Stratigraphic Architecture of Incised Valleys and Unincised Channel Systems in the Carbonera Formation (C6-C1 Members: Upper Oligocene - Lower Miocene), Llanos Basin, Colombia*

Hugo Roberto Caycedo Garcia[1] and Octavian Catuneanu[2]

Search and Discovery Article #51666 (2020)**
Posted May 25, 2020

*Adapted from oral presentation given at 2019 International Conference and Exhibition, Buenos Aires, Argentina, August 27-30, 2019
**Datapages © 2020 Serial rights given by author. For all other rights contact author directly. DOI:10.1306/51666Garcia2020

[1]Hocol S.A., Bogota, Columbia (caycedog@ualberta.ca)
[2]Department of Earth and Atmospheric Sciences and Department of Physics, University of Alberta, Edmonton, Alberta, Canada

Abstract

This work presents a sequence stratigraphic framework for the Upper Oligocene - Lower Miocene C6-C1 members of the Carbonera Formation in the Llanos Basin, Colombia. In the interval corresponding to the C5 member, facies associations that comprise middle shoreface, tidal channels and bars, tidal flat deposits, brackish bay, tidal-fluvial channels, and central estuary have been identified through the integration of core descriptions and wireline logs. The vertical assemblage of the recognized facies associations permits the definition of several cycles of transgression and regression, as well as episodes of relative sea-level fall and their consequent fluvial incision. Basinward shifts of facies, lateral changes in well-log motifs, and seismic amplitude anomalies allow the interpretation of incised-valley systems overlying deposits associated with marginal and shallow marine environments, which also present channelized sand bodies. Consequently, the sedimentary and stratigraphic architecture is composed of an interspersed set of channels with different genetic origins and contrasting potentials in terms of petroleum production. Maximum flooding surfaces, subaerial unconformities, and transgressive ravinement surfaces are the significant stratigraphic surfaces identified, which separate progradational and retrogradational stages and define sequence boundaries. In addition to the C5 member, a sequence stratigraphic model for the interval corresponding to the C6-C1 members of the Carbonera Formation is presented based on cuttings, well-log stacking patterns, and interpretation of 3D seismic horizon and time slices. In total, nine regressive-transgressive cycles (i.e., genetic stratigraphic sequences) are interpreted for the interval studied. The proposed stratigraphic framework relates oil occurrences and currently producing intervals with stratigraphic surfaces and permits a consistent classification of the petrophysical properties, establishing several families that are genetically related. The sedimentological descriptions of the Carbonera C5 member and the proposed sequence stratigraphic model highlight the marine influence in the deposition of the Carbonera Formation. Furthermore, this work emphasizes the role of relative sea-level fluctuations in deposition and erosion in coastal areas during tectonically active periods in the foreland Llanos Basin.

References Cited

Barrero, D., A. Pardo, C.A. Vargas, and J.F. Martínez, 2007, Colombian Sedimentary Basins: Nomenclature, Boundaries and Petroleum Geology, A New Proposal: Agencia Nacional de Hidrocarburos, 92 p.

Garcia, H.R.C., and O. Catuneanu, 2019, Stratigraphic Architecture of Incised Valleys and Unincised Channel Systems in the Carbonera Formation (C6-C1 Members: Upper Oligocene – Lower Miocene), Llanos Basin, Colombia: Journal of Geodynamics, v. 129, p. 202-218. doi.org/10.1016/j.jog.2018.01.011

Moreno, C.J., B.K. Horton, V.M. Caballero, and A. Mora, 2011, Depositional and Provenance Record of the Paleogene Transition from Foreland to Hinterland Basin Evolution During Andean Orogenesis, Northern Middle Magdalena Valley Basin, Colombia: Journal of South American Earth Sciences, v. 32, p. 246-263. doi:10.1016/j.jsames.2011.03.018

Stratigraphic Architecture of Incised Valleys and Unincised Channel Systems in the Carbonera Formation (C6-C1 Members: Upper Oligocene - Lower Miocene), Llanos Basin, Colombia

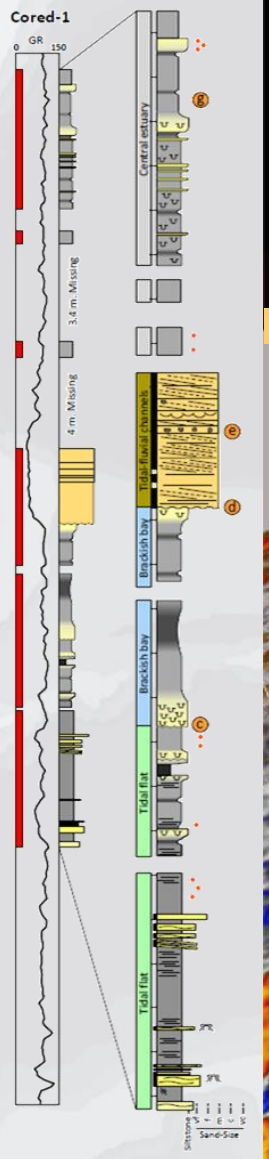
Hugo Roberto Caycedo Garcia[1] and Octavian Catuneanu[2]

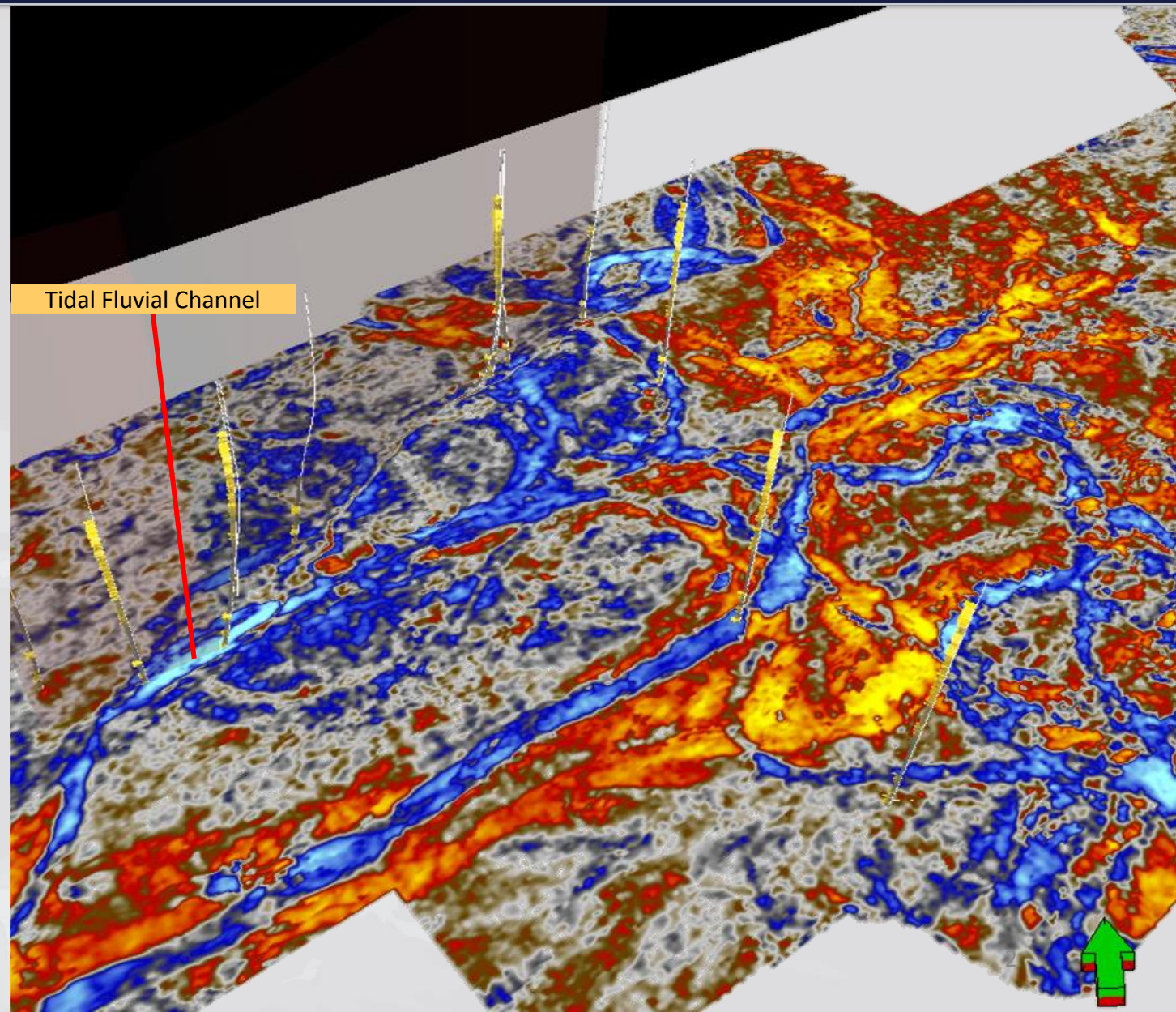
[1]Hocol S.A.
[2]Department of Earth and Atmospheric Sciences and Department of Physics, University of Alberta

Incised and Unincised systems

The vertical assembly of the facies association interpreted in several cores of the **C5 member** of the Carbonera formation, allows the interpretation of **incised-valley systems** overlying deposits associated with **marginal and shallow marine environments**, which also present channelized sand bodies.

Consequently, the sedimentary and stratigraphic architecture is composed of an **interspersed set of channels with different genetic origins** and contrasting potentials in terms of petroleum production.



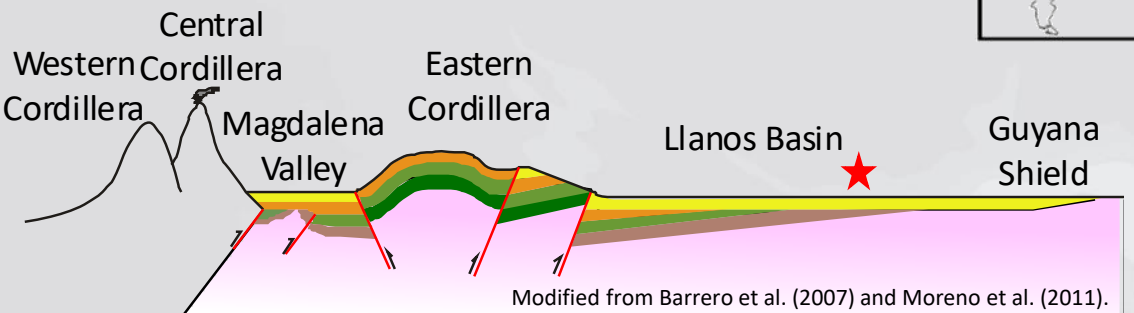


Time slice MFS C4 +28 ms

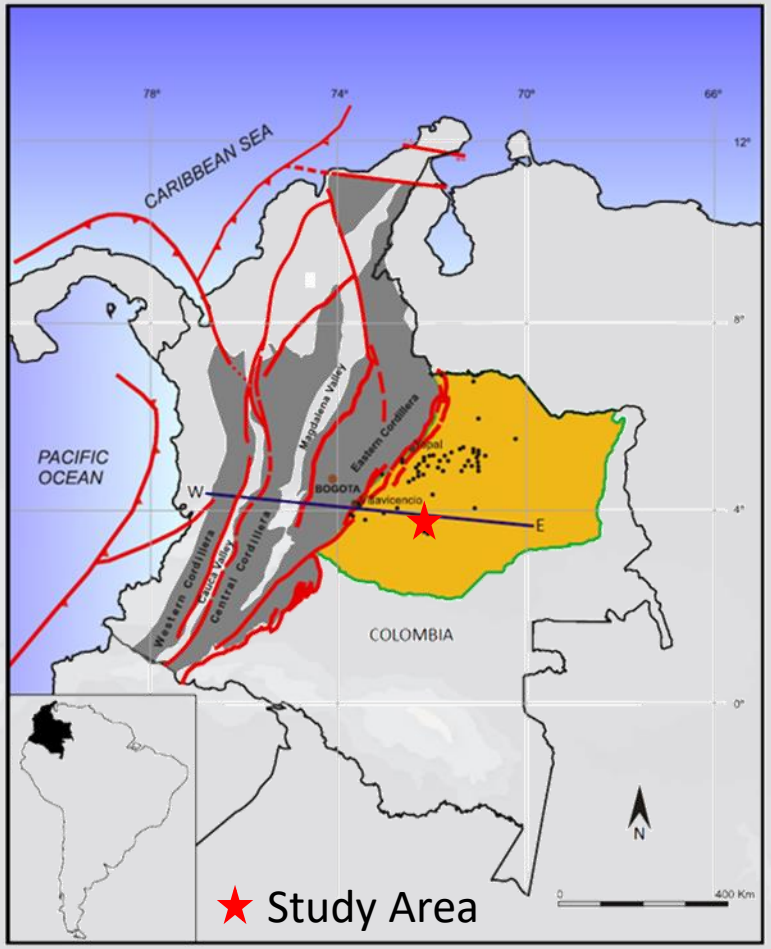
Geological Settings

The Llanos basin is the most prolific basin in Colombia. This foreland system has major oil accumulations associated with the structural traps in the orogenic front, as well as structural and stratigraphic traps in the foredeep portion.

- Cretaceous-Early Eocene contractional deformation
- Middle Eocene tectonic quiescence
- Late Eocene to Pleistocene/Holocene abrupt shortening and exhumation.

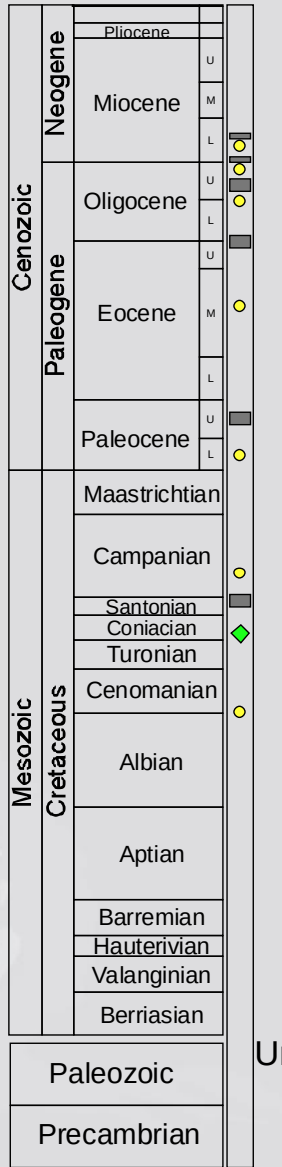


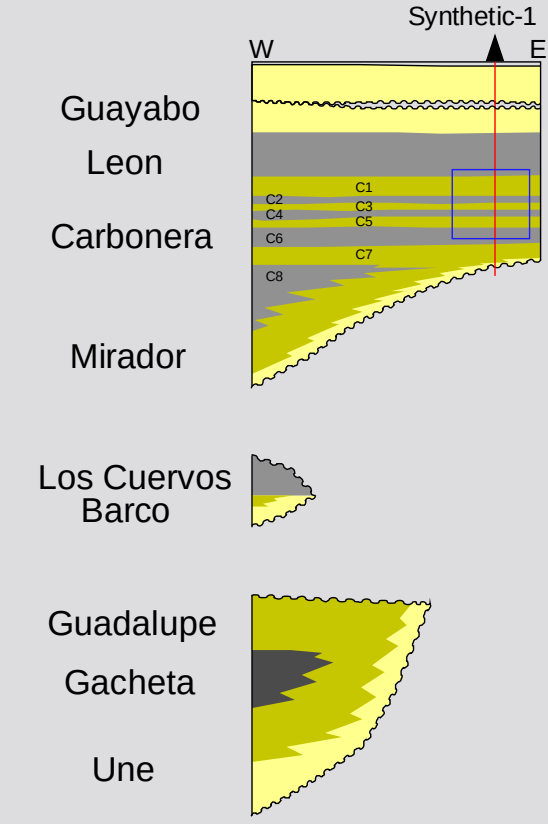
Modified from Barrero et al. (2007) and Moreno et al. (2011).

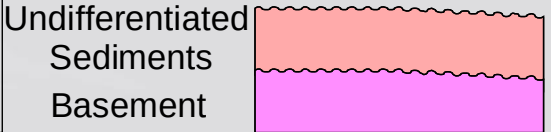


Continental Sandstones
Transitional Sandstones
Transitional Mudstones
Marine Shales
Undifferentiated Paleozoic Rocks
Precambrian Granitic Basement

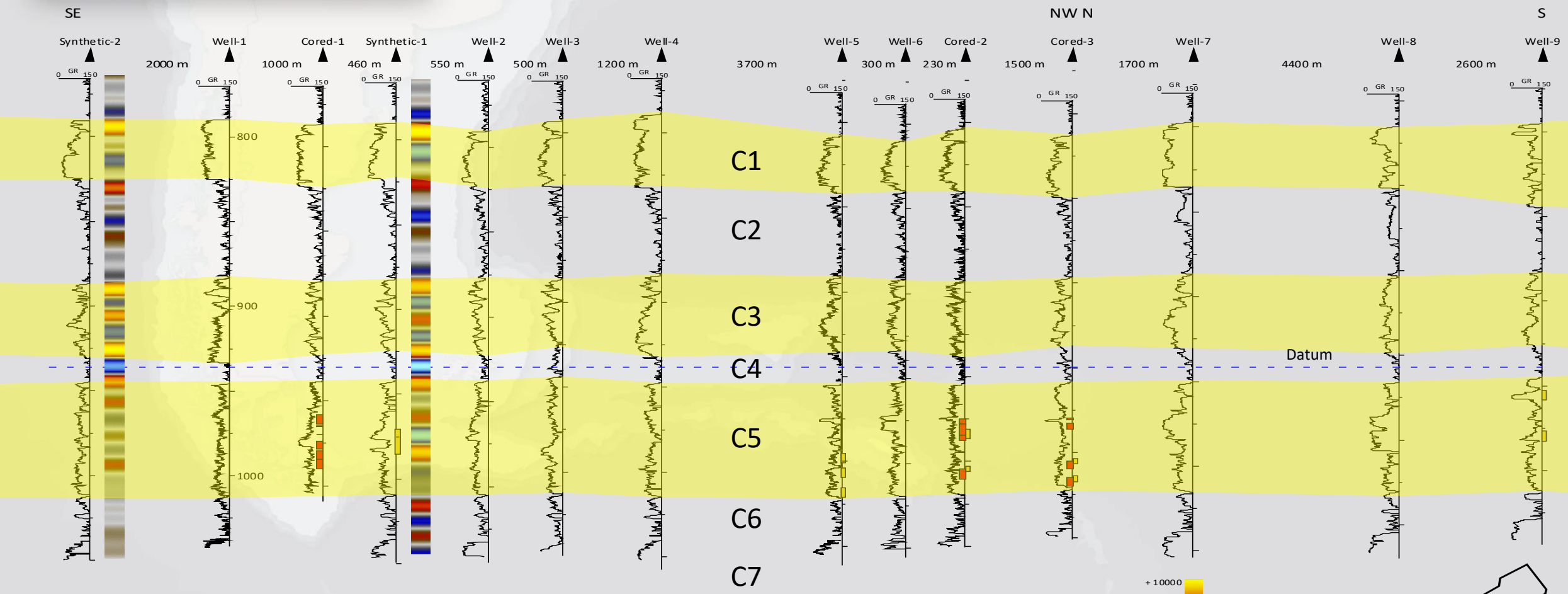
Seal
Reservoir
Source Rock







The Carbonera Formation

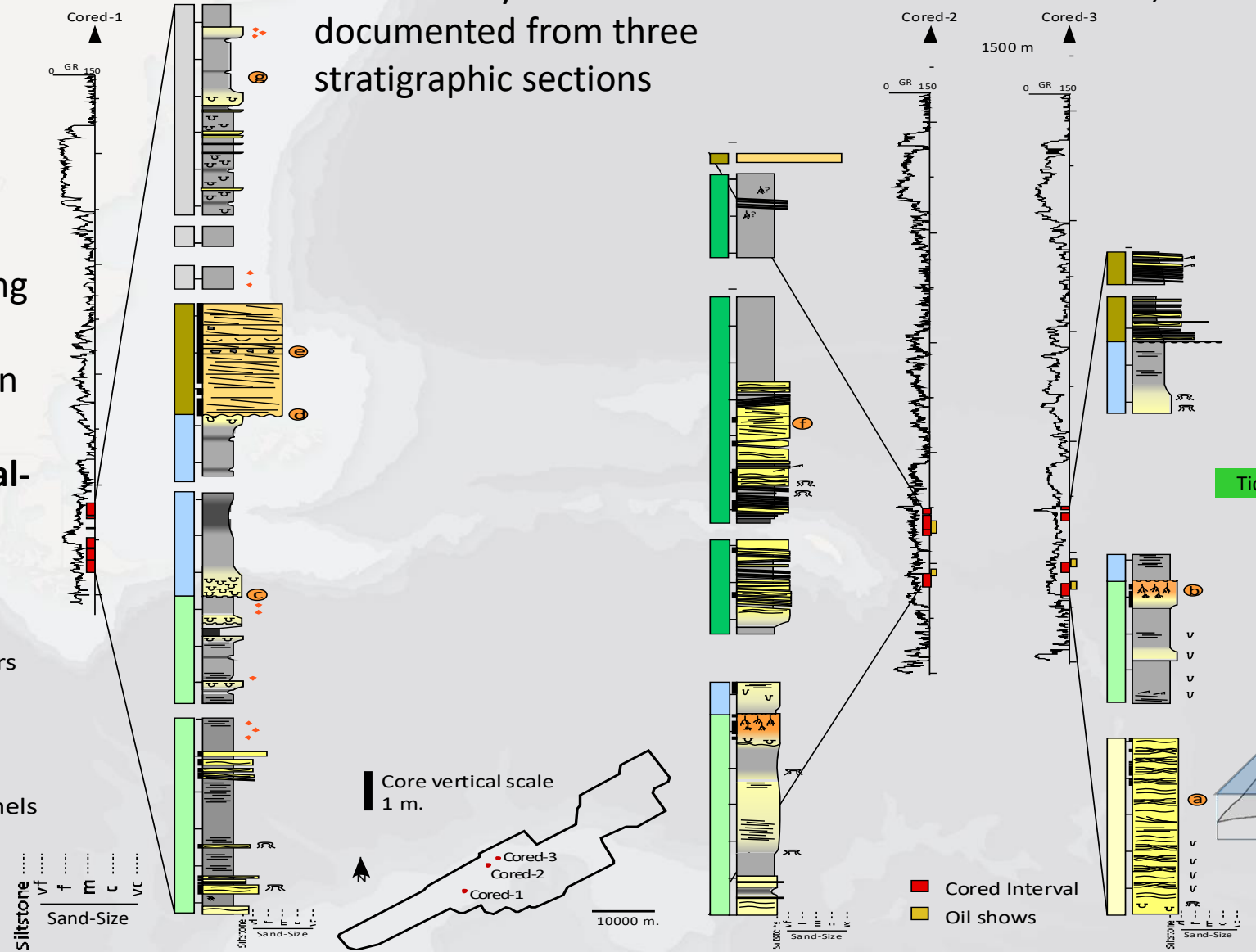


The Carbonera Formation has been litologically subdivided into 8 informal units with **odd numbers referring to sandstones** and **even numbers assigned to mudstones**.

The Carbonera Formation - Sedimentology

Sedimentary characteristics of the interval described, were documented from three stratigraphic sections

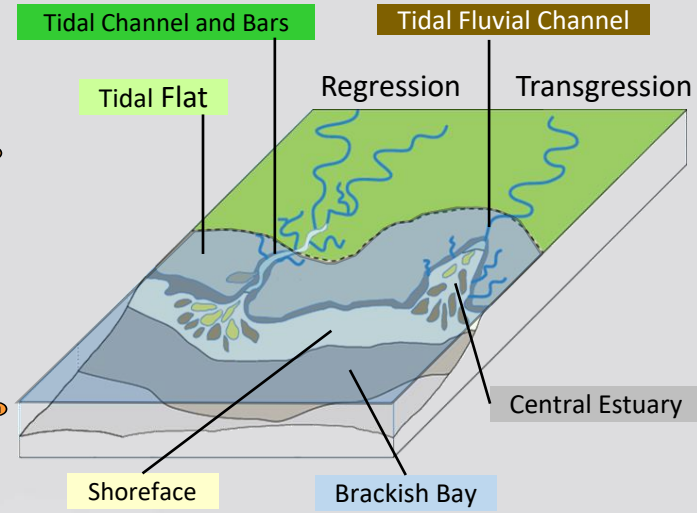
The vertical stacking of facies indicates **marine influence** in the sedimentation punctuated by **tidal-fluvial processes**



- Massive mudstone
- Laminated mudstone
- Inclined heterolithic sandstone
- Massive sandstone
- Sandstone with wavy lamination
- Compound cross-stratified sandstone
- Low-angle laminated sandstone
- Ripple cross-laminated sandstone
- Sandstone hummocky and swaley
- Trough cross-stratified sandstone
- Horizontally laminated sandstone
- Paleosol

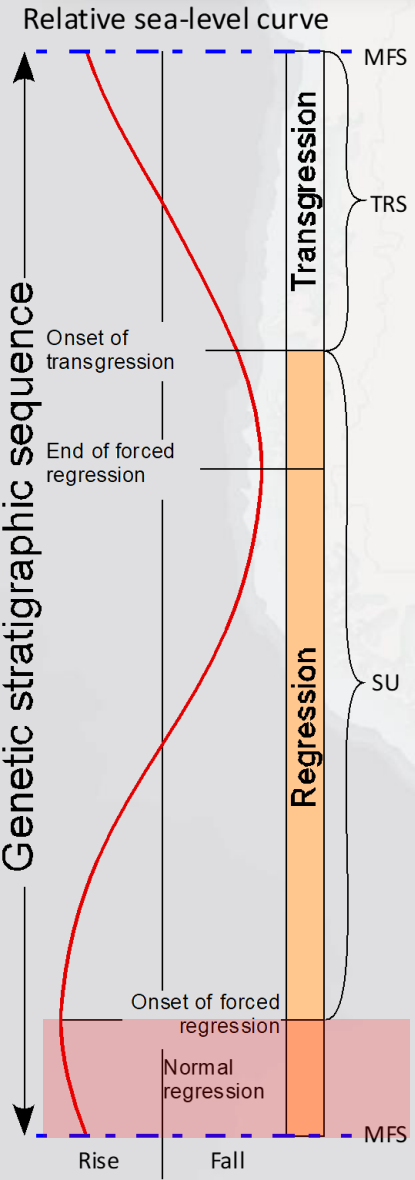
- Siderite nodules
- Synaeresis cracks
- Convolute bedding
- Burrows and bioturbation
- Rip-up clast
- Mud drapes and mud lamination

- Tidal channels-bars
- Tidal flat
- Shoreface
- Tidal-fluvial channels
- Central estuary
- Brackish bay

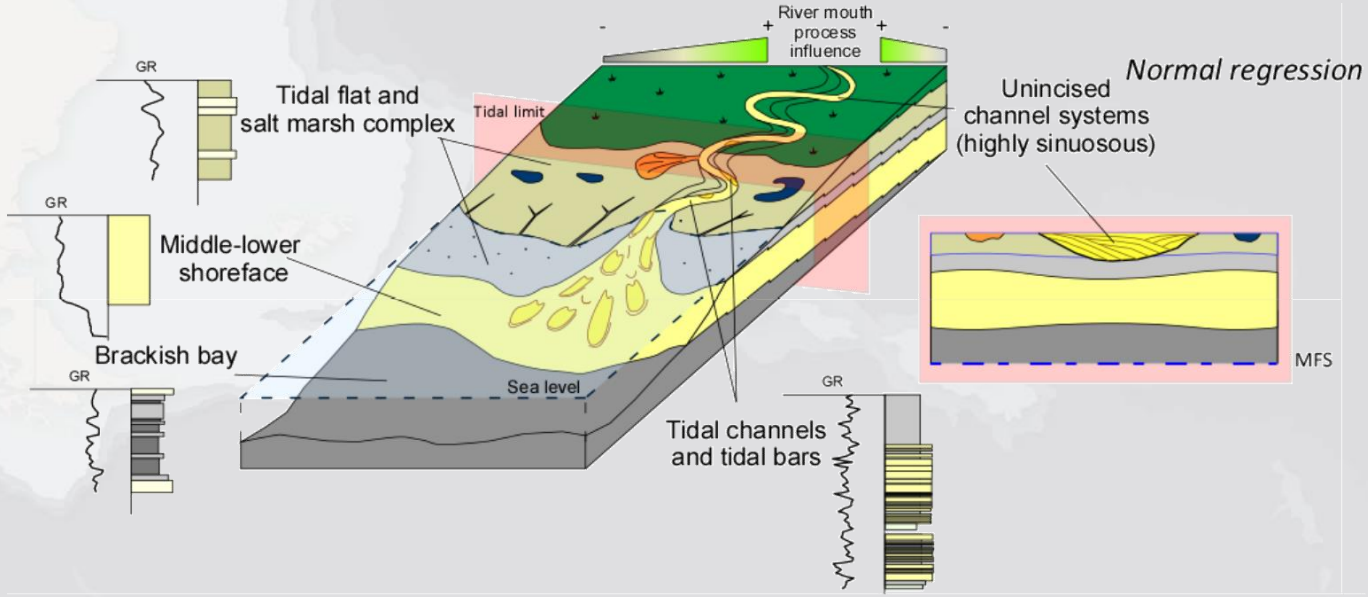


Regressive stage

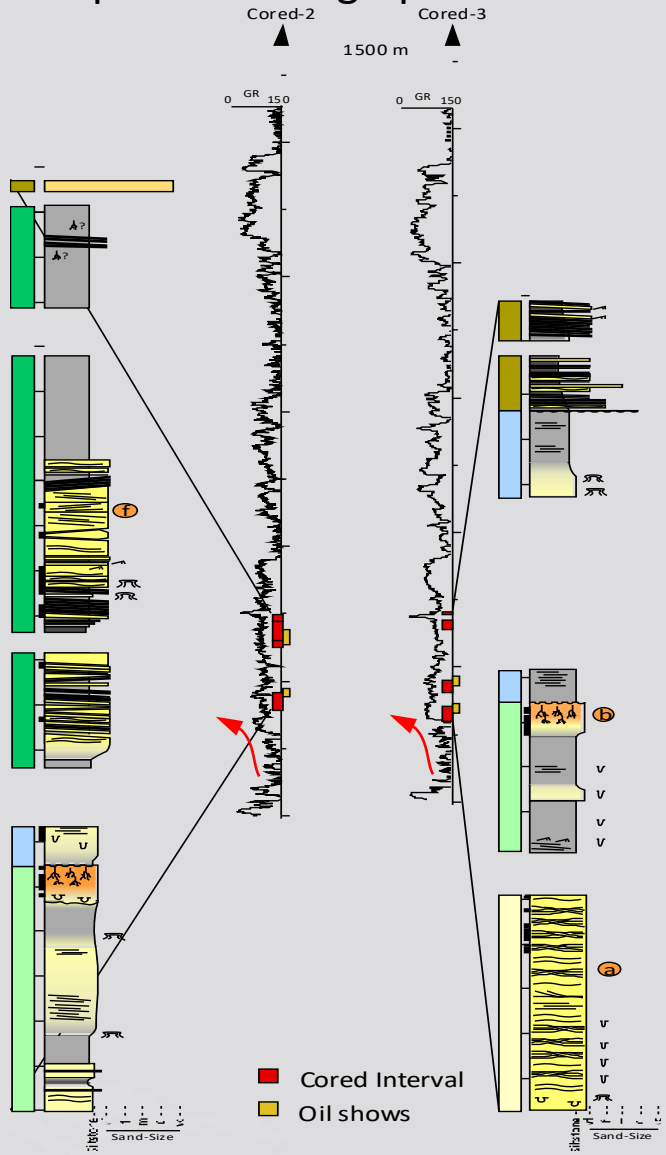
The availability of core data permits to illustrate a schematic sequence-stratigraphic behavior of all the identified genetic sequences



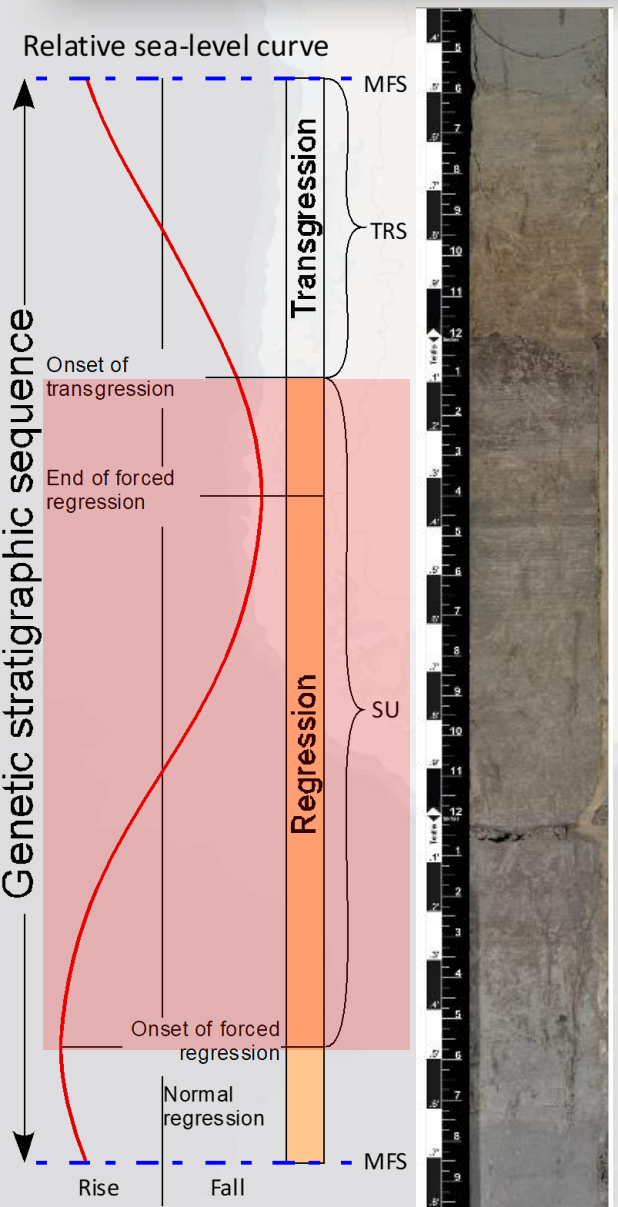
Normal regression is represented by **prograding wave-and storm-dominated shoreface** environments capped at top by **tidal flats** that indicates the transition from shallow marine to coastal systems



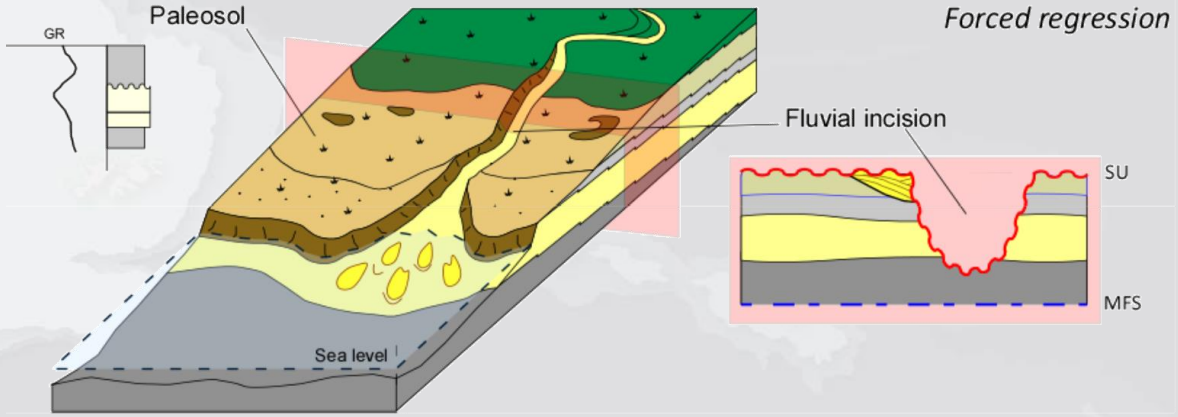
In zones of high influence of mouth river processes, IHS represents highly sinuous channelized-forms interpreted as **unincised distributary tidal channels** framed in a deltaic context influenced by tides



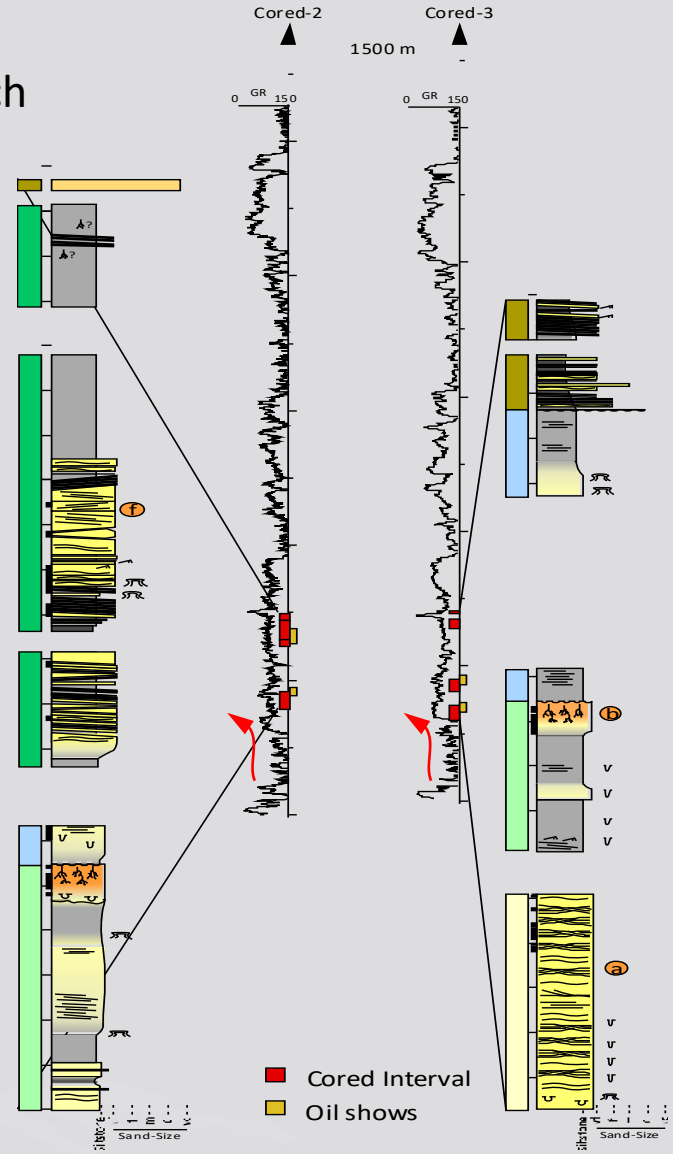
Regressive stage



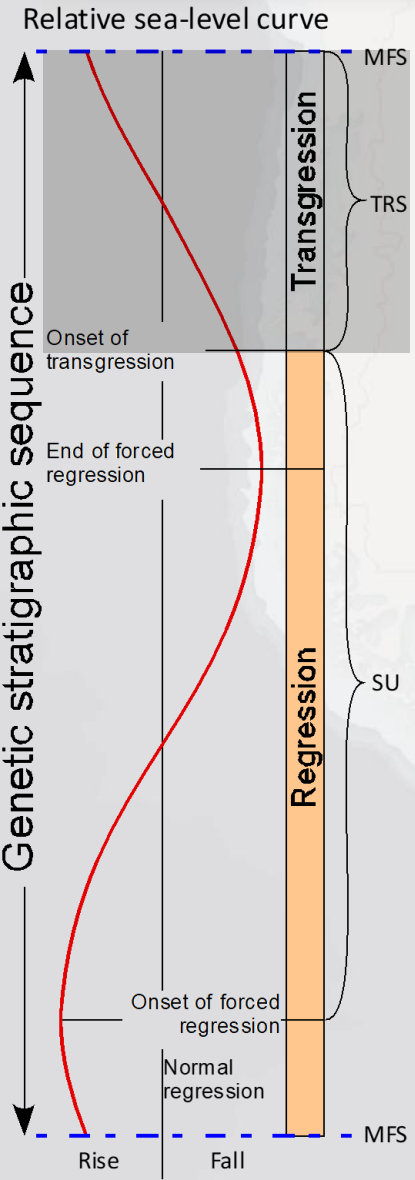
The top of the tidal flat deposits is capped by a **paleosol**, which indicates periods of subaerial exposure and non-deposition



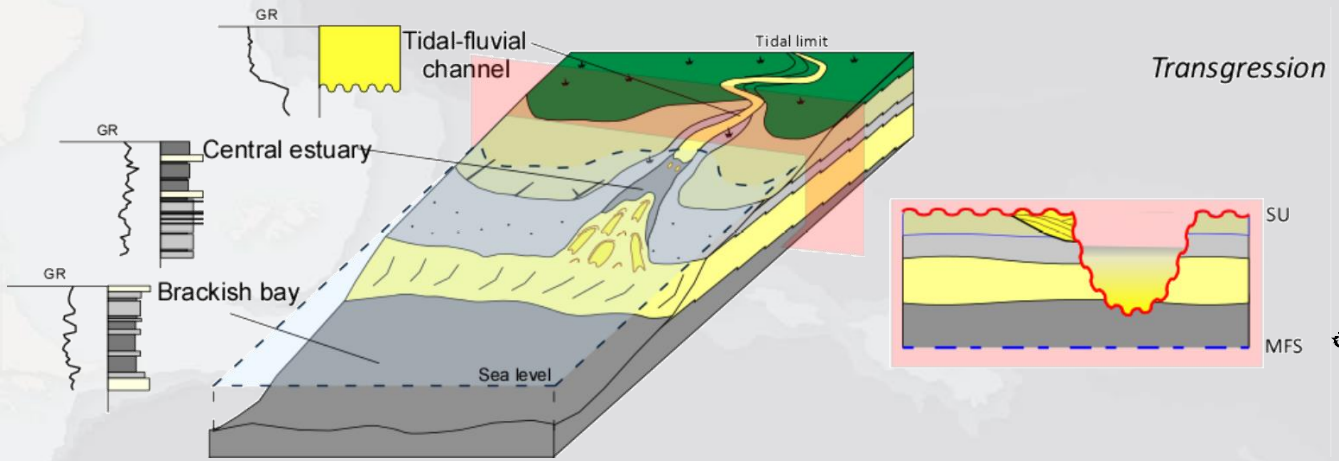
In zones of high influence of mouth river processes, the relative sea-level fall that accompanied the forced regressive stage is represented by the **incision** of the underlying strata

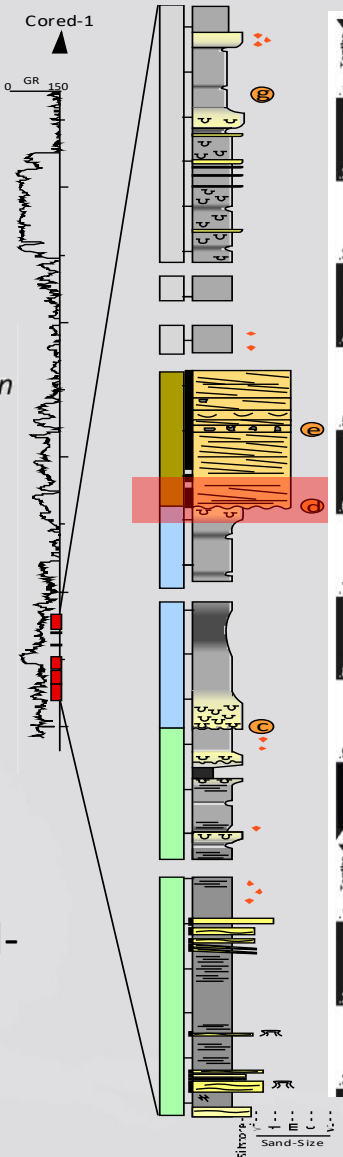


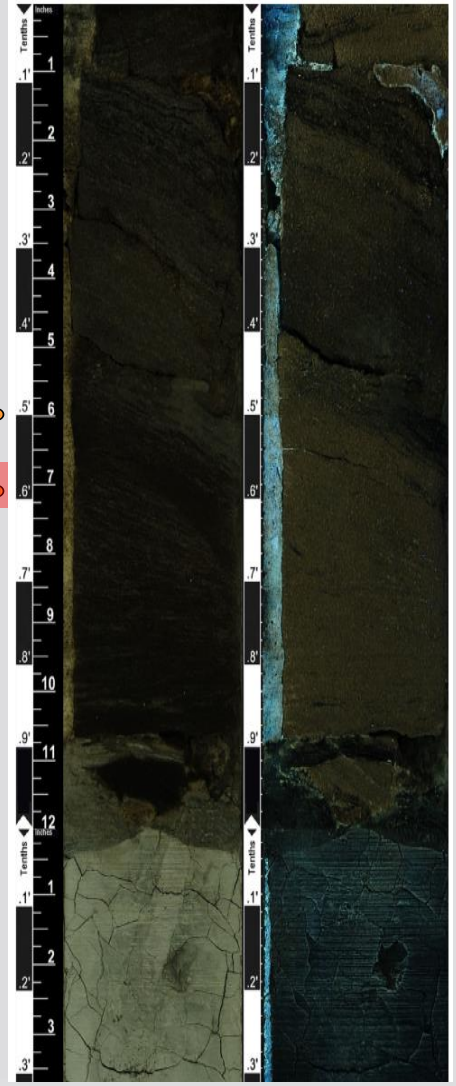
Transgressive stage



The accommodation created was subsequently filled by fluvial-estuarine deposits corresponding to the tidal-fluvial, tidal channels and central estuary facies associations

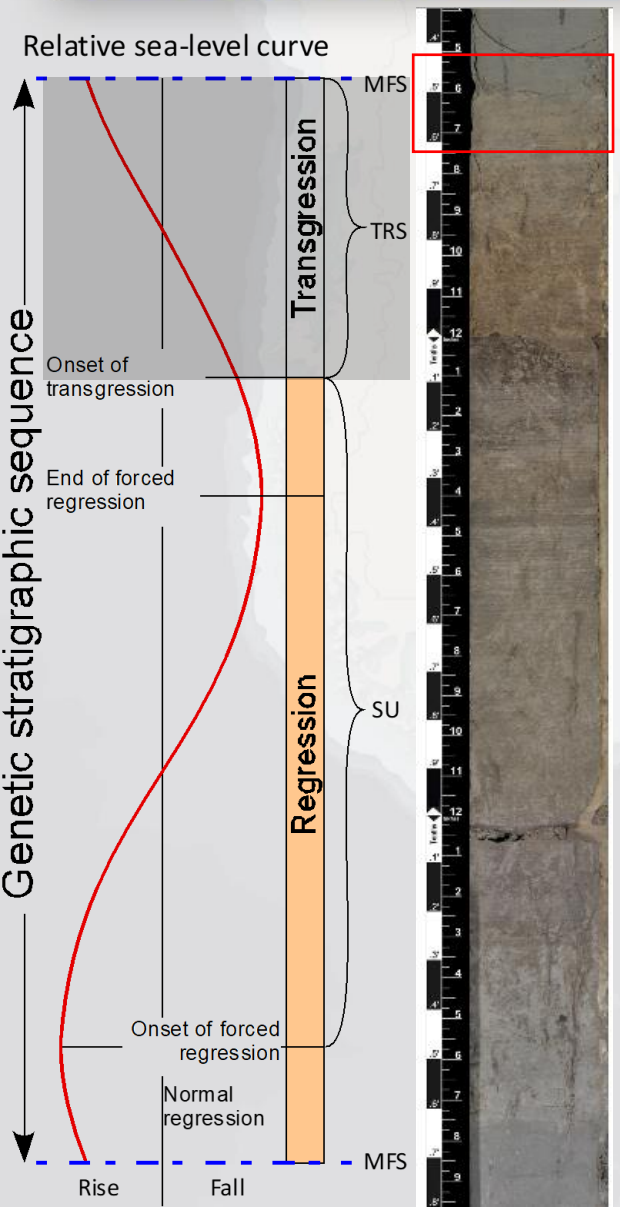




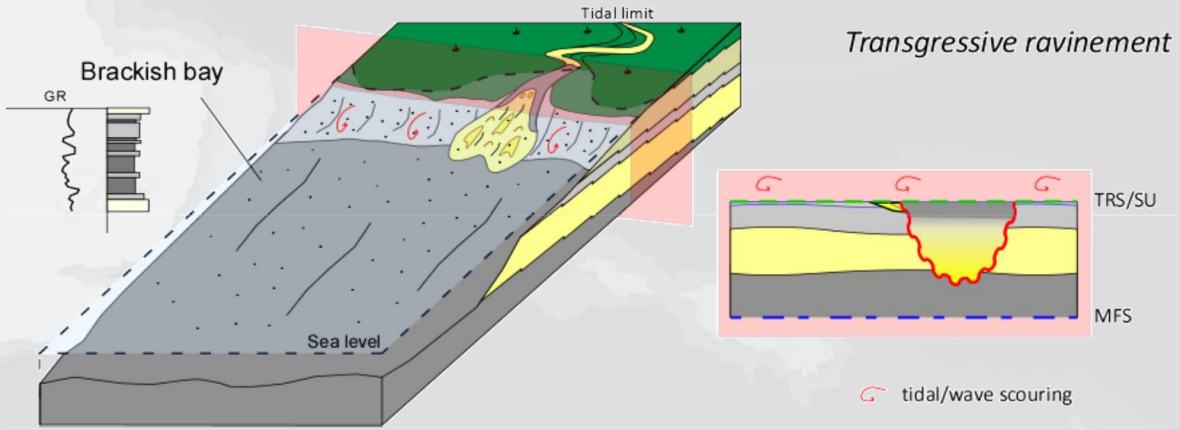


A **basinward shift of facies**, is recognized by the juxtaposition of tidal-fluvial channels over brackish bay water deposits

Transgressive stage

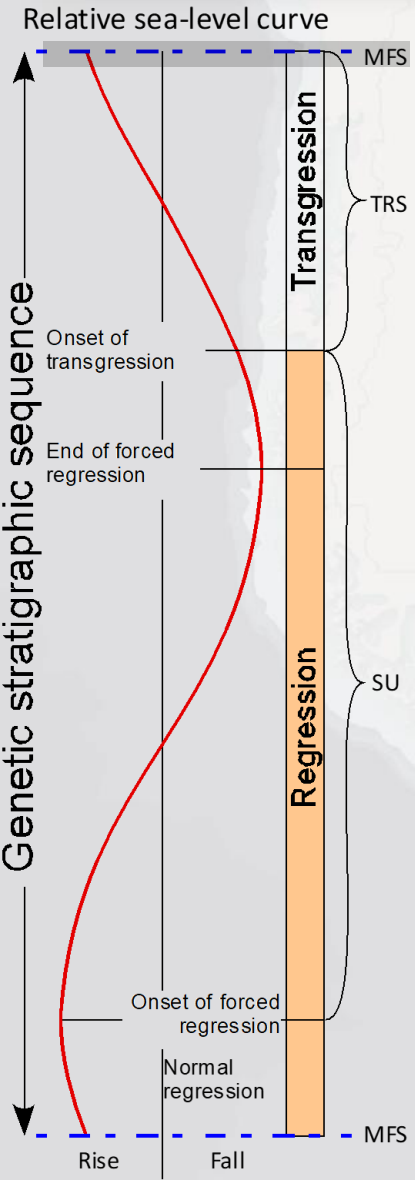


In areas with low influence of river mouth processes, paleosols are topped by a **scour surface** which marks a period of coastal erosion caused by a transgressive stage

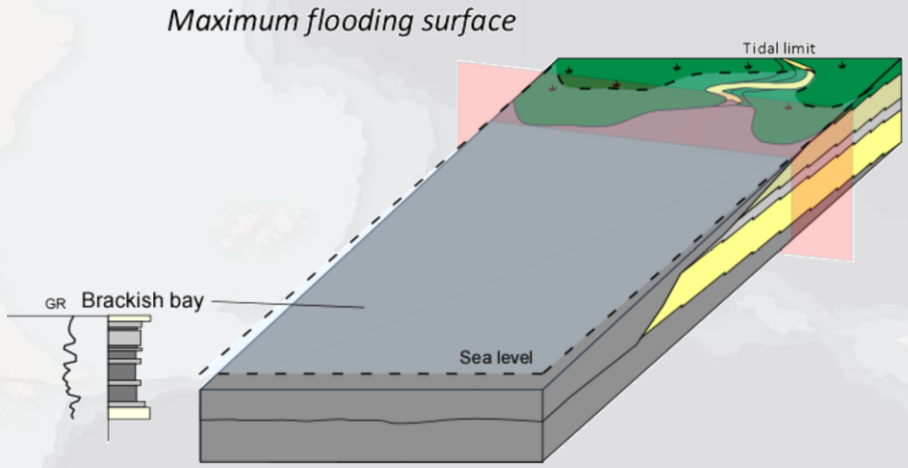


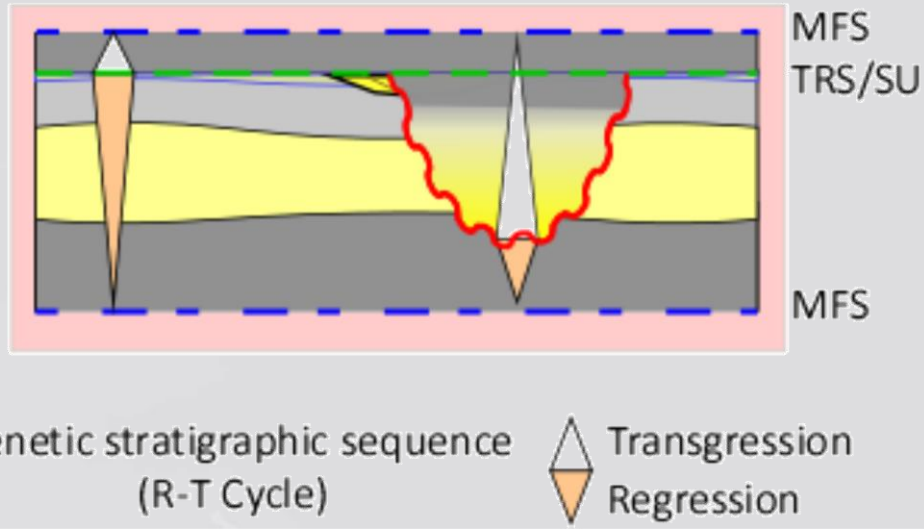
The unconformable contact between the paleosol below and brackish bay deposits above, corresponds to a **transgressive ravinement surface (TRS) reworking and replacing the subaerial unconformity (TRS/SU)**

Transgressive stage



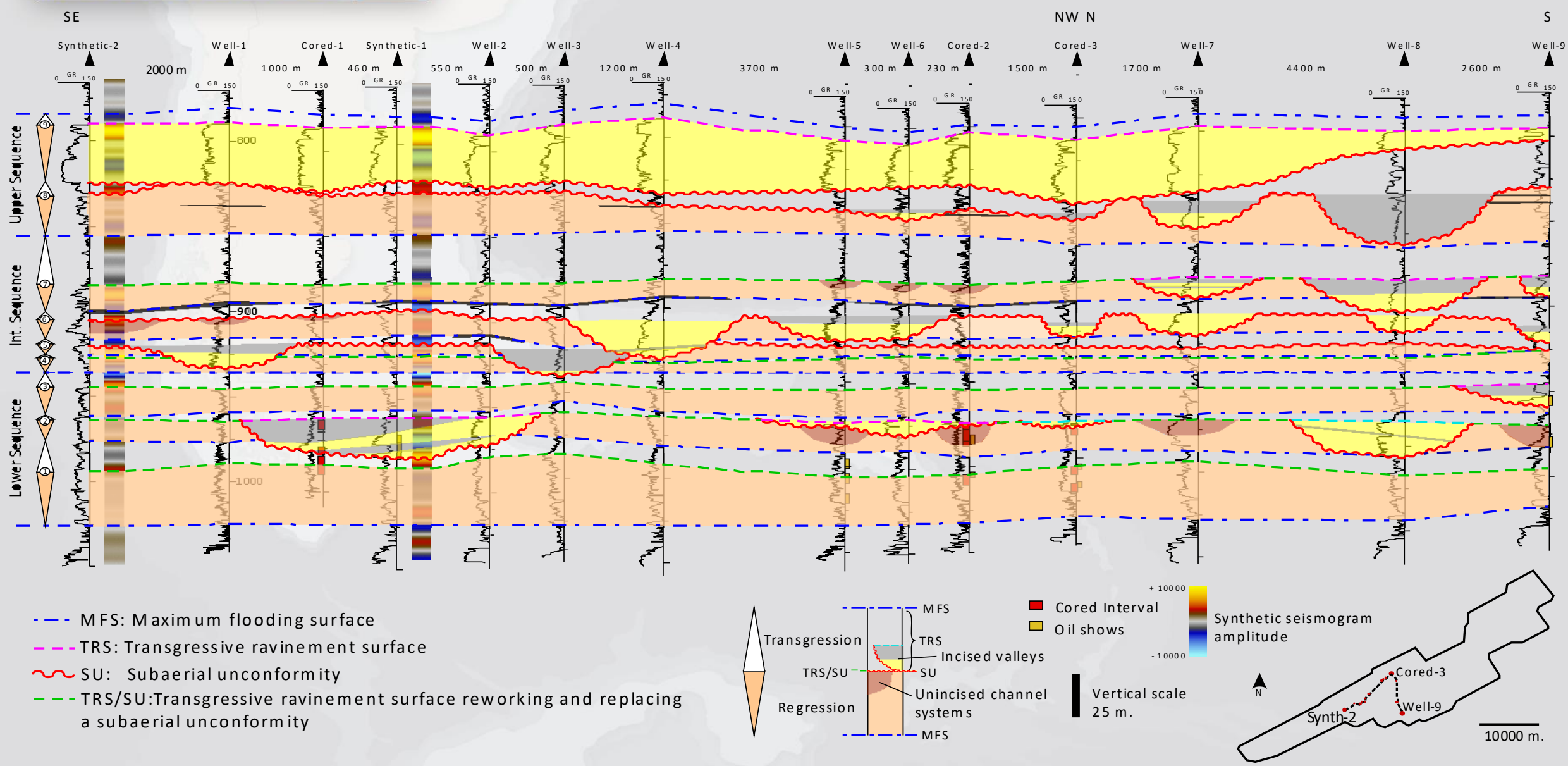
At the top, a MFS is indicated by extensive coal beds, maximum peaks of gamma ray and a change in the stacking pattern that can be traced in most of the wells correlated .



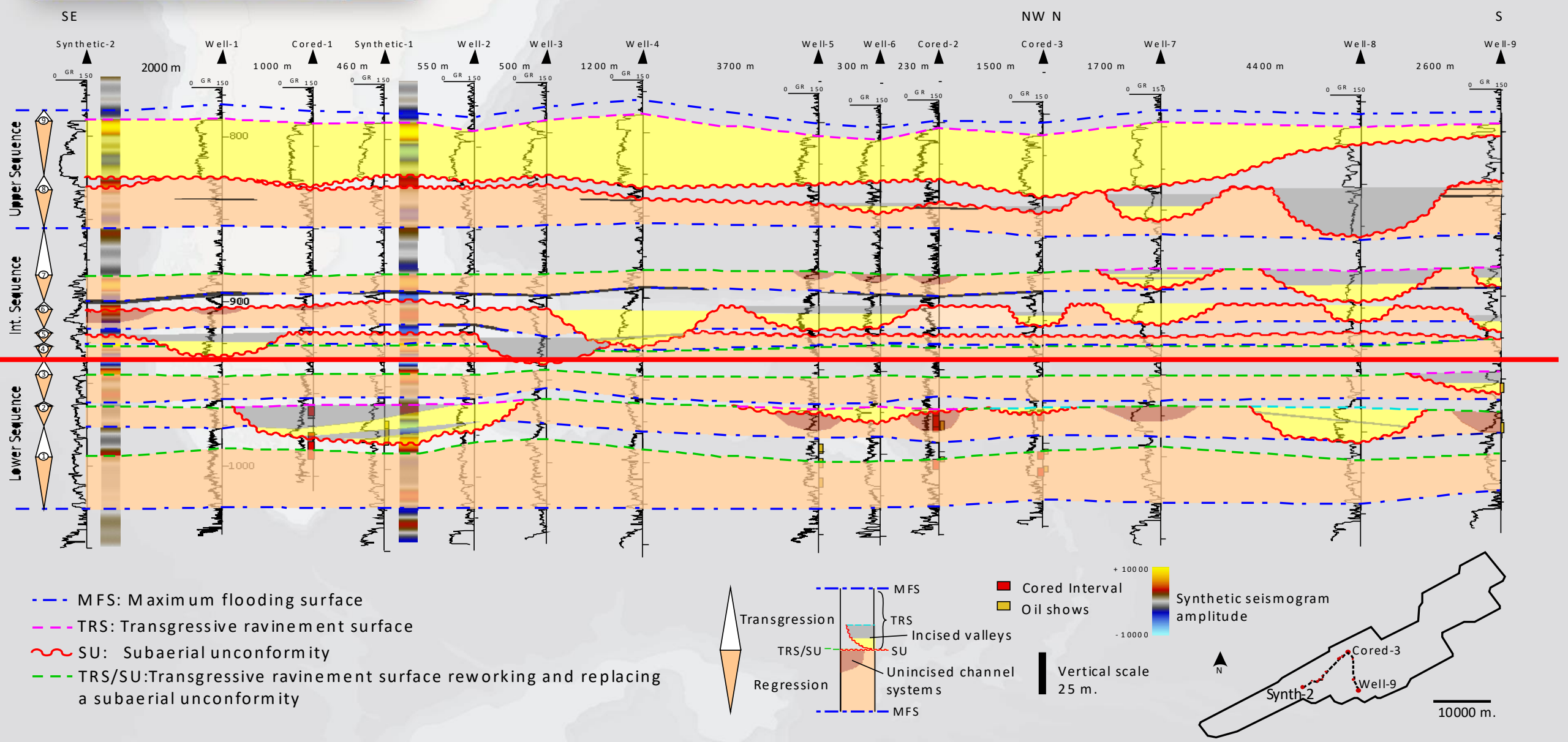


The persistent tidal influence within the sand bodies located above the subaerial unconformity permit the interpretation that the genetic stratigraphic sequences identified are composed only of transgressive and highstand system tracts

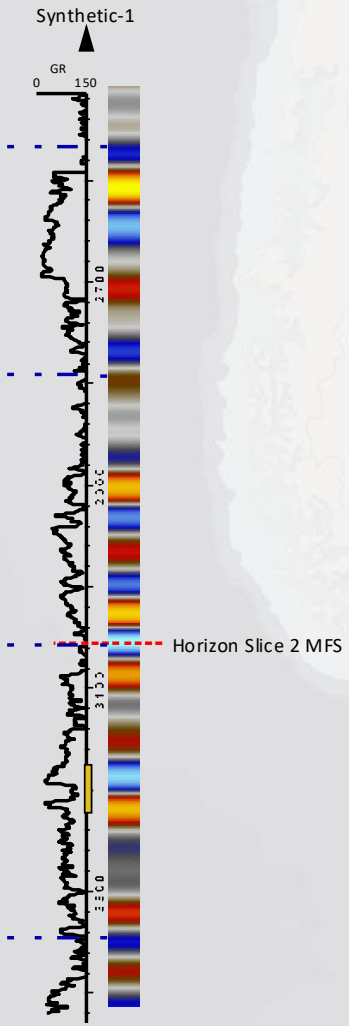
Incised vs Unincised

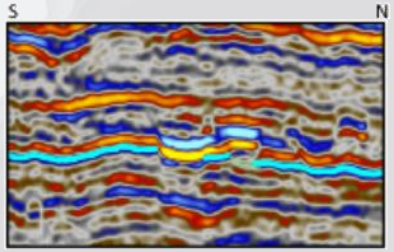


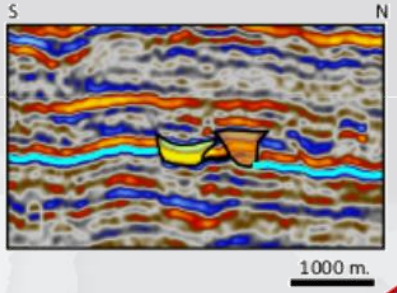
AAPG ICE 2019
International Conference & Exhibition
AAPG
27-30 August
Buenos Aires,
Argentina



MFS Horizon Slide

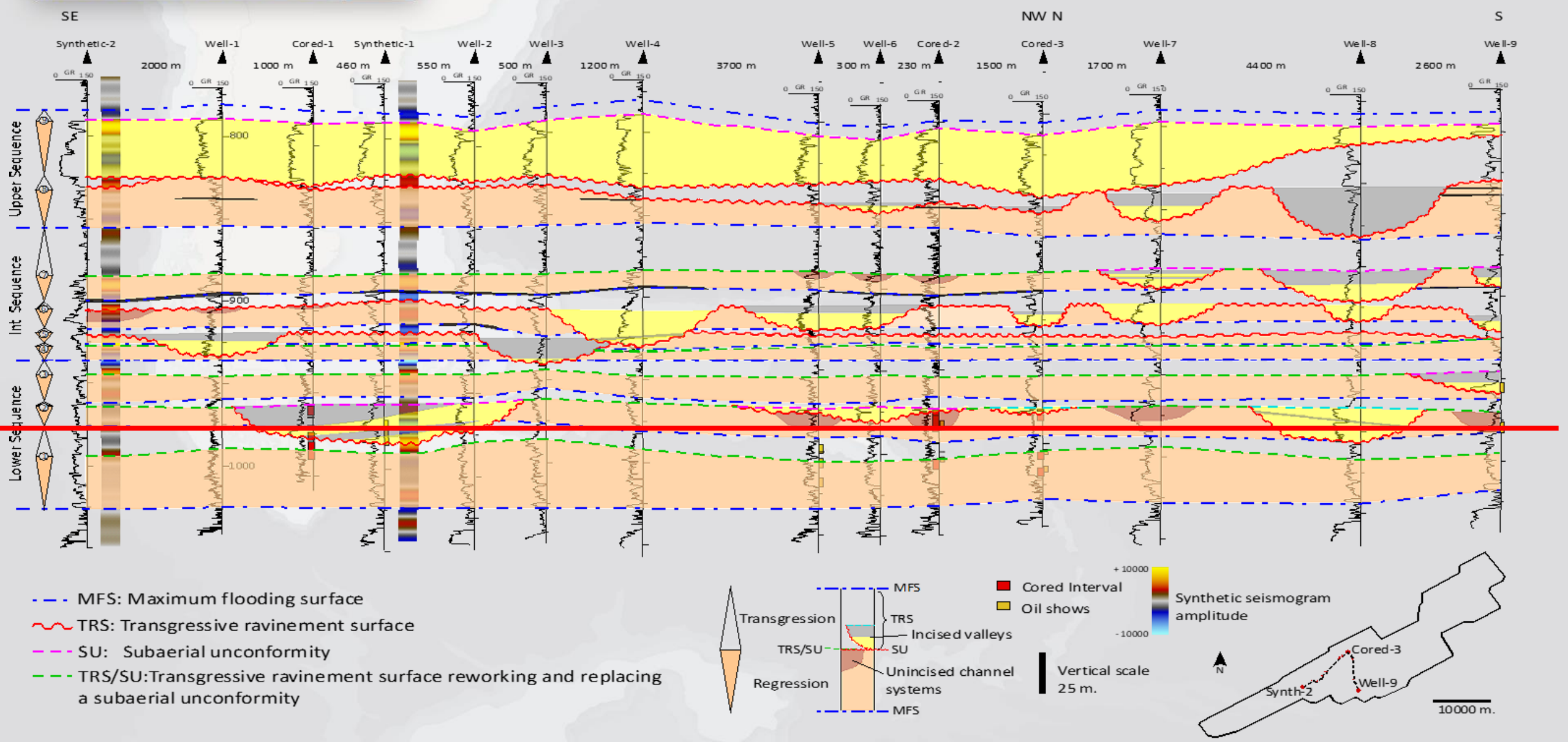




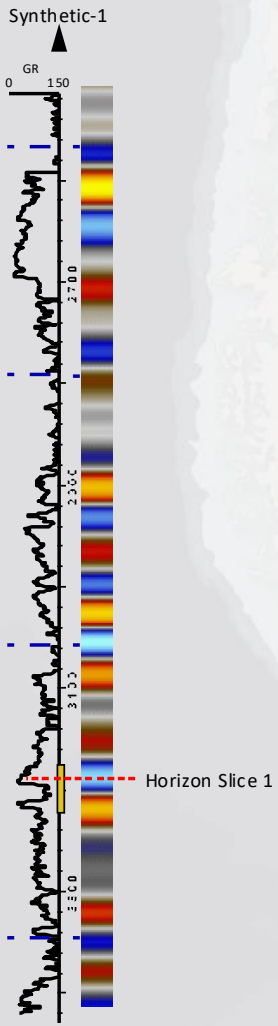


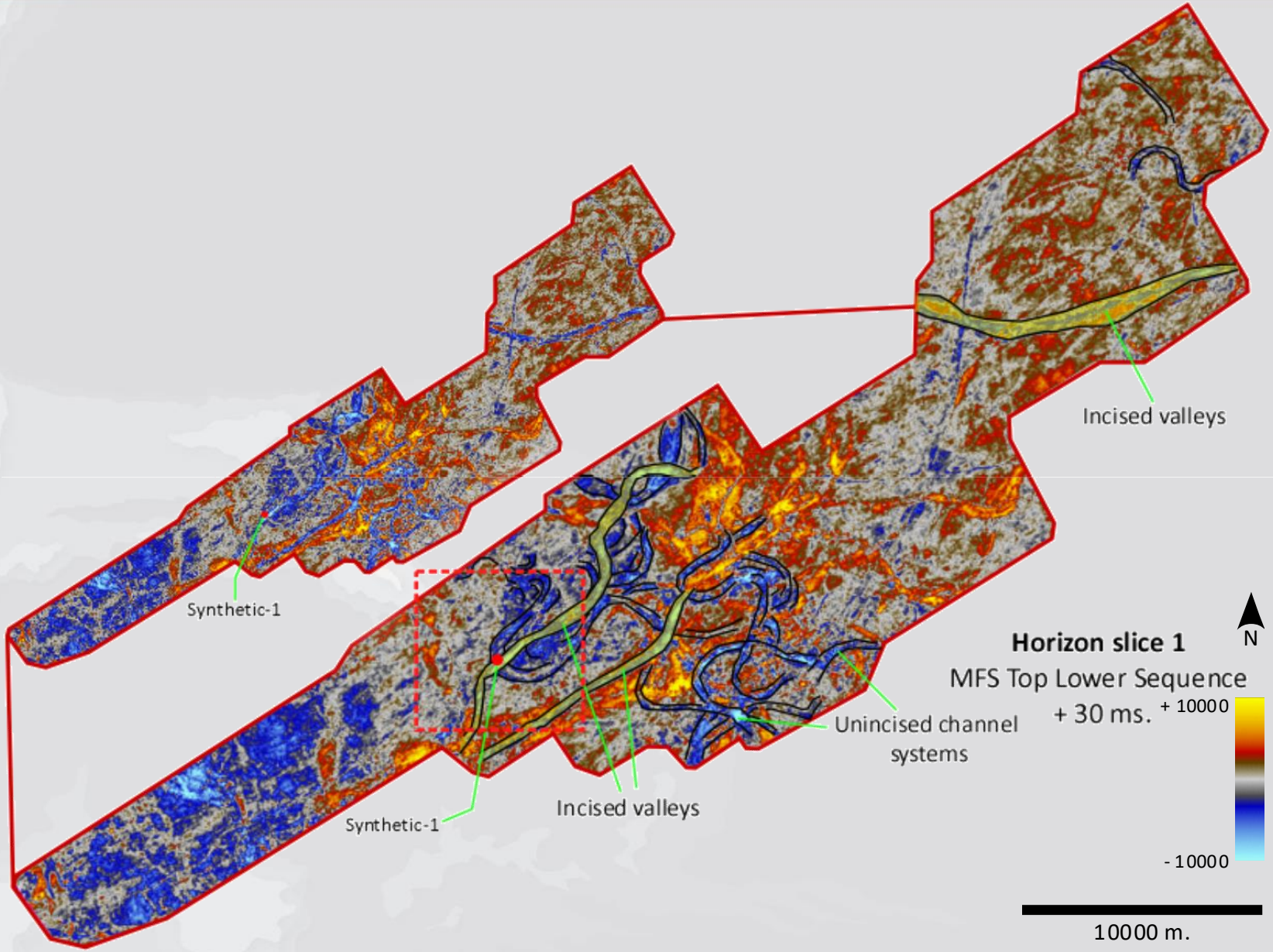
MFS eroded by overlying process of incision

AAPG ICE 2019
International Conference & Exhibition
AAPG
27-30 August
Buenos Aires,
Argentina

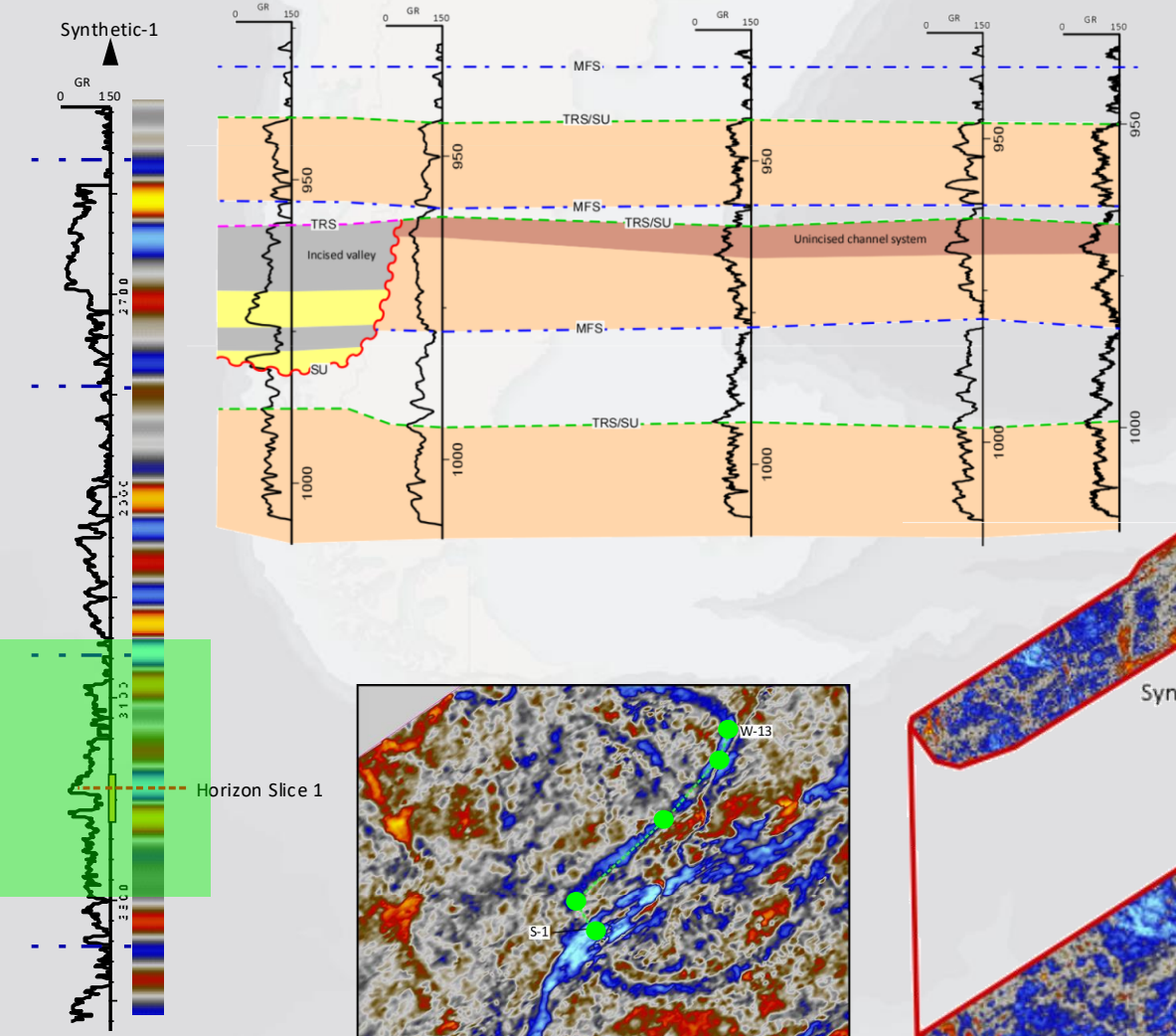


Incised vs Unincised





Incised vs Unincised

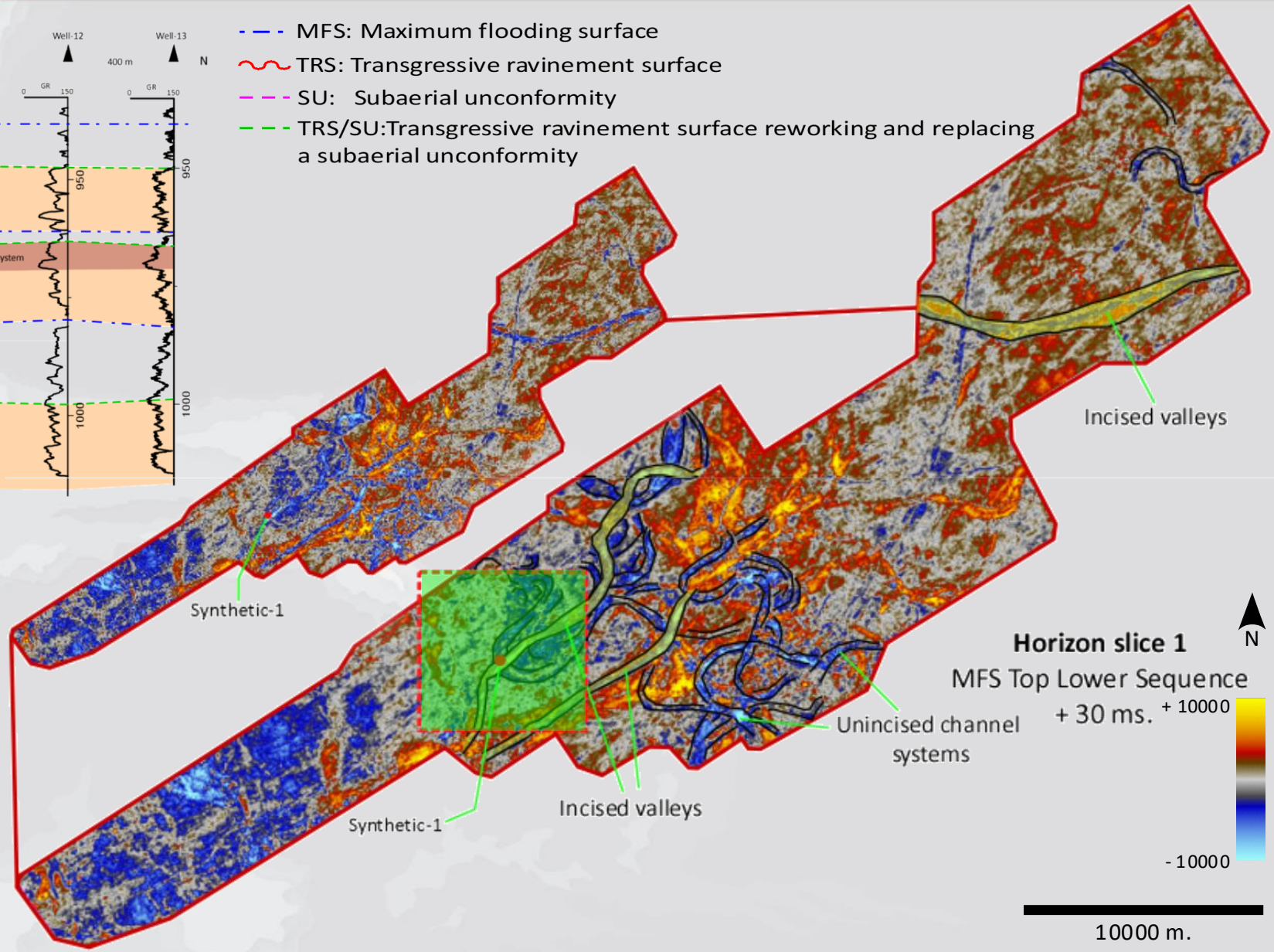


MFS: Maximum flooding surface

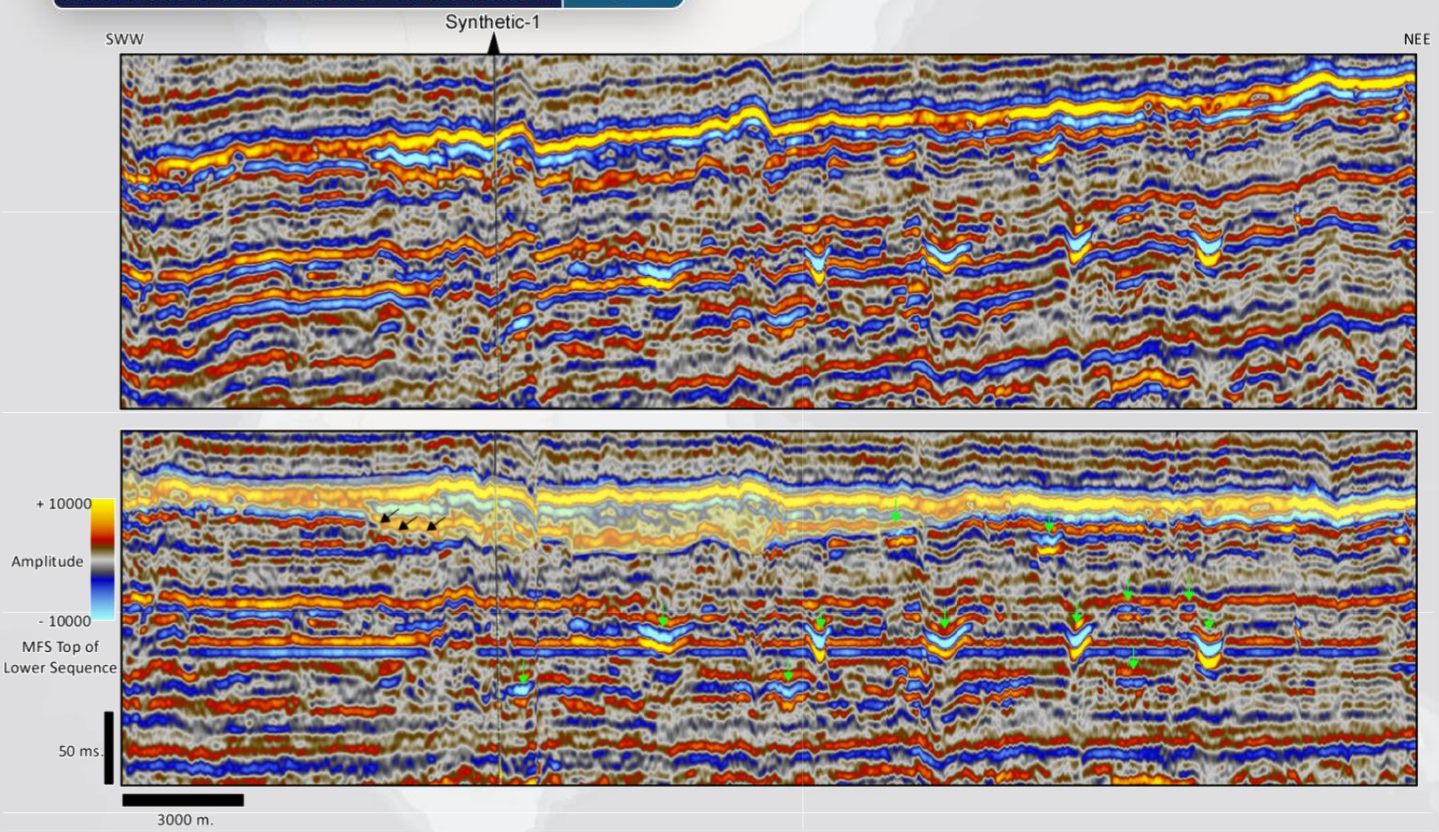
TRS: Transgressive ravinement surface

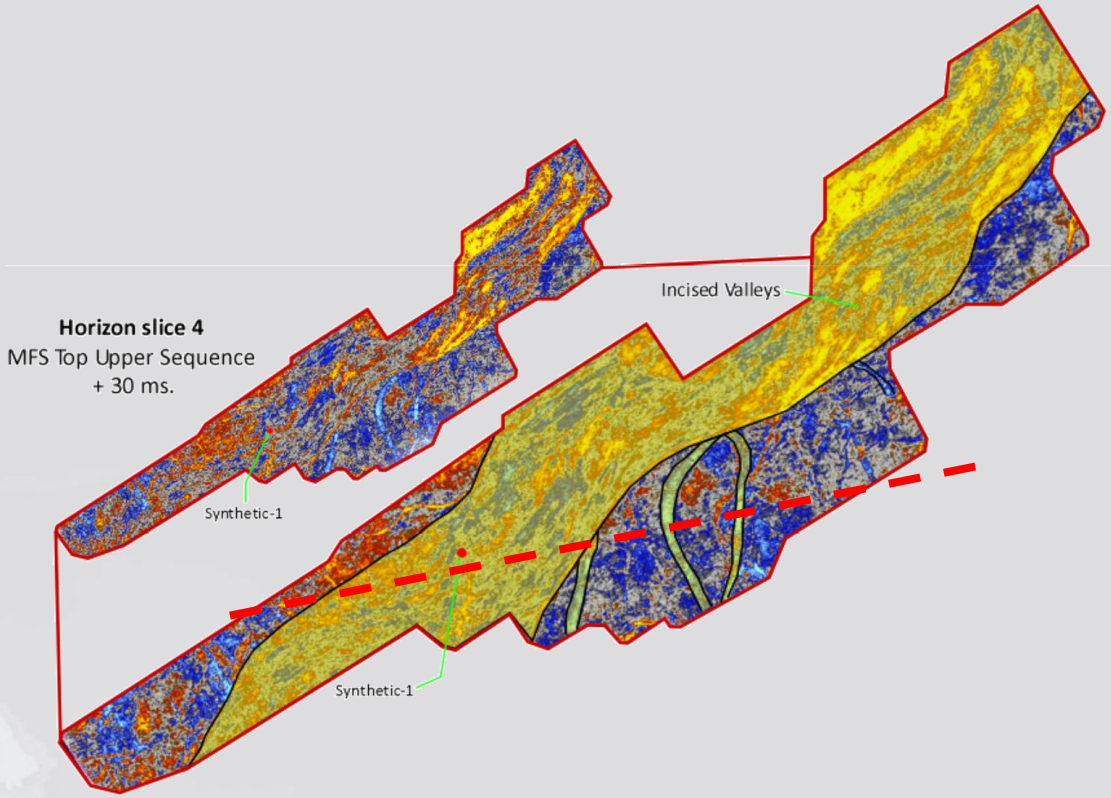
SU: Subaerial unconformity

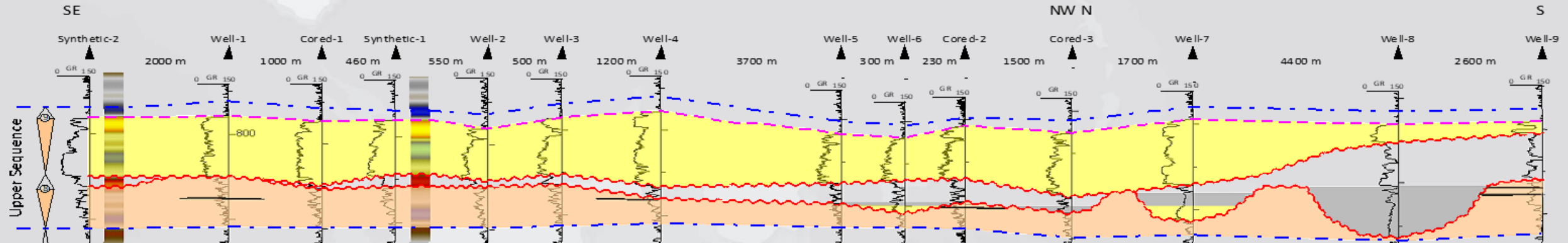
TRS/SU:Transgressive ravinement surface reworking and replacing a subaerial unconformity



Incised vs Unincised

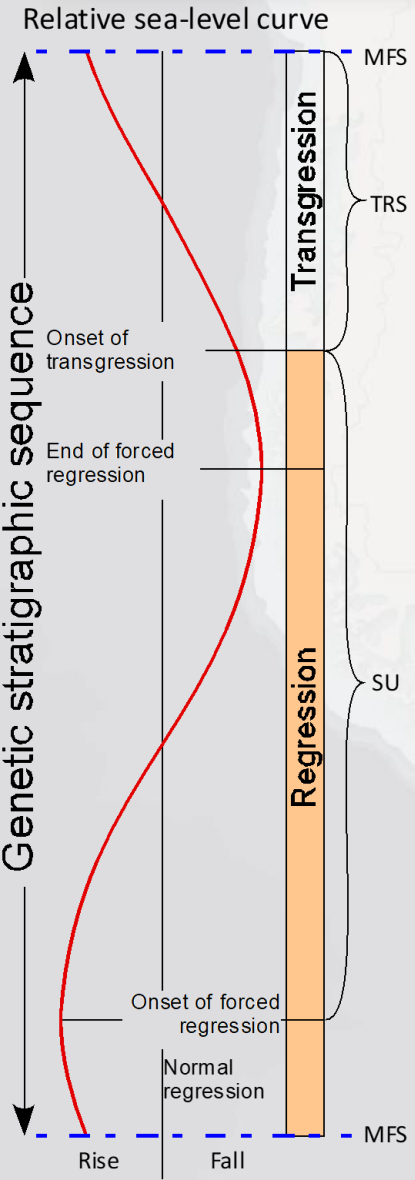




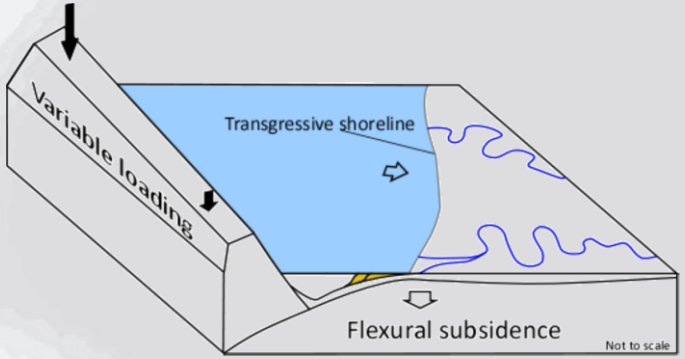


Transgressive stage

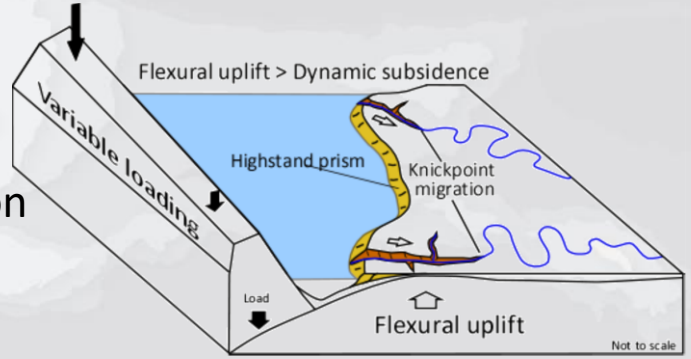
A mechanism that controls accommodation, is the **interplay between dynamic subsidence and flexural tectonics** during periods of tectonic loading and quiescence



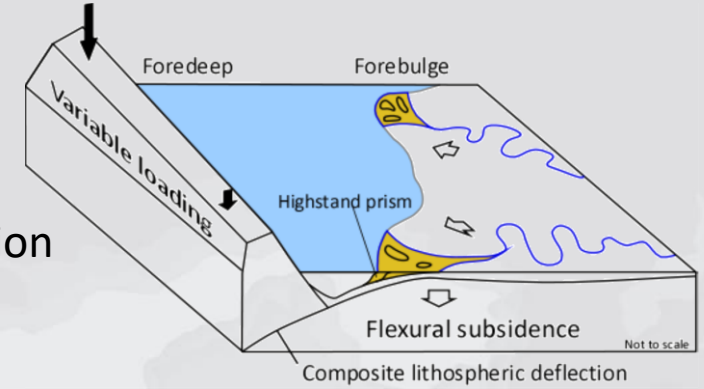
Transgression

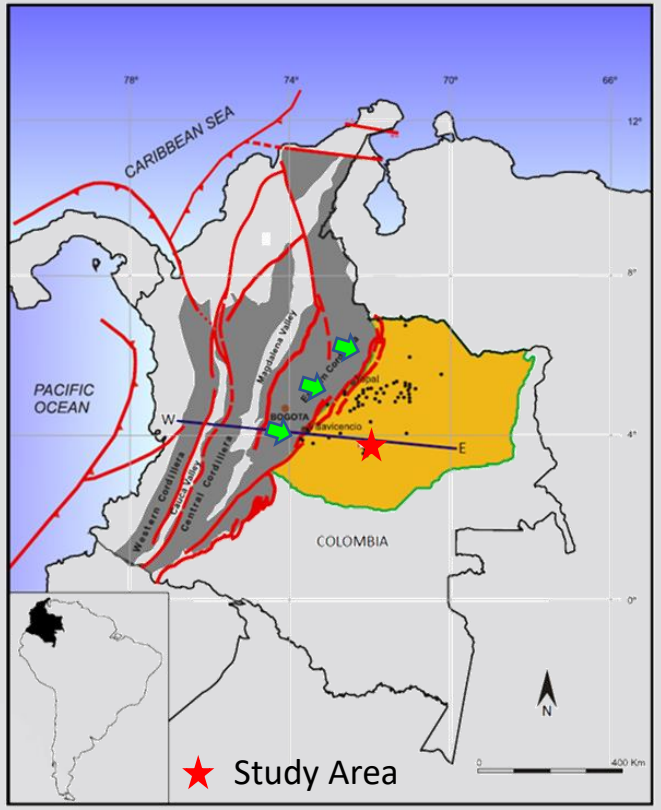


Forced regression



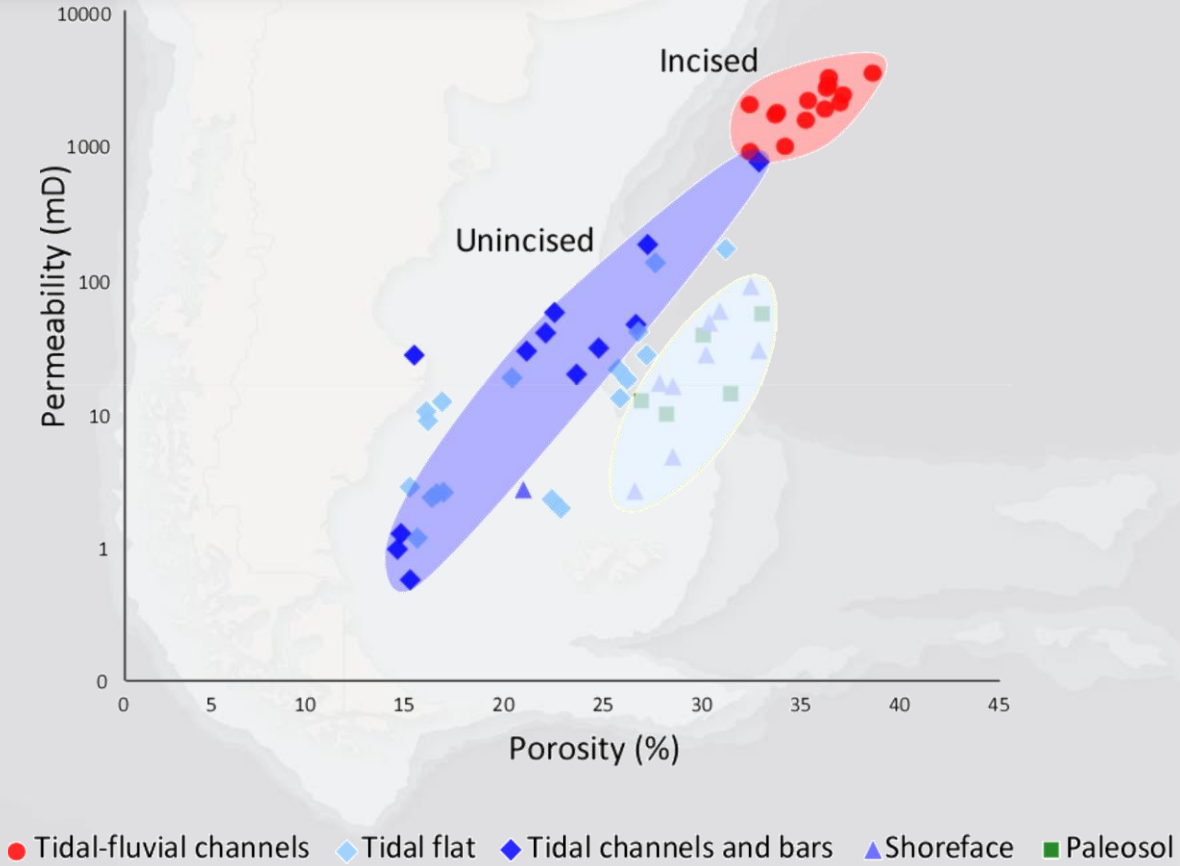
Normal regression

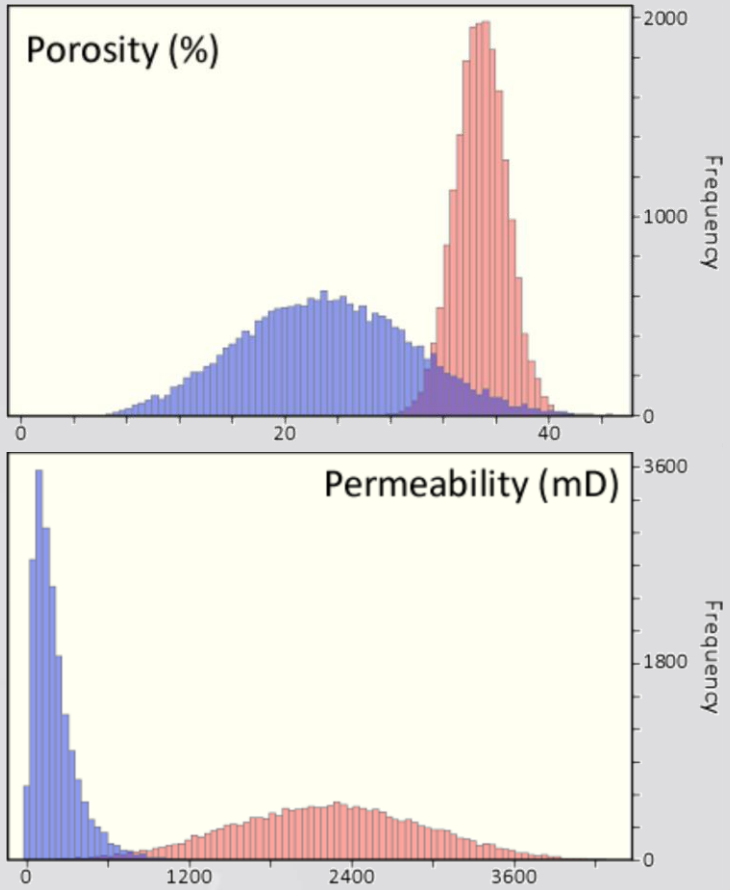




The interpreted genetic stratigraphic sequences reflect transgressive and regressive shifts of the distal shoreline of the interior seaway across the flexural forebulge of the foreland system

Petrophysical impact





Porosity and permeability distribution, place the **incised channels as main stratigraphic target** for exploration and production in comparison with their unincised counterpart.

Conclusions

- The Carbonera C5 member records a suite of facies associations that shows a broad range of depositional environments from fluvial to shallow marine. The vertical assemblage of the facies associations reveals periods of relative sea-level fall and subsequent incision of the underlying sediments.

- Due to the nature of the incision, fluvial-dominated environments and distributary tidal channels coexist laterally; this causes an overlapping of channels with different sedimentological and stratigraphic origins.

- The difference between incised and unincised channels is also observed in the porosity and permeability distribution.

- This sequence stratigraphic framework provides a better understanding of the interplay between tectonics and sedimentation in the foreland Llanos Basin during a period of major westward advance of the Eastern Cordillera.

Acknowledgements

I would like to thank Dr. Octavian Catuneanu for their guidance, Hocol S.A. for providing the data and for permission to publish this paper and Dr. Claiton Marlon Dos Santos Scherer for their contribution with the interpretation of sedimentary environments.