

# **PS Quantifying Inter- and Intra-Channel Architecture Controls on Reservoir Performance in a Deep-Water Slope Channel System, Tres Pasos Formation, Magallanes Basin, Chile\***

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## **Abstract**

The Tres Pasos Fm of the Magallanes Basin in Chile records the evolution of a prograding deep-water slope system with exceptionally well exposed depositional dip-oriented middle to lower slope strata exposed at the Laguna Figueroa locality. The outcrop contains three channel complexes comprised of 18 channel elements. While analogous slope channel deposits can contain significant reservoir potential, their channelized nature creates uncertain connectivity, which can be problematic for efficient hydrocarbon production. This work seeks to quantify the influence of reservoir architecture on reservoir productivity as a function of well placement and inter-/intra-channel architecture using a high-resolution outcrop-based geocellular model. Reservoir flow simulation is performed to assess the impact of intra-channel architecture on production profiles. Simulated production data is analyzed to elucidate potential clues useful for predicting channel dimensions and connectivity in new and/or producing fields. Reservoir simulations were run for: 1) a single channel element and 2) sector models representing areas of vertically aligned versus laterally offset channel elements. All models were represented at a 2 m × 2 m × 0.25 m grid scale. Three primary facies associations (FA) capture the lithologies present in outcrop: FA1 (axial) – thick-bedded amalgamated sandstone (95% sandstone); FA2 (off-axis) – thick- to thin-bedded semi-amalgamated sandstone with few fine-grained interbeds (81% sandstone); FA3 (marginal) – thin-bedded fine- to very fine-grained sandstone with interbedded siltstone and mudstone (39% sandstone). Three scenarios were created to quantify the influence of reservoir architecture on productivity by varying the proportion and distribution of facies within each channel element. Scenarios capture a range of possible architectural frameworks from highly connected FA1-dominant to more compartmentalized FA2- and FA3-dominant conditions. Hydrocarbon production was simulated from a single extraction well at the axis of the channel element(s) and two water flood injectors 35 meters from the channel margins. Inter- and intra-channel connectivity were evaluated based on the volume and location of oil left in place following water breakthrough. The influence of well placement on productivity was quantified by rerunning each of the realizations with injectors rotated to the center of the channel(s) up- and down-gradient of the production well.



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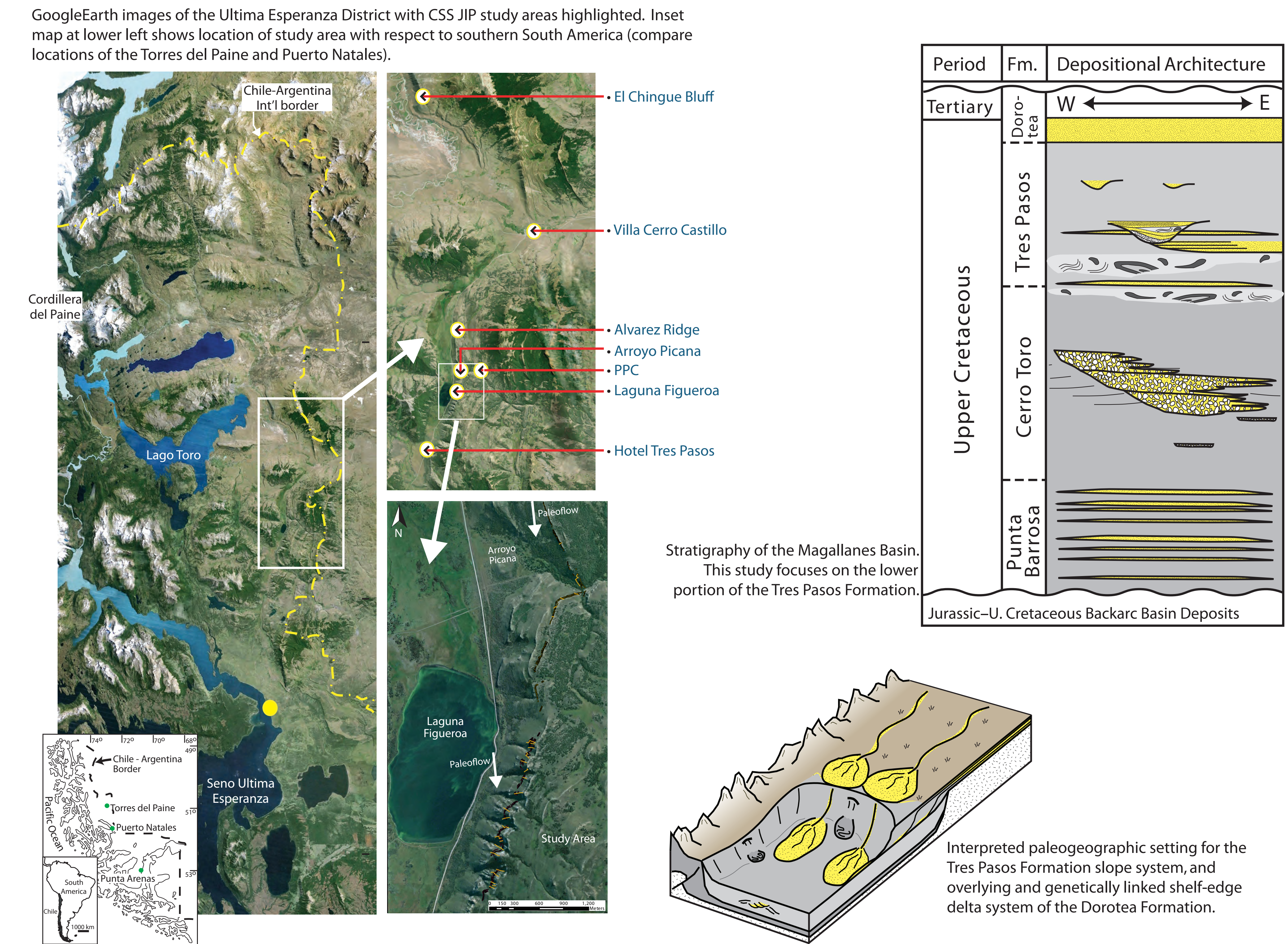
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## OBJECTIVES:

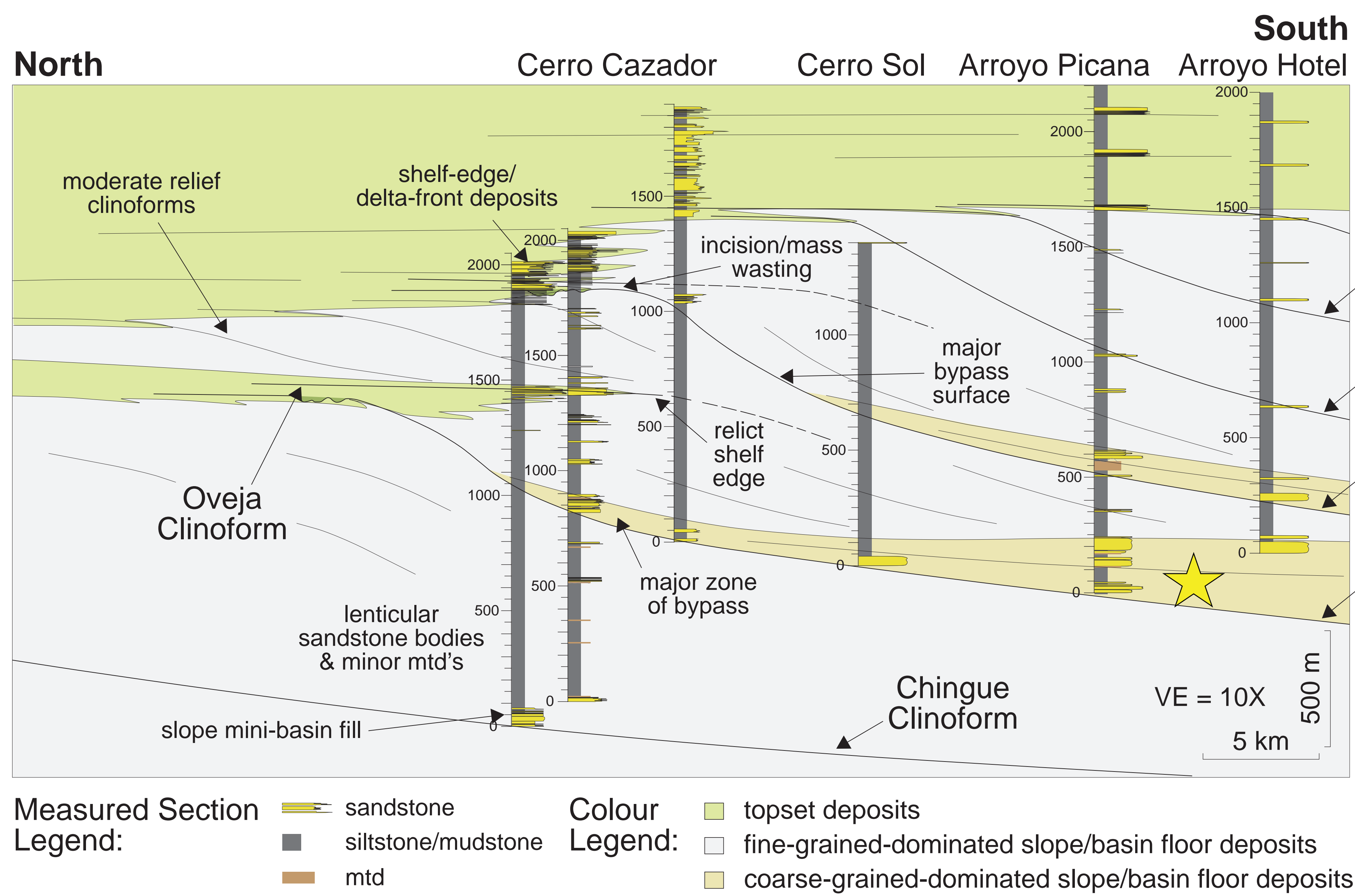
- 1) Quantify uncertainty/error introduced through simplification of fine-scale internal channel architecture.
- 2) Investigate how reservoir testing can be used to populate reservoir properties in a large-scale model.
- 3) Determine how uncertainty/error introduced through simplifying assumptions varies with differences in inter-channel relationships (stacking, overlap).
- 4) Elucidate the impact of upscaling inter- and intra-channel architecture on flow.

## Geologic Background and Study Area

The Late Cretaceous Tres Pasos Formation consists of a turbidite-dominated succession that records the terminal phase of deep-water deposition in the Magallanes foreland basin, southern Chile. Slope channel deposits accumulated along a high-relief basin margin ( $> 1$  km relief) along a depositional profile that was  $> 40$  km long. This study focuses on a 120 m thick and 2.5 km-long sandstone-rich succession of slope channel strata located adjacent to Laguna Figueroa. 3-D exposure of the strata along a depositional-dip oriented transect enables well-constrained mapping of channel architecture.



## Tres Pasos Formation, lower Laguna Figueroa section



Regional dip-oriented stratigraphic cross-section of the Tres Pasos and Dorotea formations showing large-scale clinoforms, which filled the Magallanes foredeep axially, from north to south (adapted from Hubbard et al., 2010; Bauer, 2012).

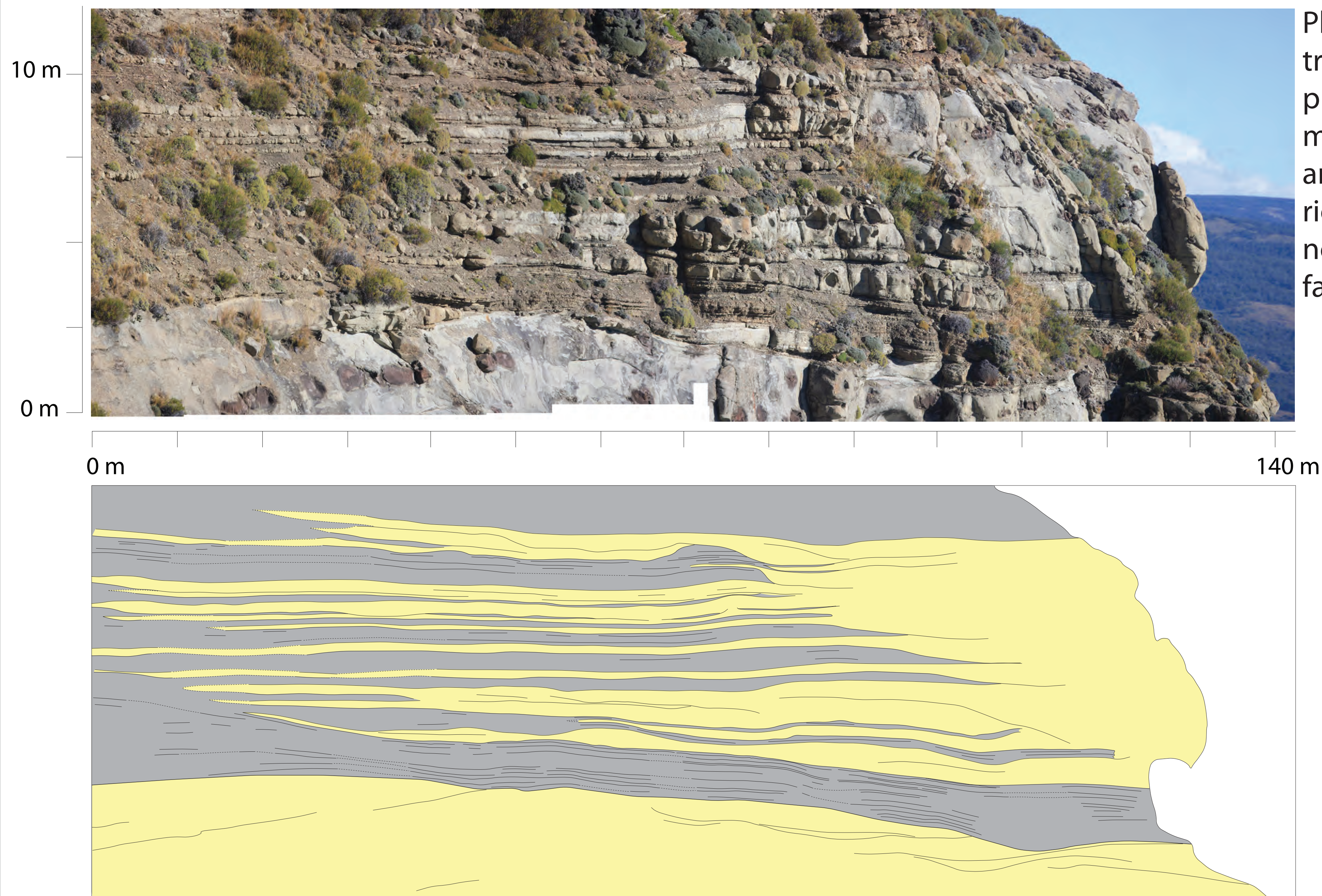
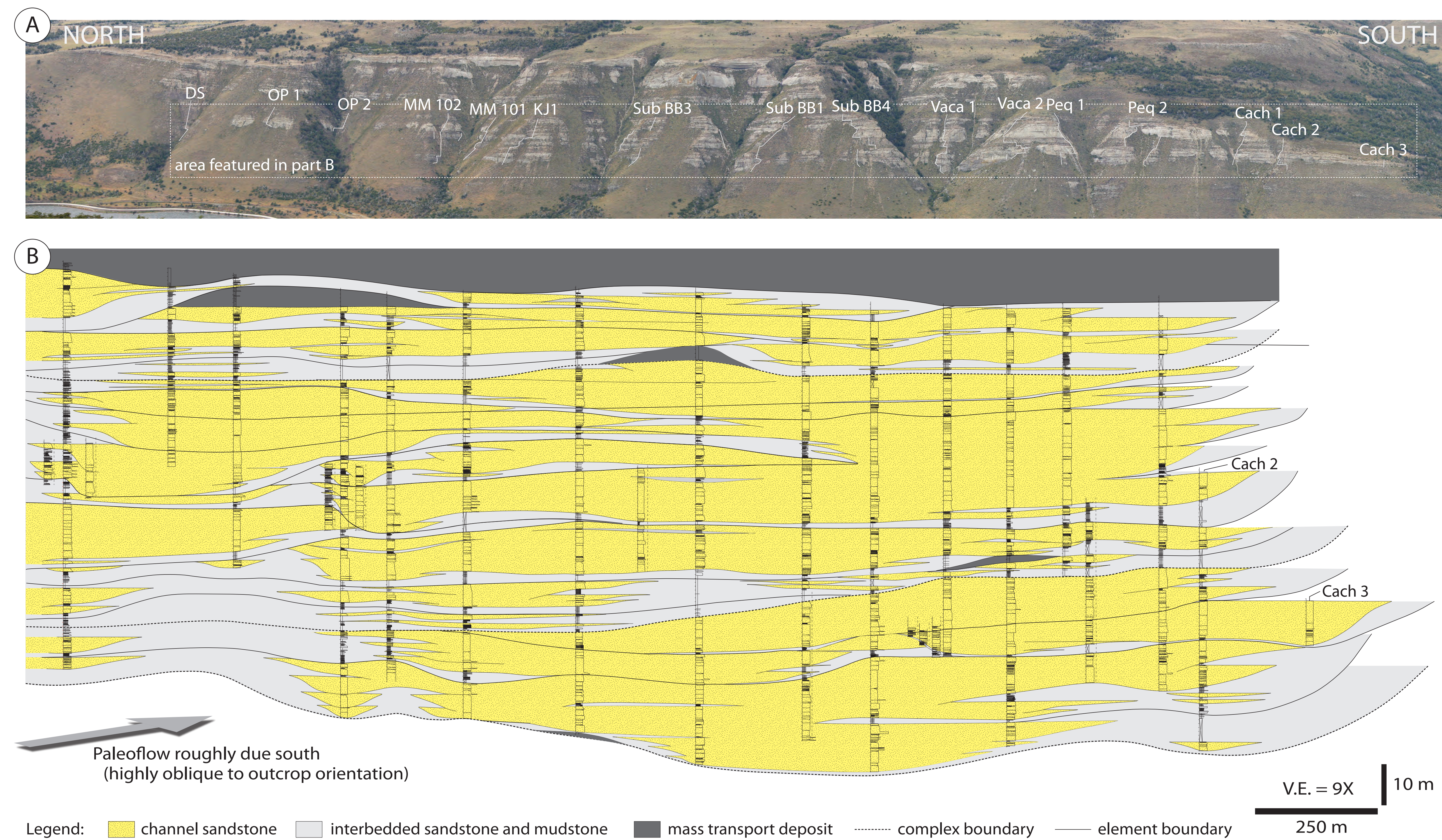
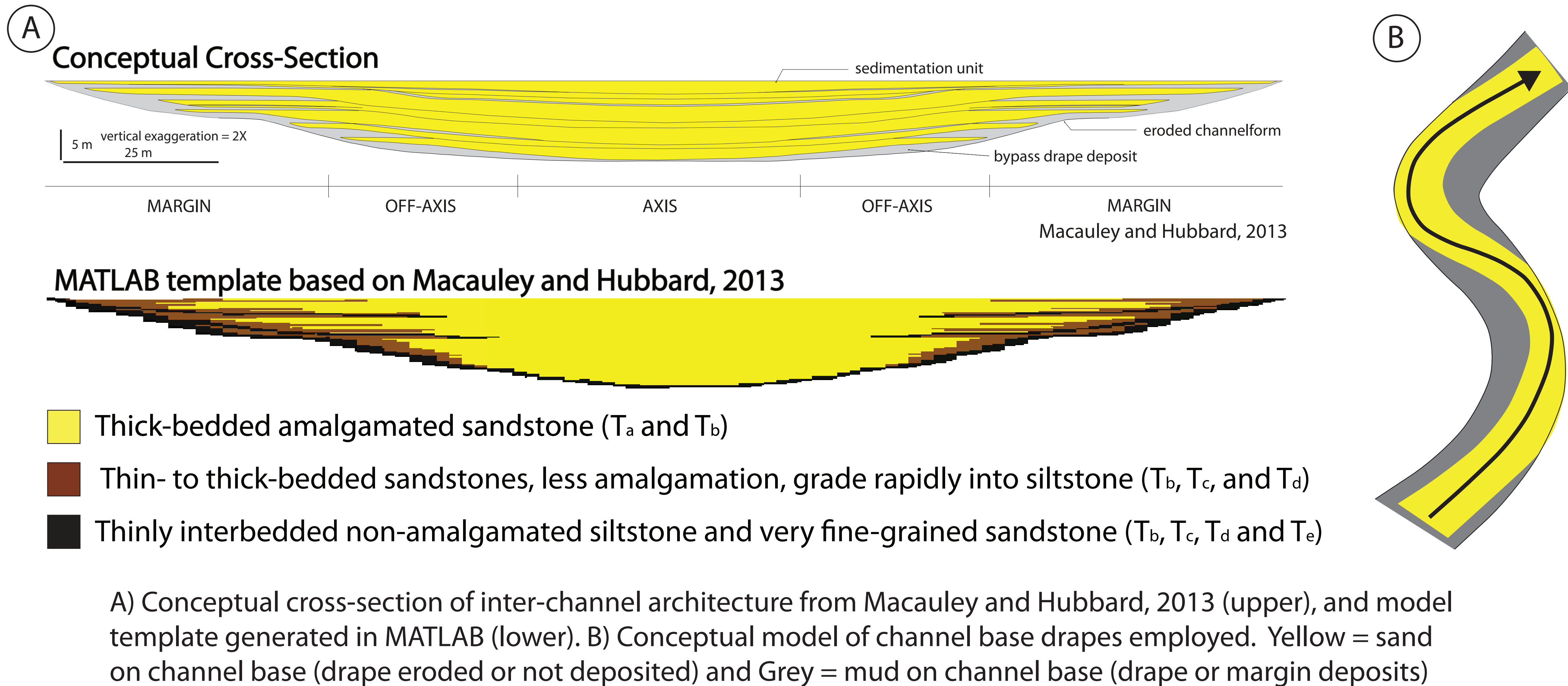


Photo (top) and line-drawing trace (bottom) of a channel, the primary building block for modeling. Note the more axial amalgamated sandstone (at right) transitions to more non-amalgamated and finer facies to the left.



The Laguna Figueroa Outcrop Belt. Two-large-scale ( $> 100$  m thick), composite channel complex sets have been delineated in the Laguna Figueroa area, which are comparable to channelized slope systems explored off numerous continental margins. The lower of the two is the focus of this analysis (Macauley and Hubbard, 2013)



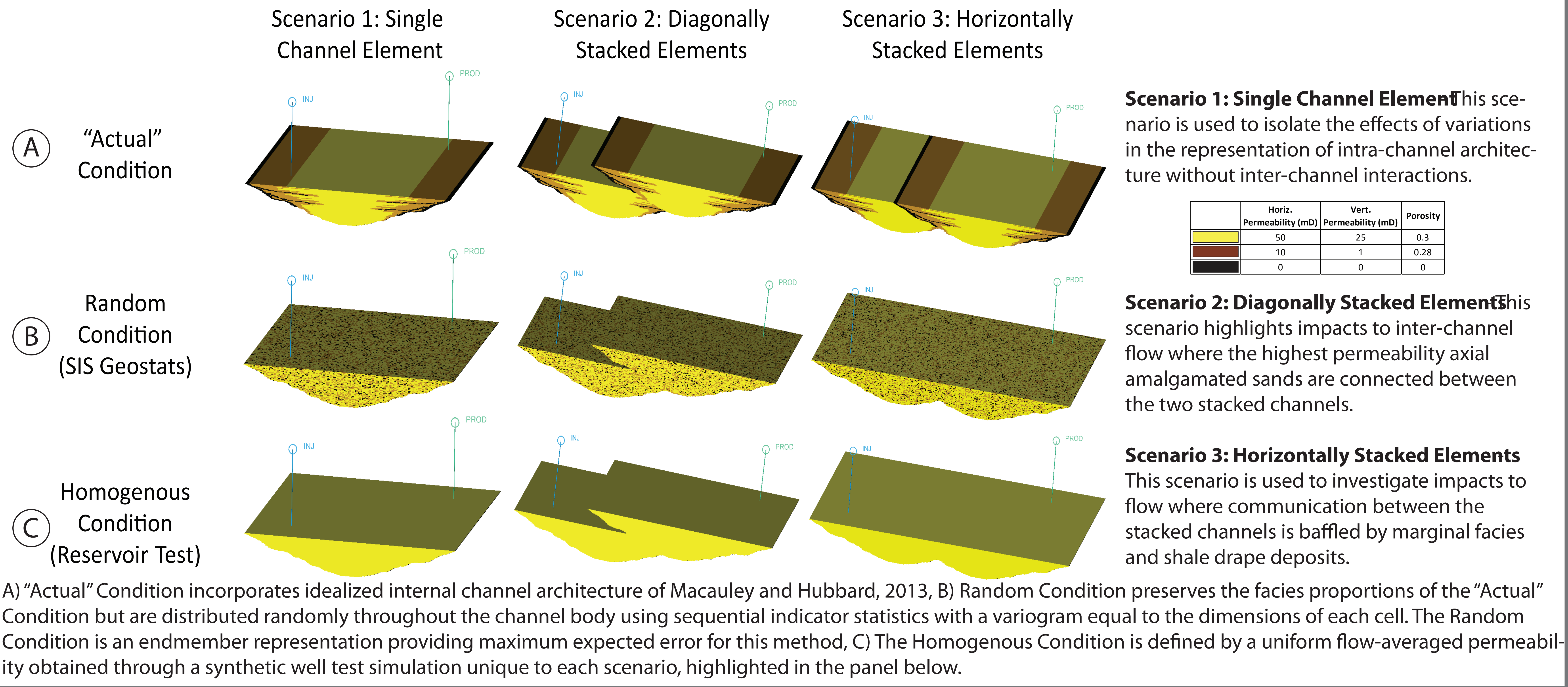


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## How does the representation of fine-scale internal channel architecture impact flow prediction?





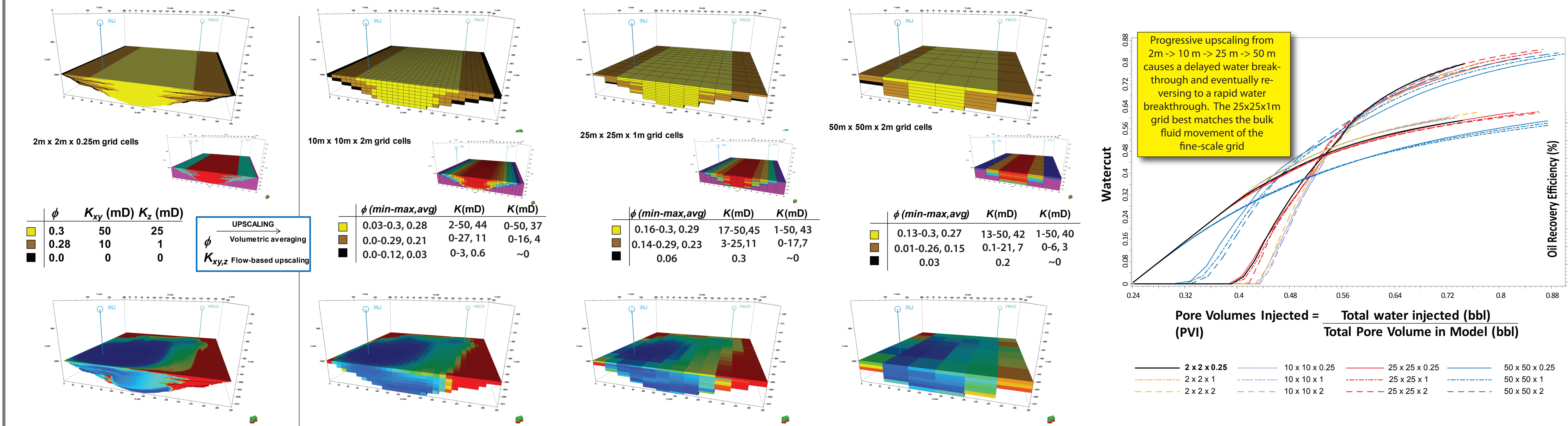
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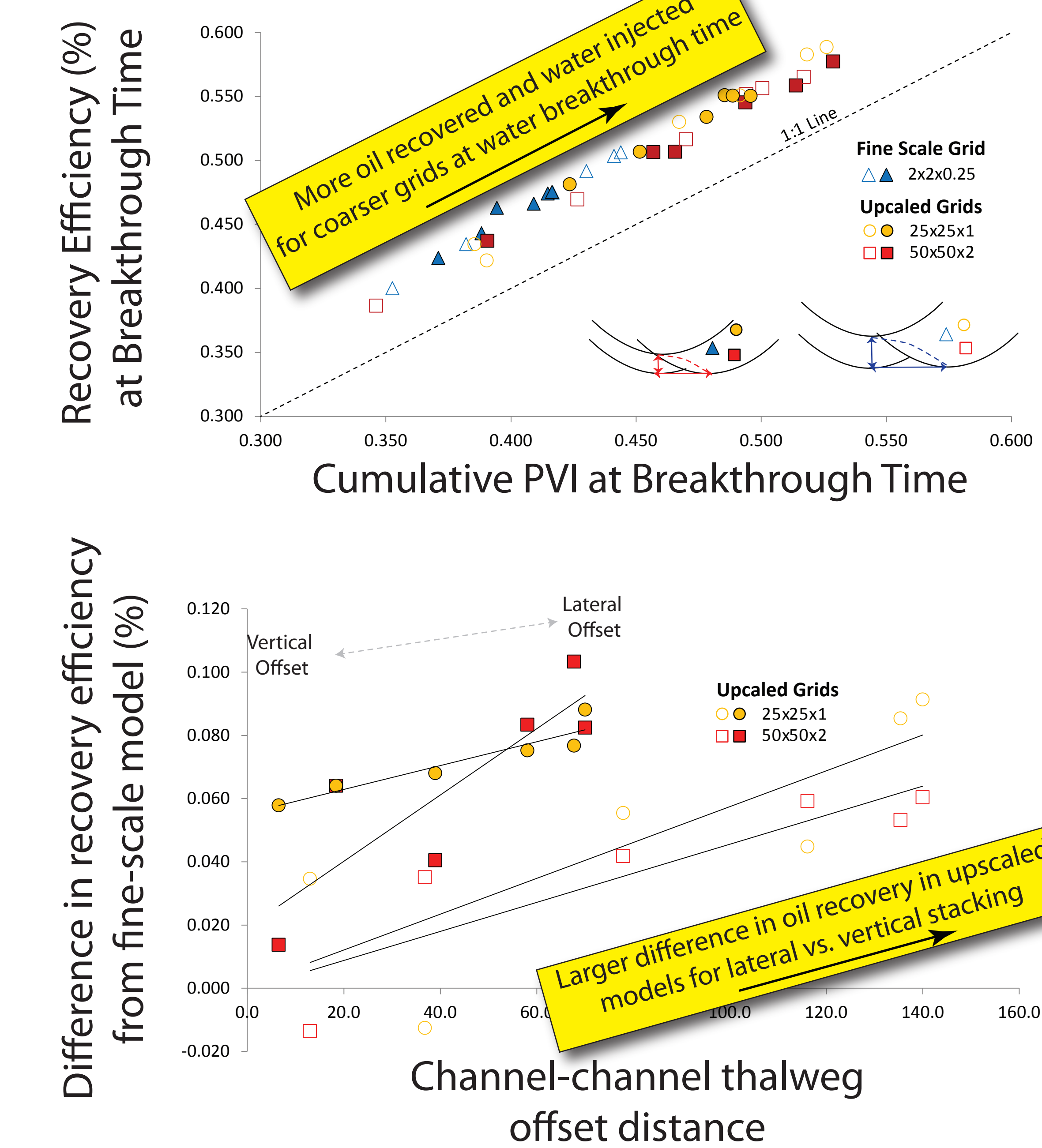
## Upscaling: Does upscaling impact flow prediction?

### Intra-channel architecture upscaling: Does upscaling of internal channel architecture impact flow?



A single channel model was used to 1) characterize the flow signature caused by the detailed internal element architecture, and 2) to test the impact of upscaling on flow. An injector/producer pair was placed in opposite marginal locations to maximize the waterflood contact across all facies. The above images show the 1) fine-scale and upscaled facies models, 2) permeability model with corresponding values at each scale, and 3) water saturation at water breakthrough. Corresponding curves of watercut and oil recovery are shown to the right.

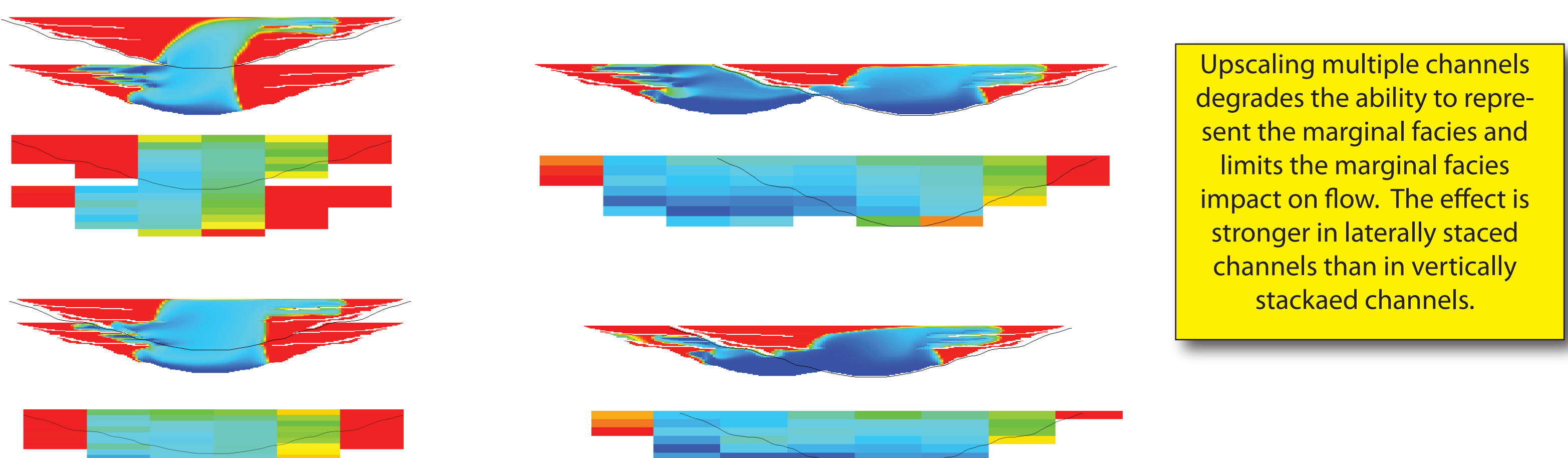
### Impact of upscaling on inter- and intra-channel architecture



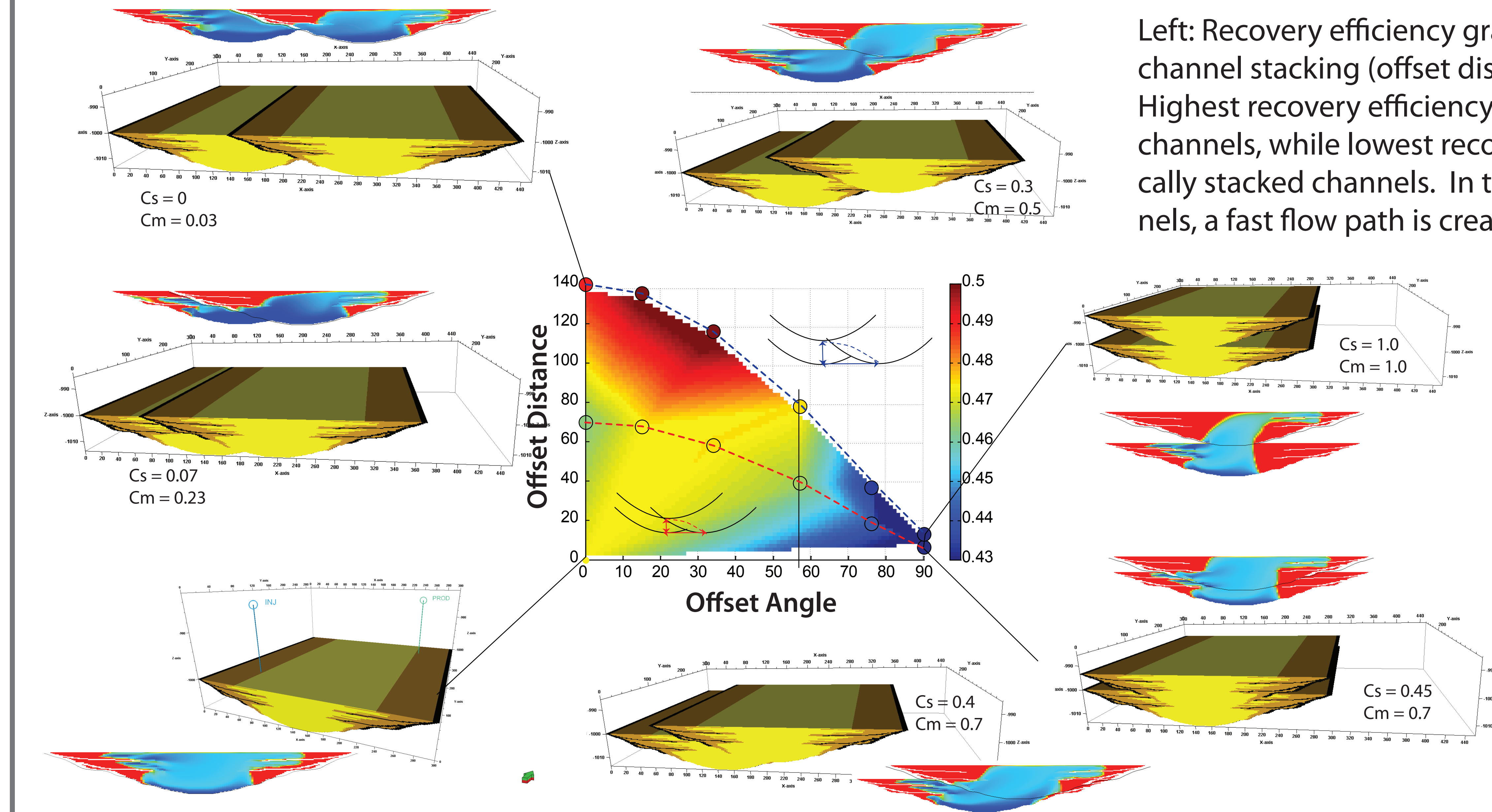
Each of the 12 different offset models, modifying the two channel stacking pattern from lateral to vertical at small to large offset (lower left box), were used to show the impact of upscaling as a function of channel stacking patterns.

Top plot: Cumulative pore volumes of water injected (PVI) at the time of water breakthrough as a function of the amount of oil recovered at water breakthrough. The upscaled models reveal that when water breakthrough, more water has been injected and more oil recovered than in the fine-scale model.

Bottom plot: The difference in oil recovery between the upscaled and fine-scale models as a function of channel stacking patterns. Smaller numbers represent vertical channel stacking, while larger numbers represent lateral offset. The error in oil recovery for laterally offset channels is higher than vertically stacked channels. Vertically stacked channels are more impacted by flow of axial facies while laterally offset channels are more impacted by flow across marginal facies. Upscaling is not able to capture the fine-scale heterogeneity of the margin facies and therefore overestimates the oil recovery.

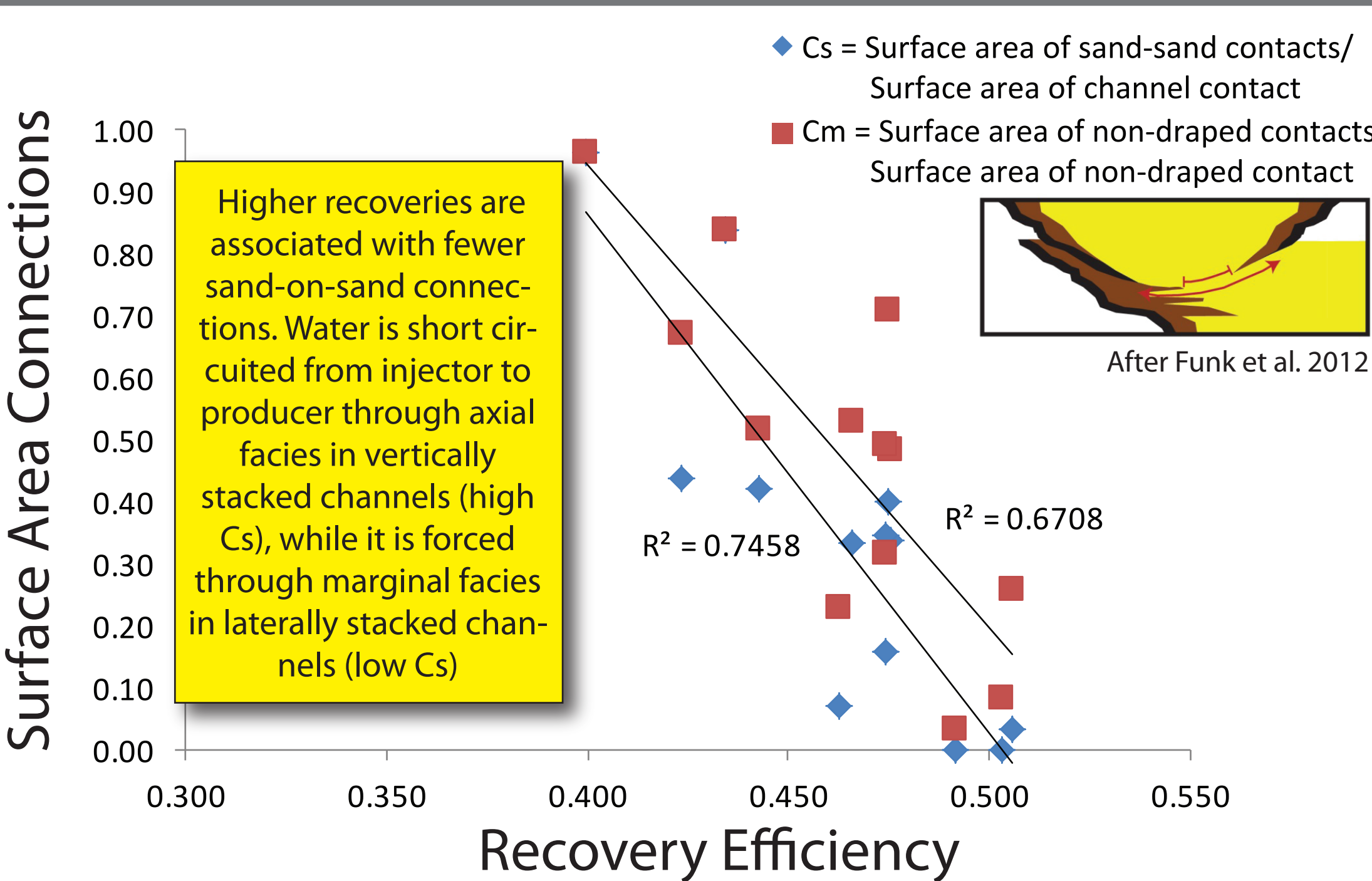


### Characterizing the impact of internal architecture and stacking patterns on flow



Left: Recovery efficiency graph plotted as a function of channel stacking (offset distance vs. offset angle). Highest recovery efficiency (red) is for laterally offset channels, while lowest recovery efficiency is for vertically stacked channels. In the vertically stacked channels, a fast flow path is created along the axis, bypassing marginal facies, while the water is forced to travel through the marginal facies when channels are laterally offset.

Right: Quantification of the interface between channel elements. A  $C_s = 1$  indicates that 100% of the channel-channel surface connection is high permeability sandstone (yellow), while a  $C_m = 1$  indicates that 100% of the channel-channel-surface connection is either high or mid permeability sandstone (yellow or orange). A  $C_s = 0$  indicates that there are no sandstone beds in connection across the channel-channel interface. A  $C_m = 0$  indicates that a connection does not exist at all and that the interface is completely draped with a non-permeable facies. There is a strong correlation between  $C_m$  and  $C_s$  and Recovery efficiency.



## CONCLUSIONS

- 1) Injection test results tend to favor axial facies and under emphasize the influence of marginal facies between overlapping channels. This issue could potentially be mitigated with test design and the use of interference testing.
- 2) Flow-averaged and random permeabilities under-emphasize the influence of the marginal and shale drape facies, resulting in greater production volumes and increased injected pore volumes prior to breakthrough.
- 3) Error introduced by flow-averaged properties increases as the connectivity of axial sands between stacked channels decreases.
- 4) Upscaling impact inter- and intra-channel architectural controls on fluid flow. These results of simulating both fine-scale and upscaled models, reveals the critical role of the marginal facies on fluid movement both within and from channel to channel.

## Sponsors

