PS Challenging the Paradigm "Missing Section - Normal Fault" - Implications for Hydrocarbon Exploration*

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Abstract

In structurally complex areas, seismic interpretation can be misled by wrongly interpreted well data. A common approach in the oil industry can be summarized by the Spanish sentence “pozo mata sismica” meaning that data from a well must prevail in a seismic interpretation. A major problem arises when well-based interpretation is taken as data; a missing section is the observation; calling it a “normal fault” is an interpretation. A series of examples will show, in various structural settings, numerous cases of missing sections that cannot be attributed to normal faulting. All field names in the text are from Venezuela if not otherwise specified.

The easiest recognizable misinterpretation occurs where wells have missing sections juxtaposed to wells with coeval massive sands; with enough well control additional support comes from recognizing the typical rhomboidal-shaped blocks; e.g., Dunlin Field, UK. Synsedimentary activity of horst blocks in the middle of major deposition centers (e.g., Brent delta) is responsible for such occurrences.

Many tools either alone or combined, can be used to diagnose problematic missing sections; e.g., hydrocarbon-column anomalies associated with fault-plane mapping, abnormal RFT pressure trends, detailed fault-throw map or perfectly identical TVDss depths of fault cuts in different stratigraphic units.

Unusual approaches can also be successful at recognizing misinterpreted normal faults, as in the Lama Field: the TDs of every well that failed to reach their targeted depths were analyzed by plotting their coordinates in 3-D. This revealed the existence of three

previously unrecognized steeply dipping reverse faults that only one third of the wells had been able to penetrate; each of the latter group showed missing sections where crossing these faults.

While 3-D seismic is the norm, 2-D lines can be invaluable in better defining the tectonic style of very complex areas. Large amount of hydrocarbons can be present below faults which have been obliquely reactivated and which appear at first glance to have the geometry of normal faults (e.g., Western Canada Foothills).

Implications for the examples cited above range from redesign of water injection wells for pressure support (Lama Field) to major bypassed pay zone (Santa Barbara Field), change in reserve estimates (Dunlin) and finally to a new hydrocarbon discovery (near Bosque Field).

Selected References

Chatellier, J-Y., Rueda, M.E., Charles, S., and Romero, I., 2008, Why 3D seismic missed a giant field in the Eastern Venezuela thrust belt; postmortem of a late discovery, CSPG Convention Calgary (4-page abstract) (http://www.cspg.org/conventions/abstracts/2008abstracts/130.pdf) (accessed June 8, 2010).

Chatellier, J-Y., and Zambrano, J., 2007, A multidisciplinary 4D integration delivers a reliable reservoir model for the Santa Barbara Field, Venezuela: Data Fusion Workshop, SEG-AAPG-SPE, Vancouver, October, 2007

Chatellier, J-Y., and Porras, C., 2004, The Multiple Bischke Plot Analysis, a Simple and powerful graphic tool for integrated stratigraphic studies: AAPG Search and Discovery Article #40110 (2004) (http://www.searchanddiscovery.net/documents/2004/chatellier/index.htm)

Chatellier, J-Y., de Sifontes, R., Mijares, O., and Muñoz, P., 1999, Geological and production problems solved by recognizing the strike slip component on reverse faults, VLA-31, Lake Maracaibo, Venezuela: SPE Annual Technical Conference, Houston, SPE No. 56558

Challenging the Paradigm

“Missing Section – Normal Fault”

Implications for Hydrocarbon Exploration

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Abstract

In structurally complex areas, seismic interpretation can be misled by wrongly interpreted well data. A common approach in the oil industry can be summarized by the Spanish sentence “pozo mata sismica” meaning that data from a well must prevail in a seismic interpretation. A major problem arises when well-based interpretation is taken as data; a missing section is the observation, calling it a normal fault is an interpretation. A series of examples will show, in various structural settings, numerous cases of missing sections that cannot be attributed to normal faulting. All field names in the text are from Venezuela if not otherwise specified.

The easiest recognizable misinterpretation occurs where wells have missing sections juxtaposed to wells with coeval massive sands; with enough well control additional support comes from recognizing rhomboidal shaped blocks as in the Upper Ness E of the Dunlin Field - UK. Log facies maps are most effective at indicating these occurrences because of the patterns on the maps; this also works well in compressive structural settings as in one Oligocene unit of El Furrial Field. Synsedimentary activity of horsts in the middle of major deposition centers (e.g., Brent delta) is responsible for such occurrences.

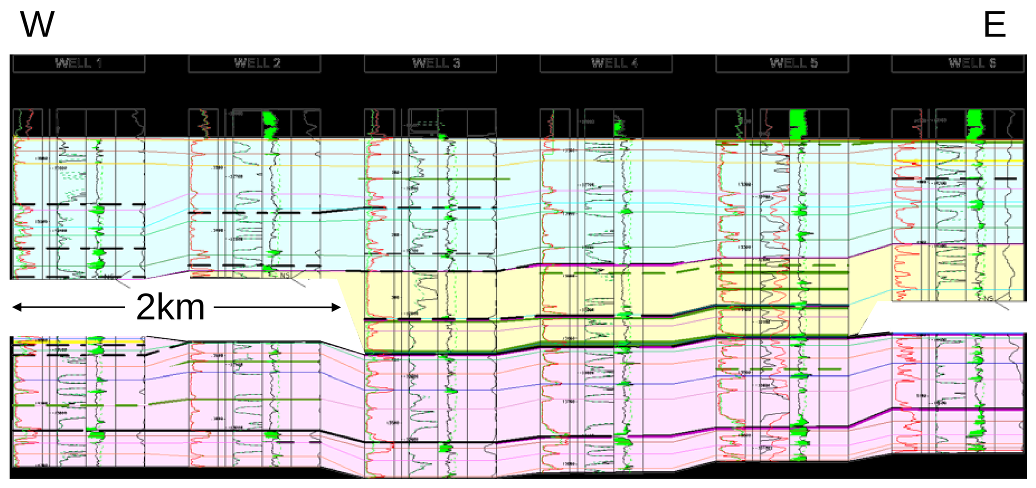
An unusual approach was successful at recognizing misinterpreted normal faults in the Lama Field: the TDs of every well that failed to reach its targeted depth were analyzed by plotting their coordinates in 3-D. This revealed the existence of three major steeply dipping reverse faults that only one third of the wells had been able to penetrate; each of the latter showed missing sections. Oblique slip associated with these Riedel Shears has been invoked for the missing section along reverse faults.

In the Western part of El Furrial Trend, different tools either alone or combined, were used to diagnose problematic missing sections; e.g., hydrocarbon column anomalies associated with fault-plane mapping, abnormal RFT pressure trends, detailed fault-throw map or perfectly identical TVDss depths of fault cuts in different stratigraphic units. When dealing with problematic missing sections, core observations may also help significantly as in the Carito Field where timing and geometry of deformation bands revealed by a diagenetic study indicate a multiphase complex tectonic history with rotation of transport direction.

While 3-D seismic is the norm, 2-D lines can be invaluable in defining the tectonic style in very complex areas. Large amount of hydrocarbons can be present below faults which have been obliquely reactivated and which appear at first glance to have the geometry of normal faults (e.g., Western Canada Foothills).

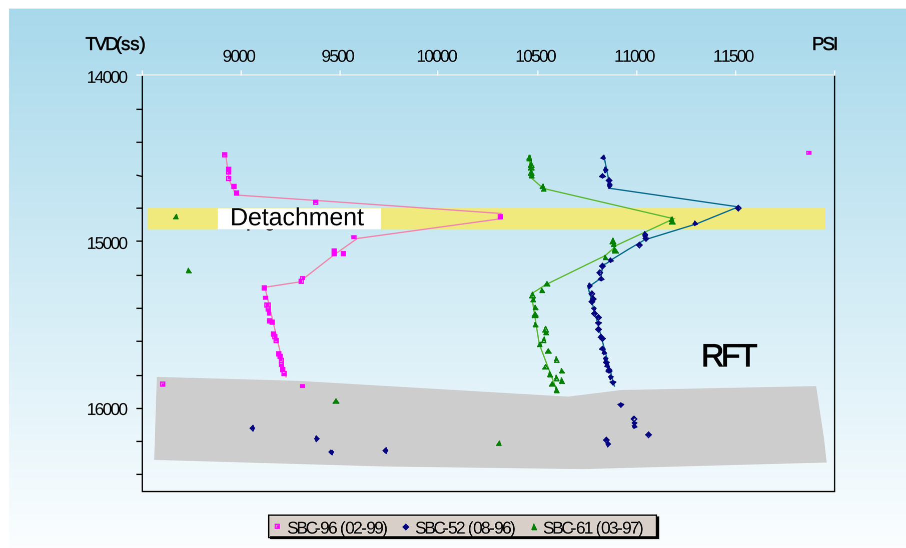
Implications for the examples cited above range from redesign of water injection wells for pressure support (Lama Field) to major bypassed pay zone (Santa Barbara Field) and finally to a new hydrocarbon discovery (near Bosque Field).

Problems at same stratigraphic levels
(Furrial Field)

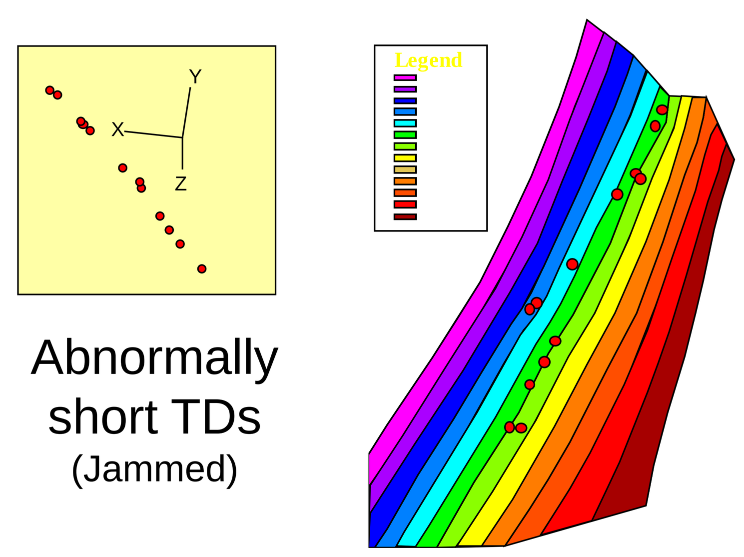


Many wells are missing sands from the exact same stratigraphic interval

Pressure problems at same depth
(Santa Barbara Field)

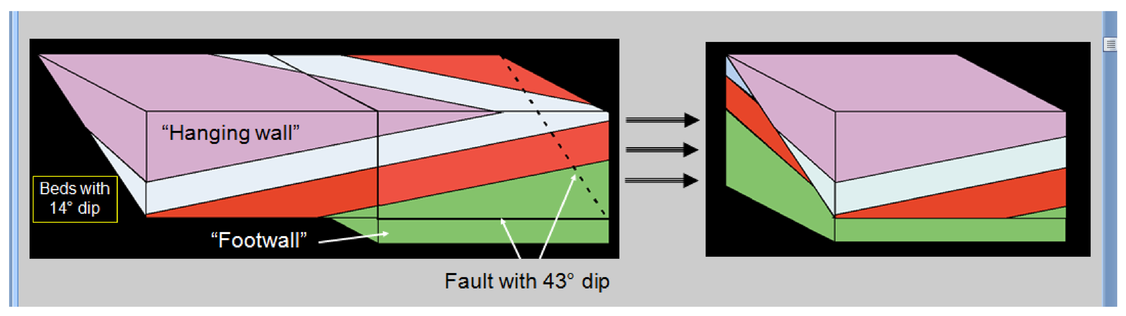


Drilling problems on single plane
(Lama Field)



Abnormally short TDs
(Jammed)

Fault-plane dip different from bed dip
(modelling)



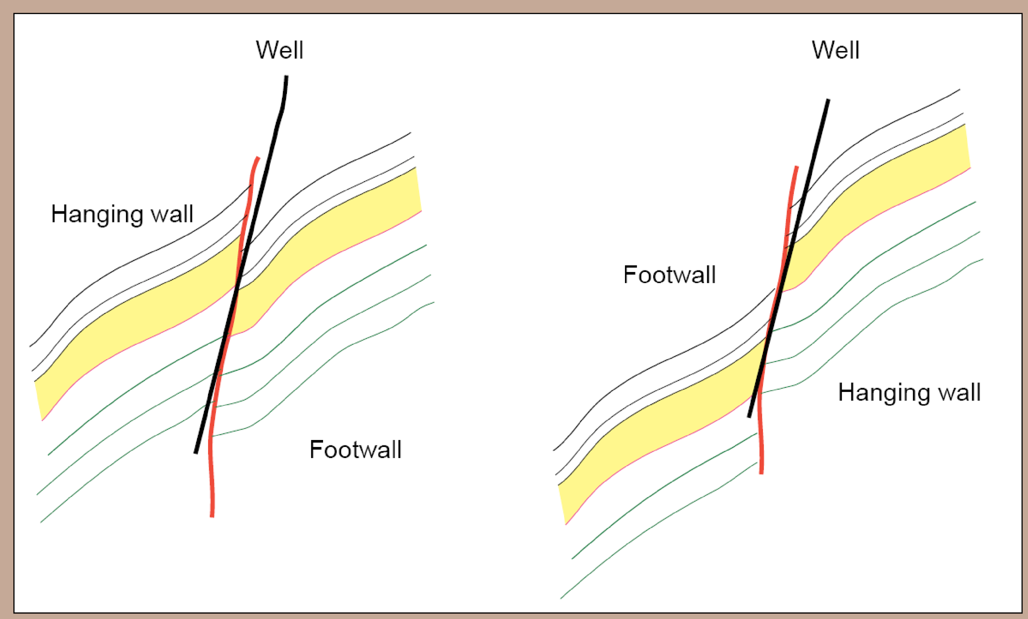
Syn-sedimentary tectonic activity

Keywords | Pattern on maps | Blocky sands | Same units missing

Observations

Borehole geometry (especially in offshore wells)

Reverse fault
with
Missing section



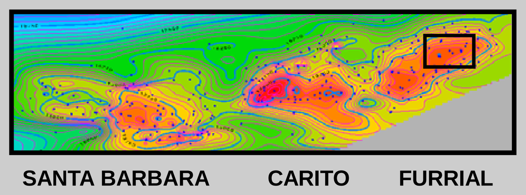
Normal fault
with
Repeat section

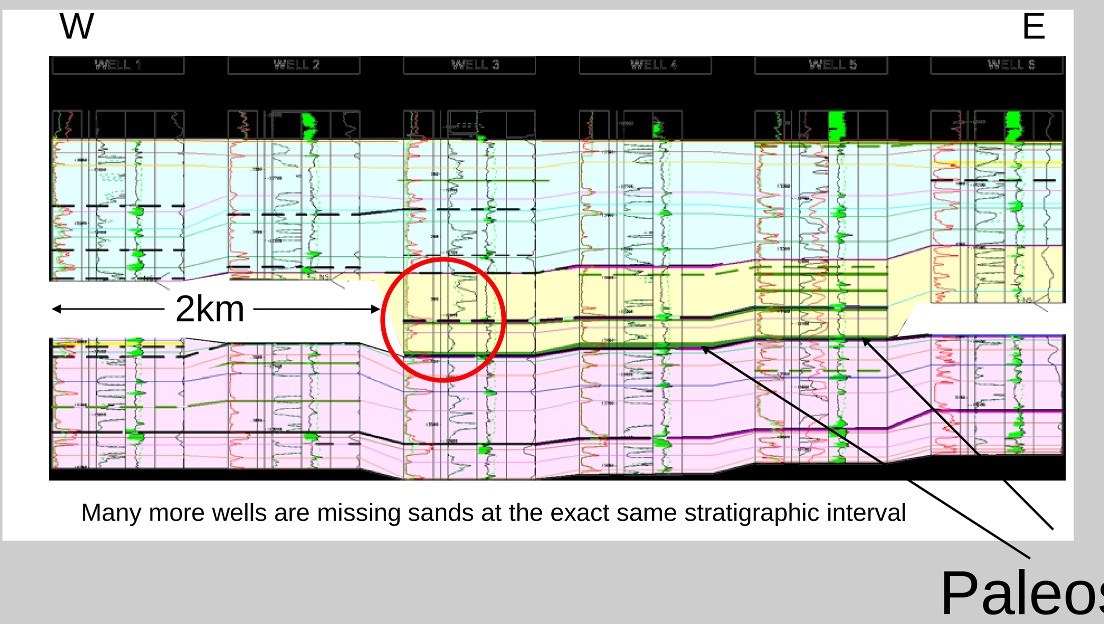
In particular instances the well trajectory could lead to misinterpretation

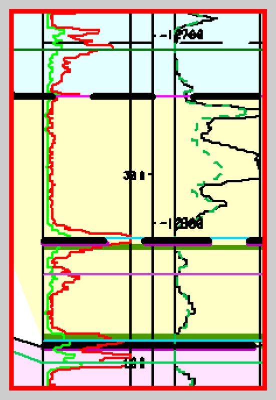
Synsedimentary tectonic activity creating havoc

Furrial Field

Venezuela
OGIP = 7.5 Billion bbls







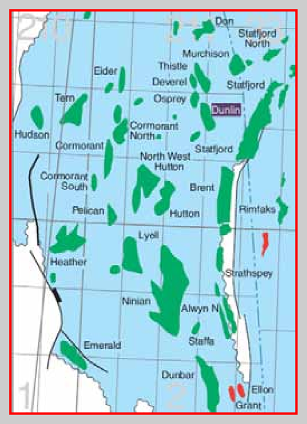
Best sand in Furrial
(zoomed view)

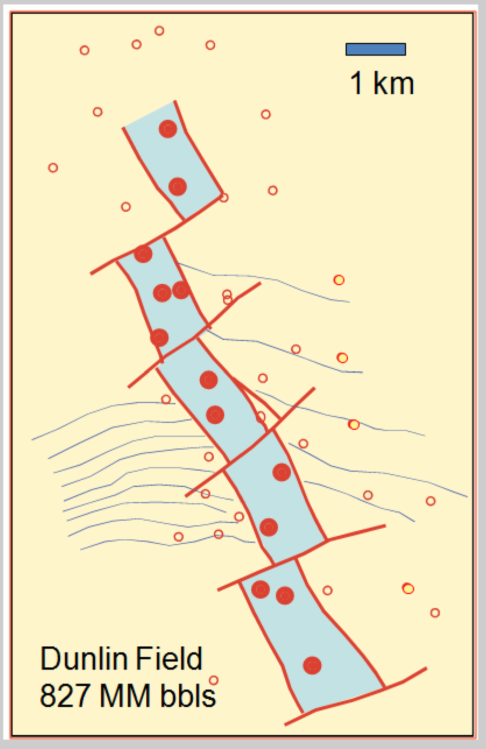
Best blocky sands are missing at the same stratigraphic level

Missing sections commonly misinterpreted as being associated with normal faults

Dunlin Field

UK North Sea
OGIP = 0.827 Billion bbls





Blocks in blue indicate where the blocky sands of the upper Ness E (Brent Group) are missing

In the Dunlin Field, all of the red dots correspond to wells drilled and for a while misinterpreted.

Lessons

- Ø Major mistakes in **reserve estimates** can be linked to syn-sedimentary tectonics
- Ø Missing sections are often found in horst blocks next to the thickest and best sands of a field
- Ø Development scheme can aim at **sands that do not exist**
- Ø **Blocky sands** next to missing sections should trigger your attention
- Ø Same pattern is usually found at the same stratigraphic level in various neighboring fields

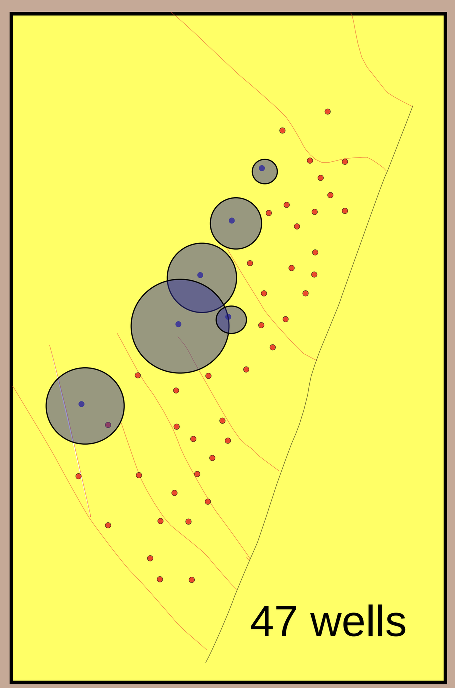
Missing Sections in Strike-Slip Regimes

Example from the Lama Field (Block VLA 31) Lake Maracaibo, Venezuela

Key points | Oblique slip | Displaced facies | MBPA

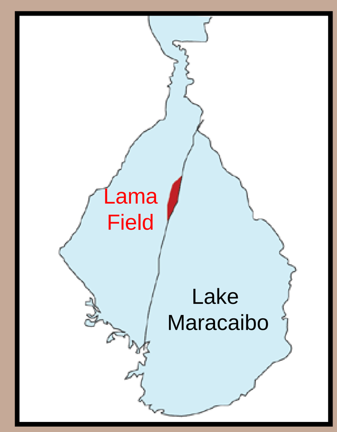
Observations

Lama Field
Block VLA 31



Geological Model is wrong

Lama Field
Venezuela
OOIP = 7.6 Billion bbls



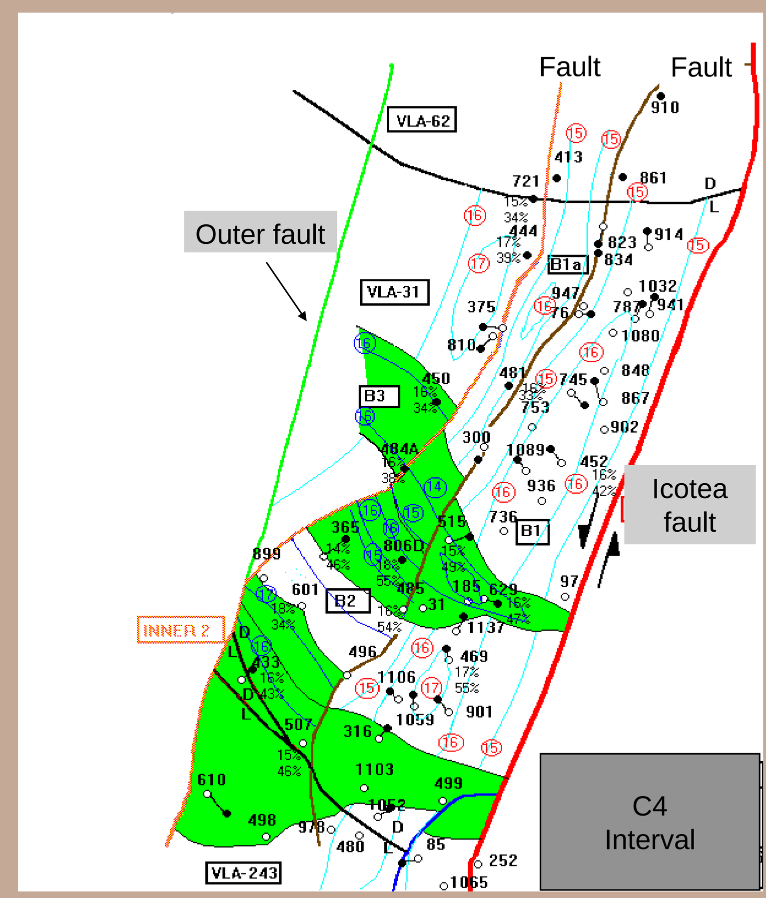
9 wells with missing sections

1 well with a small repeat

29 wells not reaching the objective (jamming)

More than 15 years of water injection has not helped maintain the pressure of the field

Misoa C4 facies map



Final **Interpretation**

Channels dissecting the marine bars.

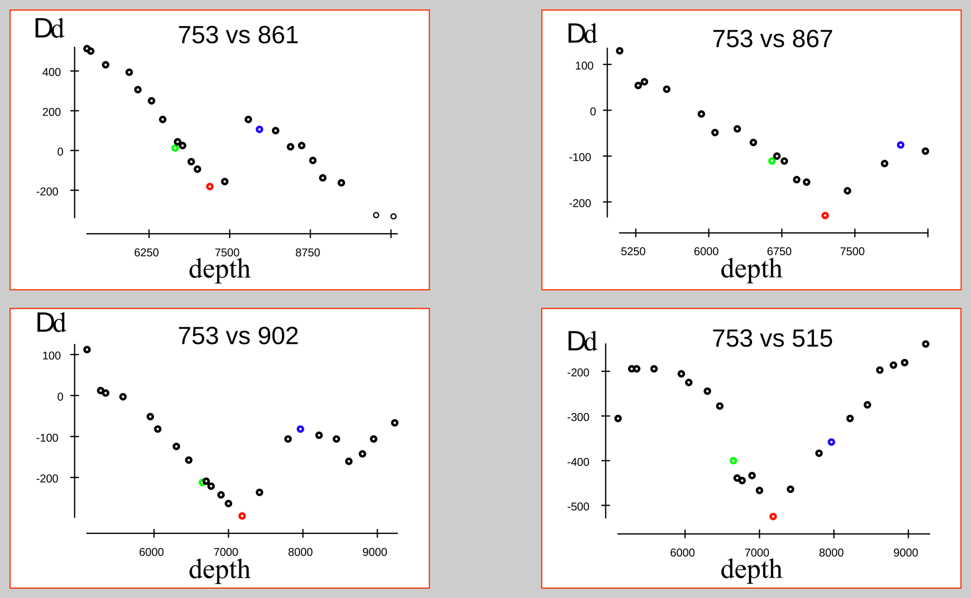
Channels perpendicular to the Icotea Fault

Estuarine channels
Marine bars

Resolving the Problems

Multiple Bischke Plot Analysis

Disagrees with normal faulting



The stratigraphy of Well 753 is compared to four non-faulted wells

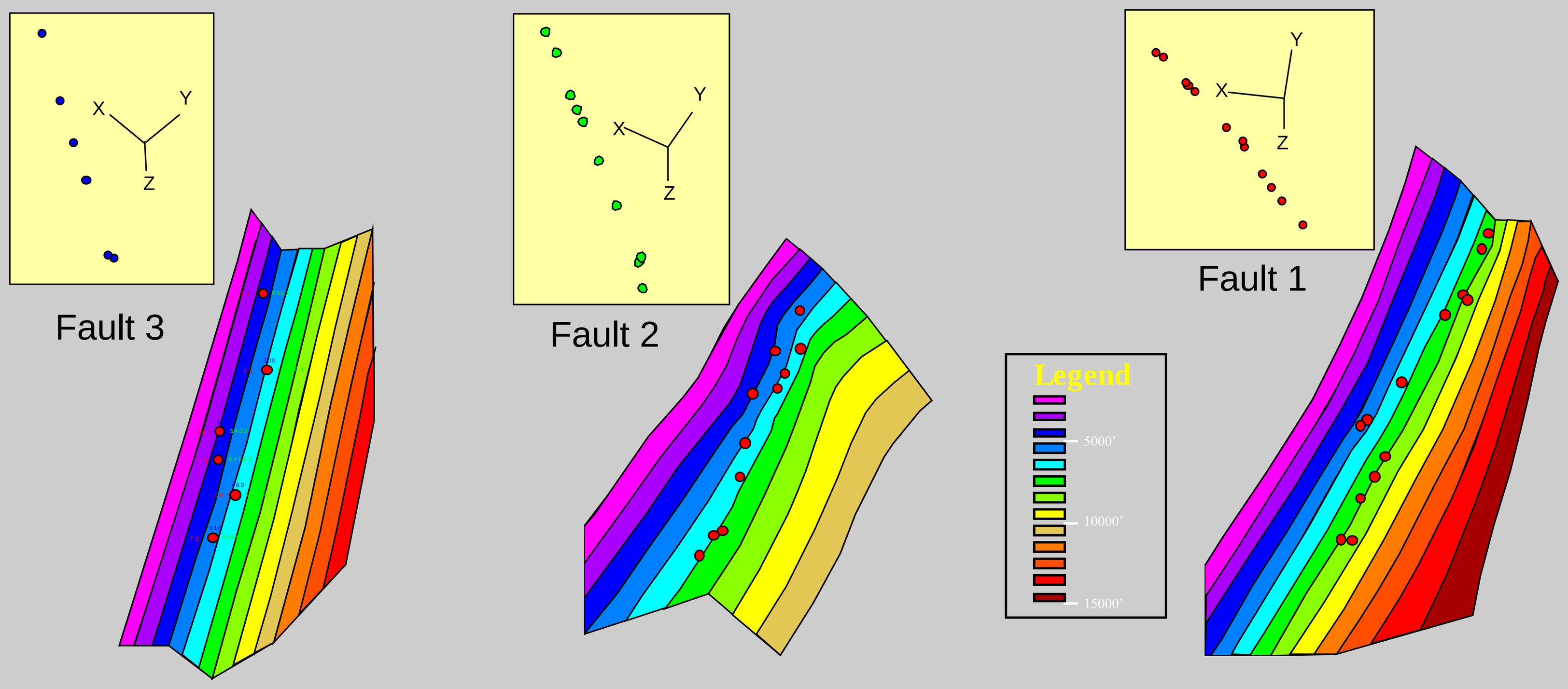
Conclusion = the red marker is misinterpreted

MBPA graphical method allowed confirmation of the position of the faults where missing sections are found; however, the MBPA demonstrates that these are not missing sections but miscorrelations.

+

3D analysis of all abnormally short TD

delivers 3 perfect fault planes



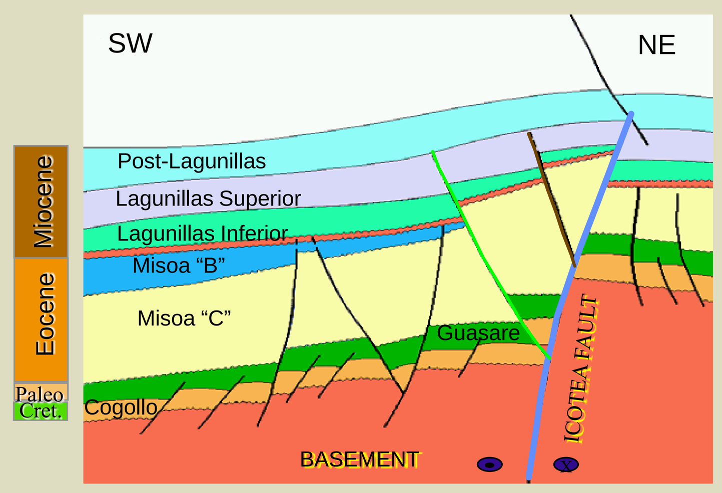
6 abnormally short TDs | 11 abnormally short TDs | 12 abnormally short TDs

Each of the fault cut-out fits on one of the three planes defined by the abnormal TD of the wells that did not reach the planned objective (the Guasare Formation)

Lessons

- Ø Lateral motion along faults in strike-slip settings can induce :
  - Missing sections associated with reverse faults
  - Repeats not recognized because the **repeats are from different facies**
- Ø The Multiple Bischke Plot analysis can help review the stratigraphy
- Ø TDs of **jam-terminated wells** can indicate the presence of faults

Cross-section of final model



Multiphase Deformation on Low Angle Reverse Faults

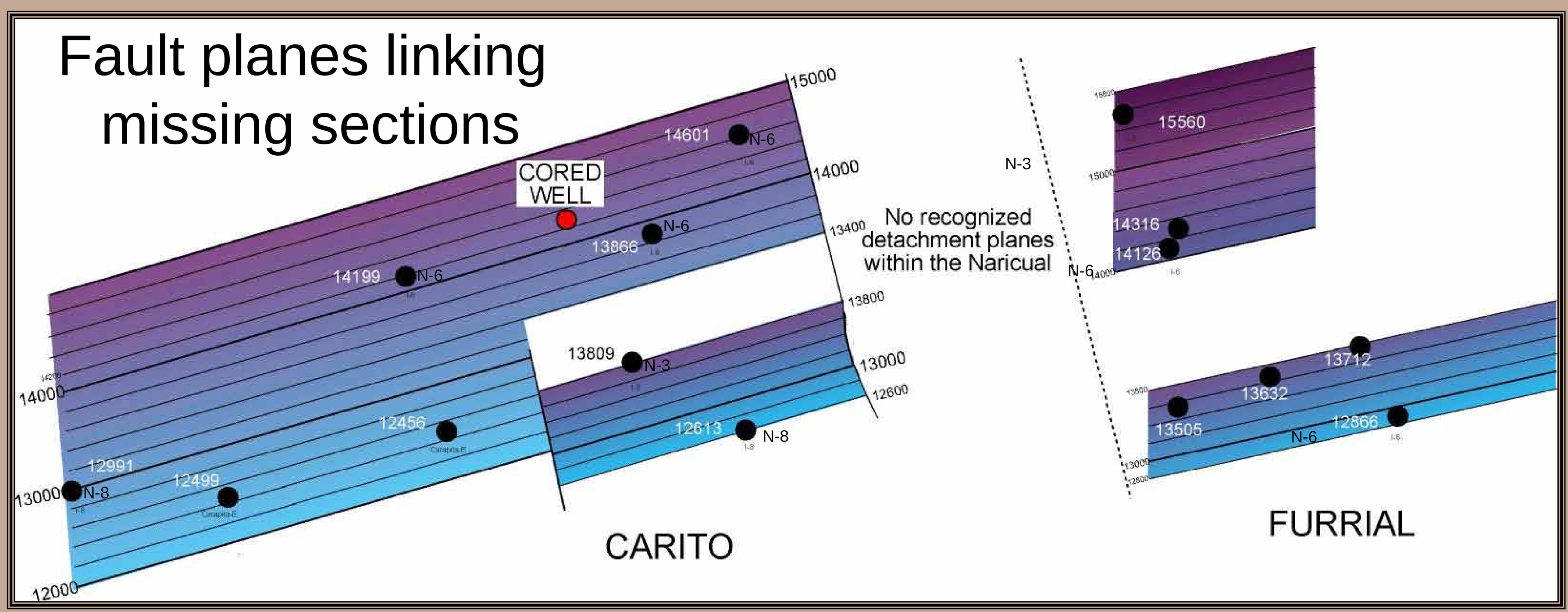
Key points | Fault cut-out on **planes** | Pressure trends | Polyphase deformation

Problem 1

Each well on the following maps exhibits **missing sections**

Each was first interpreted as **normal fault**

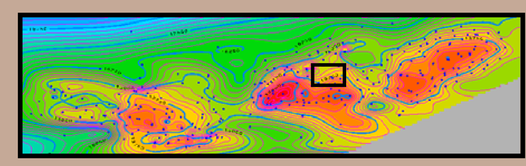
depths in feet are indicated on map

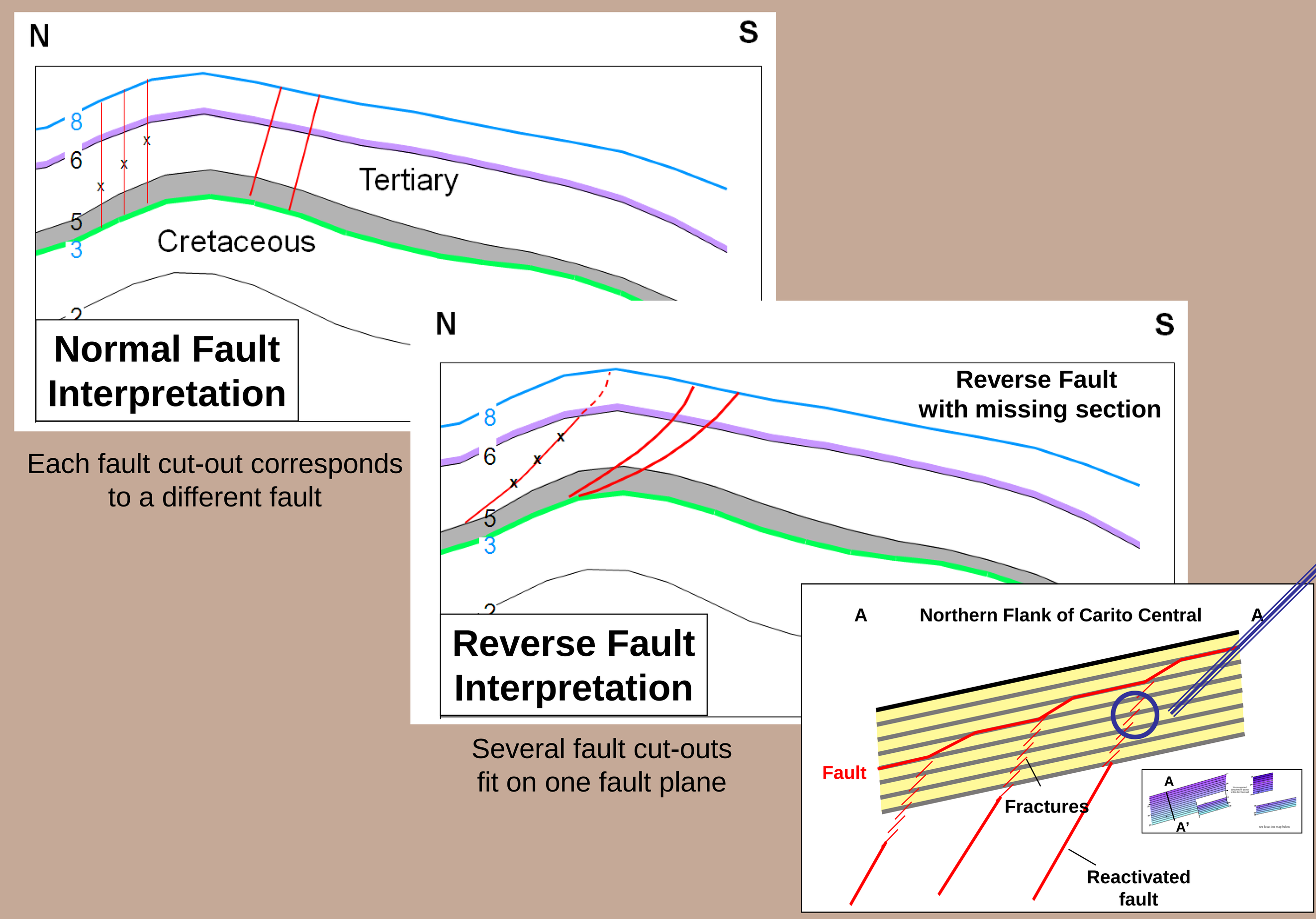


Carito Field

Venezuela

OOIP = 6.7 Billion bbls

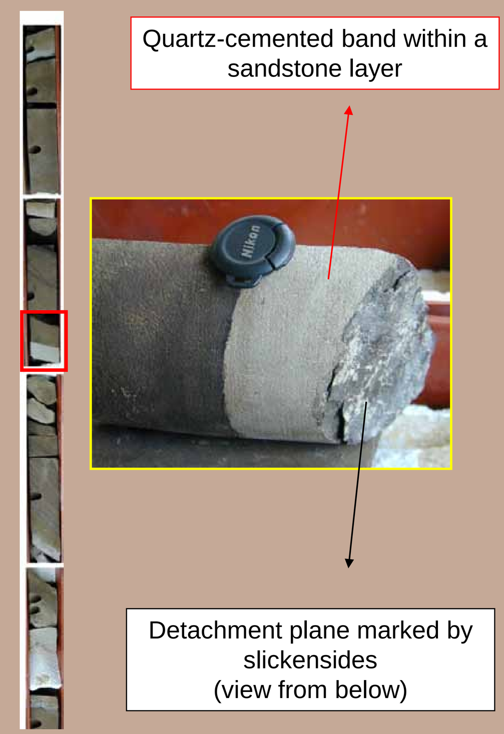




Each fault cut-out corresponds to a different fault

Several fault cut-outs fit on one fault plane

Proposed mechanism (detail)



Problem 2

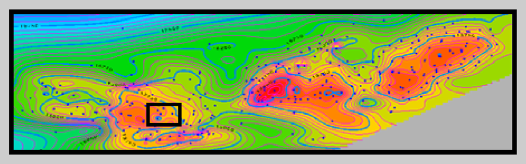
Santa Barbara Field

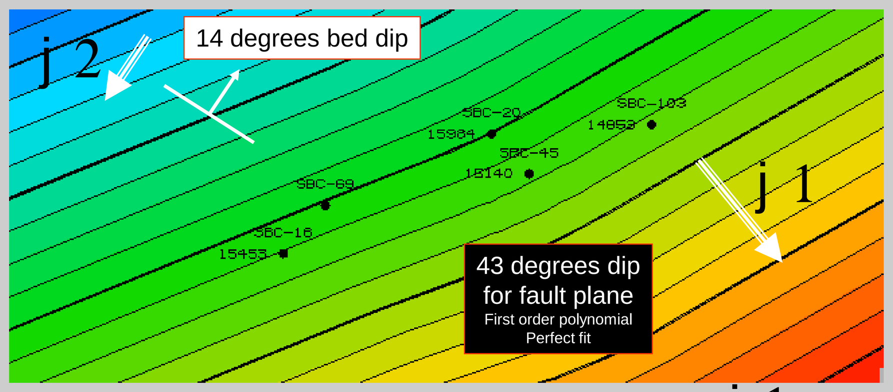
Venezuela

OOIP = 6.1 Billion bbls

+ OGIP = 21 Tcf

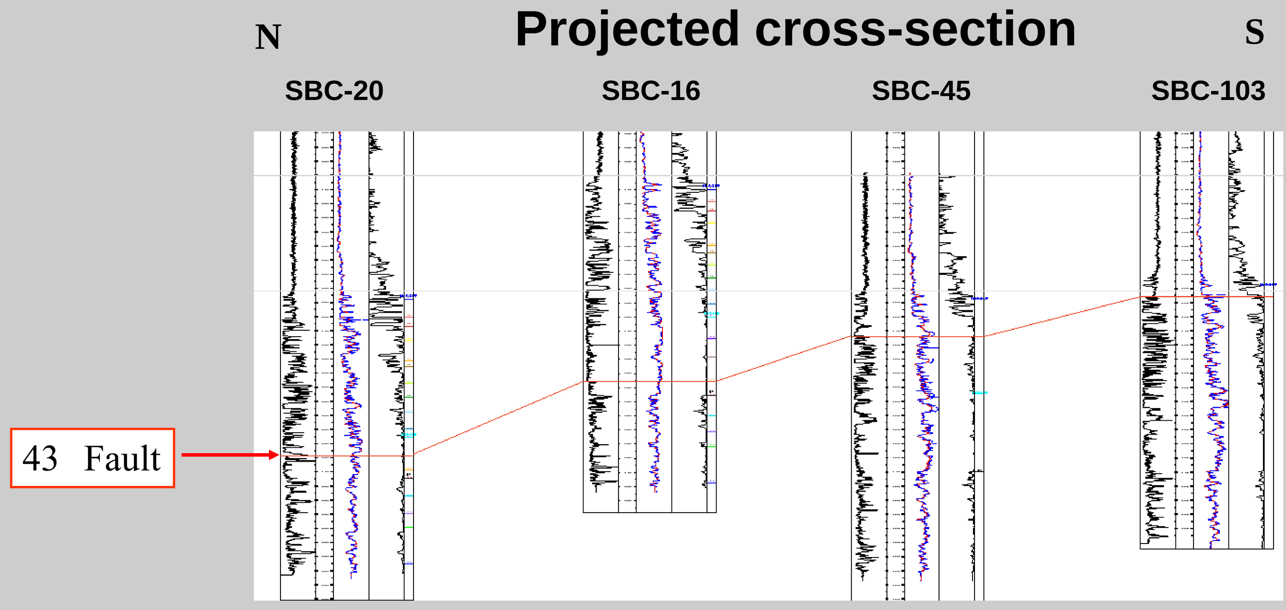
Total = 9.6 Billion BOE





Fault plane generated by first deformation phase j 1

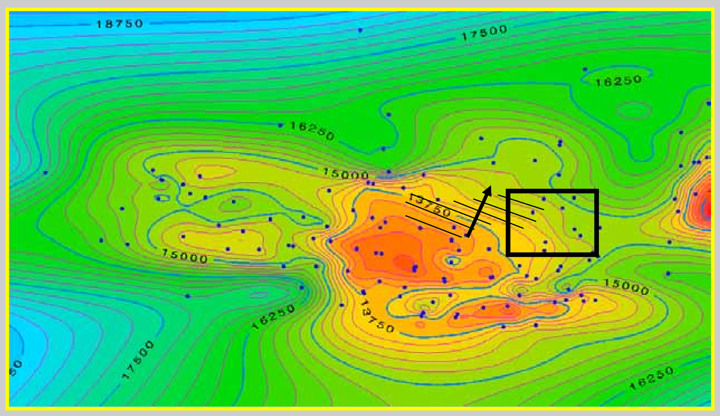
Oblique slip was generated by the second phase of deformation j 2



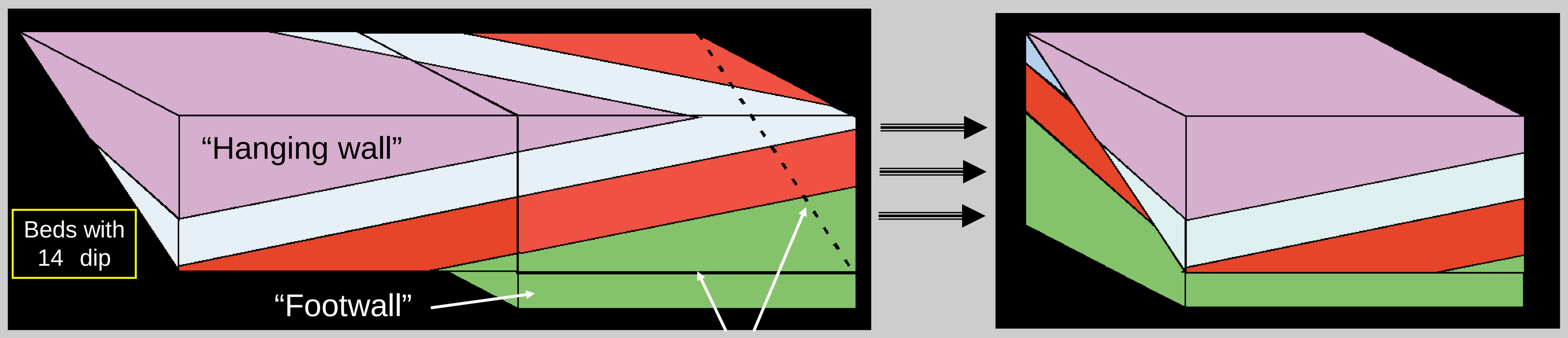
Each fault is associated with a missing section at a different stratigraphic level

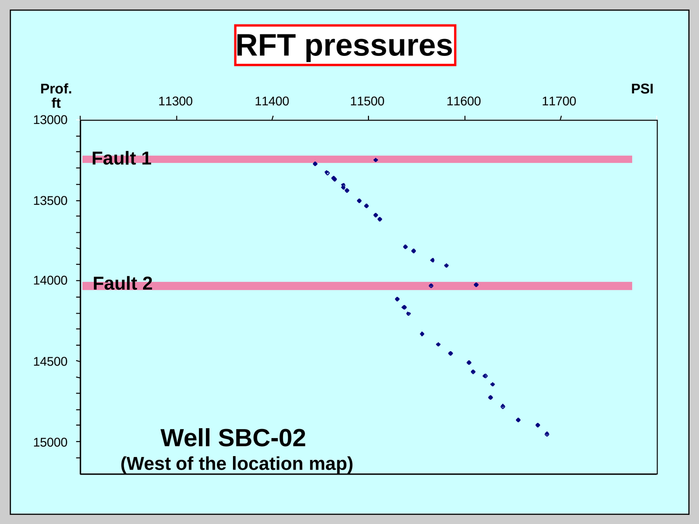
SBC-116 was a very successful infill well drilled as a follow-up of that new interpretation

(8000 bopd)



Missing sections associated with strike-slip or oblique slip





Tectonic post-hydrocarbon emplacement is reflected in the pressure trends

Reverse faulting is interpreted from pressure data (despite a missing section)

Lessons

- Ø Planar alignments of fault cut-outs can help indentify misinterpretations :
  - Fault planes between 30º and 60º can be associated with multiphase deformation
  - Missing section is obtained by sedimentary sequences gliding obliquely on a preexisting fault plane
- Ø Large untapped hydrocarbon pools are found below such faults (e.g., SBC-116 with 8000 bopd)
- Ø Sealing capacity of these faults is common and can be related to reactivation and cataclasis

Missing Sections Associated with Detachments

Key points | at same depths | Pressure problems | Gradual throw change

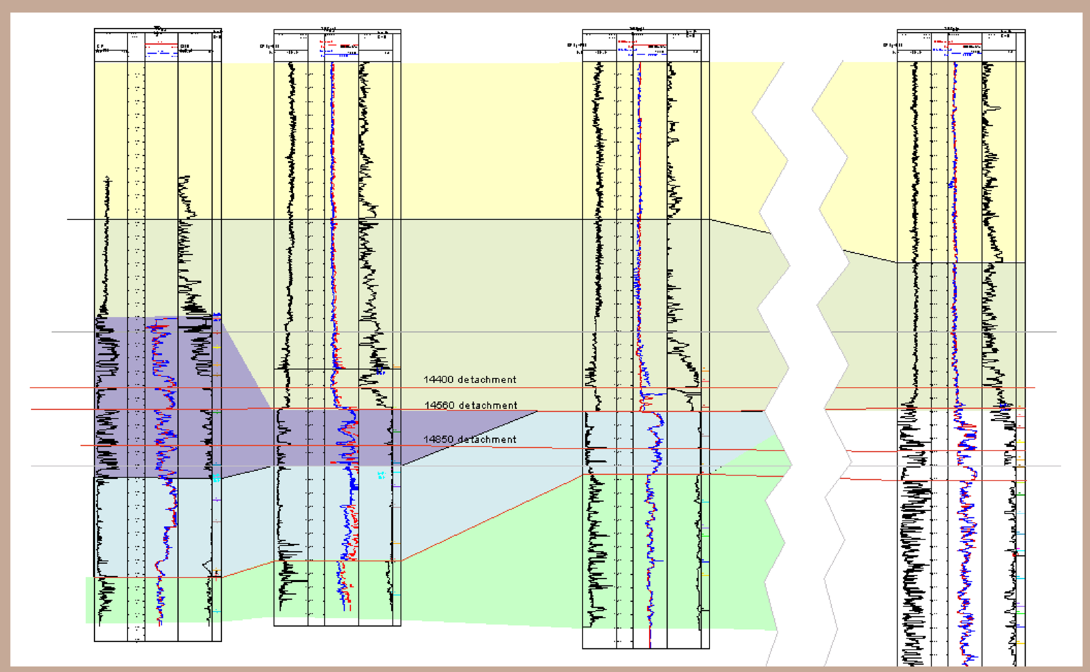
Problem 1

Santa Barbara Field

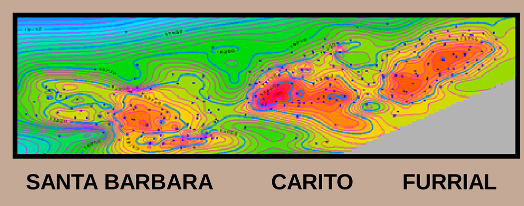
Venezuela

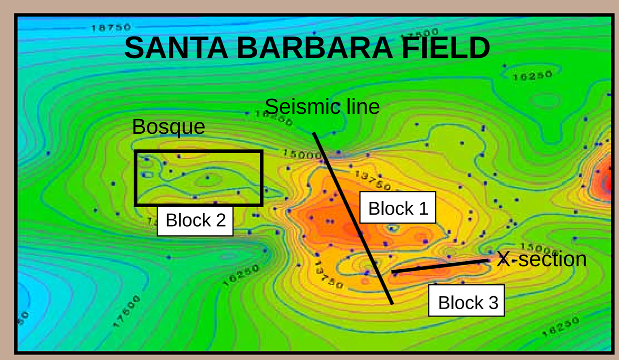
OOIP = 6.1 Billion bbls
+ OGIP = 21 Tcf
Total = 9.6 Billion BOE

Example from Santa Barbara block 3

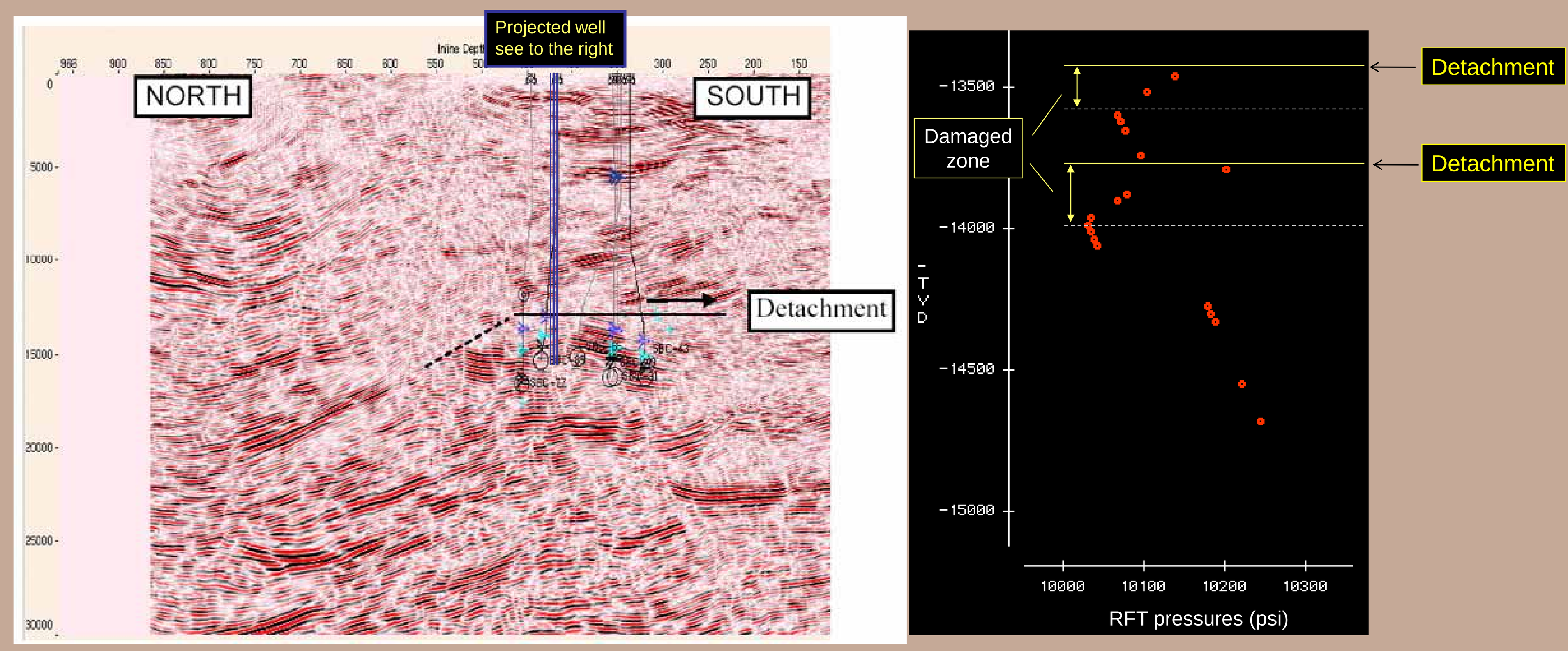


Missing sections at the **same depth** in every well
Very different units are missing





Example from Santa Barbara block 1

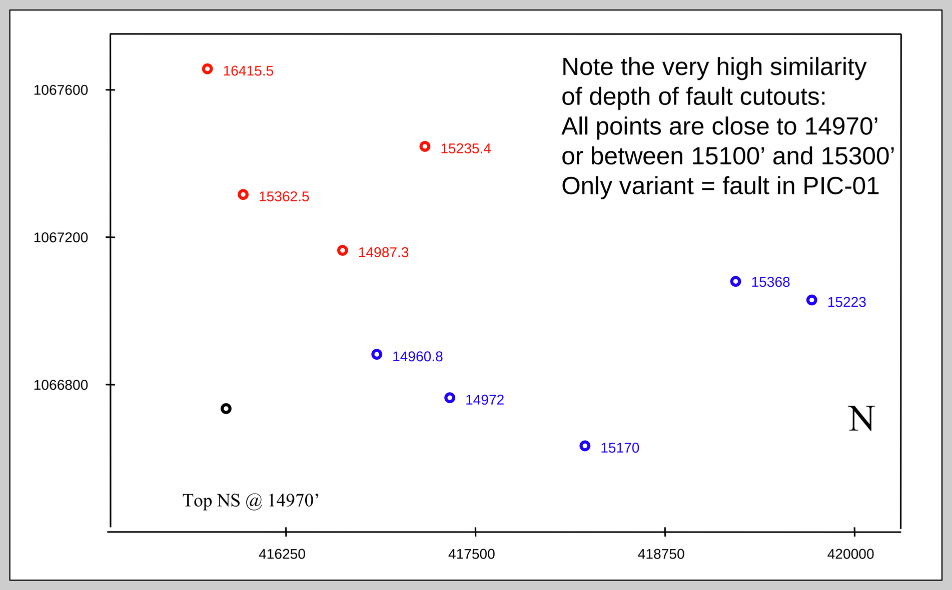


Detachment as seen on seismic
Missing sections observed (see right)

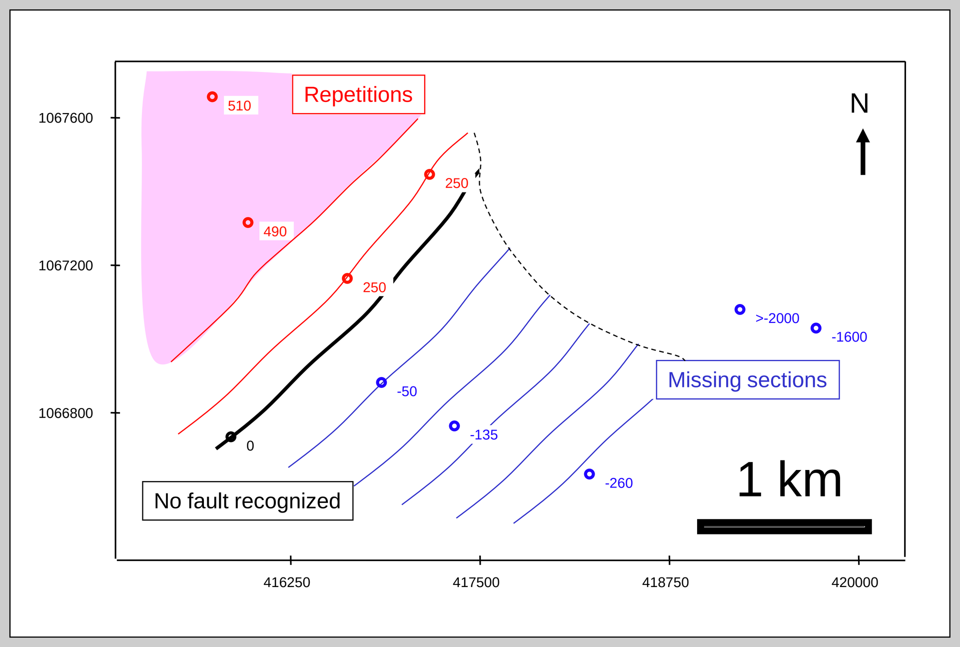
Note the "Herringbone" pattern

Problem 2

Example from Santa Barbara block 2



Depths of major faults in the wells located at the limit between Block2 and Block 4

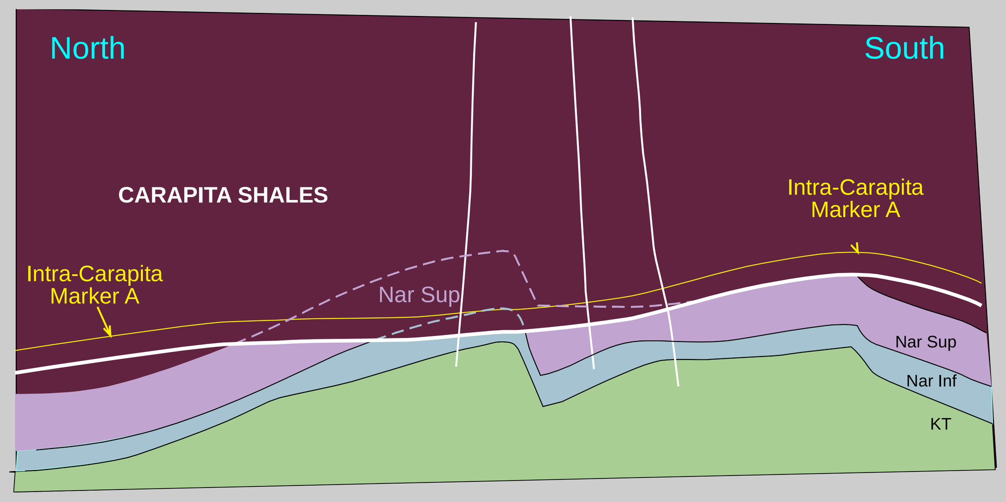


Faults with missing sections and faults with repeats
at nearly the **same depth** in every well.

Whereas the sequence of reservoir is 4000 feet thick
These are the only faults interpreted in each of these wells.

Fault throws are gradually changing on a map view.
Very different units are missing

Example from Santa Barbara block 2



Section from 3-D modelling

Footwalls and hangingwalls associated with each fault cut-out
do not exhibit any drag folding

A major detachment is responsible for all of the missing sections
and repeat sections

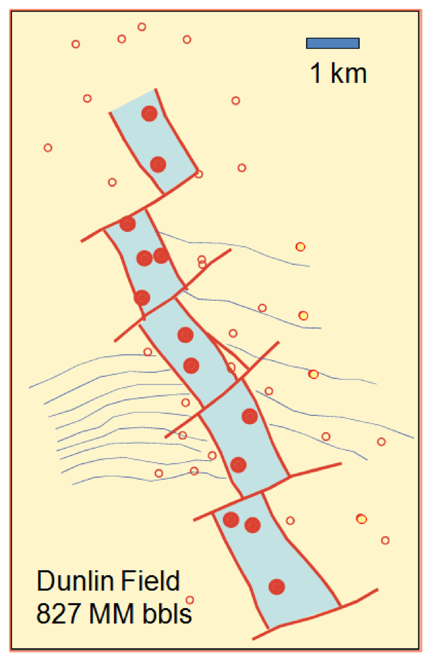
Lessons

- Missing sections occurring at the **very same depth** are linked to **detachment planes**
  - No drag folding and gradual thickness change is found on either side of the fault
  - Bed dip can be different above and below the fault
- **Pressure data** can be very helpful in determining the depth of the detachments
- **Fault-throw maps** can validate the newly developed geological model

Implications for Hydrocarbon Exploration

Implications for hydrocarbon exploration

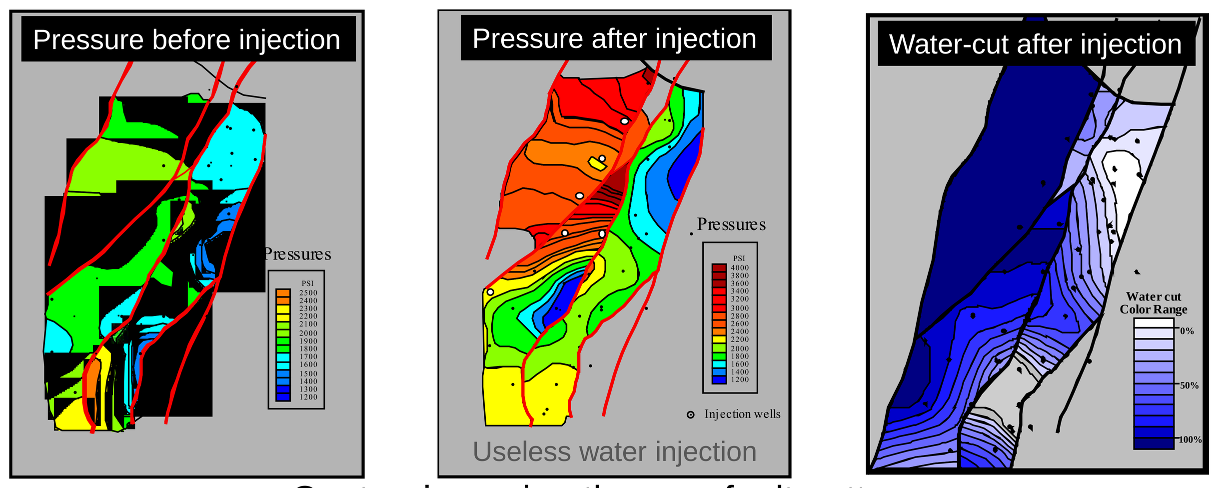
Reserves overestimation and far from optimum development scheme
(Dunlin and Furrial fields)



Non-official interpretation

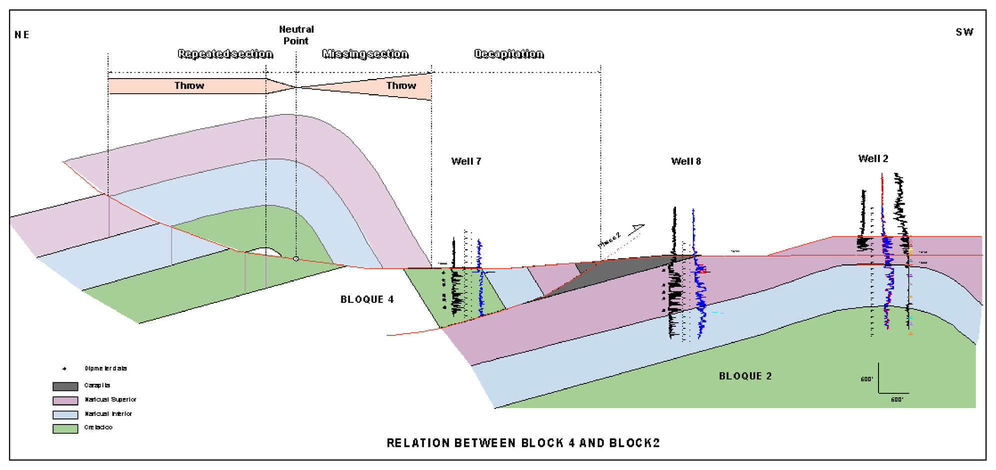
Best sands are absent on the horsts

Wrong injection scheme
And wrong structural model
(Lama Field)

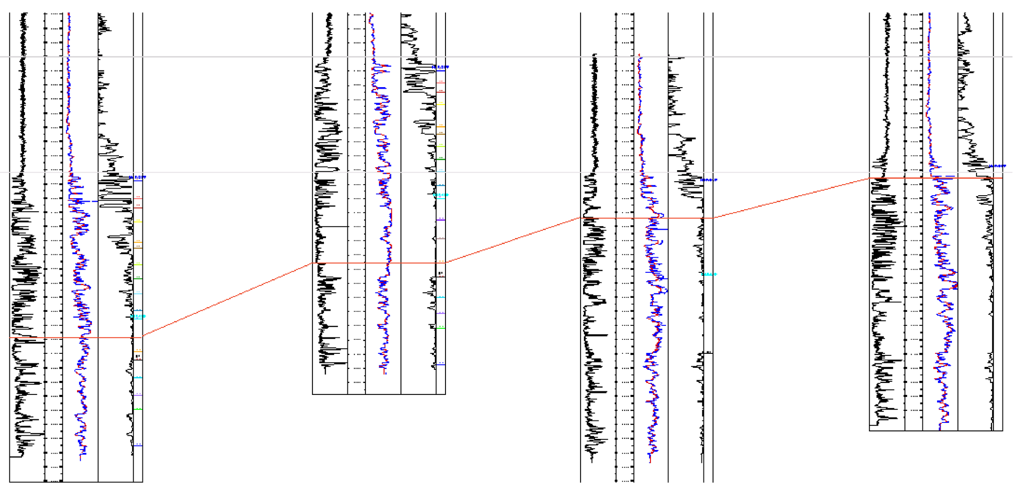


Contouring using the new fault pattern

Missing a giant field
(Bosque Field North of Santa Barbara Field, block 2)



Misunderstanding of by-passed zones
(Santa Barbara Field, block 1)



Much by-passed oil below the fault plane

Main lessons

You may want to be aware of:

Missing sections at the **same stratigraphic level** in many wells

Missing sections at the **same depth** in neighbouring wells

Missing sections on a **well defined plane**

Reservoir pressure problems

Drilling problems (Jamming)

A few selected references

Chatellier, J-Y., Rueda, M.E., Charles, S. and Romero, I., 2008, Why 3D seismic missed a giant field in the Eastern Venezuela thrust belt; postmortem of a late discovery, CSPG Convention C4lgary, 4 page Abstract http://www.cspg.org/conventions/abstracts/2008abstracts/130.pdf

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