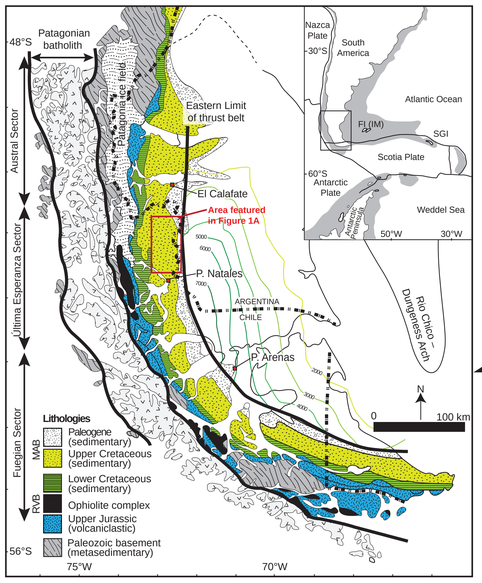
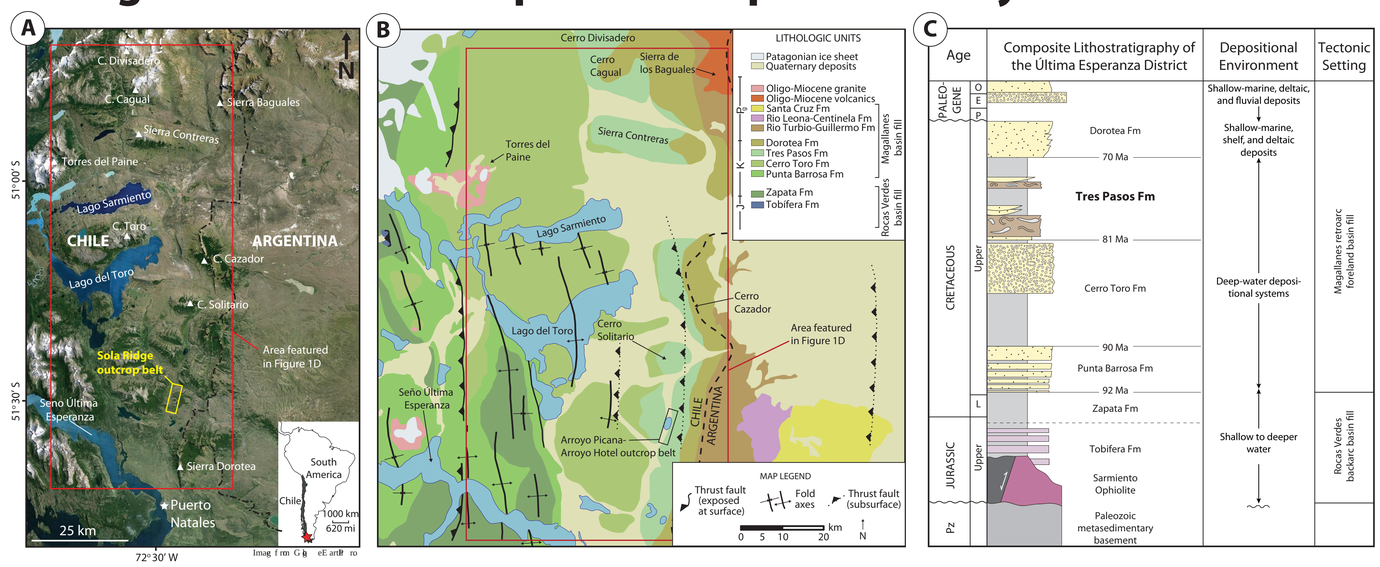


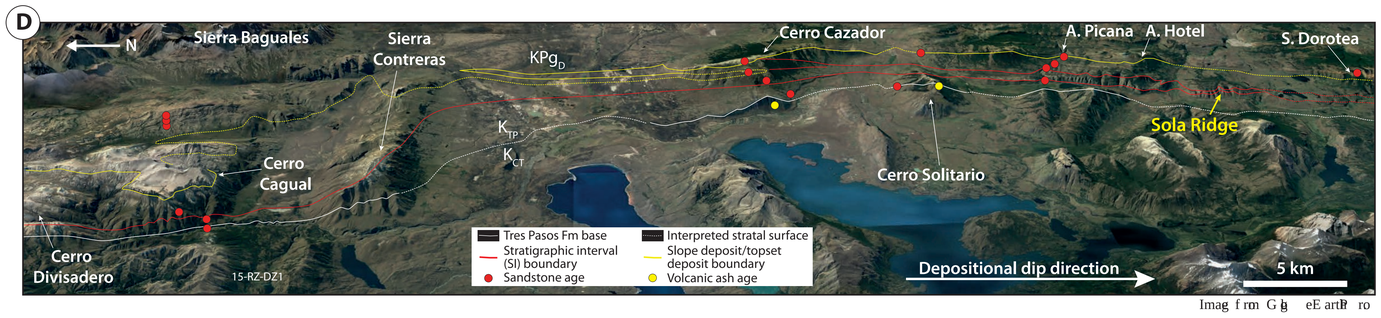
Modified from Malkowski *et al*., 2018

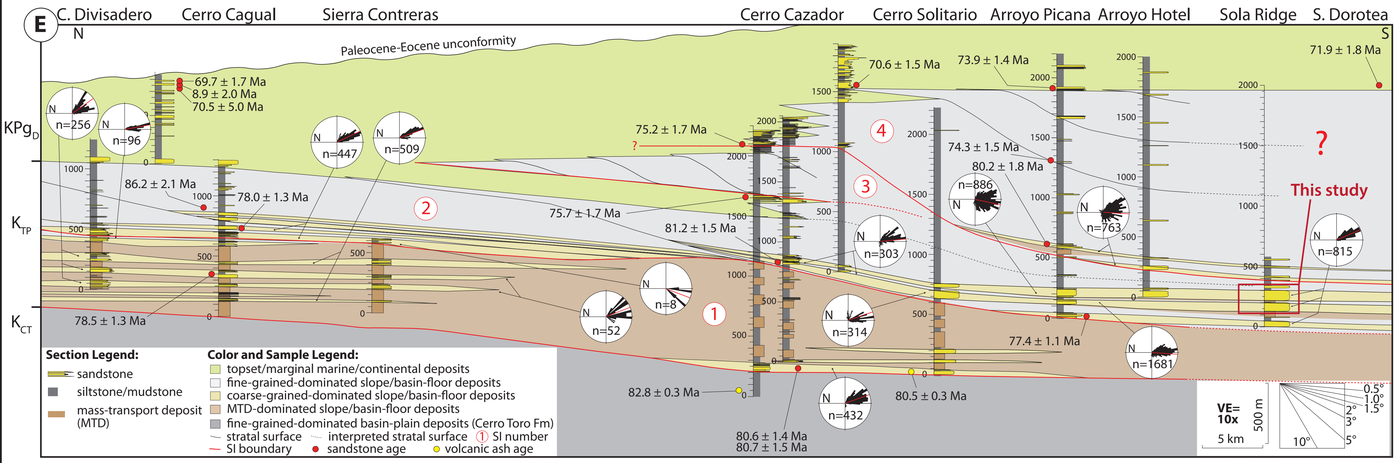
Generalized geological map of southern South America highlighting the Mesozoic sedimentary belt. The Cretaceous sedimentary outcrop belt in the study area is the result of the inherent evolution of fold-thrust belt propagation and progressive uplift of basinal segments in foreland basins setting.
Structure contour (depth in meters) represents the undeformed Magallanes Foreland Basin on top of the Jurassic Tobífera Formation.

Overview of the deep-water slope system of the Magallanes Basin. (**A**) Satellite image with key locations where slope-channel systems of the Tres Pasos Fm have been studied. (**B**) Geologic map of the Magallanes-Austral Basin in the Última Esperanza Province, Chile. (**C**) Lithostratigraphy and depositional enviroment of the Magallanes Basin fill in the study area. (**D**) Perspective satellite image of the slope-channel system outcrop belt parallel to the sedimentary dip. (**E**) Regional cross-section of the Cretaceous shallow- to deep-water system formed by the Dorotea Fm (shelf), Tres Pasos Fm (slope) and Cerro Toro Fm (basin floor) equivalent to figure D. Geochronology sample locations in Daniels *et al*. (2018).

1. Magallanes Basin Deep-water Depositional System



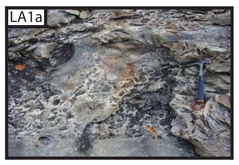


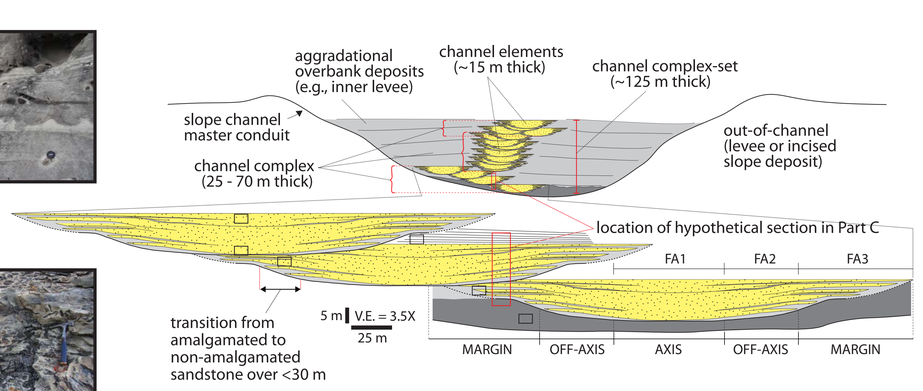


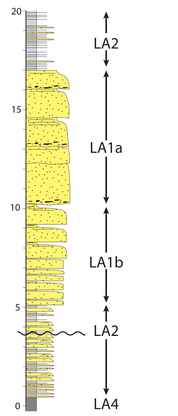
A, **B**, **D** & **E** modified from Daniels et al. (2018). **C** Adapted from Wilson (1991); Fildani & Hessler (2005); Fosdick *et al*. (2011); and Schwartz *et al*. (2017).

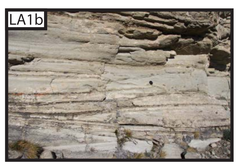
2. Lithofacies Associations & Depositional Environment Interpretation

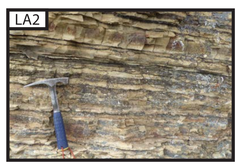
	Name	Description	Dep. Proccess
LA1	**LA1a:** Thick-bedded, amalgamated sandstone	Thick-bedded (> 50 cm), medium- and sometimes coarse-grained sandstone beds. Structureless at the base (Ta) and/or with planar lamination (Tb) normally graded up to fine-grained sandstone. Ripple cross lamination can be present (Tc), but commonly absent/eroded by the following unit. The basal contact is usually undulated and can show flame structures. Dewatering structures (dish and pillars) can be recognized in this units. Mudstone intraclast rich sandstones and gravelly sandstones are included in this category.	Channel Axis: High density turbidity current.
	LA1b: Thin- to thick-bedded, semi-amalgamated sandstone	Less than a 1 m thick units composed of medium- to very fine-grained sandstone beds interbedded with siltstone. Normally graded, massive at the base with development of planar lamination (Tb), ripple cross lamination (Tc) and sometimes siltstone laminae (Td) and millimetric mudstone caps (Te). Bioturbation and organic rich sediments are common.	Channel Off-Axis: High and low density turbidity current.
LA2	Thinly interbedded siltstone and sandstone	Centimetric scale interbedding of siltstone and fine- to very-fine sandstone. Sandstone beds are usually less than 10 cm and ripple laminated (Tc). Siltstone may be present as very fine-grained sandstone laminae (Td) or be massive (Te). Bioturbation is common and thicker sandstone beds in this unit will frequently be organic rich.	Channel Margin: Low density turbidity current. Overbank deposits: Low density turbidity current.
LA3	Concordant siltstone-dominated deposit	Massive siltstone. Millimetric beds of very fine-grained sandstone may be present.	Low density turbidity current; Mud density flow.
LA4	Discordant siltstone-dominated deposit	Siltstone- and mudstone-dominated deposits, no apparent bedding planes, although it may preserve contorted sandstone beds. Sometimes pebble-size extra-basinal clasts can be incorporated in the siltstone. Tops are commonly very bioturbated and organic rich.	Inside channelized surfaces: Debris flow; Mass Transport deposits.











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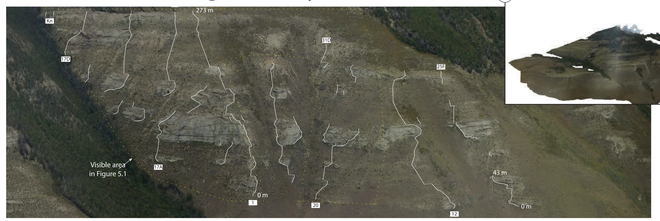
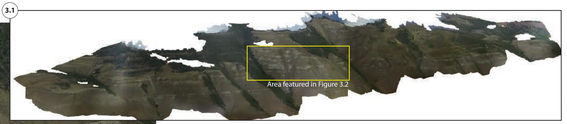
Sedimentary Systems Research, Virginia Tech Geosciences

CHILE SLOPE SYSTEMS — Universith of Calgary, Virginia Tech, University of Utah

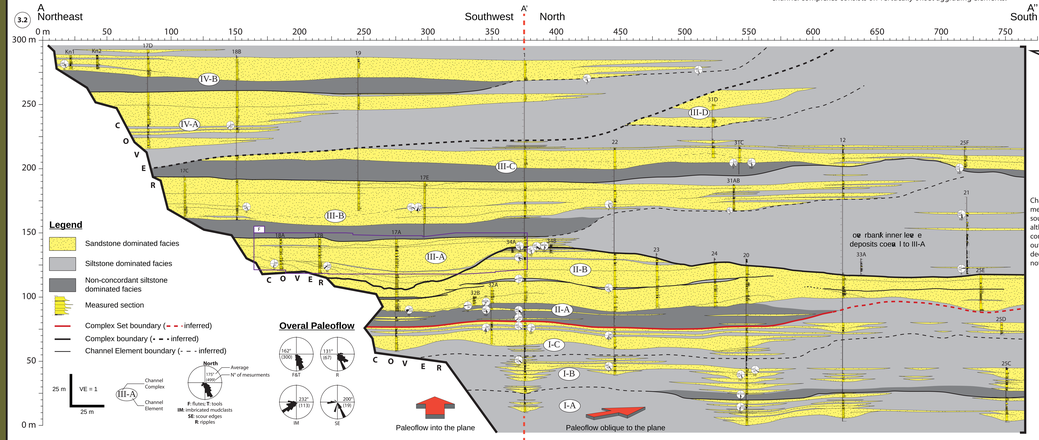
3. Field Data & Photogrammetry Model





3.1 Photogrammetry model of the 7 km long Sola Ridge, where the studied outcrop is located. The model was built with Agisoft PhotoScan using 943 different photos taken with a Dji drone.

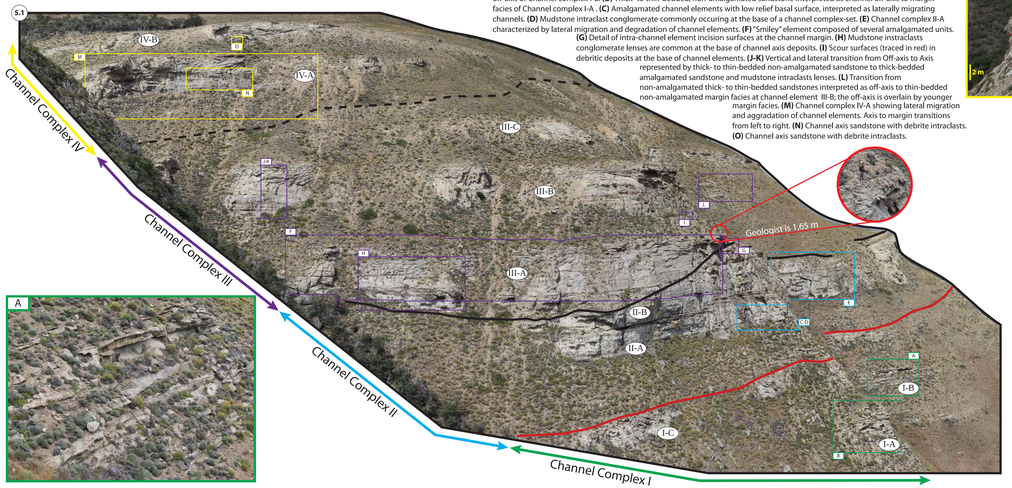
3.2 Stratigraphic cross-section showing the distribution of slope-channel strata; in the nomenclature of Sprague *et al.* (2002), the outcrop is divided into a lower channel complex set, where only the final three elements are outcropping in a laterally offset and aggradational stacking pattern, and an upper channel complex set comprise by three channel complexes. The base of the upper complex set is characterized by lateral migration and degradation of channel elements, whereas the overlying two channel complexes consists on vertically offset aggrading elements.

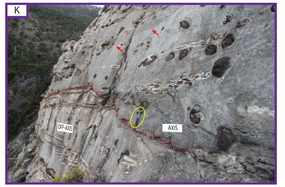


4. Element III-A "Smiley"

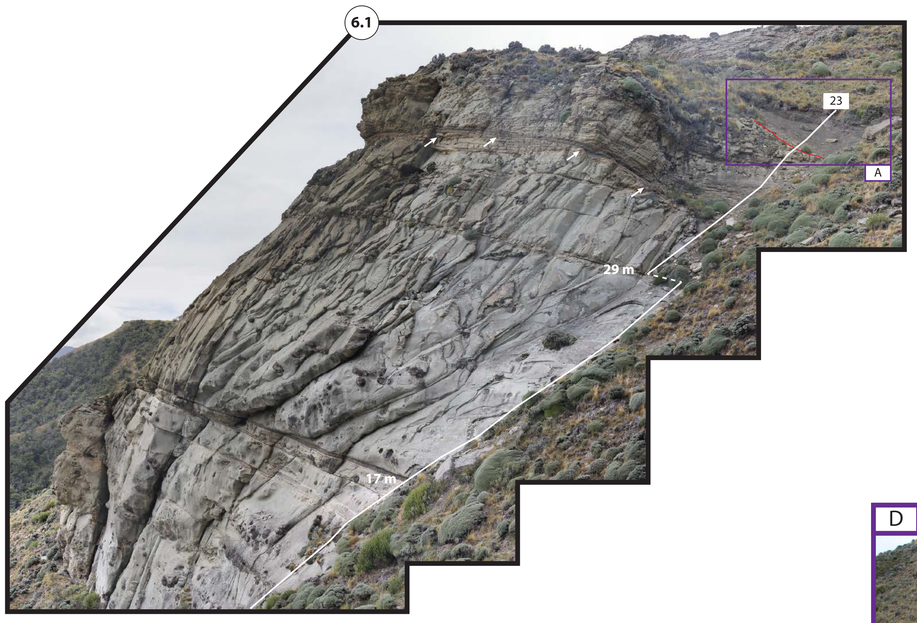
5. Channel Complexes & Elements

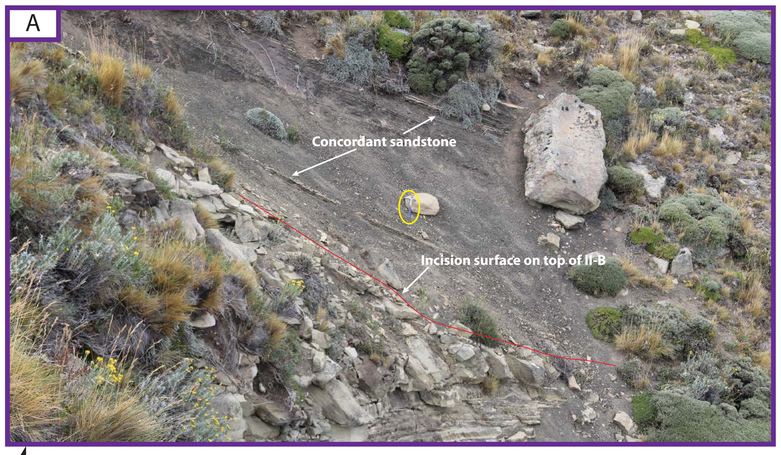
Architectural features of channel complexes and elements. **(A)** Thick-bedded, non-amalgamated sandstone interpreted as channel off-axis of Channel complex I-B. **(B)** Thick- to thin-bedded, non-amalgamated sandstone interpreted as channel off-axis to margin facies of Channel complex I-A . **(C)** Amalgamated channel elements with low relief basal surface, interpreted as laterally migrating channels. **(D)** Mudstone intraclast conglomerate commonly occuring at the base of a channel complex-set. **(E)** Channel complex II-A characterized by lateral migration and degradation of channel elements. **(F)** "Smiley" element composed of several amalgamated units. **(G)** Detail of intra-channel element incision surfaces at the channel margin. **(H)** Mudstone instraclasts conglomerate lenses are common at the base of channel axis deposits. **(I)** Scour surfaces (traced in red) in debritic deposits at the base of channel elements. **(J-K)** Vertical and lateral transition from Off-axis to Axis represented by thick- to thin-bedded non-amalgamated sandstone to thick-bedded amalgamated sandstone and mudstone intraclasts lenses. **(L)** Transition from non-amalgamated thick- to thin-bedded sandstones interpreted as off-axis to thin-bedded non-amalgamated margin facies at channel element III-B; the off-axis is overlain by younger margin facies. **(M)** Channel complex IV-A showing lateral migration and aggradation of channel elements. Axis to margin transitions from left to right. **(N)** Channel axis sandstone with debrite intraclasts. **(O)** Channel axis sandstone with debrite intraclasts.





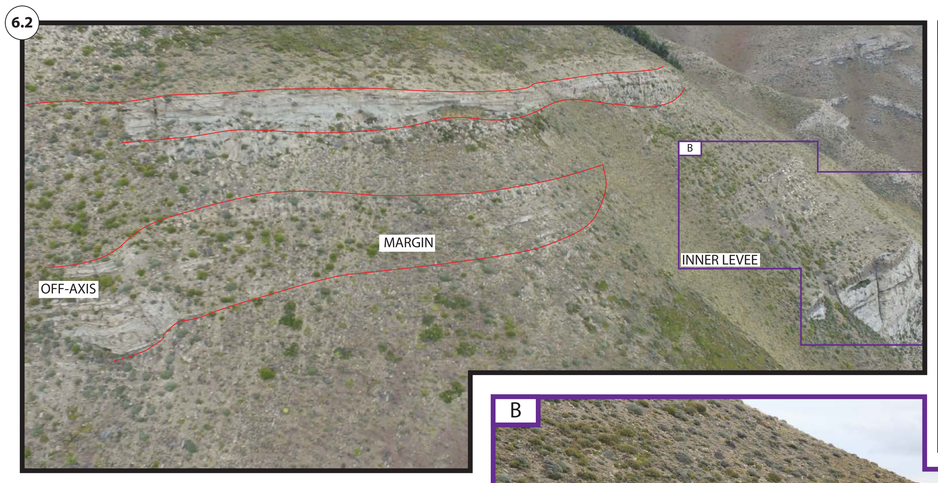
6. Incision surface & inner-levee deposits

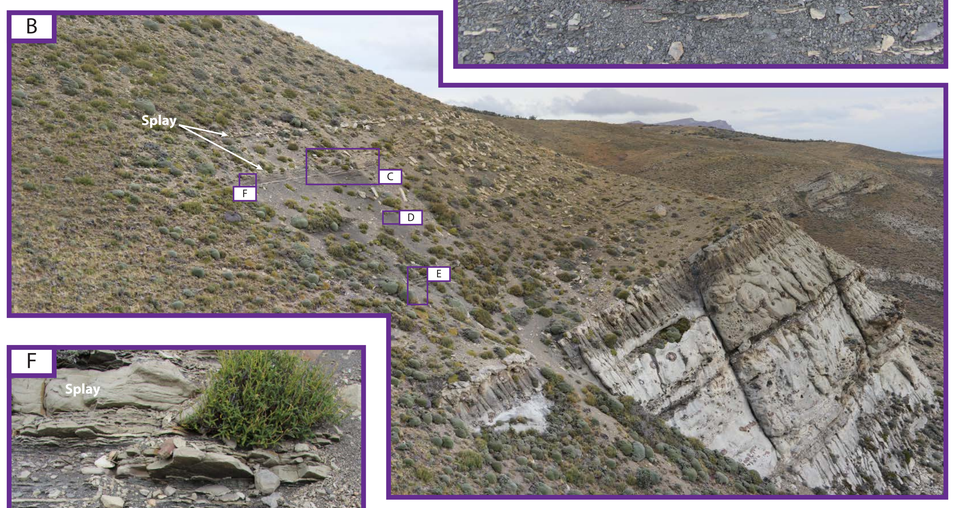




Details of the incision surface found on the top of unit II-B. This surface correlates to the base of unit III-A to the North. In this outcrop the the incision is overlain by concordant fines.

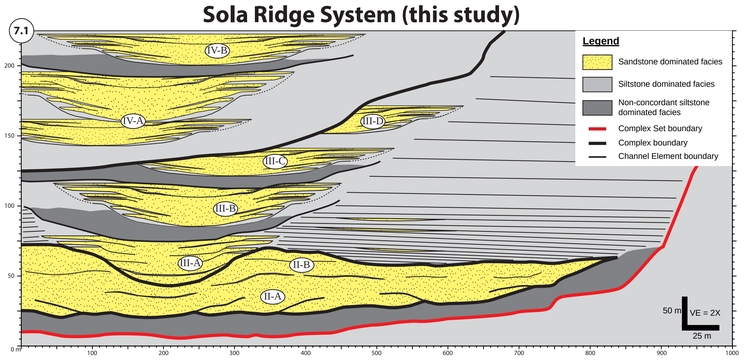
To the South, a siltstone succession occurs lateral to channel fills of unit III-A and III-B. This succession is dominated by very thin (mostly <5 cm), very fine-grained sandstone laminae interpreted as an inner levee or terrace deposit. Thicker and coarser (medium-grained) sandstone beds appear towards the top of the succession and are interpreted as splay deposits related to the inception of unit III-B.



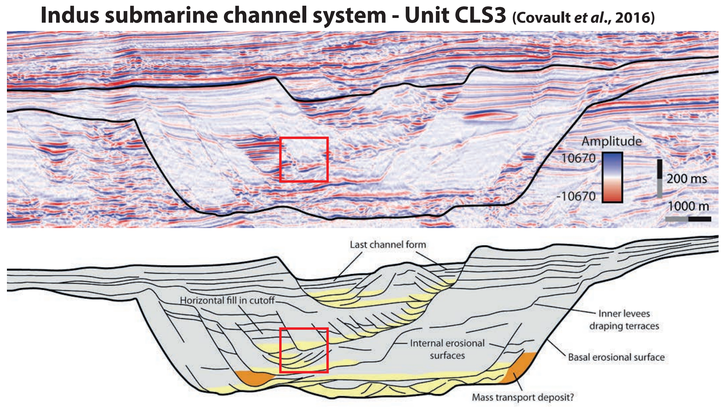


7. Analogy to other systems

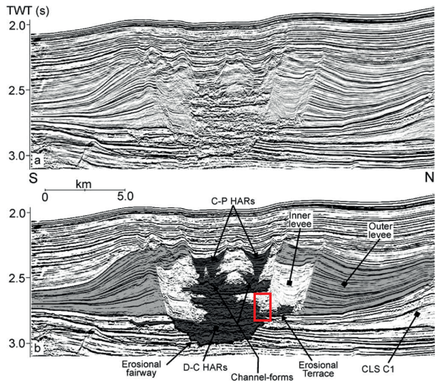
Sola Ridge System (this study)



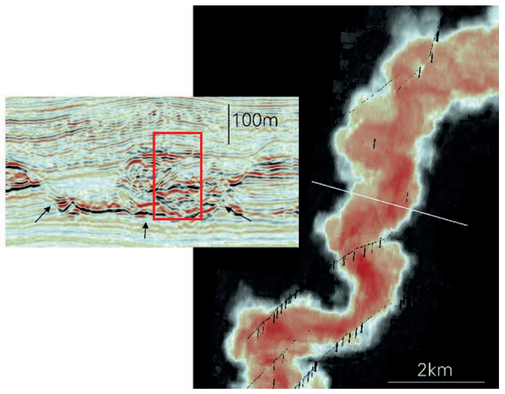
Indus submarine channel system - Unit CLS3 (Covault *et al.*, 2016)



Indus submarine channel system - Unit CLS2 (Deptuck *et al.*, 2003)



Offshore Angola (Mayall *et al.*, 2006)



8. Ongoing/future work

The presence of a rarely outcropping inner-levee portion in the system provides an unique opportunity to generate a **quantitative characterization of siltstone rich facies** in context of architecture (*eg.* margin vs overbank facies).

Additionally, the regional context of this research allow us to integrate this and other outcrop's data along Sola ridge (see figure 3.1) in context of **longitudinal changes in slope channel architecture** (see Daniels *et al*. poster for further information).

Finally, the possibility to refine conceptual models of composite channel systems in relation to prominent erosion surfaces at the boundary between basal, laterally migrating and low aggradation channel complex and overlying vertically stacked and high aggradation channel complex. **¿Does erosion surfaces predict down-slope sandstone-prone facies distribution?**

Acknowledgments

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