[PS]New Insights in the Characterization of the Springhill Fm Play in the Austral Basin, Tierra del Fuego, Argentina*

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Abstract

The Springhill Fm is the main productive reservoir of the Austral/Magallanes basin in southern Patagonia. The Austral basin is a Jurassic extensional basin, that went into a sag phase in the Late Jurassic/Early Cretaceous, and into a foreland basin stage since the Cenomanian. The Springhill Fm represents the transgressive infill, in several pulses, of a paleo relief at the onset of the sag phase. Its distribution is inherited by the previous extensional fabric, that generated a complex estuary with fluvial systems flowing through valleys, that were progressively flooded. In the austral summer of 2016/2017 exploration was relaunched in the Austral basin to the conventional Springhill Fm play in the Tierra del Fuego island. This underexplored remote area with the Springhill Fm at substantial depths poses a challenge for reservoir quality prediction. Two exploration wells were drilled to structural 4-WD closures within the same paleo valley, with a total Springhill Fm thickness of up to 120 meters. A geological model was prepared from integration of seismic and well data, including electric logs, and descriptions of cuttings and cores. Core description, and detailed petrography and petrophysical analysis from core samples were carried out to characterize reservoir properties and the diagenetic history. Moreover, cutting samples were recovered during drilling for detrital zircon analysis. Morphological characterization of detrital zircon crystals permitted the identification of several grain populations. Selected zircon grains were dated using U-Pb geochronology. Results were integrated into a provenance study that points to a differentiation of Jurassic synrift from Paleozoic basement sources, that is consistent with petrographic analysis. The stratigraphic model indicates a typical incised valley fill, with amalgamated fluvial sand bars at the base, and increasing shale content towards the top, indicating a more estuarine environment. The section is capped by open marine deposits. Petrography indicates that not only shale content increases to the top, but also green clay minerals indicating larger marine influence. Data integration in a multi-disciplinary approach, allowed a calibration of a more robust geological model for the study area and opens new opportunities in the Austral basin that should be tested with future exploration activity.

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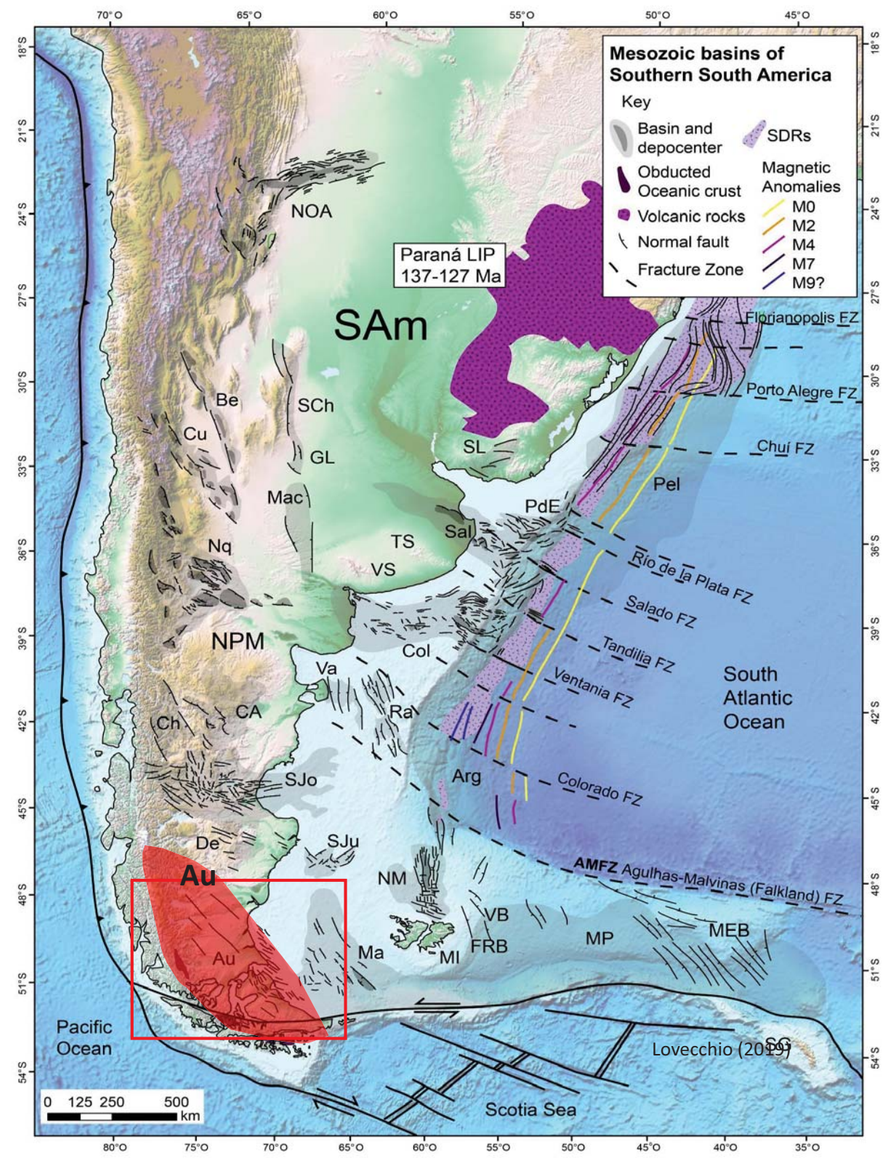
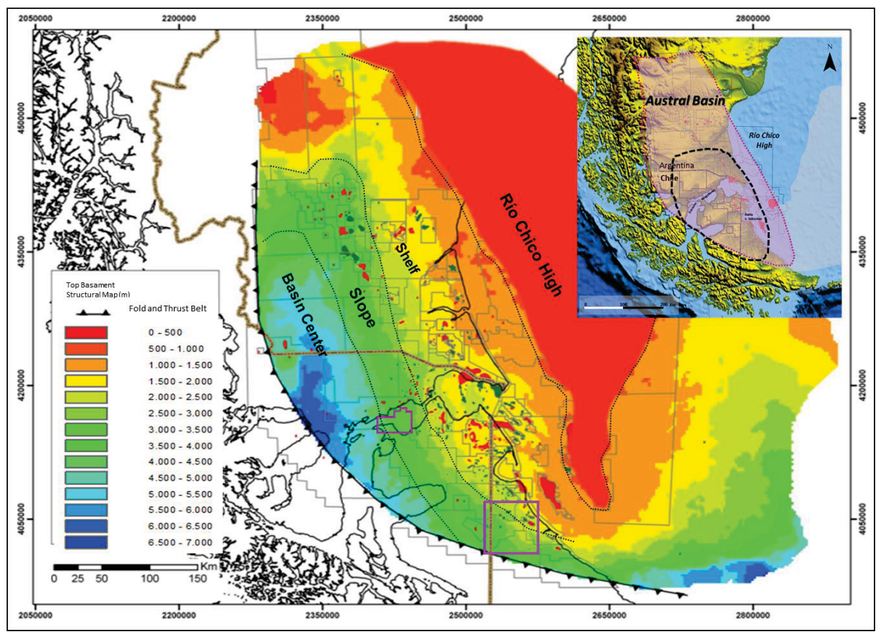
(*) YPF SA - Exploration

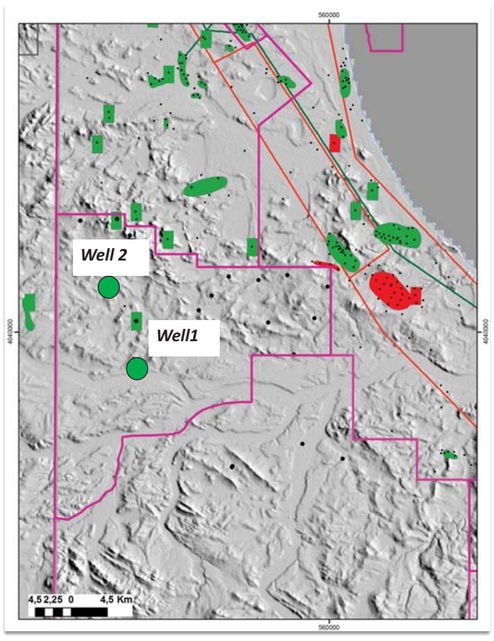
1- Introduction



- ✓ In early 2017, exploration was relaunched in Tierra del Fuego (southern Austral basin) to the 'unconventional' Springhill Fm (tight) play. Two exploration wells were drilled in the Uribe block.
- ✓ The objective of this work was to characterize the Springhill Formation through data integration from different sources, and to open new exploration opportunities in an underexplored remote area in the Austral basin.
- ✓ In the Uribe block, the Springhill Fm (main productive unit) is deeply buried, at depths of up to 3200 m, hence diagenesis exerts a strong control on reservoir quality.



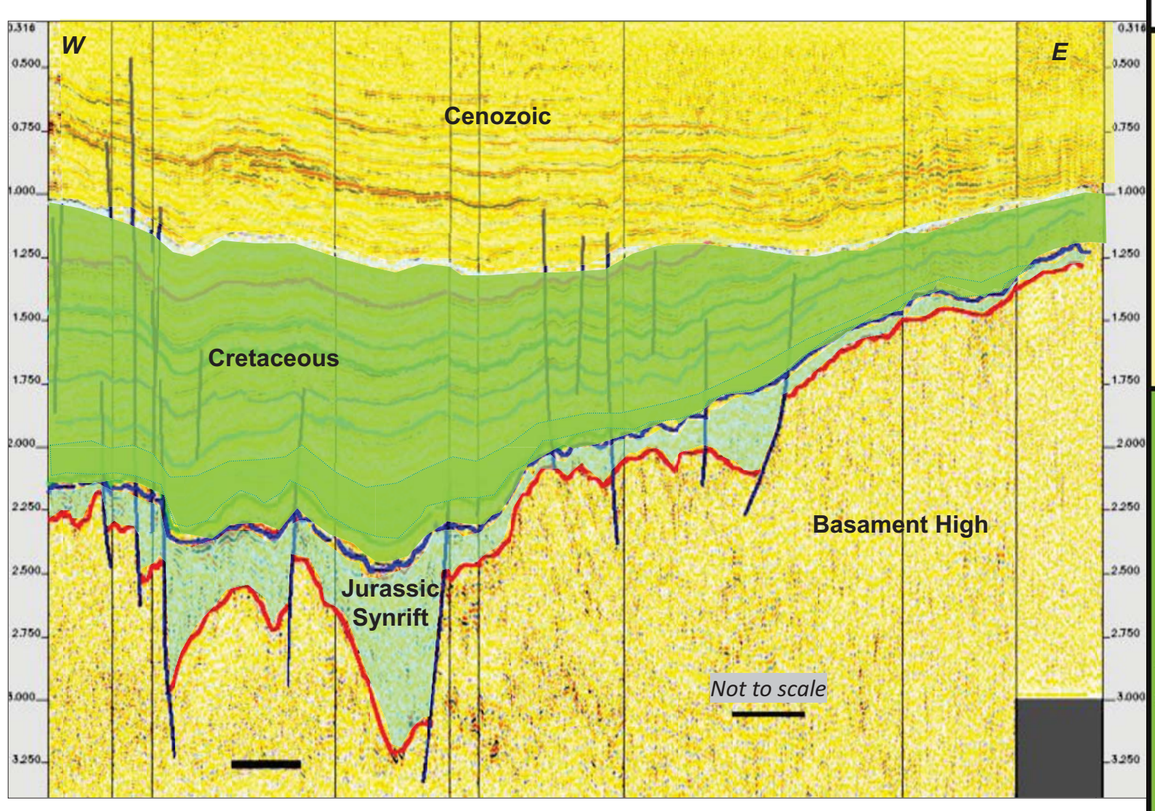
Area of Study

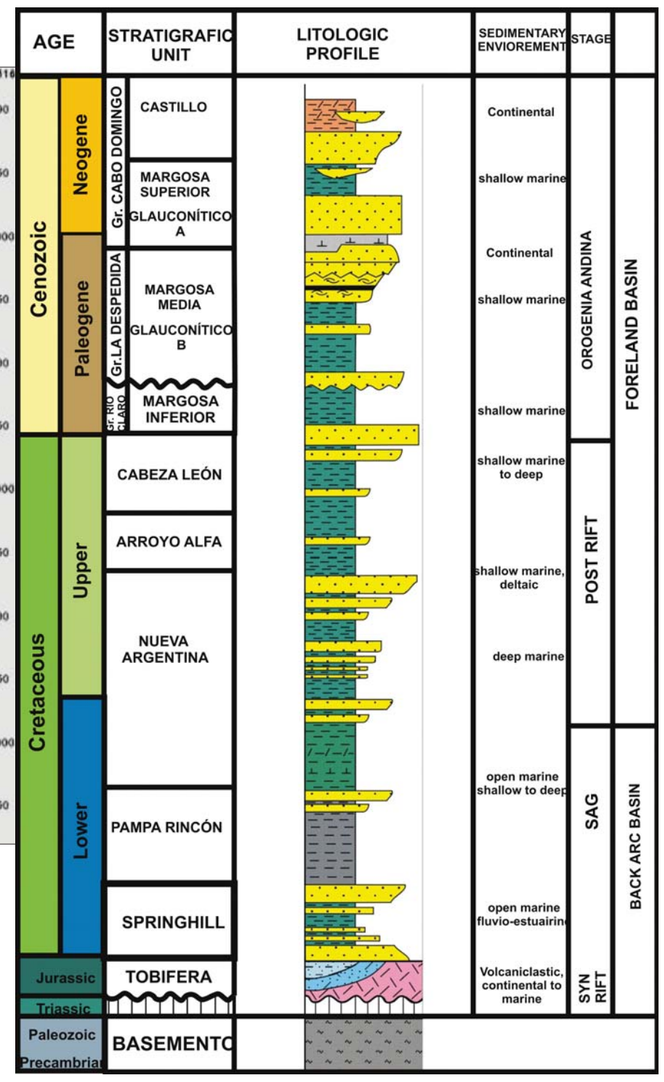


2- Geological Framework

Stratigraphy

- ✓ The Austral basin is a Jurassic extensional basin, that went into a sag phase in the Late Jurassic – Early Cretaceous, and into a foreland stage since the Cenomanian.
- ✓ The pass from synrift to sag is marked by a diachronous transgression and the deposition of the Springhill Formation in several transgressive pulses.





Modified from Hlebszevitsch y Cortiñas (2005)

- ✓ Springhill deposits correspond to estuarine environment with fluvial channels, affected by tidal currents.

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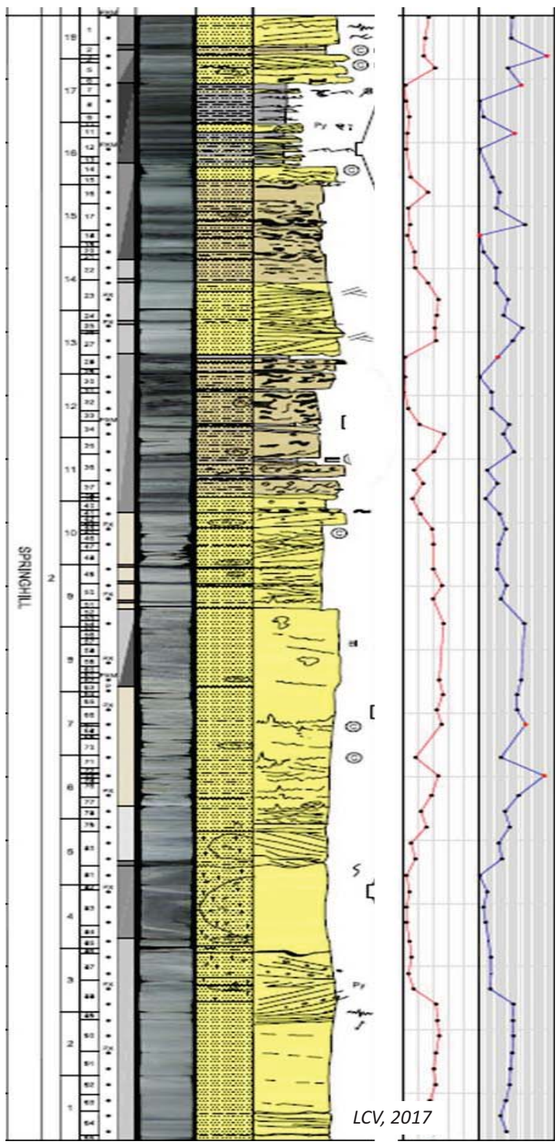
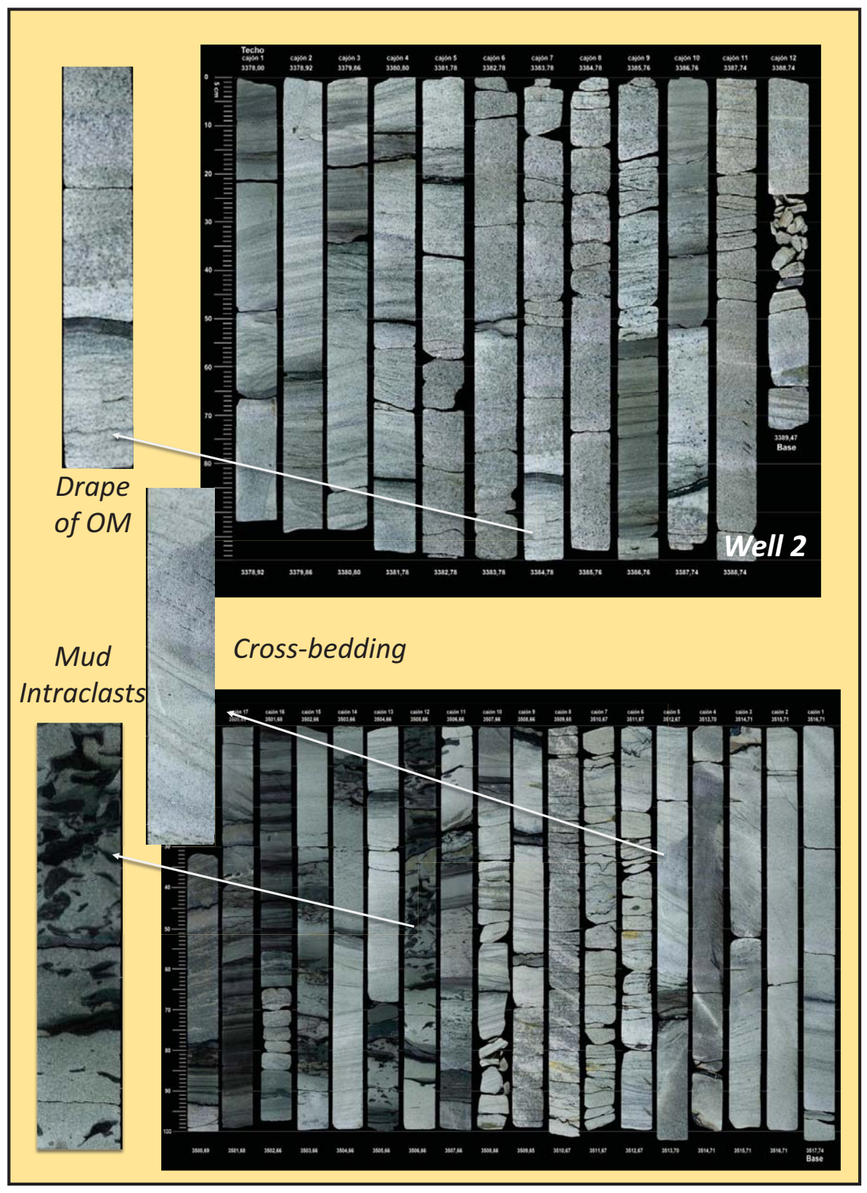
3- Sedimentology

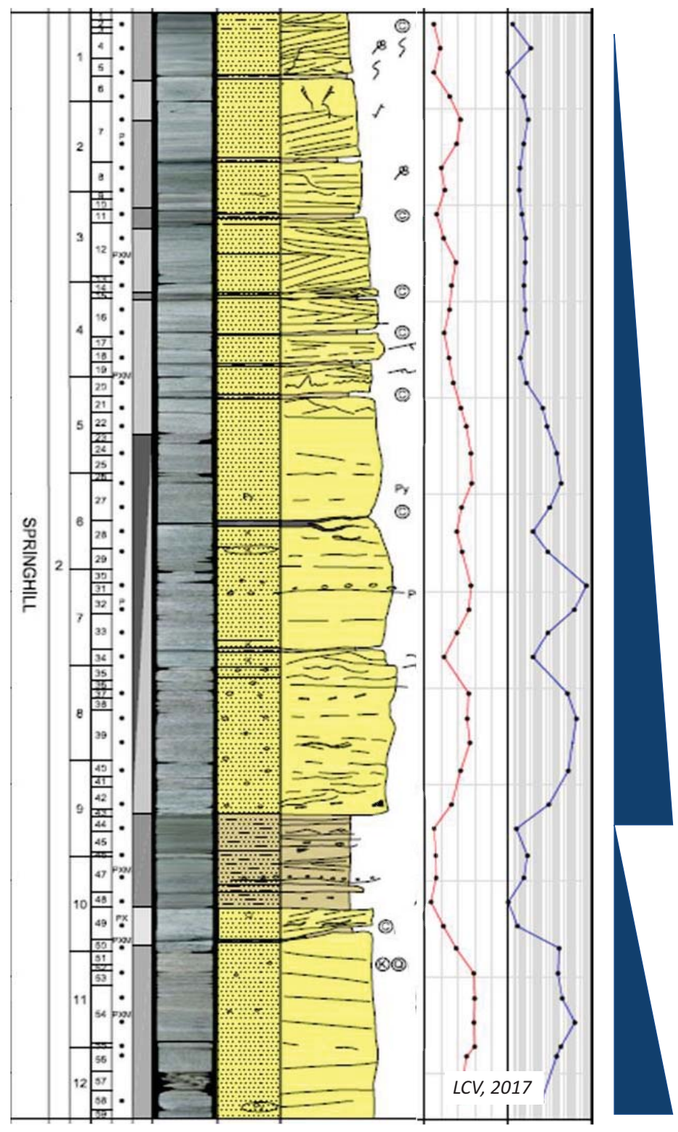
- ✓ From the two recently drilled wells, two cores were recovered from the Springhill Fm (18 m and 11.5 m respectively).
- ✓ The studied intervals start with fluvial channel fill, characterized by massive and trough cross-bedded, medium-to-coarse grained sands.
- ✓ Tidal influence: mud-drapes rich in organic matter interbed with fine sands.
- ✓ Cycles display an overall fining-up pattern, with larger abundance of fine sands, laminated shales and mud intraclasts (rip-up clasts).

Well 1

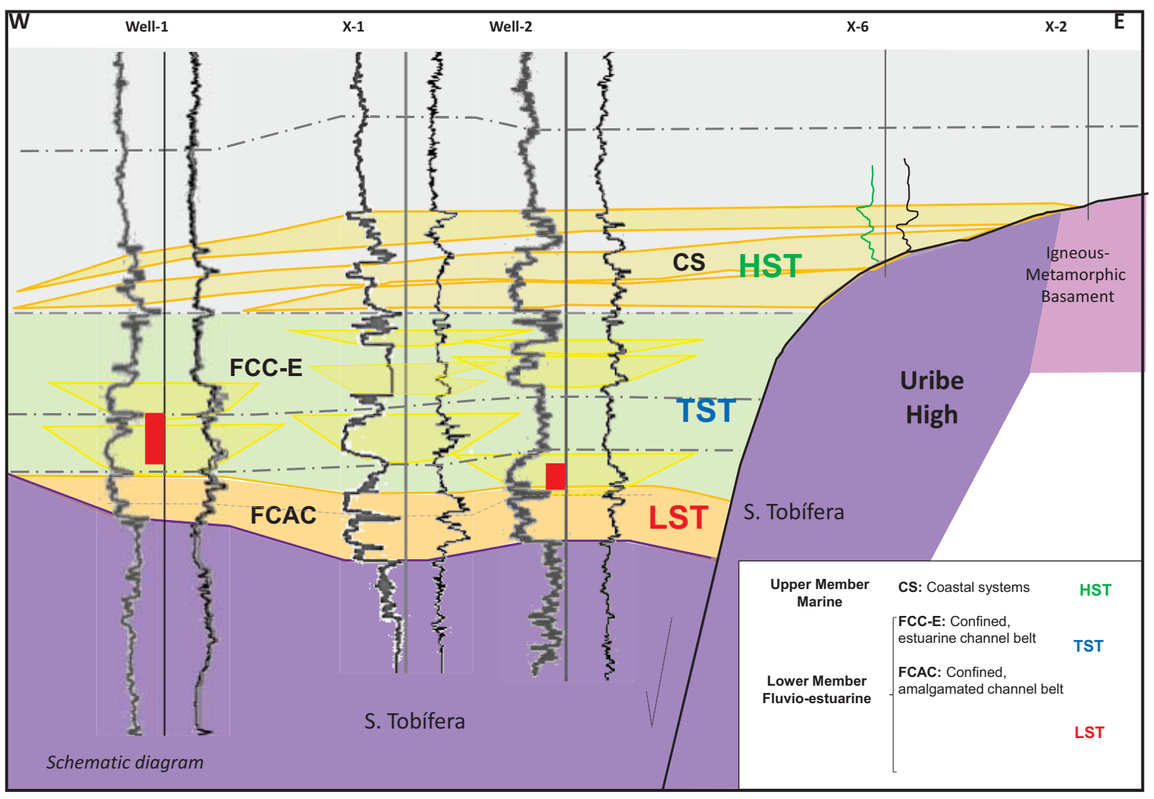


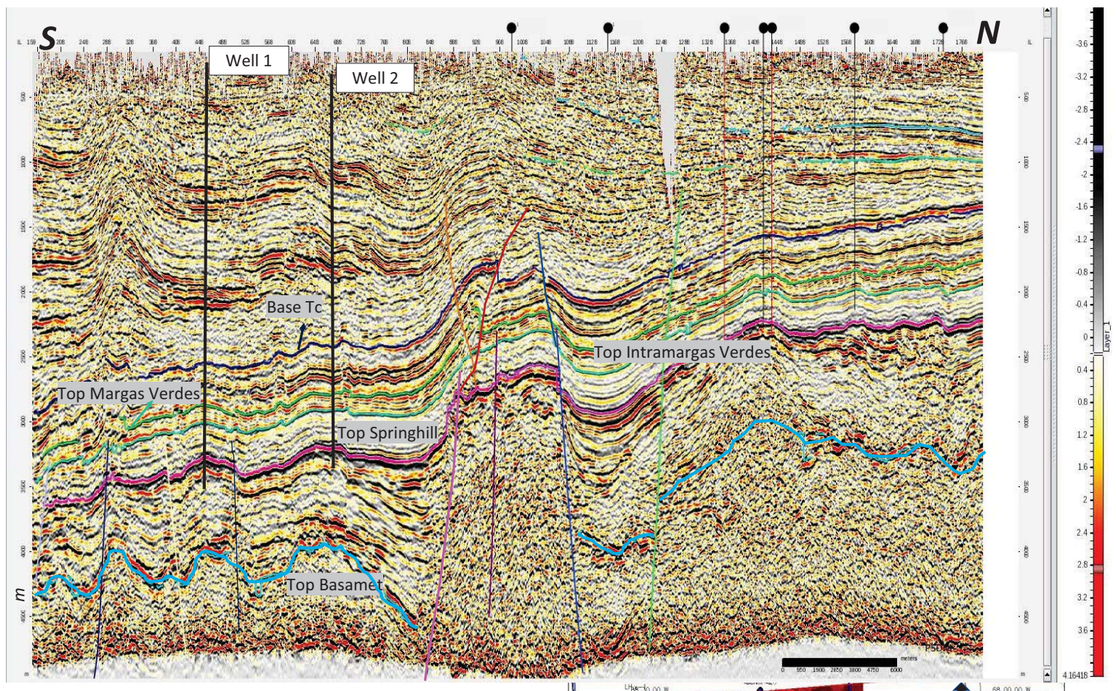


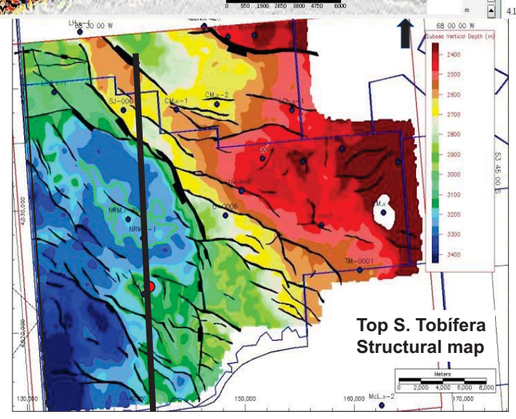
Well 2



4- Stratigraphic Model







- ✓ The Springhill Fm fills incised valleys on the eastern shelf of the Austral basin (Río Chico high).
- ✓ Infill occurs in several cycles as the base-level rises. With onset of base-level rise, fluvial-estuarine channels with high amalgamation are deposited as part of the LST. During TST, with maximum base-level rise rate, finer deposits are preserved at the top of the channel fills. Finally, after maximum flooding (HST) open marine systems develop around the Río Chico and other minor highs (such as the Uribe high).

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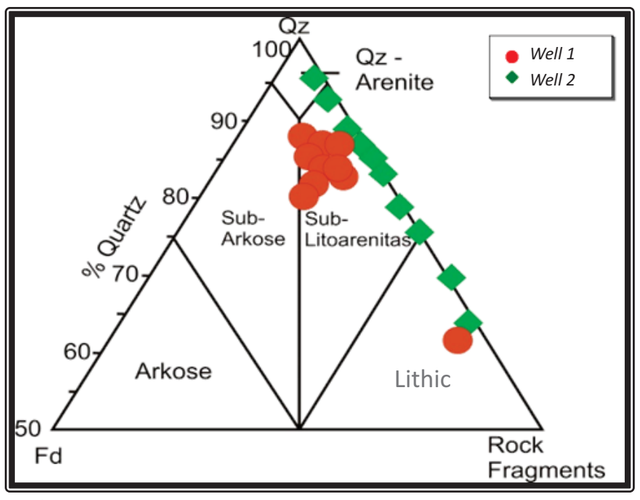
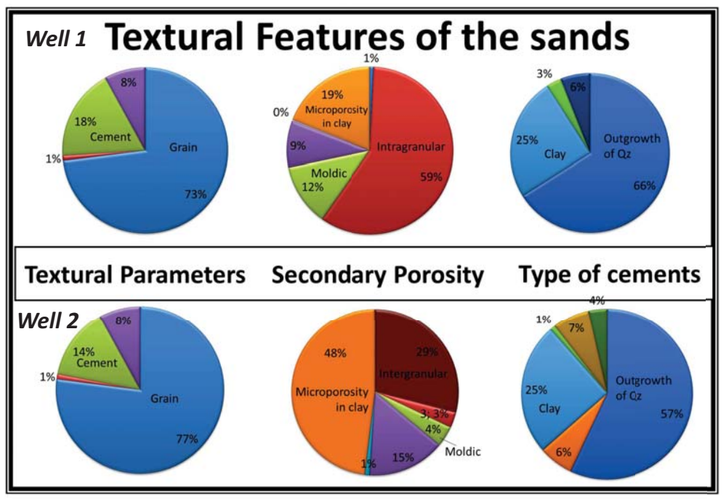
5- Petrography

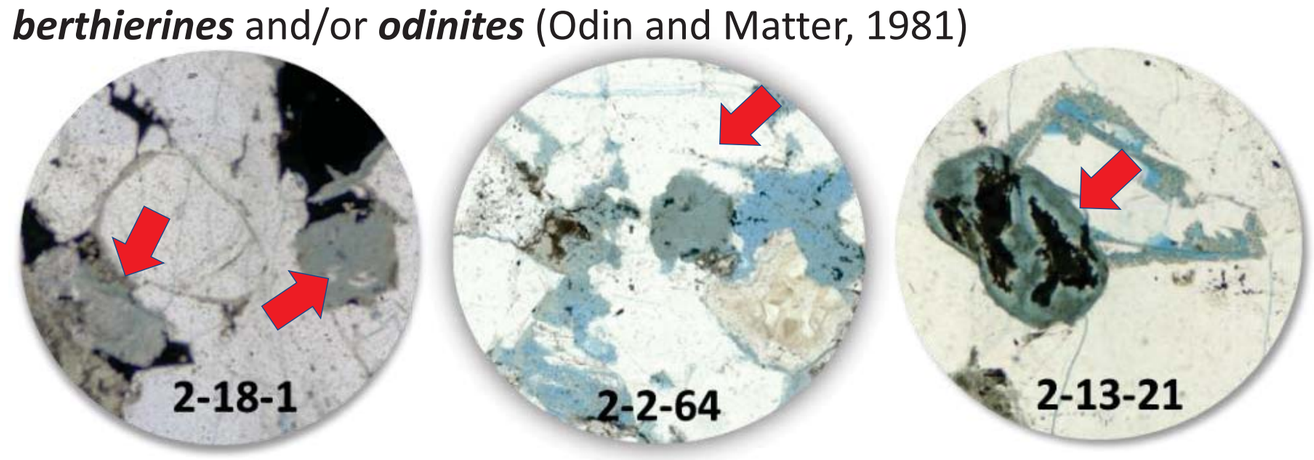




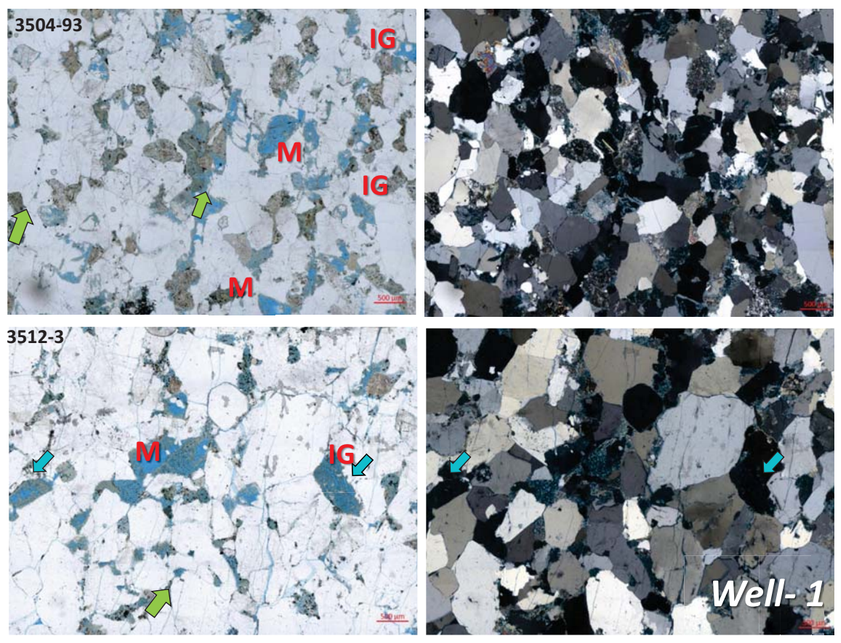
✓ **Cements**:

Silica is the most abundant cement, with overgrowths of secondary quartz. **Clay minerals** such as replacements of detrital grain or partial coating grain are represent.

Some green clay minerals were identified in **Well 1** such as ***"ooids"*** of ***berthierines*** and/or ***odinites*** (Odin and Matter, 1981)

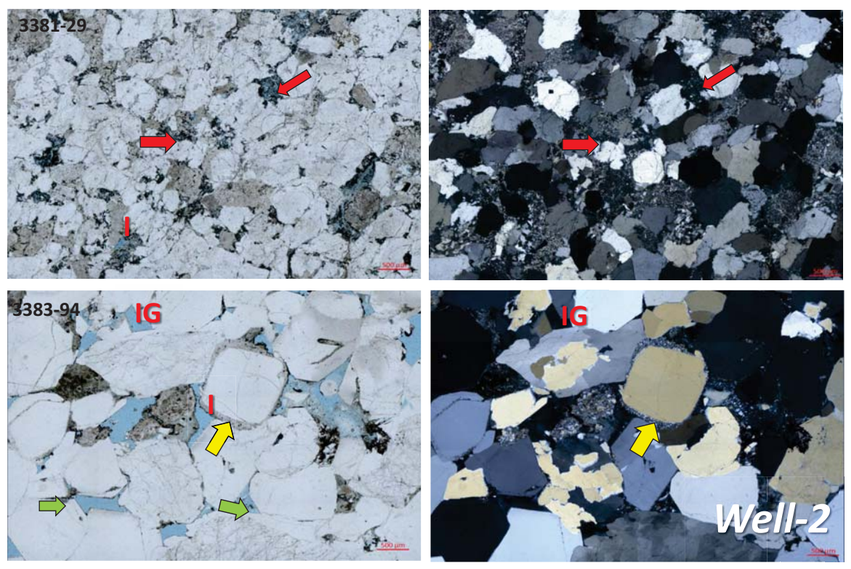


*Cements and porosity **Well 1***



Optical micrographs (plane-polarized light) show: Moldic (**M**), Intragranular (**IG**) porosity. Outgrowths secondary quartz (**green arrow**). Rest of feldspar grains (**blue light arrow**).

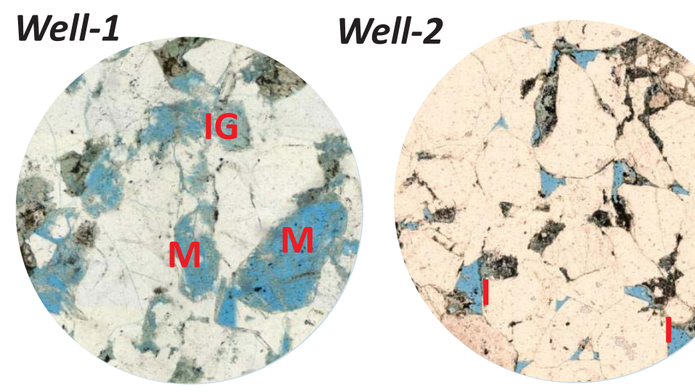
*Cements and porosity **Well 2***



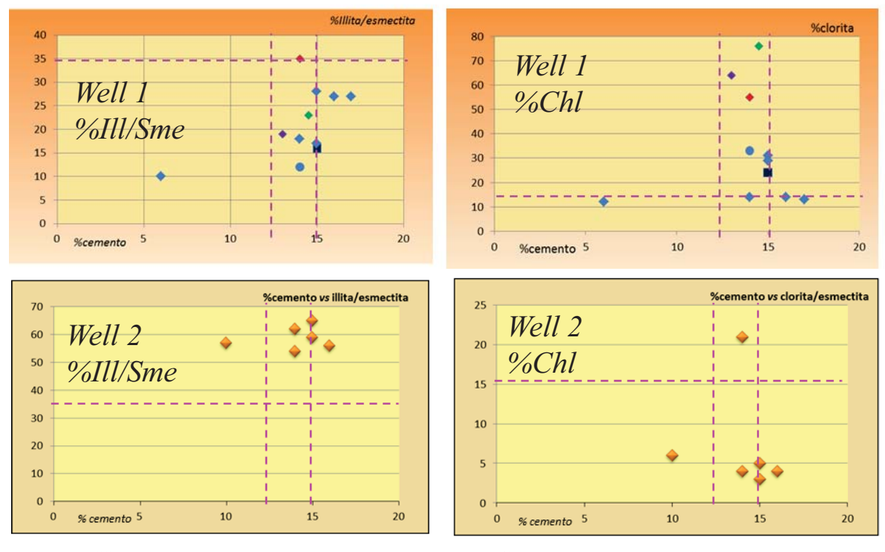
Optical micrographs (plane-polarized light) show: Intragranular (**IG**), Intergranular (**I**) porosity. Clay cement surrounded grain (**yellow arrow**) Outgrowths secondary quartz (**green arrow**), clay minerals partially replace grains (**red arrow**).

✓ **Mineralogy** of the Springhill Fm varies. Feldspars are observed only in Well 1 displays.

✓ **Porosity Types**:

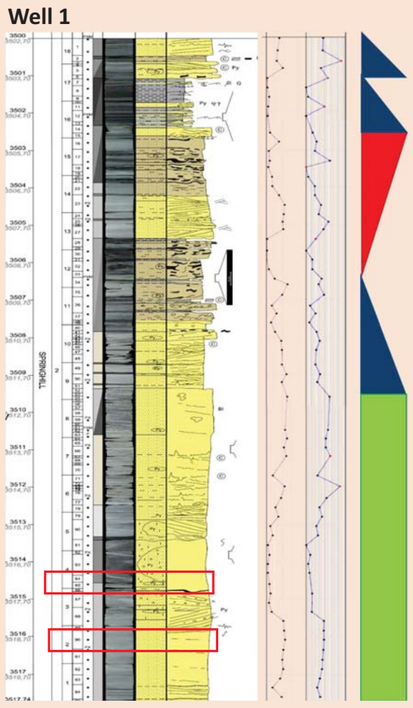


✓ **Clays in XRD:**

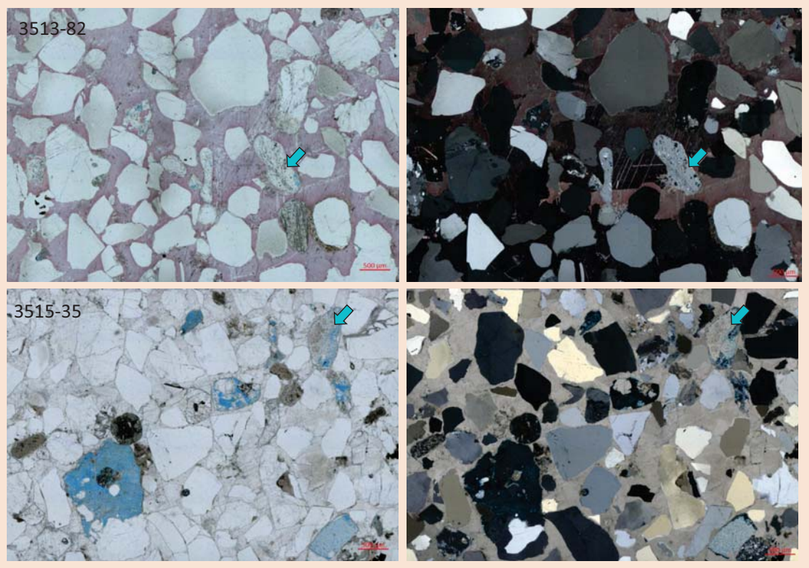


Well 1 has larger proportions of Chlorite and Smectite

Carbonate Cement



✓ In Well 1, at the base of fluvial channels, where grain sizes are larger, early carbonate cement dominates.



Conceptual Diagenetic History (**Well 1**)

Initial compaction → *Total Carbonate cementation of coarser grain facies* → *Partial dissolution of cement and feldspar* → *Cement of outgrowths of secondary quartz and clay cement replacements.*

EODIAGENESIS | **MESODIAGENESIS**

Conceptual Diagenetic History (**Well 2**)

No early Carbonate cementation → *If the size of grain is coarse:*
-Outgrowths of secondary Quartz
- Clay coating of grains
-Outgrowths of secondary Quartz
-Clay cement replaces grains → *If the size of grain is fine:*
- *More compaction*
- *Grain in contact and silica cement develops*
- *Clay cement replaces grains*

MESODIAGENESIS

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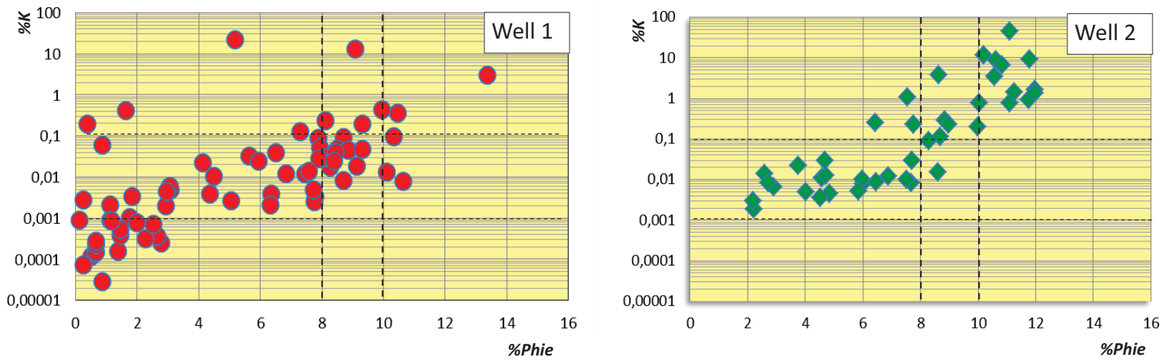
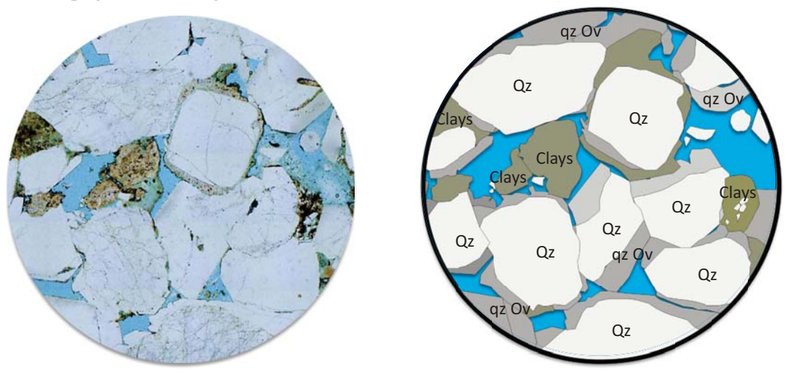
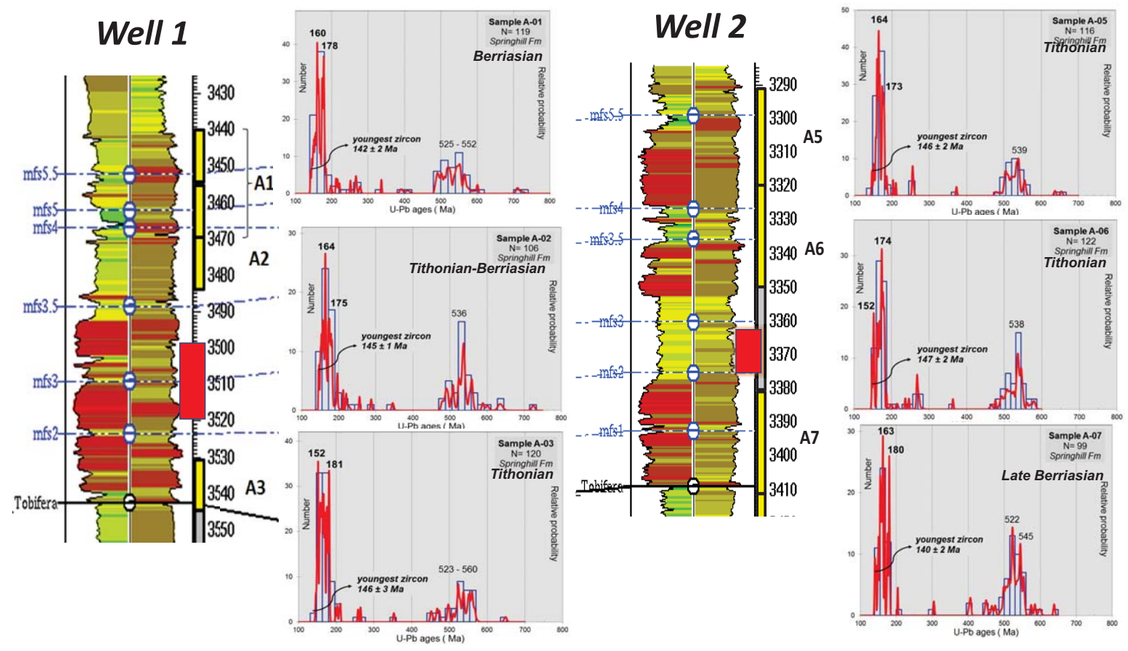
6- Petrophysics



- ✓ The studied units display in K-Phi cross plots characteristics of tight reservoirs.
- ✓ The core from Well 2 displays the best quality reservoirs, with higher K-Phi ratio.
- ✓ The core from Well 1 displays more shaly estuarine facies. Also, intragranular and moldic porosity (produced by feldspar dissolution) are dominant in Well 1.
- ✓ Intergranular porosity is more abundant in the core from Well 2 together with other events: cementation with clay minerals which inhibit overgrowth Quartz (qz Ov), preserving porosity.



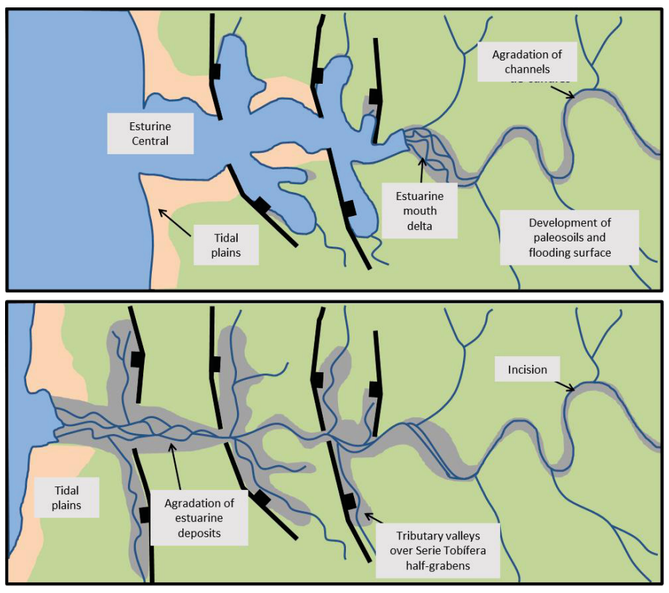
7- Detrital Zircon Geochronology

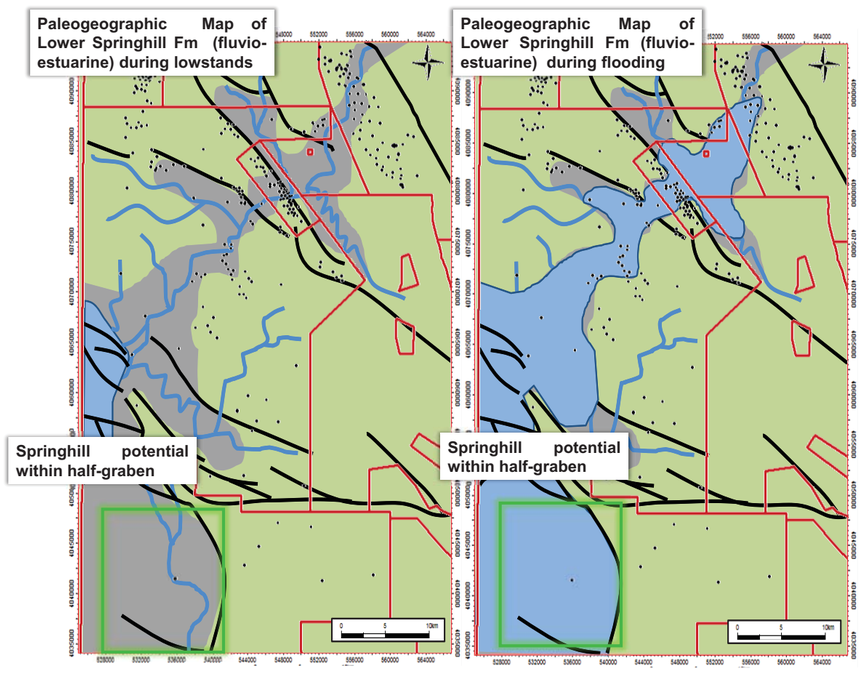


- ✓ Six cutting samples, recovered during the drilling of the two wells, were analyzed for their detrital zircon content.
- ✓ A Tithonian/Berriasian maximum age of sedimentation was determined for the Springhill Fm in the area of study.
- ✓ Provenance analysis indicate two main sources:
  - A Jurassic population of zircons associated with the Chon Aike Magmatic Province or the Early Jurassic Patagonian Subcordilleran Batholith.
  - A Neoproterozoic-Cambrian population related to the igneous-metamorphic Tierra del Fuego complex, a local source as this complex constitutes the basement of the Uribe High.

8- Paleogeographic Model and Final Remarks

- ✓ Conceptual Model: A tributary system strongly influenced by the structural framework.
- ✓ Paleovalleys develop on ancient half-grabens and discharge into a main collector.
- ✓ During floodings, the system is inundated and shales are deposited. During base level falls, the system is exposed and eroded.
- ✓ Data integration in a multi-disciplinary approach, allowed calibrating a more robust geological model for the study area.





- ✓ The identification of ***ooids***, typical of estuarine environments (Odin, 1985, Ketzer et al., 2003) and confirms the model.
- ✓ This validation opens new opportunities in the Austral basin that should be tested with future exploration activity.
- ✓ This work upgrades the prospectivity of the proximal areas compared to the distal ones.