

Reservoir Architecture of Climatic Driven Sedimentary Cycles Within a Fluvial Fan Sequence and its Implication for 3-D Modeling*

Remi Lehu¹, Pablo Barros-Arroyo², Agustín Arguello Scotti¹, Ignacio Weisman¹, and Silvana Gandi¹

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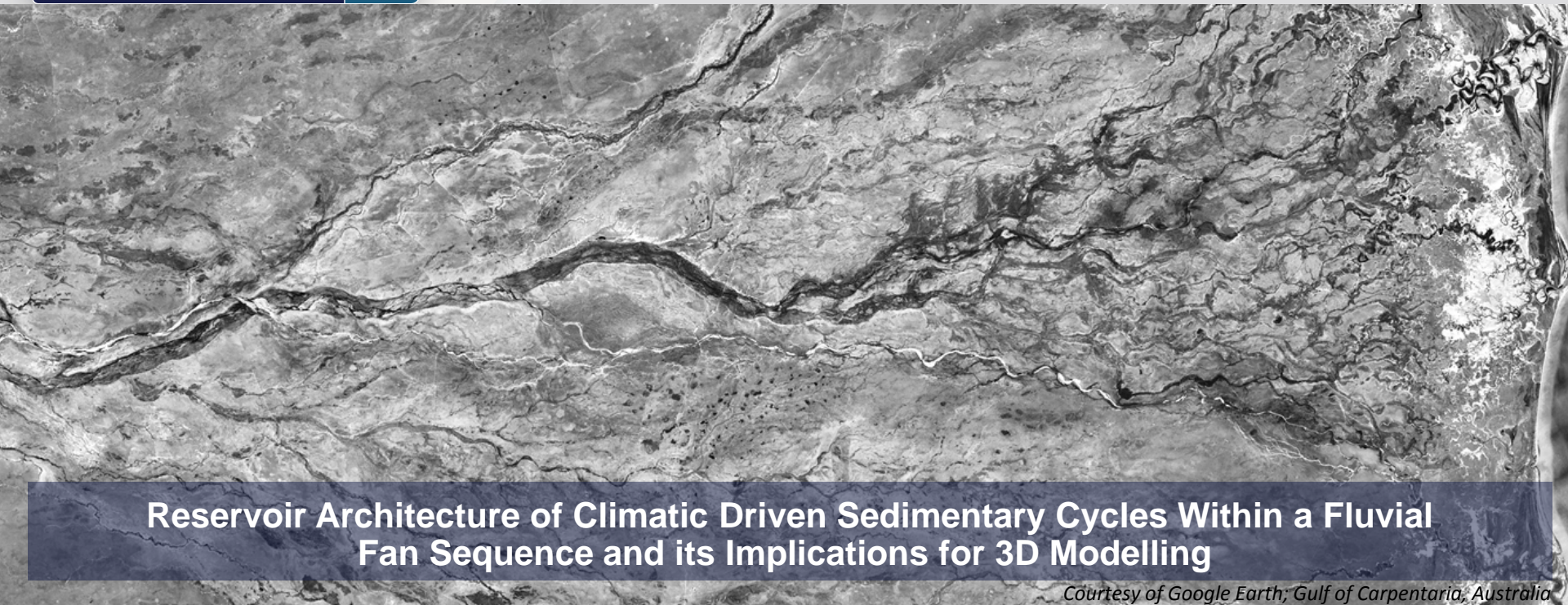
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Abstract

Ongoing economical polymer and chemical injection projects have shown that some geological parameters such as sand connectivity or mineralogical composition may be crucial uncertainties upon project success. Since most of these parameters are hardly captured by seismic data, modeling in the inter-well area is usually based on statistical methods and several 3D scenarios are used to tackle uncertainties. The Rayoso Formation (Neuquén Basin, Argentina) is currently under secondary and tertiary recovery. Reservoirs in this unit are comprised by sandstone bodies associated to an ephemeral fluvial fan accumulation system. Given the remarkably complex sand/mud distribution inherent of these systems, robust conceptual models and system characterization are critical to provide more deterministic 3D models. Moreover, reservoir architecture of widely correlatable sand reservoir bodies becomes a key uncertainty when modeling fluid connectivity. Thus, the aim of this study is to analyze and characterize the sedimentary architecture of the Rayoso Fm. sandbodies and discuss the impacts in the building of 3D static models. Four stratigraphic sequences have been described showing thickening and coarsening upward trends. Each sequence shows transition from relatively stable fluvial channels within low net-to-gross intervals into extensive fluvial depositional bodies or fans. Climatic variations affecting sediment discharge are interpreted to be the main control over such sequences. Apparently continuous reservoirs at the top of the sequences, ~8 meters thick with excellent reservoir properties, are the targets of secondary and tertiary recovery. Production data and dynamic modelling at pilot-scale showed good fluid connectivity at the top of the described sequences. However, field-scale and multifield-scale production data indicated evenly spaced east-west discontinuities oriented perpendicular to the depositional dip, suggesting a stratigraphic disconnection of a subseismic scale. These discontinuities are interpreted as lobes progradations and lateral stackings expected in these systems. Modern outcrop and numerical analogues were used as reference to constrain modeling scenarios with robust geological concepts. This concept-based relatively deterministic approach was critical to represent fluids distribution and flow paths.



Reservoir Architecture of Climatic Driven Sedimentary Cycles Within a Fluvial Fan Sequence and its Implications for 3D Modelling

Courtesy of Google Earth; Gulf of Carpentaria, Australia

Remi Lehu, Pablo Barros-Arroyo (1), Agustín Arguello Scotti, Ignacio Weisman, Silvana Gandi

YPF

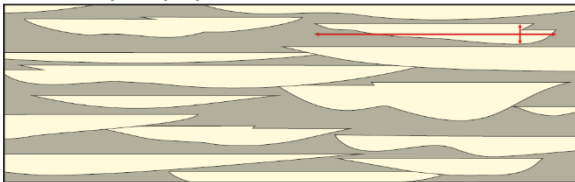
Geological parameters critical for chemical/polymer injection projects?

Reservoir connectivity?

Channel-deposit proportion = 26%



Channel-deposit proportion = 52%



Courtesy of Nigel Mountney

Reservoir heterogeneities?



Courtesy of Google Earth

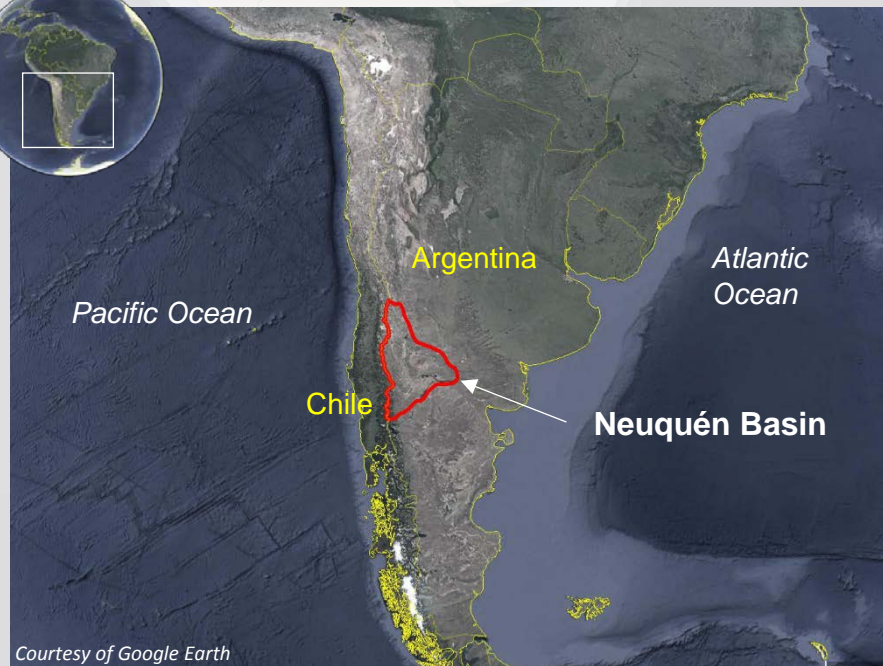
Parameters hardly captured by seismic data



Need to understand the reservoir architecture

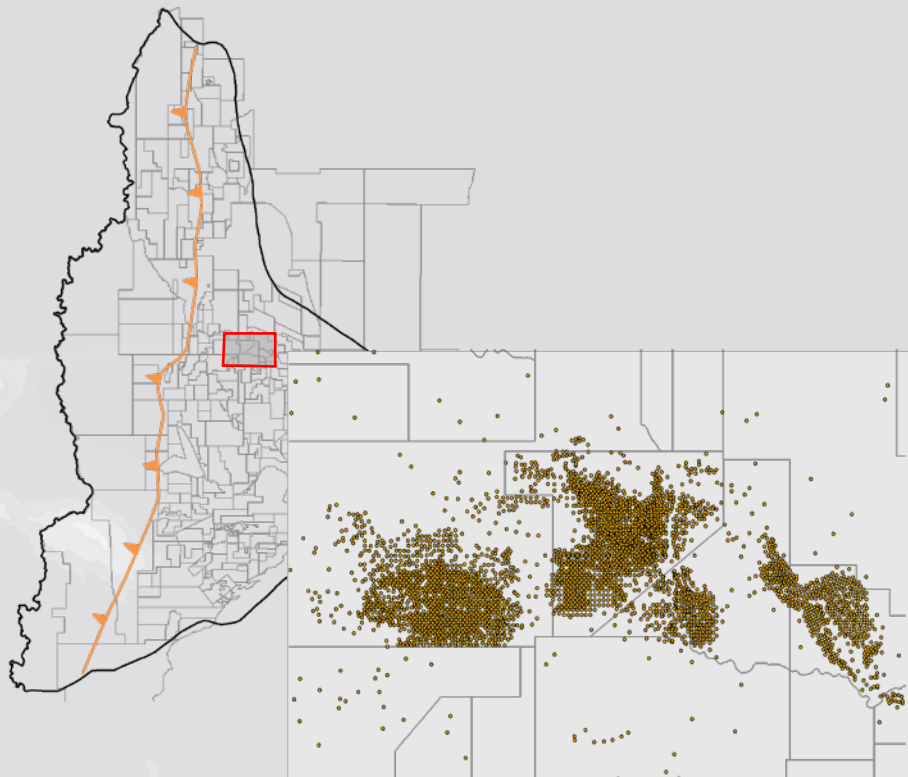


3D model scenarios to tackle uncertainties



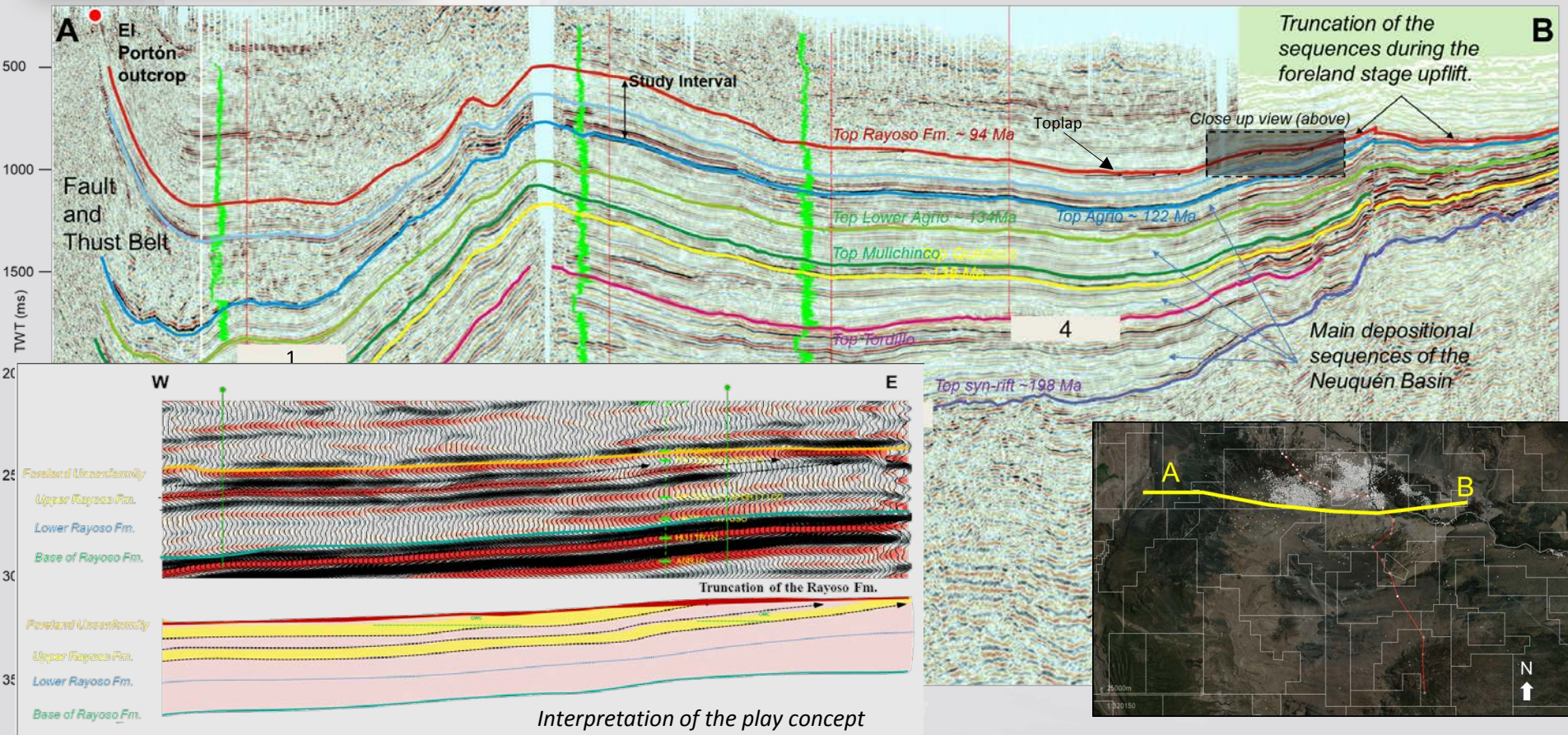
> 4800 wells

Geological unit of interest in this project



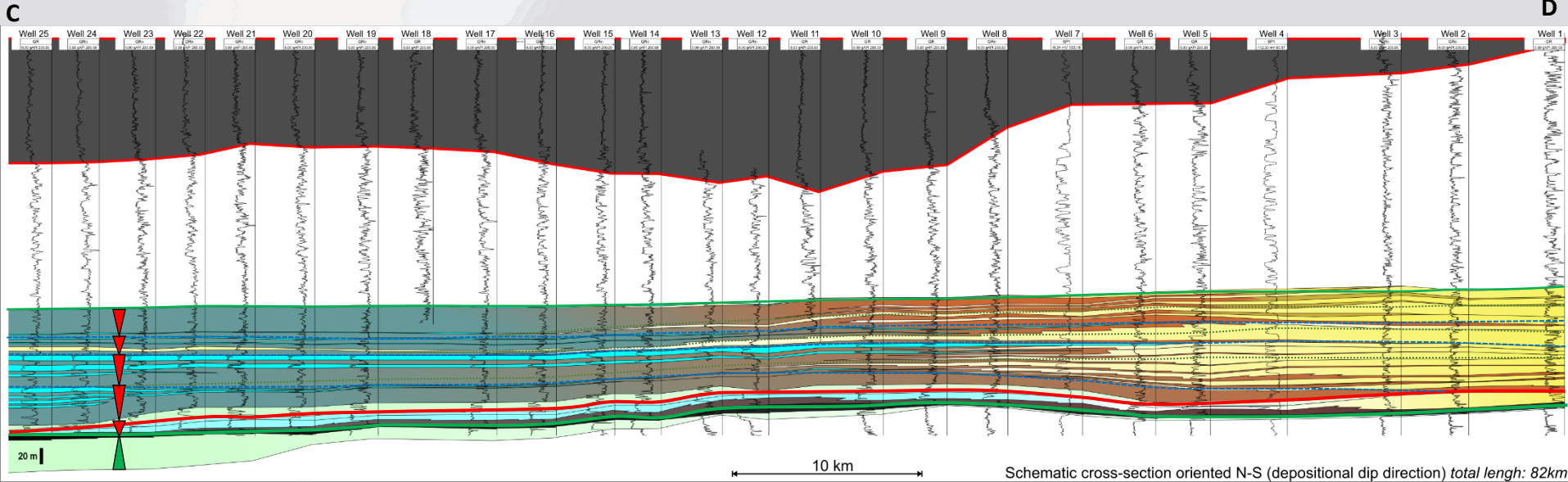
The Cretaceous R₁

Geological setting and stratigraphy



Geological setting and stratigraphy

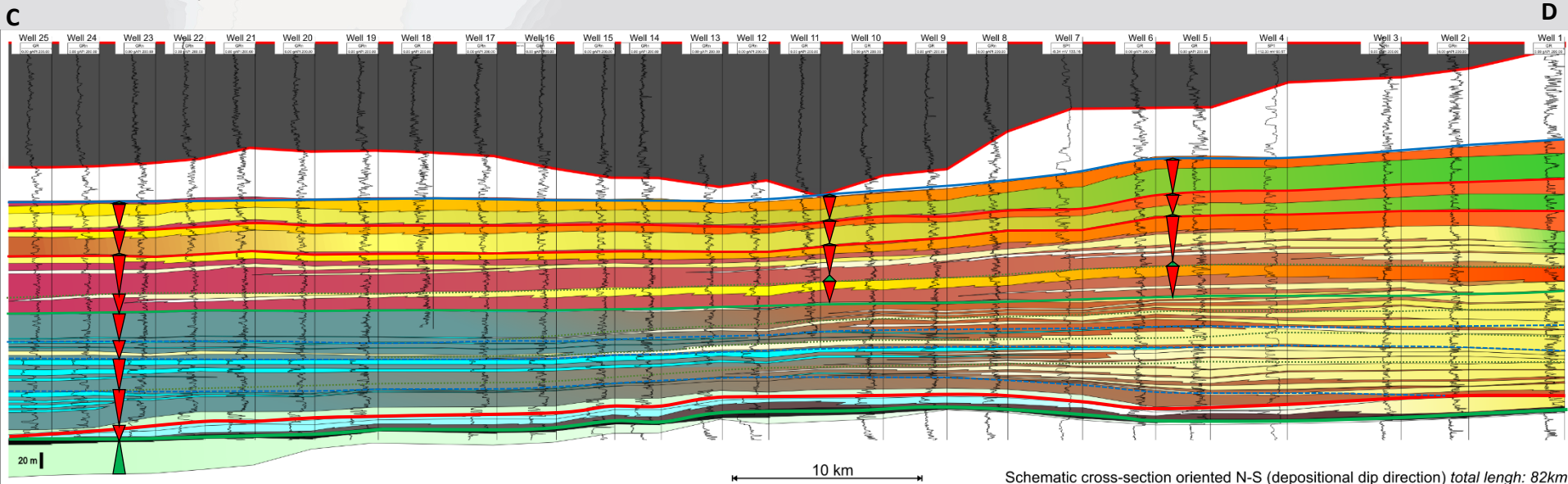
Barremian - Aptian



- Regionally traceable gypsum bed marks the upper boundary of the “Evaporitic Rayoso” (subsurface) / “Las Salinas member” (outcrop) Interval.
- This gypsum bed is used as a regional datum surface.

Geological setting and stratigraphy

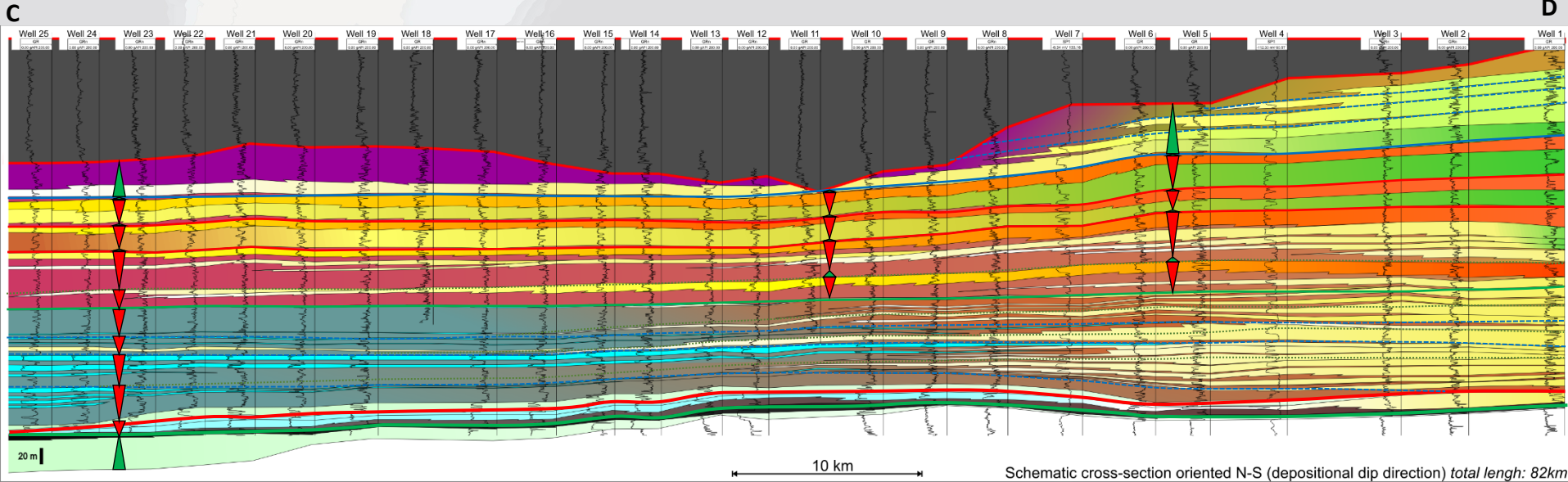
Barremian - Aptian



- “Clastic Rayoso” interval characterized by the dominance of clastics and absence of evaporites.
- According to vertical and lateral sandstone distribution in the study area, a fluvial clastic system is interpreted to prograde from south to north (ACC<SUP).

Geological setting and stratigraphy

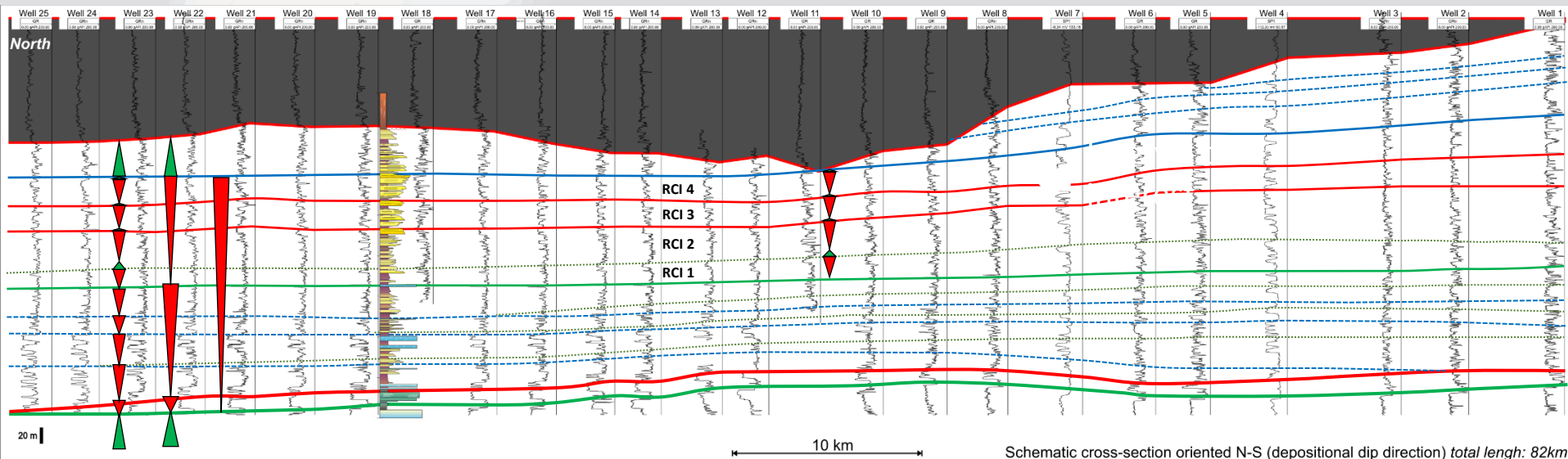
Barremian - Aptian



- Change in stacking pattern. Inferred retrogradation of the system (ACC>SUP).
- This interval is called “Evaporitic Rayoso II”

Geological setting and stratigraphy

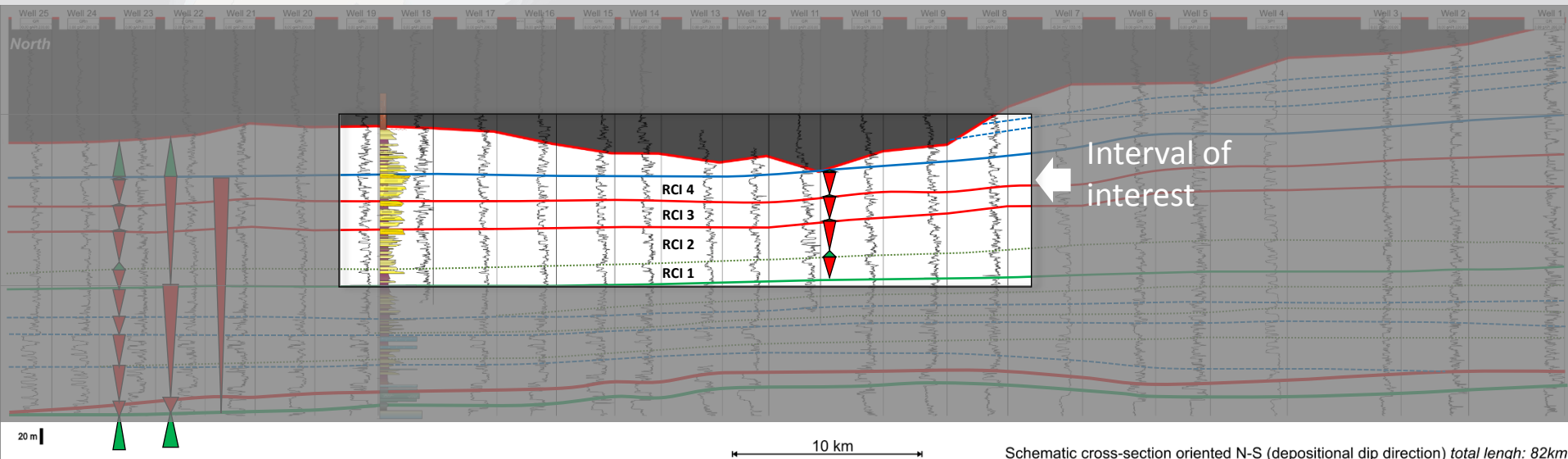
Summary:



- Stacking patterns suggest cyclicity at different scales.
- Major interest in this Project is to establish the characterize and clarify the origin of cyclicity within the high N/G Interval of the Clastic Rayoso (main productive Interval).

Geological setting and stratigraphy

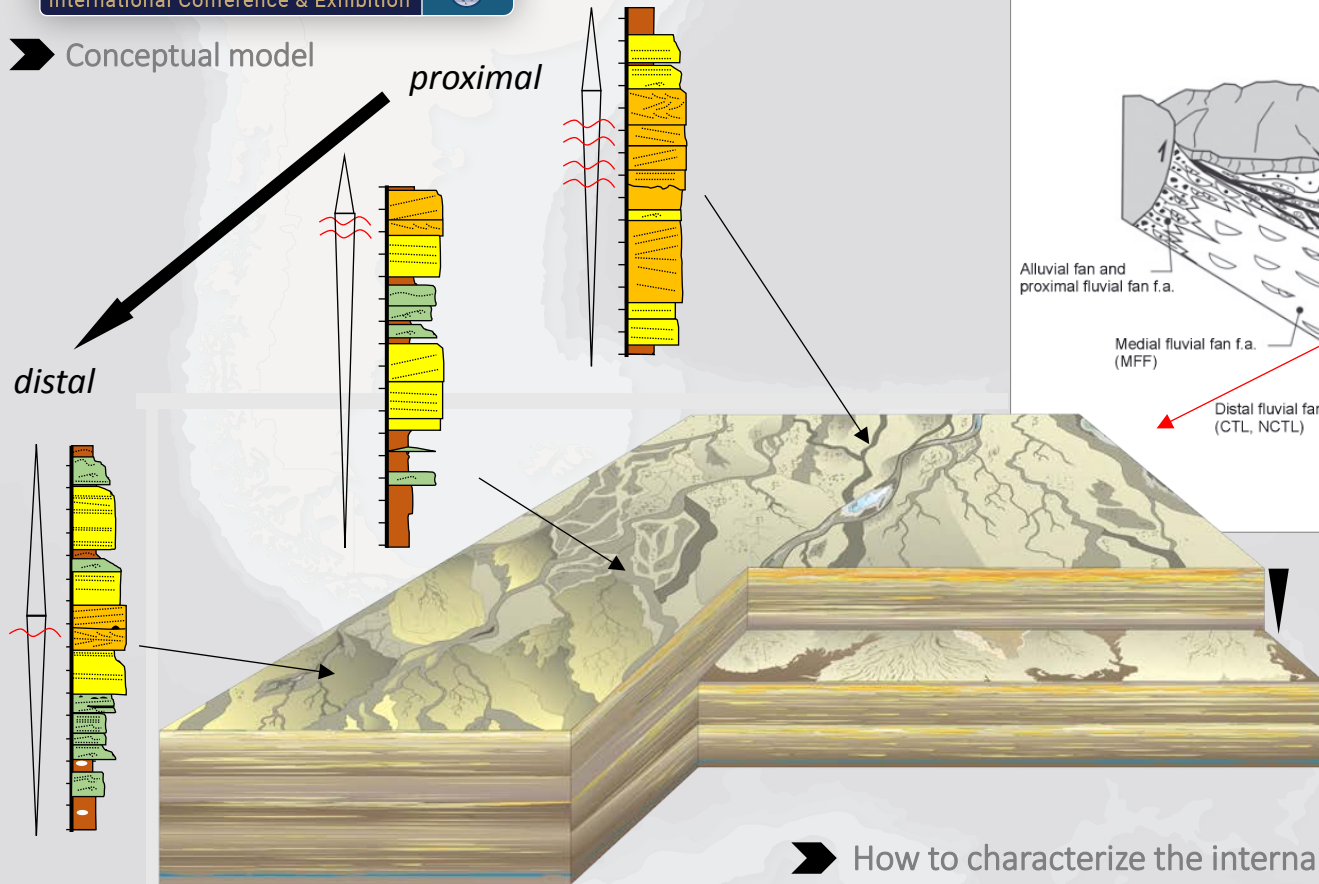
Summary:



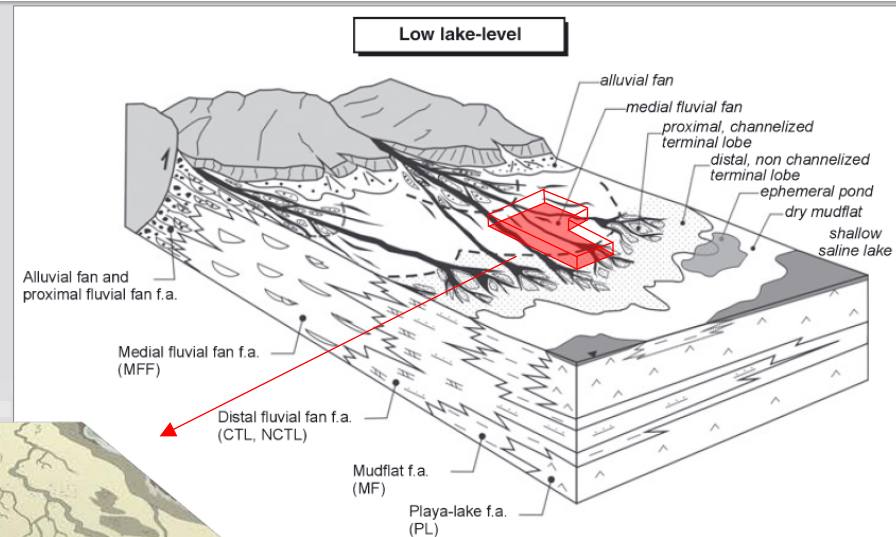
- Stacking patterns suggest cyclicity at different scales.
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Sedimentary analysis

Conceptual model



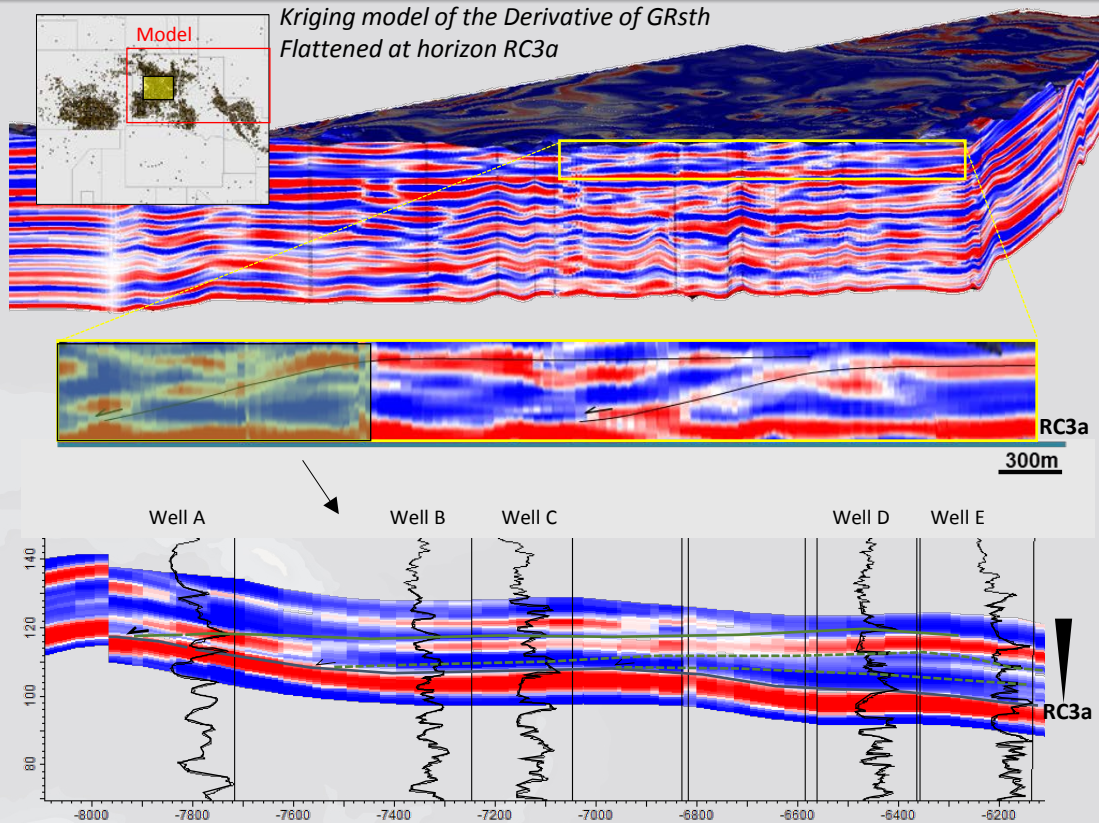
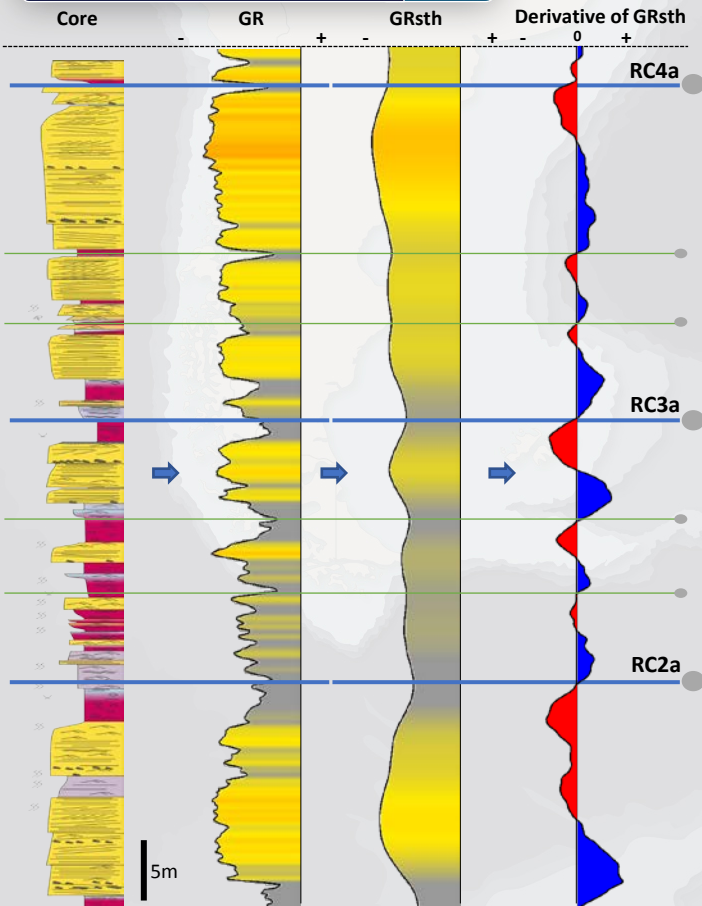
From Barros et al. 2016



From Saez et al. 2006

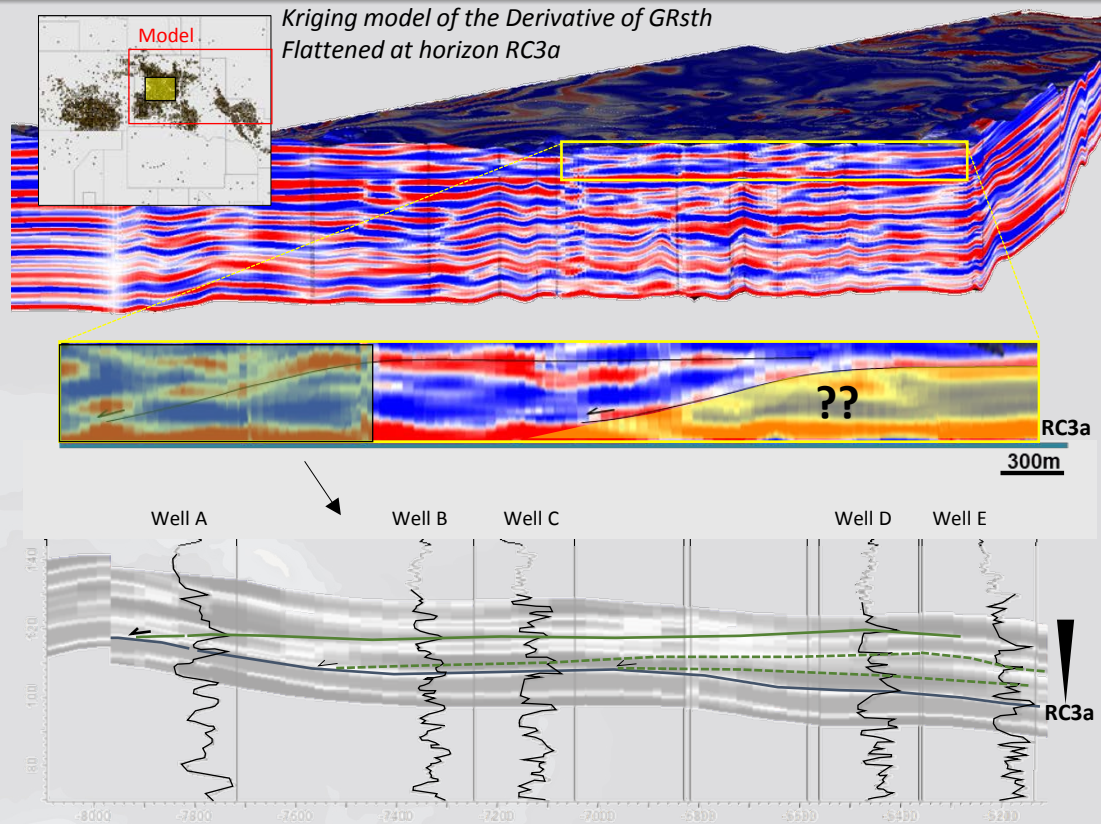
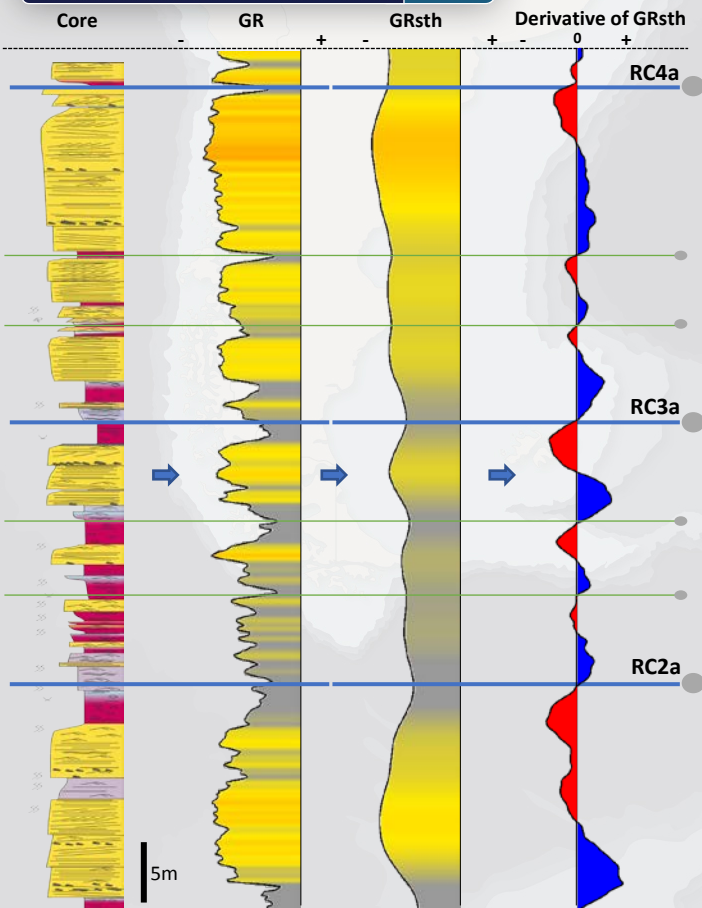
➤ How to characterize the internal architecture of such a system?

Reservoir geometry analysis



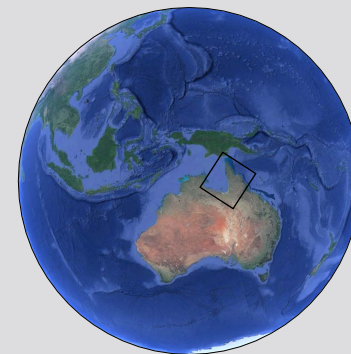
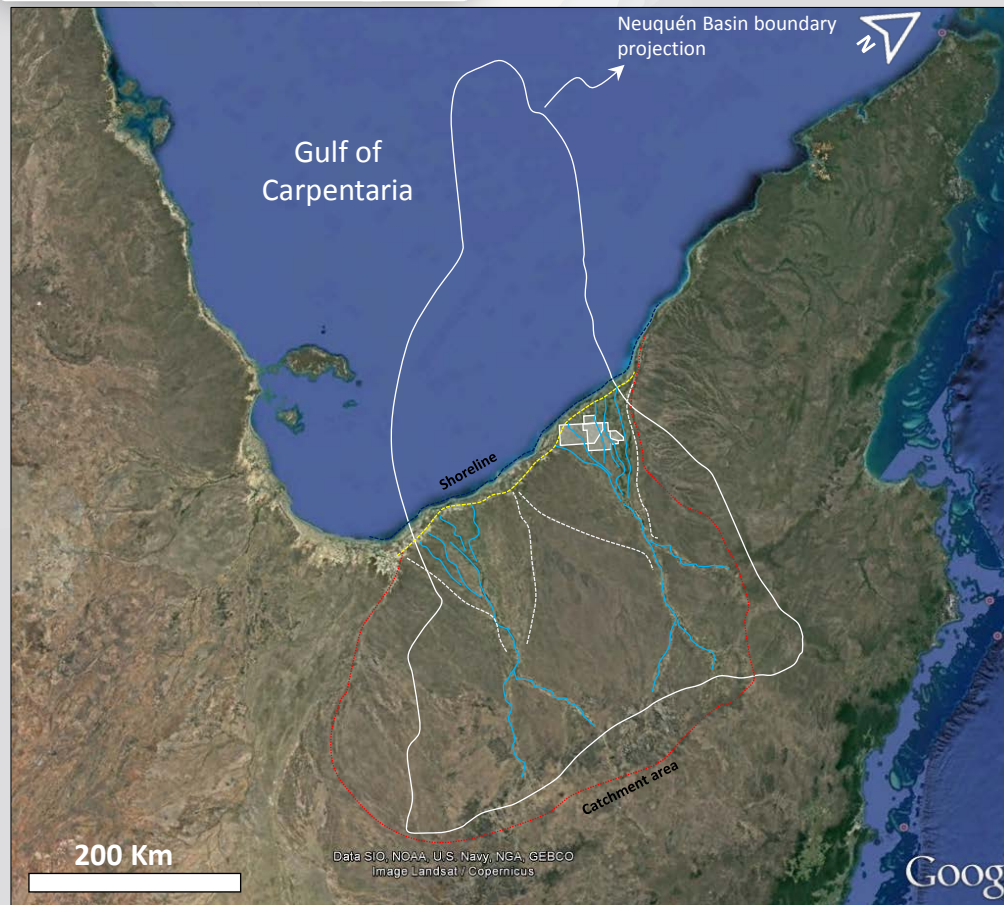
- Shingled geometries observed that could control the reservoir connectivity
- How is the rock heterogeneity distributed within the reservoir?

Reservoir geometry analysis



- Shingled geometries observed that could control the reservoir connectivity
- How is the rock heterogeneity distributed within the reservoir?

Scales in fluvial fan systems & analogies



➤ Scale of an analogue system vs. the study area

➤ What dip and lateral variation of depositional facies are expected?

Scales in fluvial fan systems & analogies

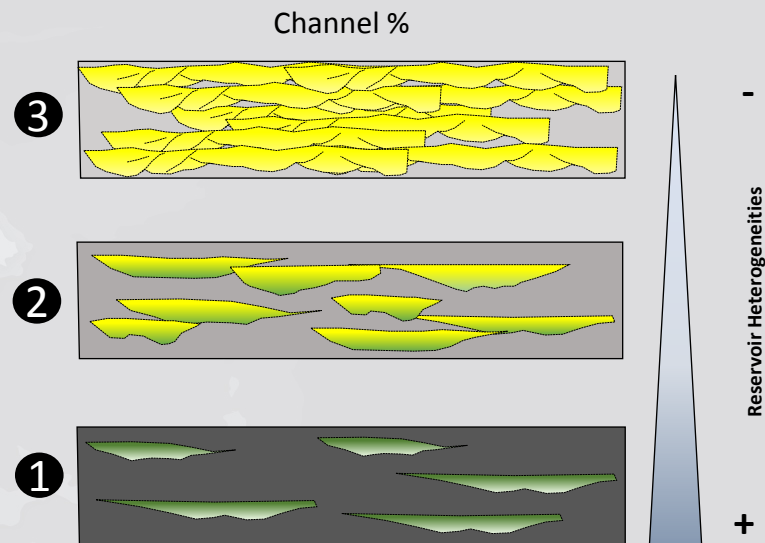
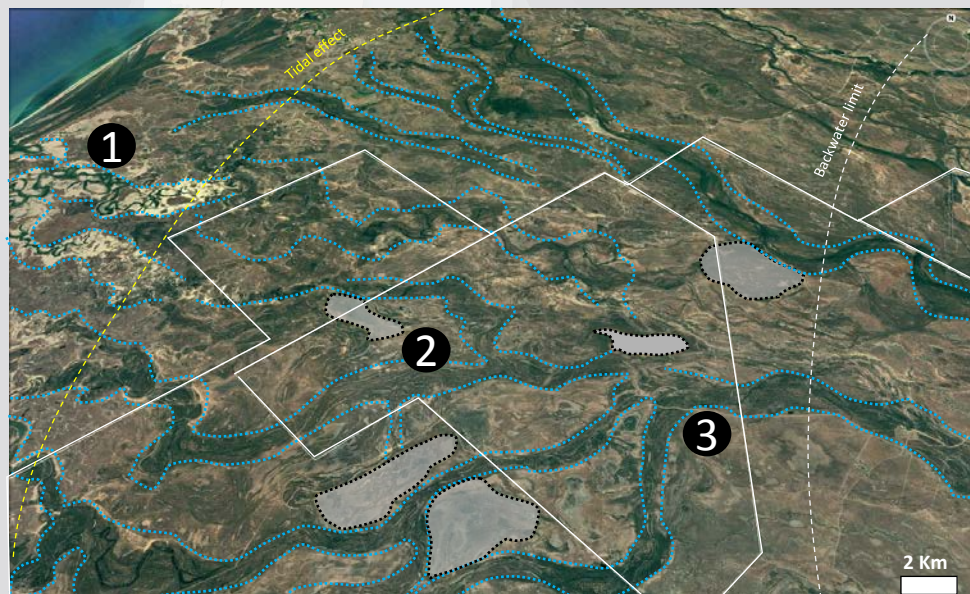


300km

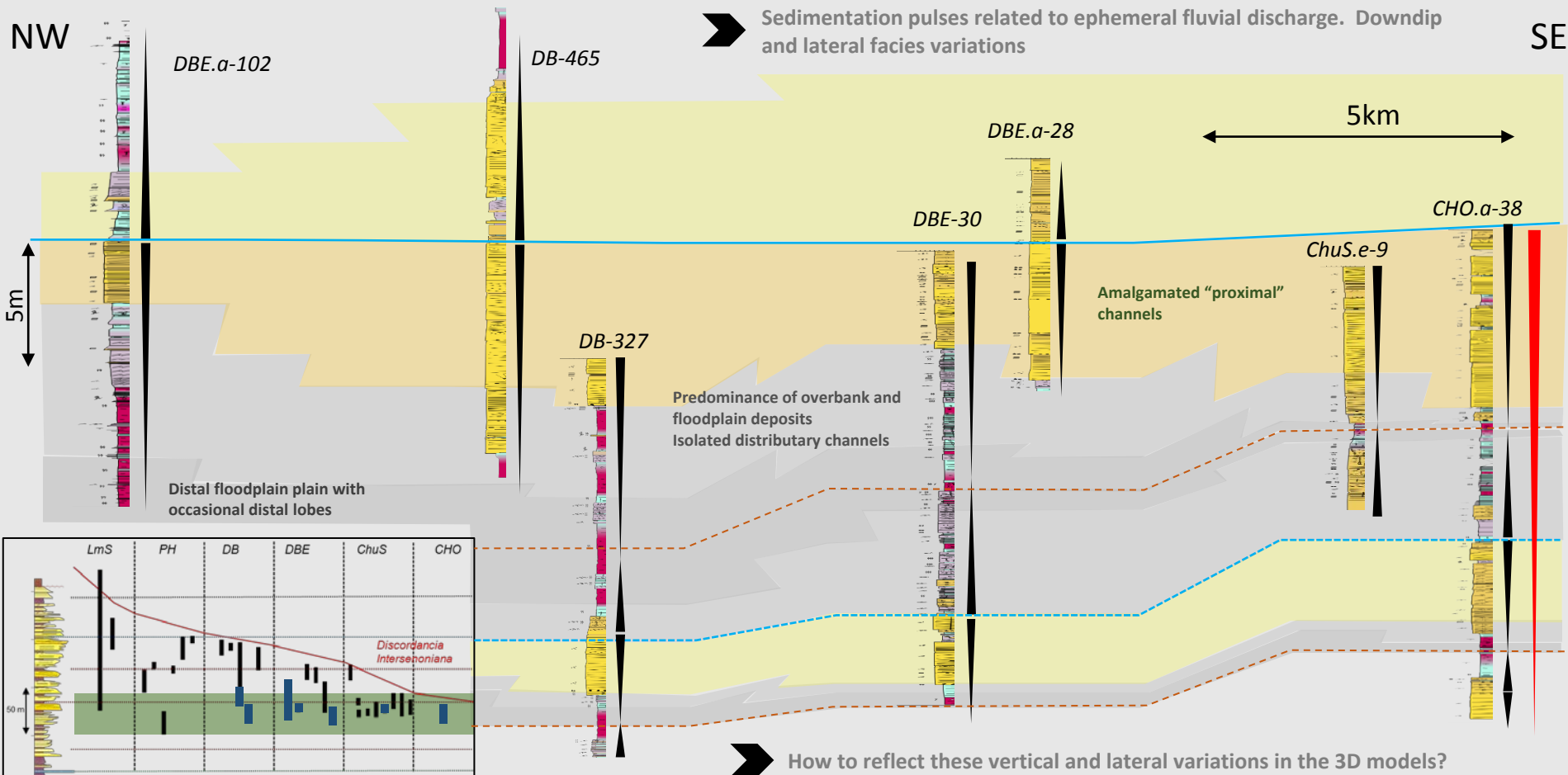
Scales in fluvial fan systems & analogies



Reservoir quality



Stratigraphic correlation of the Rayoso Fm.



Modelling with depositional elements

➤ Concept

VERTICAL
FACIES
RELATIONSHIPS

ELEMENTS =
"Geological bodies"



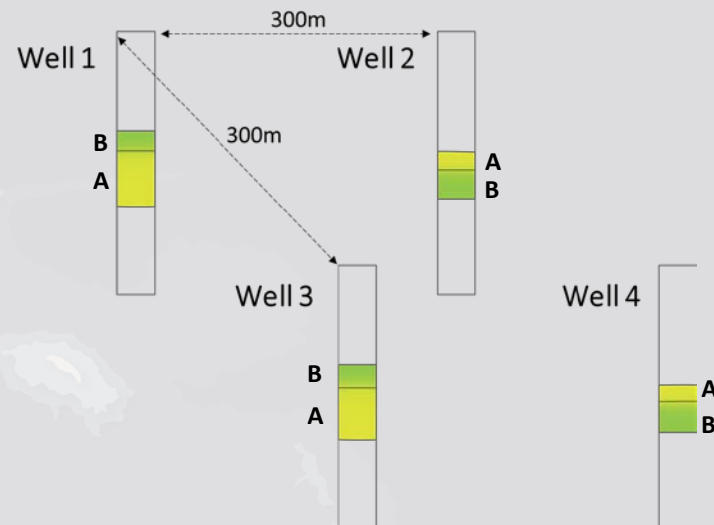
E.g. = channel



E.g. = lobe

Facies quality $A > B$

➤ Hypothetical scenario



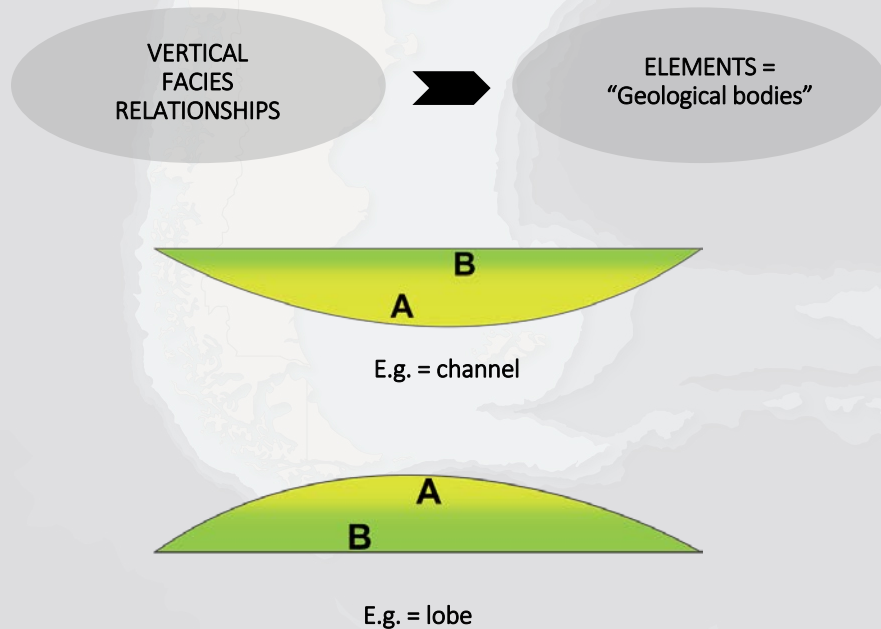
- Facies of 4 wells in a same sedimentary cycle



Facies distribution may be controlled by element geometry

Modelling with depositional elements

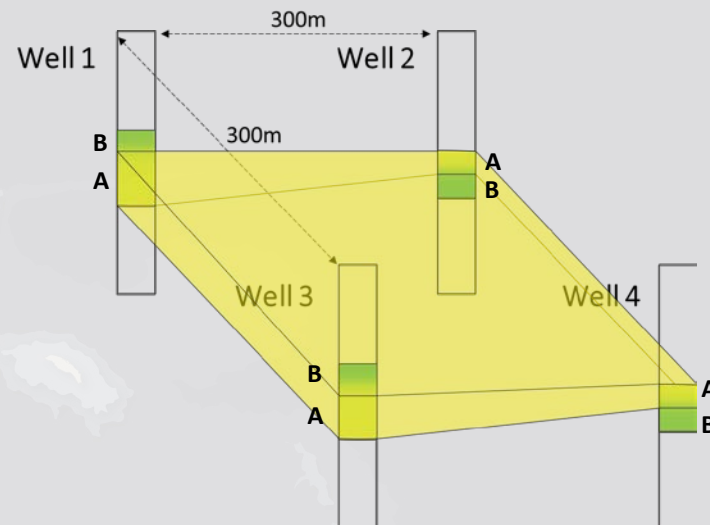
➤ Concept



Facies quality $A > B$

➤ Hypothetical scenario

- Connectivity between wells without Geological bodies: all **Facies A** will always connect between wells 1,2,3 and 4
- Overestimation of connectivity?



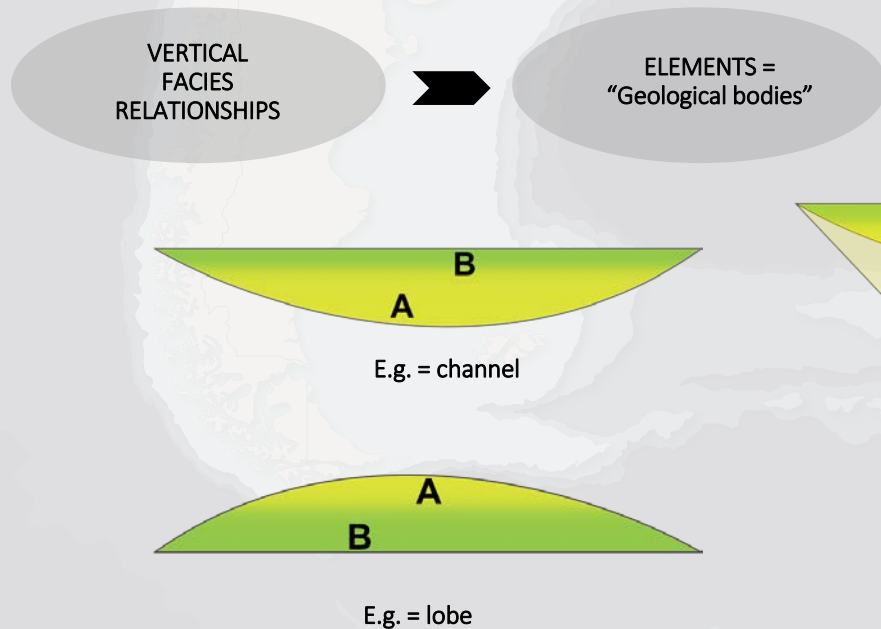
- Facies of 4 wells in a same sedimentary cycle



Facies distribution may be controlled by element geometry

Modelling with depositional elements

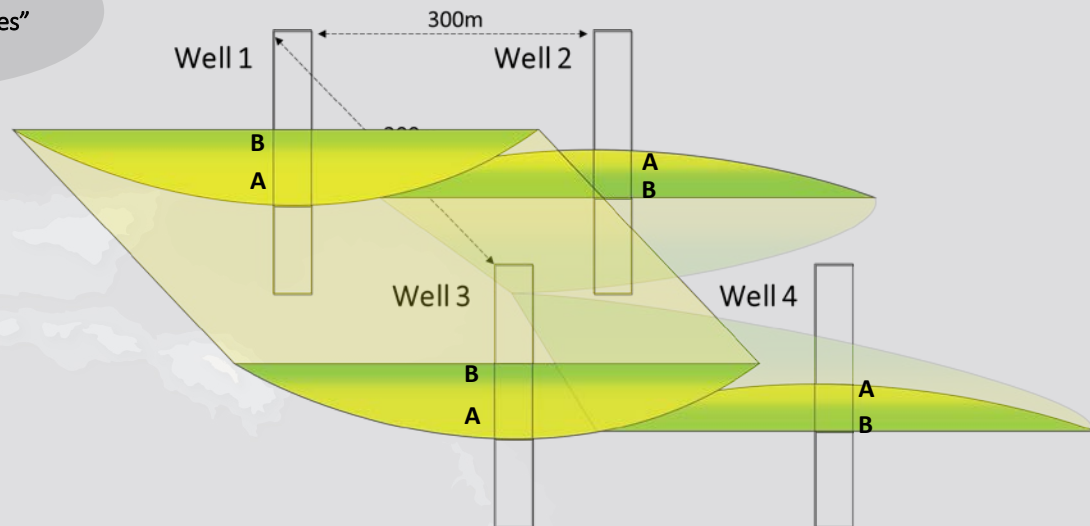
➤ Concept



Facies quality $A > B$

➤ Hypothetical scenario

- Stacking pattern observed in wells 1,2,3,4 suggest different geological Elements (I.e. channel, Lobe)
- How connectivity would change?



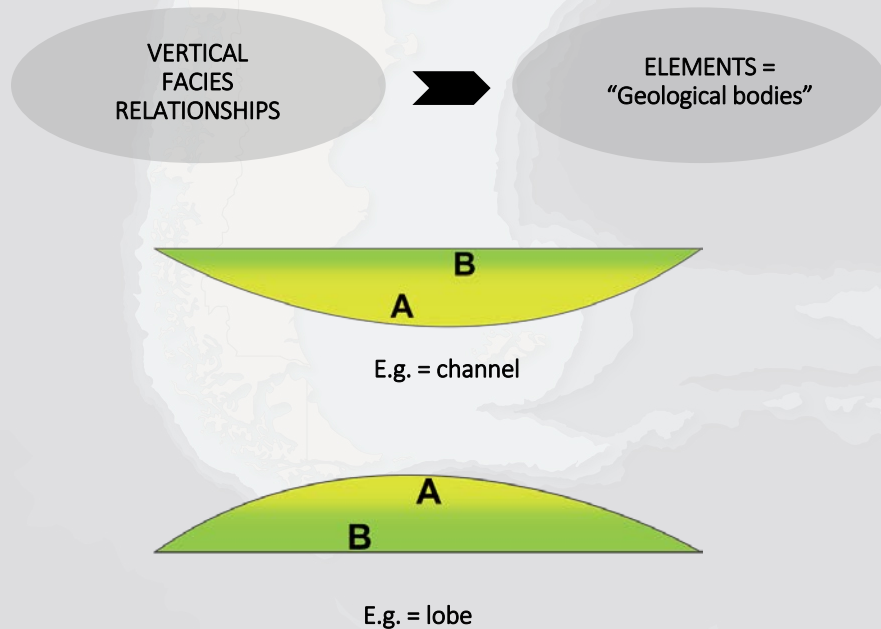
- Facies of 4 wells in a same sedimentary cycle



Facies distribution may be controlled by element geometry

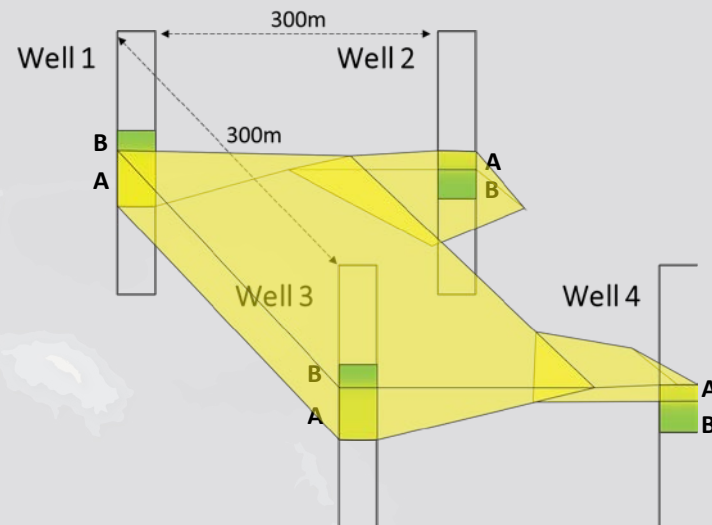
Modelling with depositional elements

➤ Concept



➤ Hypothetical scenario

- Stacking pattern observed in wells 1,2,3,4 suggest different geological Elements (I.e. channel, Lobe)
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- Facies of 4 wells in a same sedimentary cycle

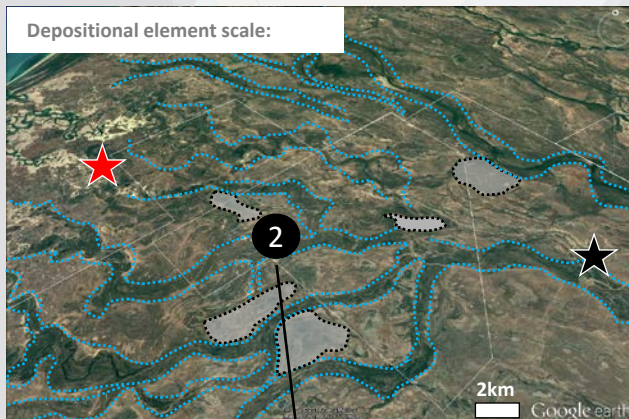


Facies distribution may be controlled by element geometry

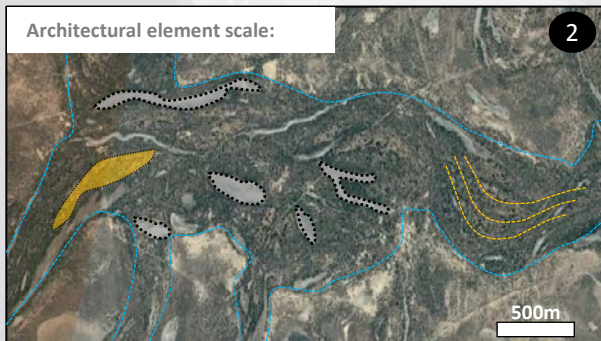
Modelling with depositional elements

Analysis of the FAKTS database

Depositional element scale:

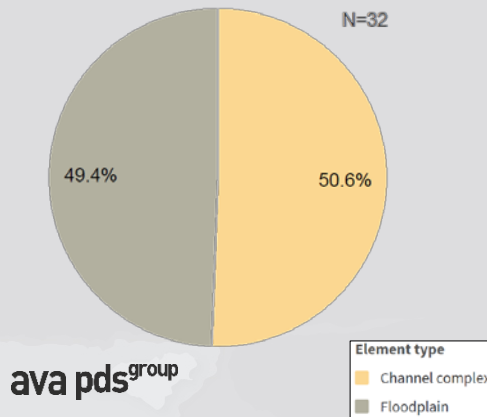


Architectural element scale:

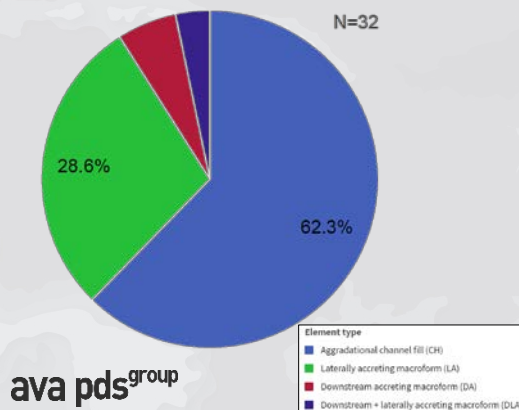


Colombero et al. 2012 (FAKTS) and Ava Clastics PDS.

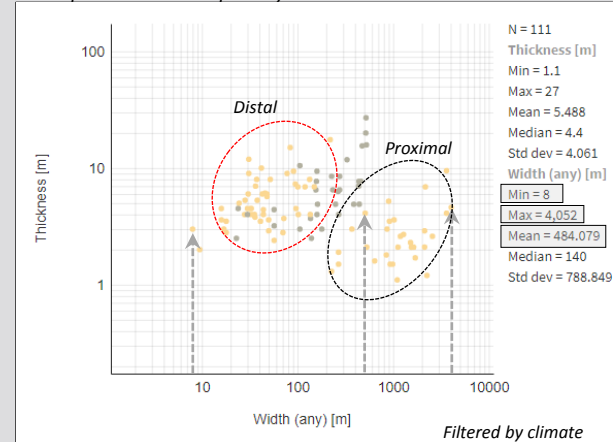
Element proportions chart



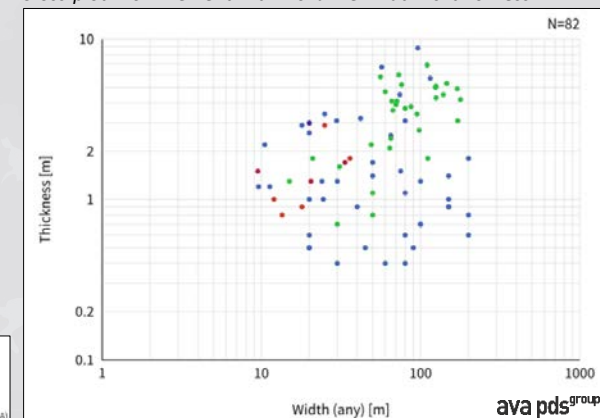
Element proportions chart



Cross-plot channel complex style: width vs. thickness

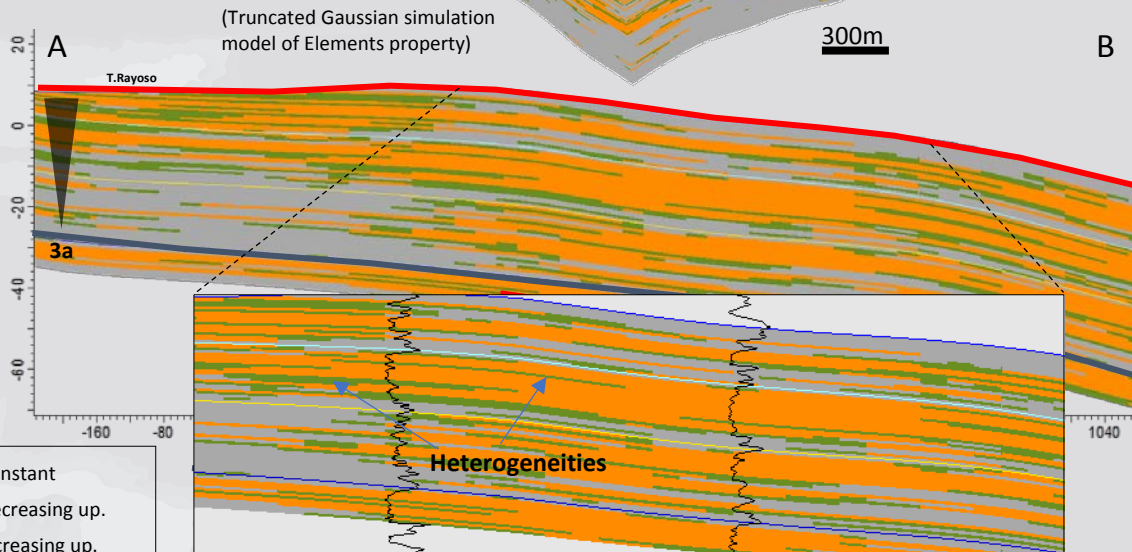
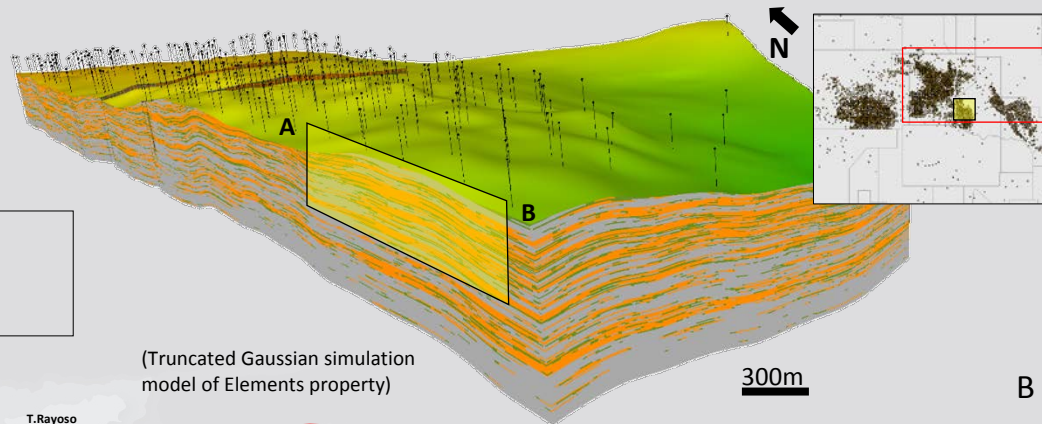
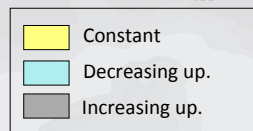
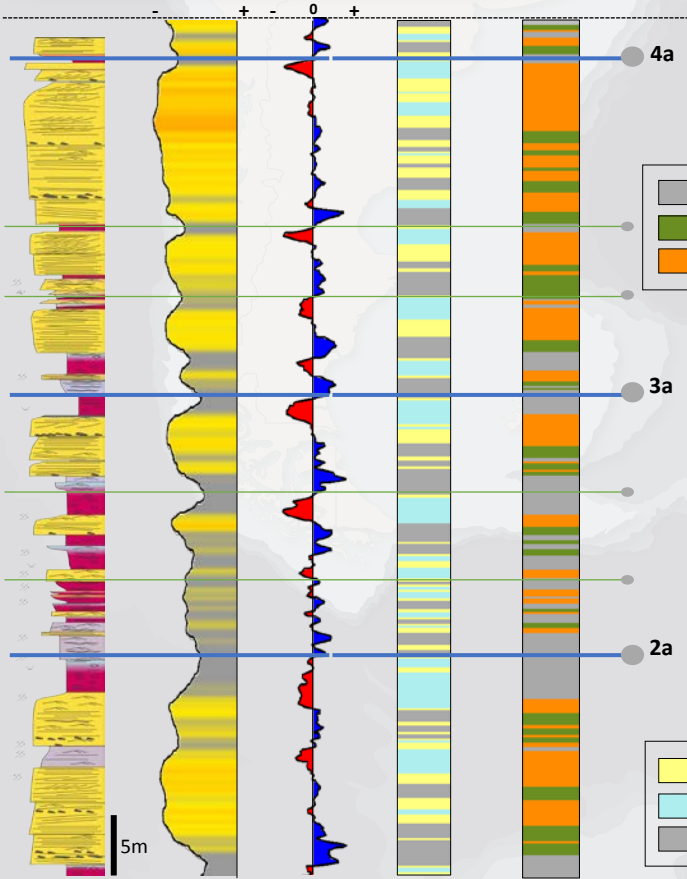


Cross-plot Arch. Element within channel width vs. thickness



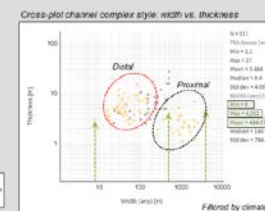
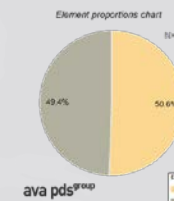
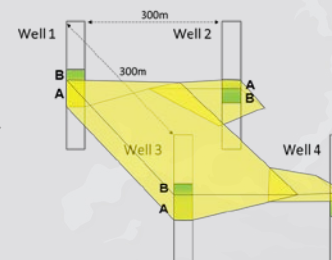
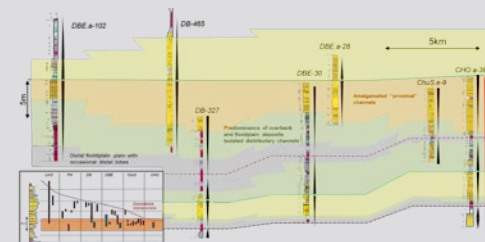
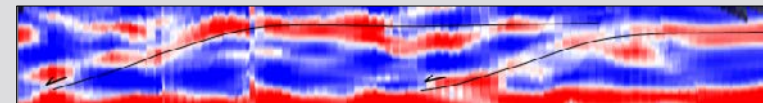
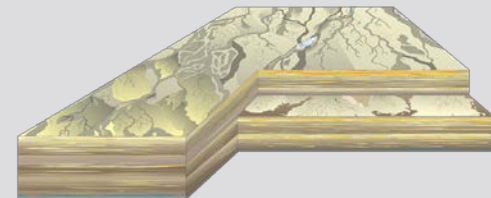
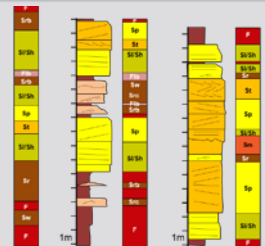
Modelling with depositional elements

Core GRstH Der Trends Elements (Trends+Vsh)



Summary-conclusions

- Based on detailed stratigraphic analysis and well data we characterized the internal architecture of fluvial fan sequence
- This reservoir architecture will control the **reservoir connectivity and consequently fluid distribution**
- We analysed the lateral and vertical distribution of the geological elements in such a fan system based on analogue data
- Following these concepts, 3D models of these elements at depositional scale help to represent the **reservoir heterogeneities** critical para EOR projects
- Ongoing work: model elements using MPS, build porosity/permeability relationships for each elements and dynamic model to test the effect of the heterogeneities on fluid distribution





Thank you!

Special thank: José Luis Massaferro (EOR Team, YPF S.A), Alejandro Saccomano (YPF S.A), PDS Group and ERG-FRG group (Univ. Leeds)