PS Successful Exploration in a Thrust Belt, Lessons Learned from the Giant Fields of Eastern Venezuela (the Furrial Trend)*

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Abstract

In the last 20 years very large discoveries have been made in the Eastern Venezuelan Thrust Belt, a region often referred as the Furrial Trend. It is composed of a series of giant oil fields with reserves of about 26 MMMbbls and 50 TCF and a gross reservoir thickness exceeding 2500 feet. From East to West these fields are known as El Furrial, El Carito, Santa Barbara fields, and the recently discovered Tacata Field. The Furrial Trend covers an area of approximately 50 by 15 km. Lessons have been learned from this outstanding data set that encompasses more than 500 deep and very deep wells and that has been covered by numerous 2-D and 3-D seismic surveys.

The structural style is laterally changing from a simple fault bend fold in Furrial to a well-developed triangle zone in Tacata. Numerous tools and methods have been developed that allow seeing through this maze of data. The structural complexity of the area is responsible for many abnormal observations, many of which are now better understood. These include anomalies in seismic or petrophysical responses and include geochemical or pressure trends as well as geological puzzles. Recognition and understanding of some particular structural features have permitted the discovery of very large accumulations in unexpected locations.

Because of the large number of wells, the Furrial Trend constitutes an ideal database and an excellent analogue for any exploration and production in thrust belts. Lessons learned from these giant fields should be tested in other thrust belts around the world.

SUCCESSFUL EXPLORATION IN A THRUST BELT
lessons learned from the giant fields of Eastern Venezuela (the Furrial Trend)

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** Texas A&M University, College Station, TX

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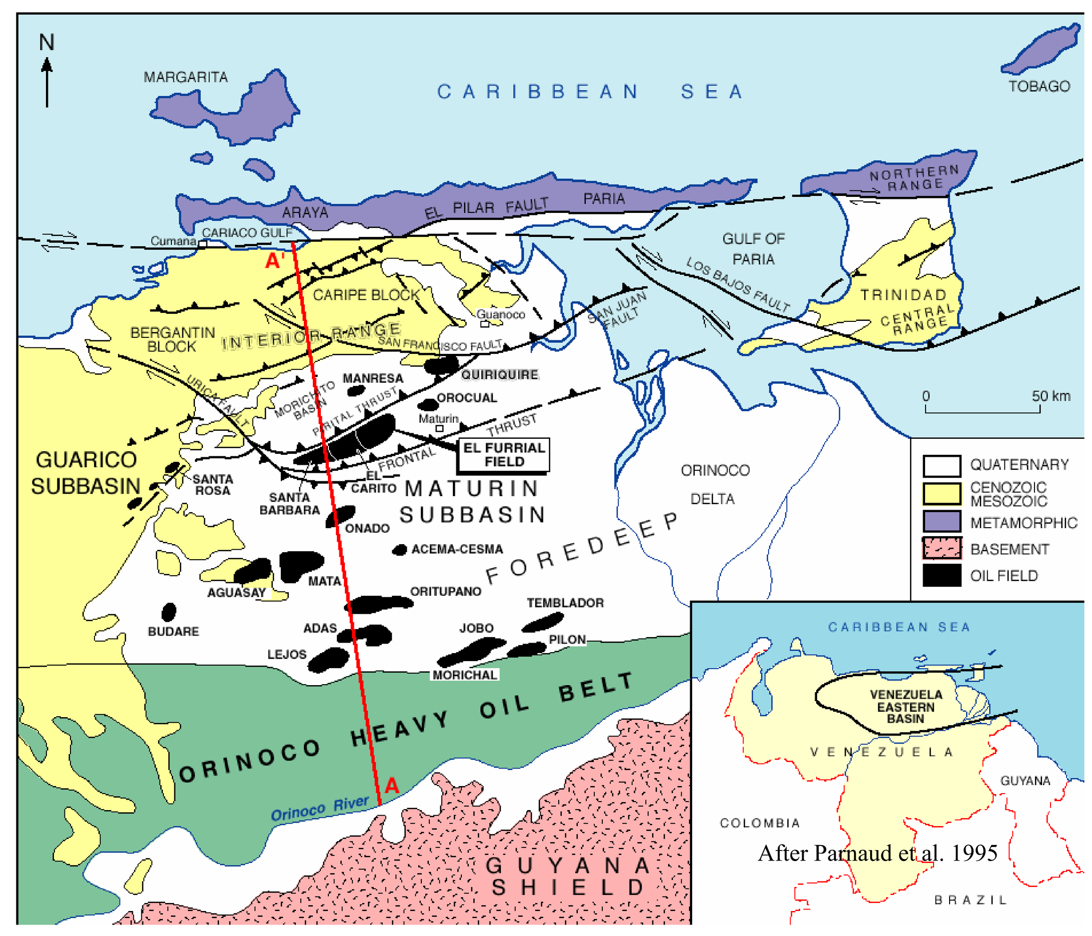
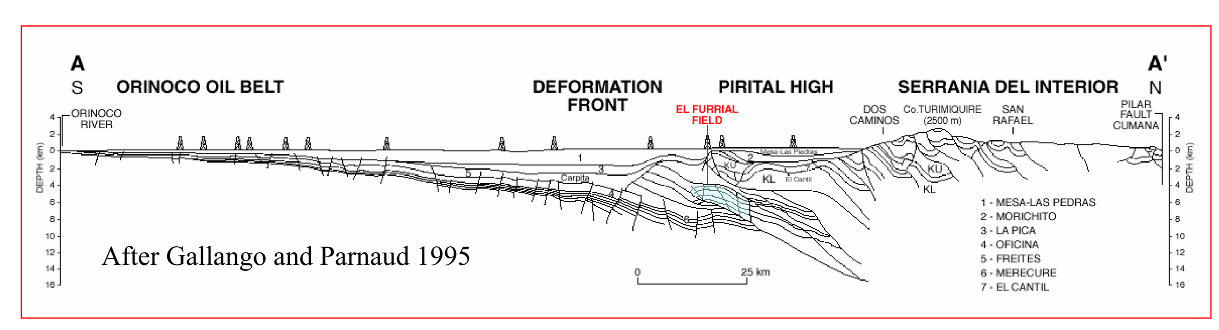
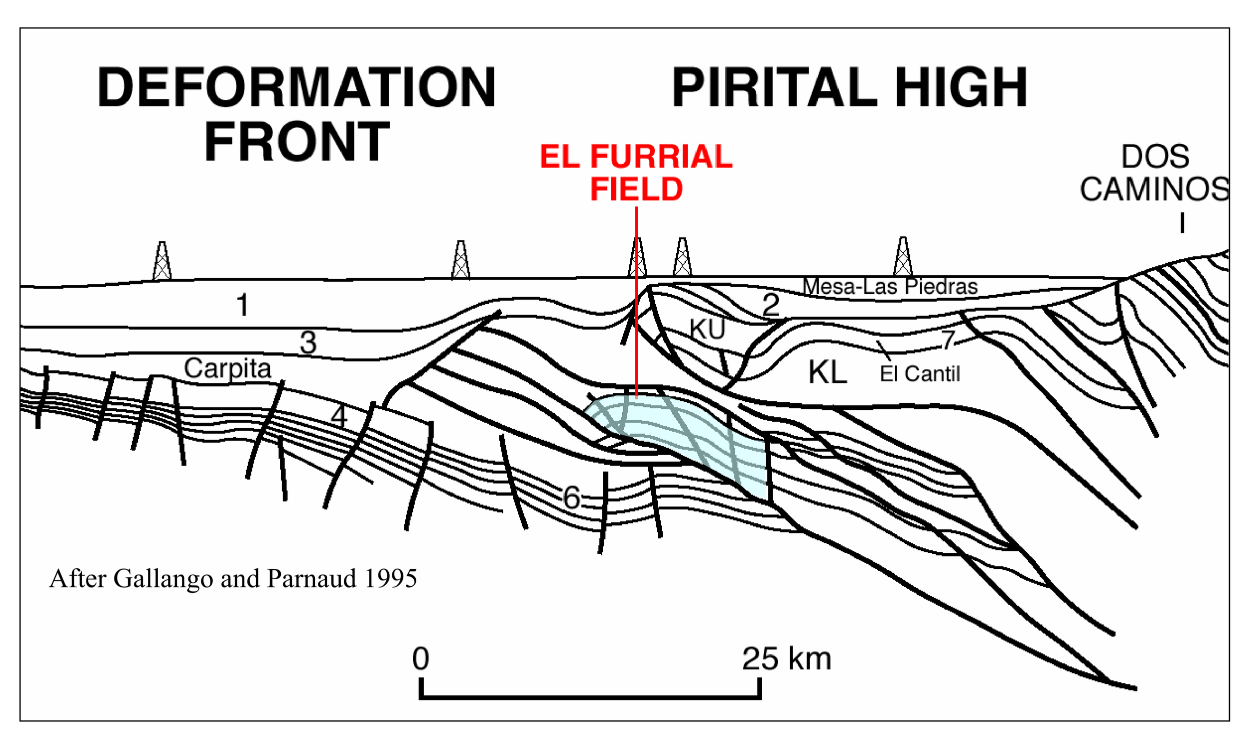
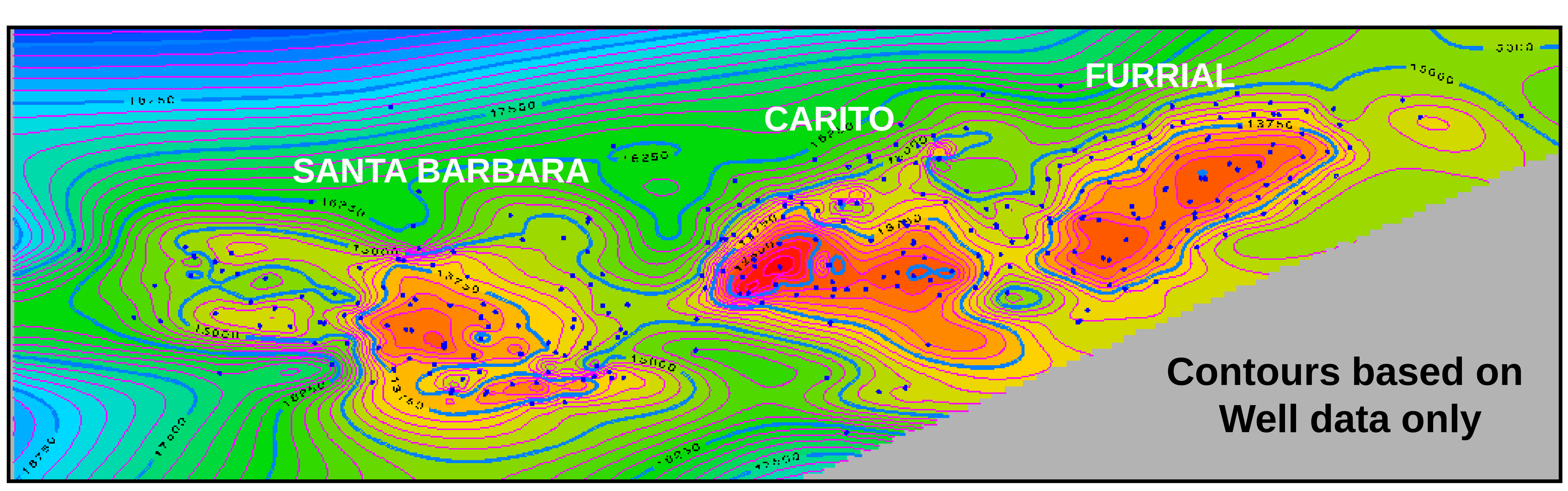


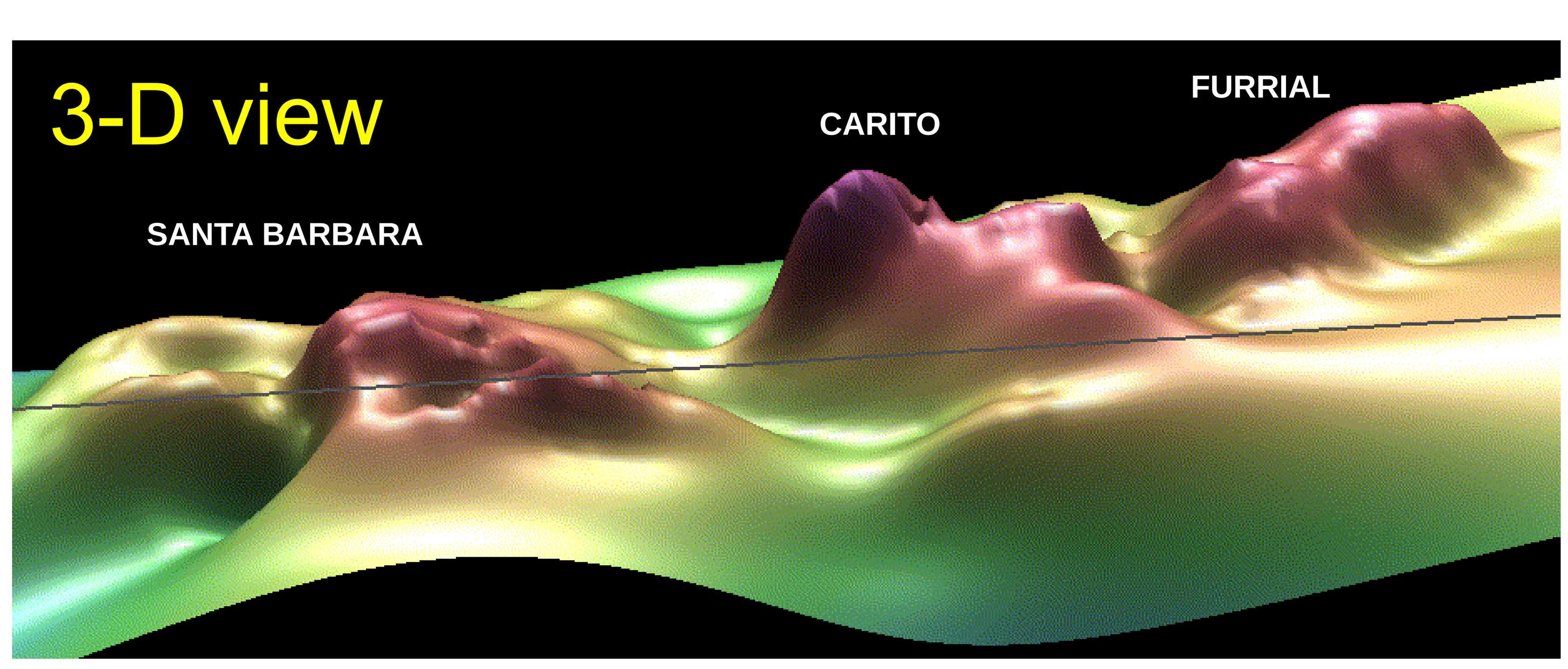
Cross-section through El Furrial trend



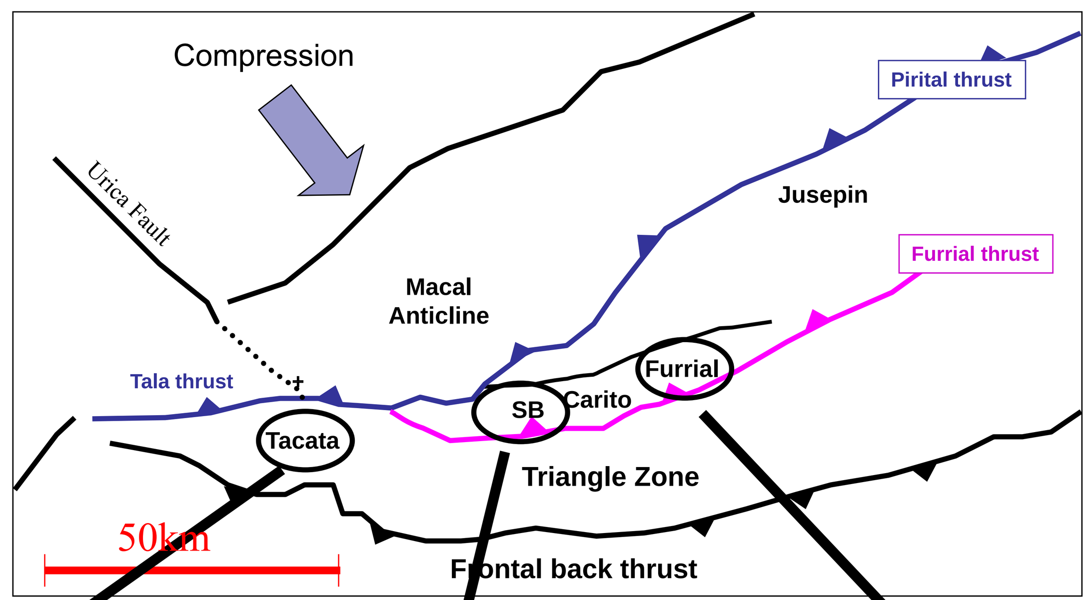


Map view



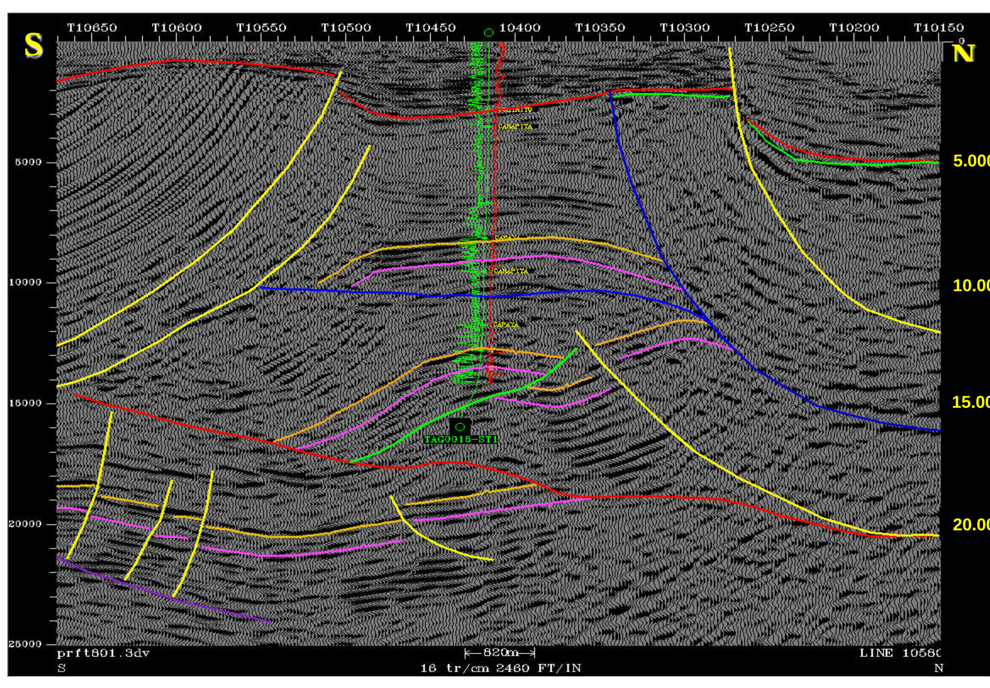


VARIABILITY ALONG EL FURRIAL TREND



After Linares et al 2004

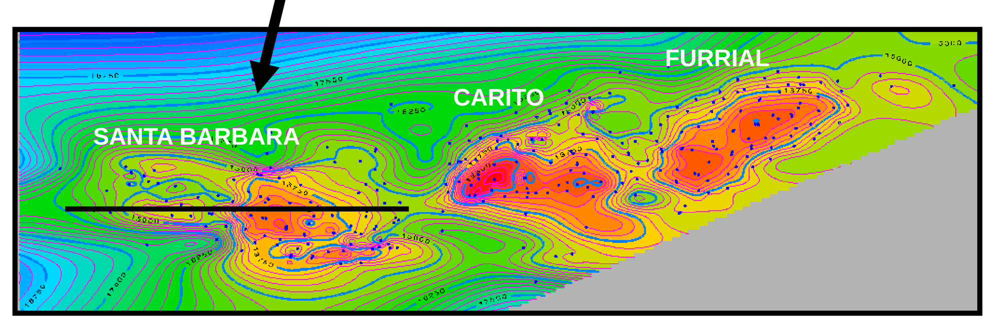
Tacata Triangle zone



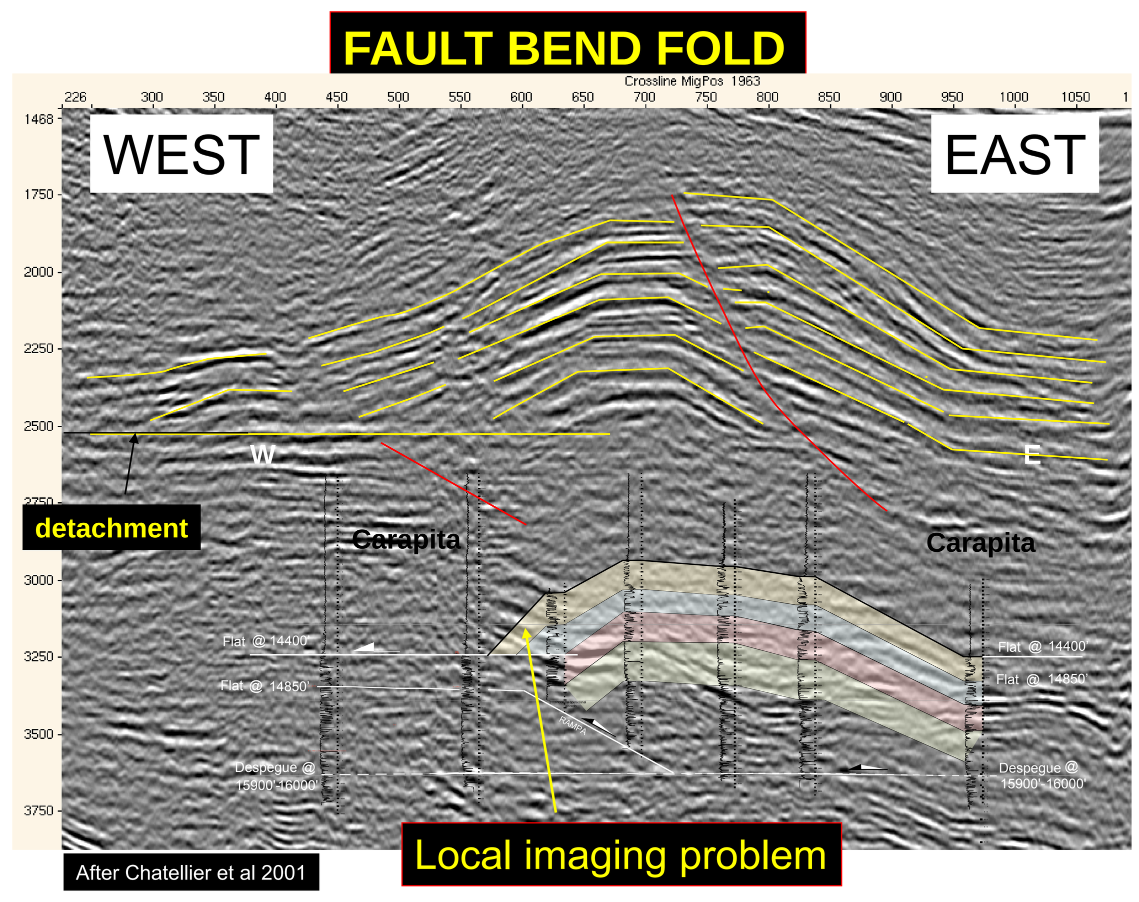
After Mijares et al 2004

Triangle Zone
In Tacata

A recent very large discovery



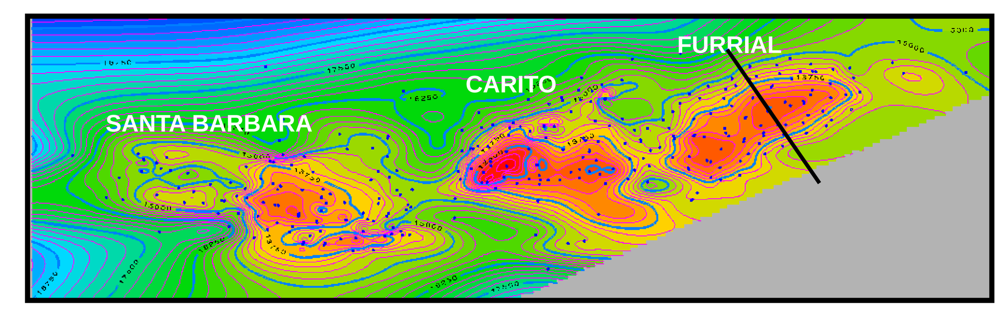
FAULT BEND FOLD

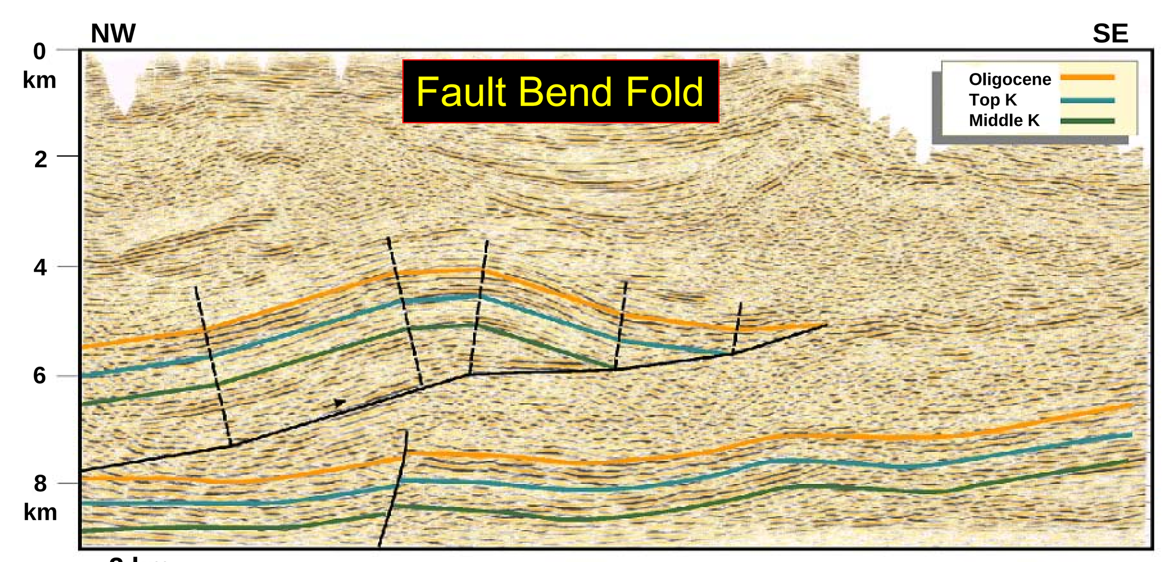


After Chatellier et al 2001

Complex geometries in shallow horizons may dramatically alter the image of deeper horizons

(if not taken into account in processing)

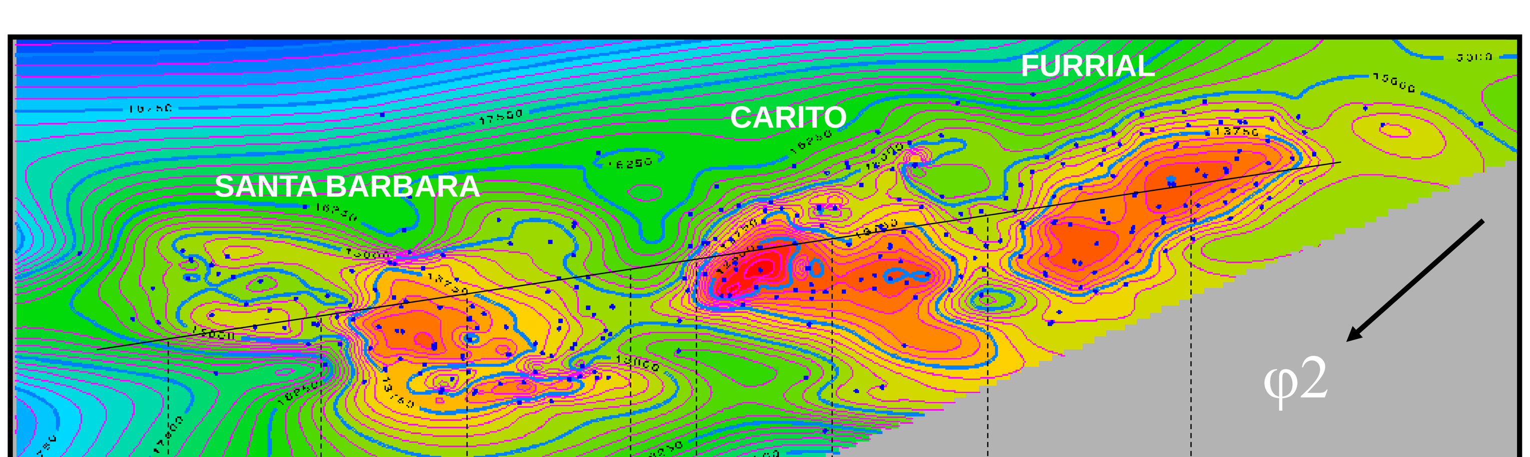


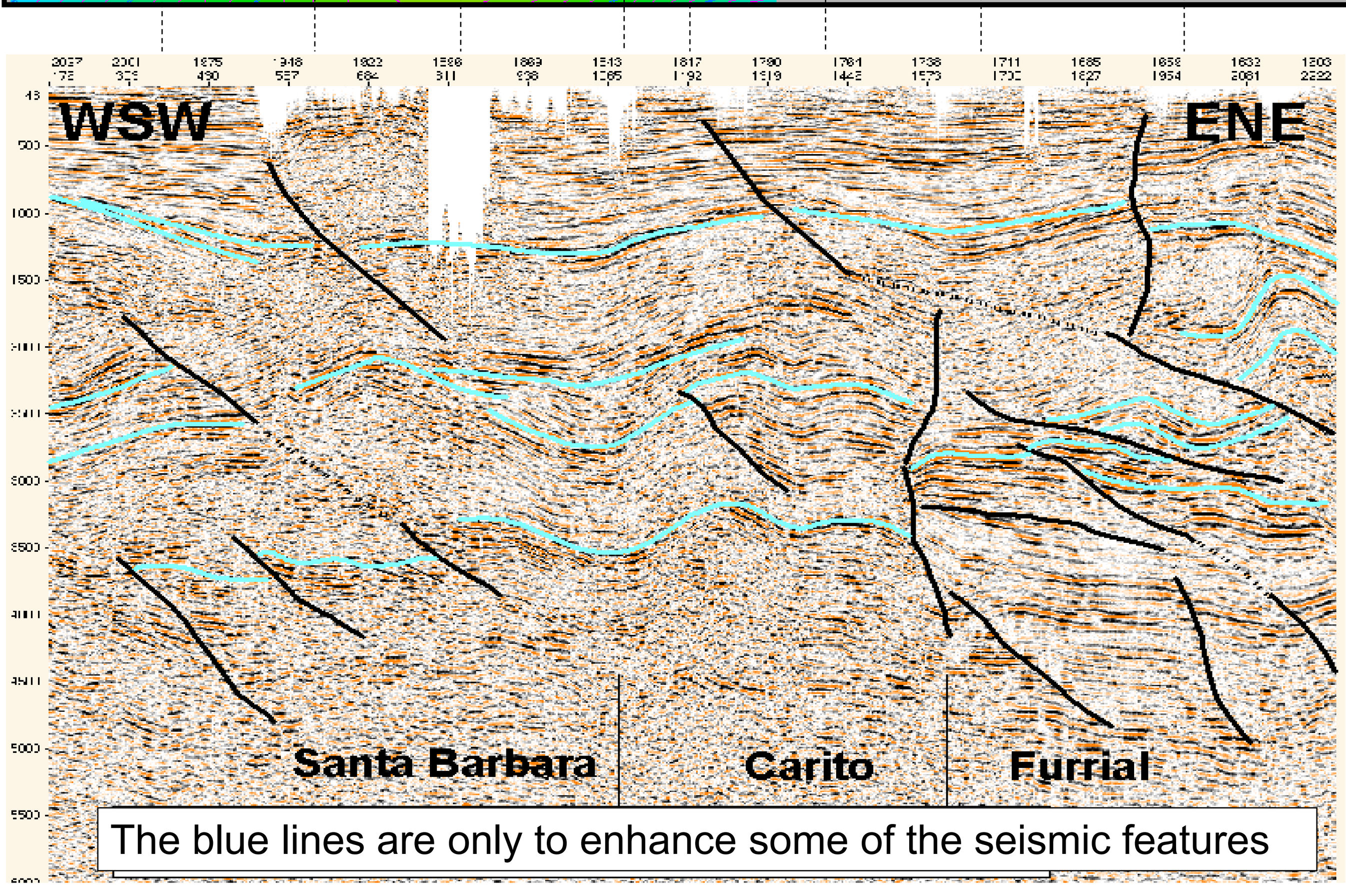


From Morales et al. 2005

Fault bend Fold
in El Furrial

In direction of maximum stress (Phases 1 and 3)





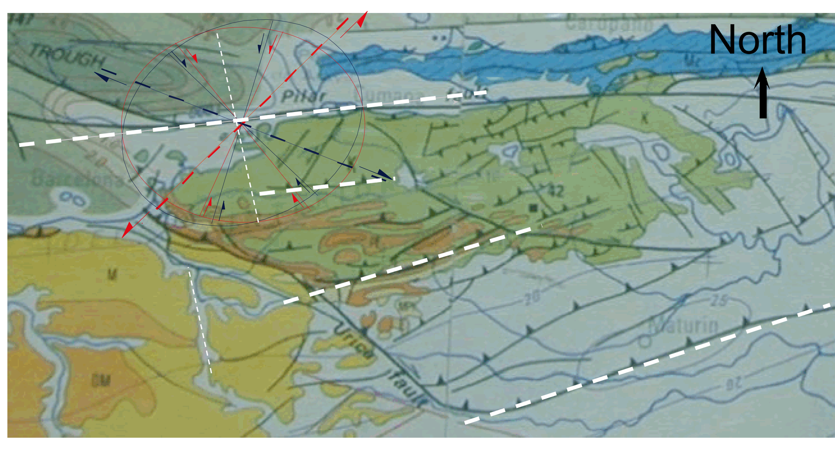
From Chatellier et al 2002

Multiphase deformation and lateral ramps may be best expressed in crosslines

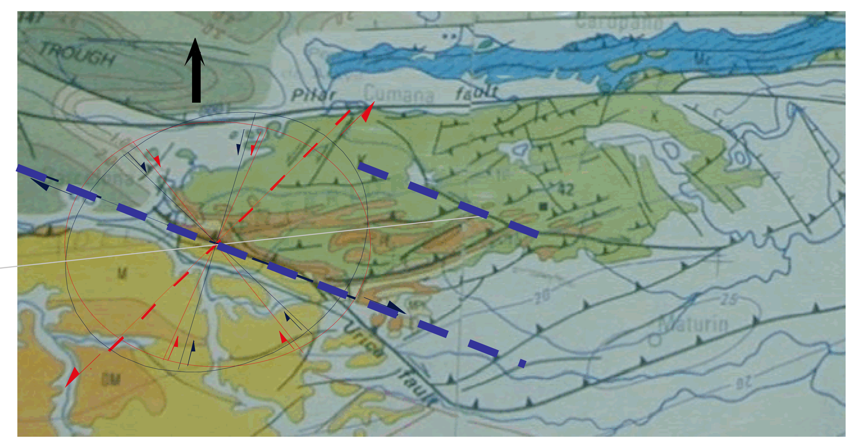
Crosslines should not be neglected in a seismic interpretation

STRUCTURAL GRAIN IN EL FURRIAL TREND

Main structural elements of the thrust belt

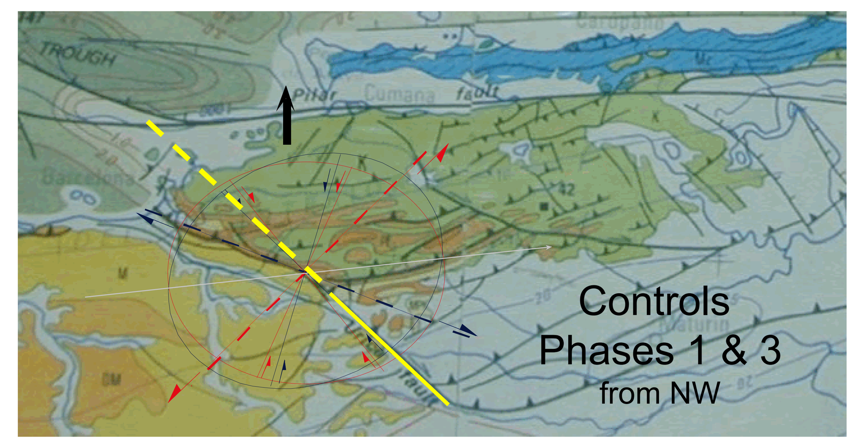


Normal Faults
Tethys
extension



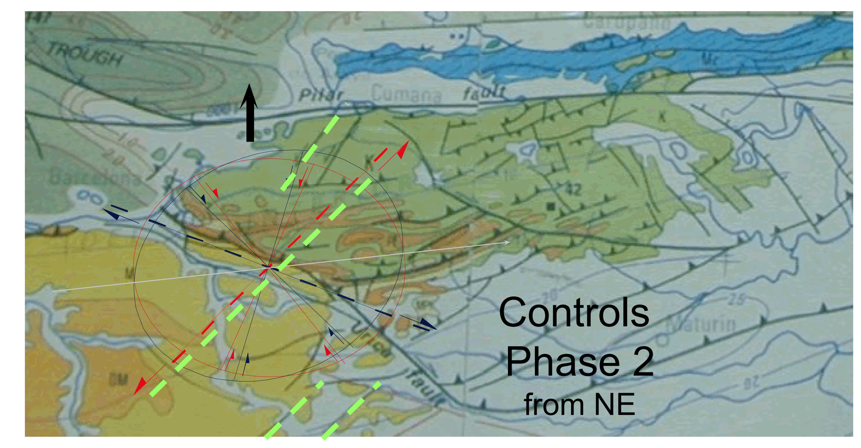
Strike-slip faults
Parallel to the
Urica Fault

Activity: Paleocene to Present



Synthetic riedels
Associated with
Urica Fault

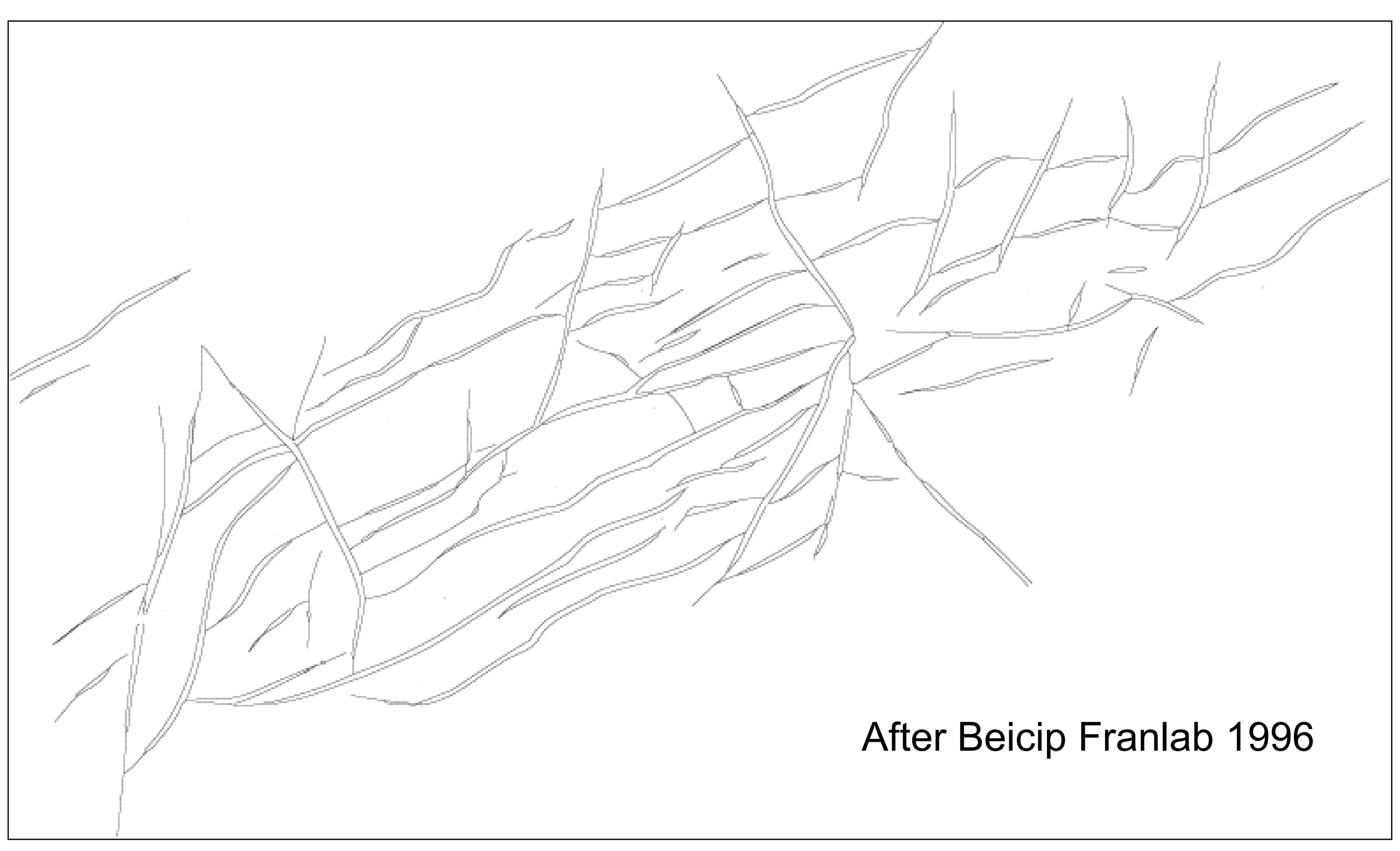
Creation & activity: Paleocene to Present



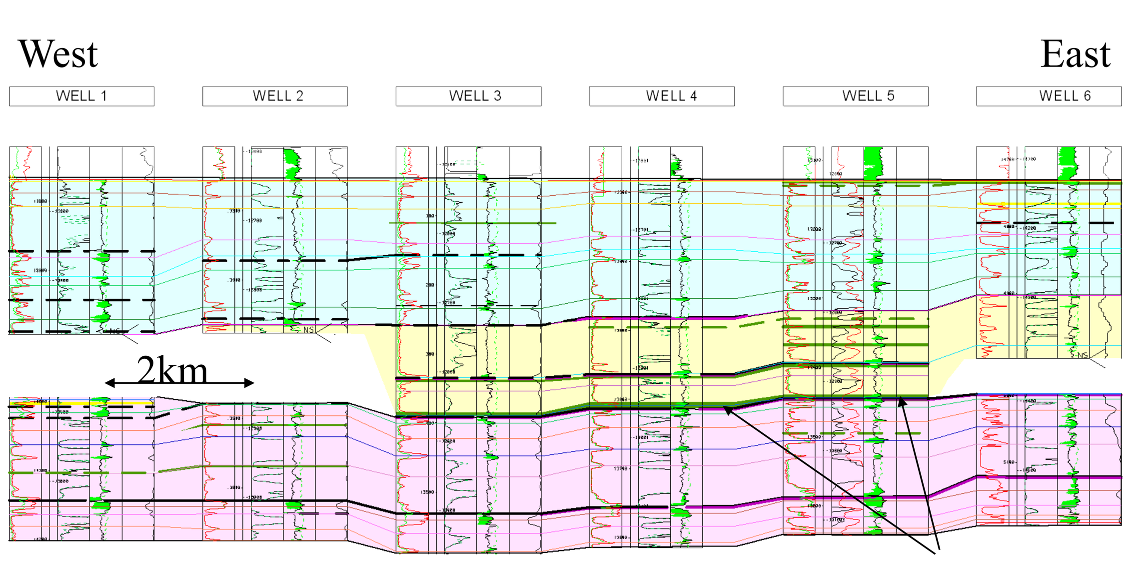
Strike-slip faults
parallel to
Anaco Fault

Activity limited: Paleocene to Present

Furrial Fault interpretation



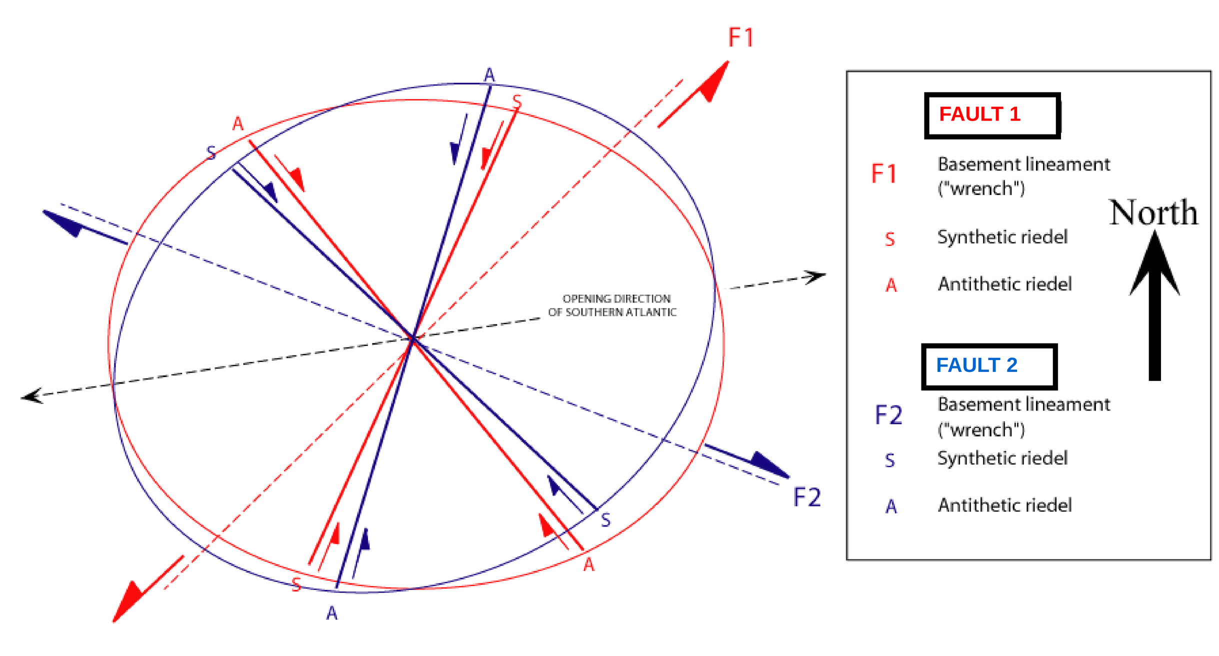
After Beicip Franlab 1996



Many more wells have missing sections starting around the same interval

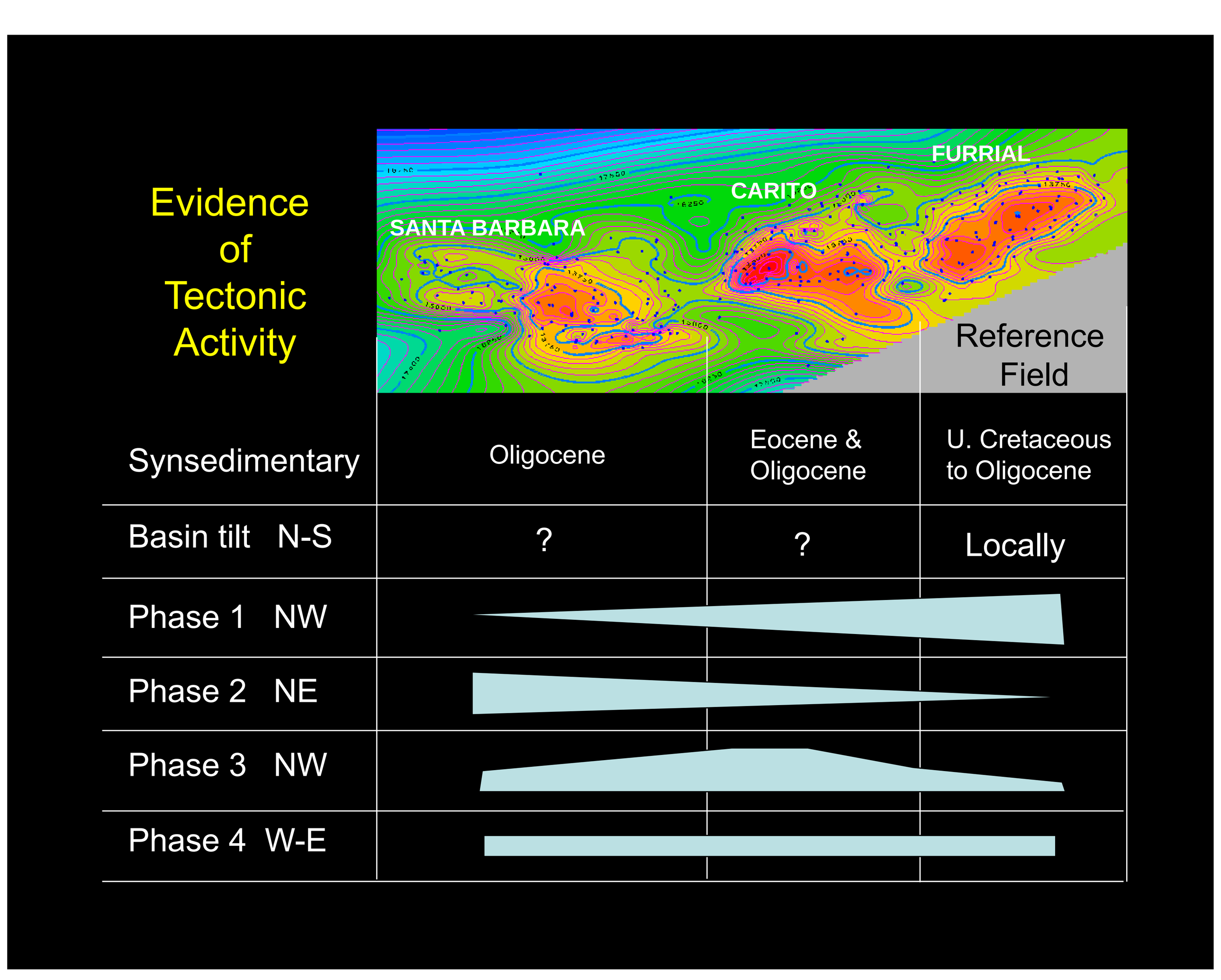
Example from the Furrial Field (Norte de Monagas) extracted from one section by C. Uroza

Pattern of synsedimentary Faulting in El Furrial



Alternate activity of faults F 1 and F2 and activity of their associated synthetic and antithetic riedels have controlled both the sedimentation through time and later the development of the Furrial Trend

Most of the faults mapped (by Beicip franlab) in the El Furrial Field have been active during the Tertiary and have controlled the sedimentation. The activity of such faults is recognized by well defined sedimentary wedges or by “horst and grabens”. The horsts are characterized by an absence of sedimentation whereas the lows present the thickest and best developed blocky sands of the entire Tertiary sequence (see West-East cross-section).



The expression and intensity of each identified deformation phase differs between each of the fields that compose the Furrial Trend. A detailed study shows that each field has a simple eastern part and a more complex western part.

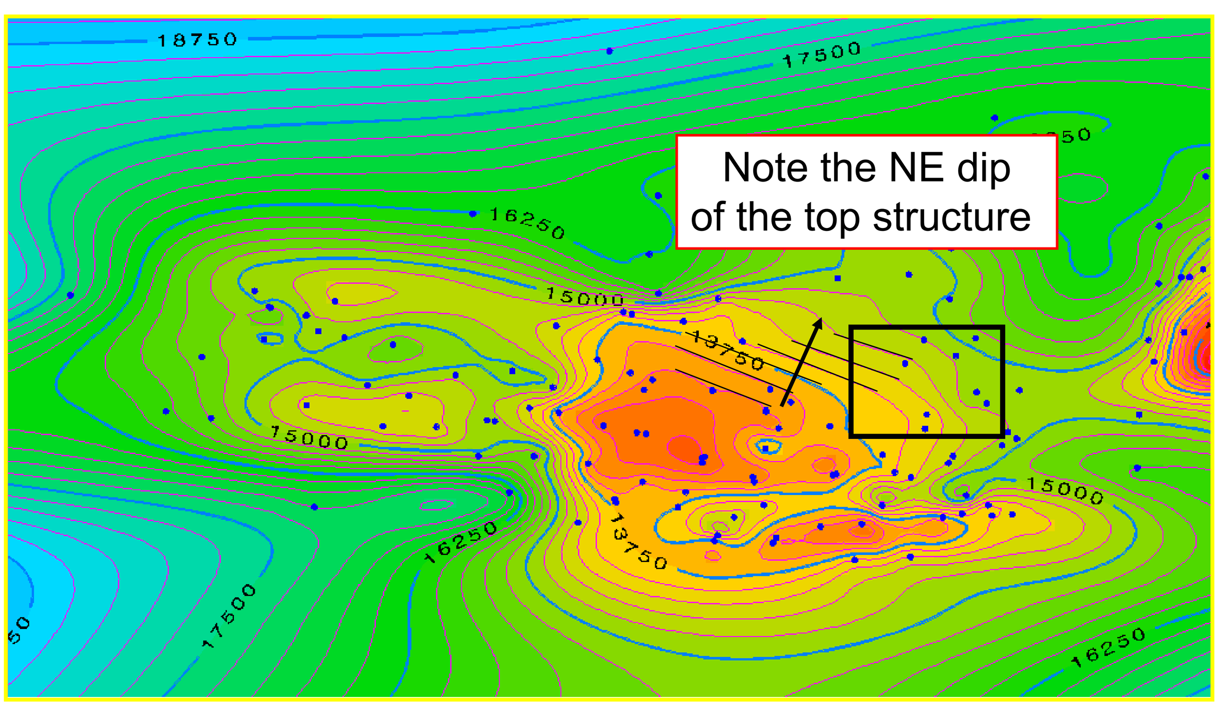
MISSING SECTION PARADIGM

SANTA BARBARA FIELD

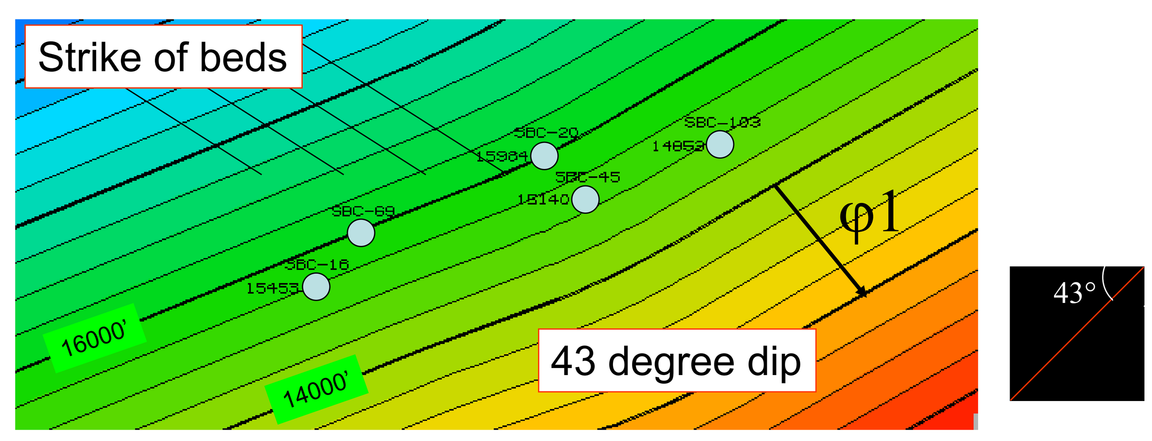
Observations:

Five wells with missing sections
Original interpretation = Normal fault
Gas oil contacts not compatible with normal faults
3D visualization shows planar alignment of the 5 fault intersects

Santa Barbara Field

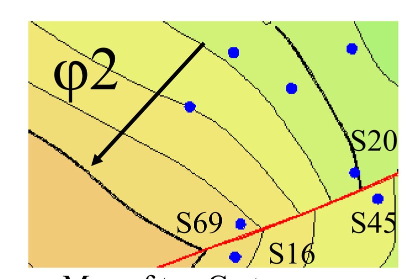


Fault plane



Fault plane generated during first phase of compression

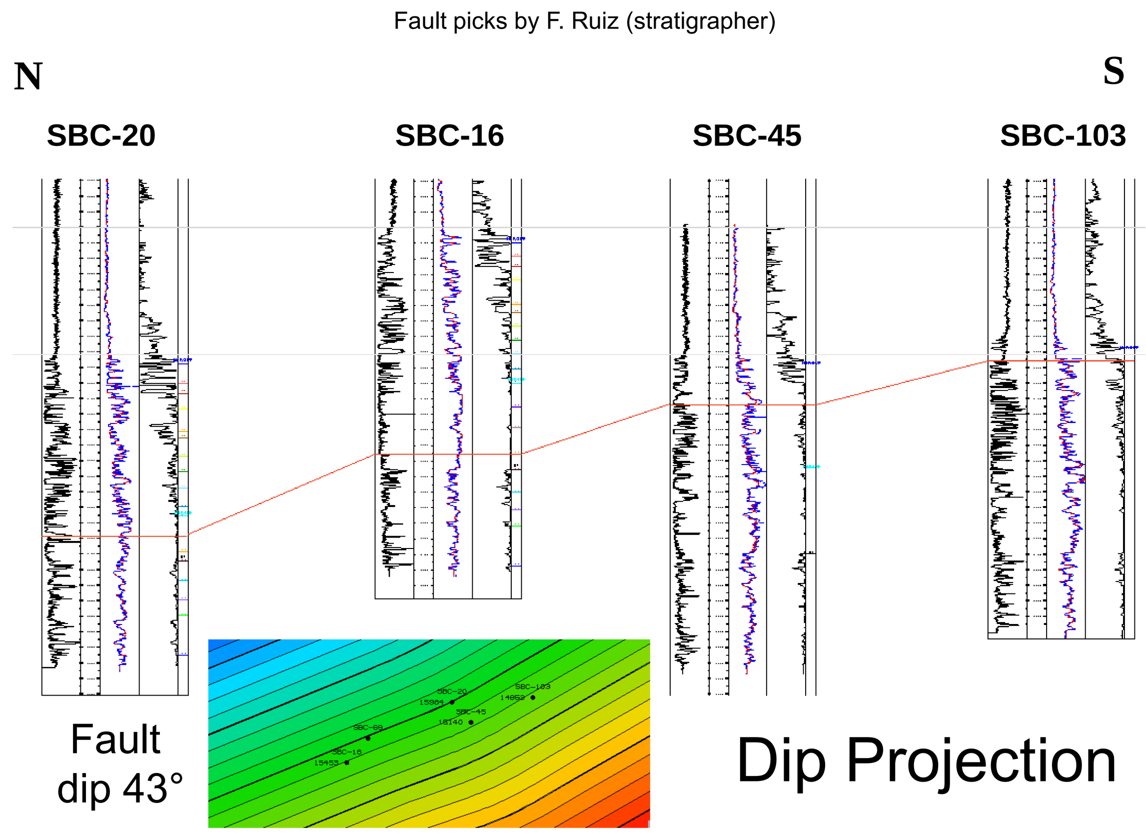
Oblique slip generated by second compression phase



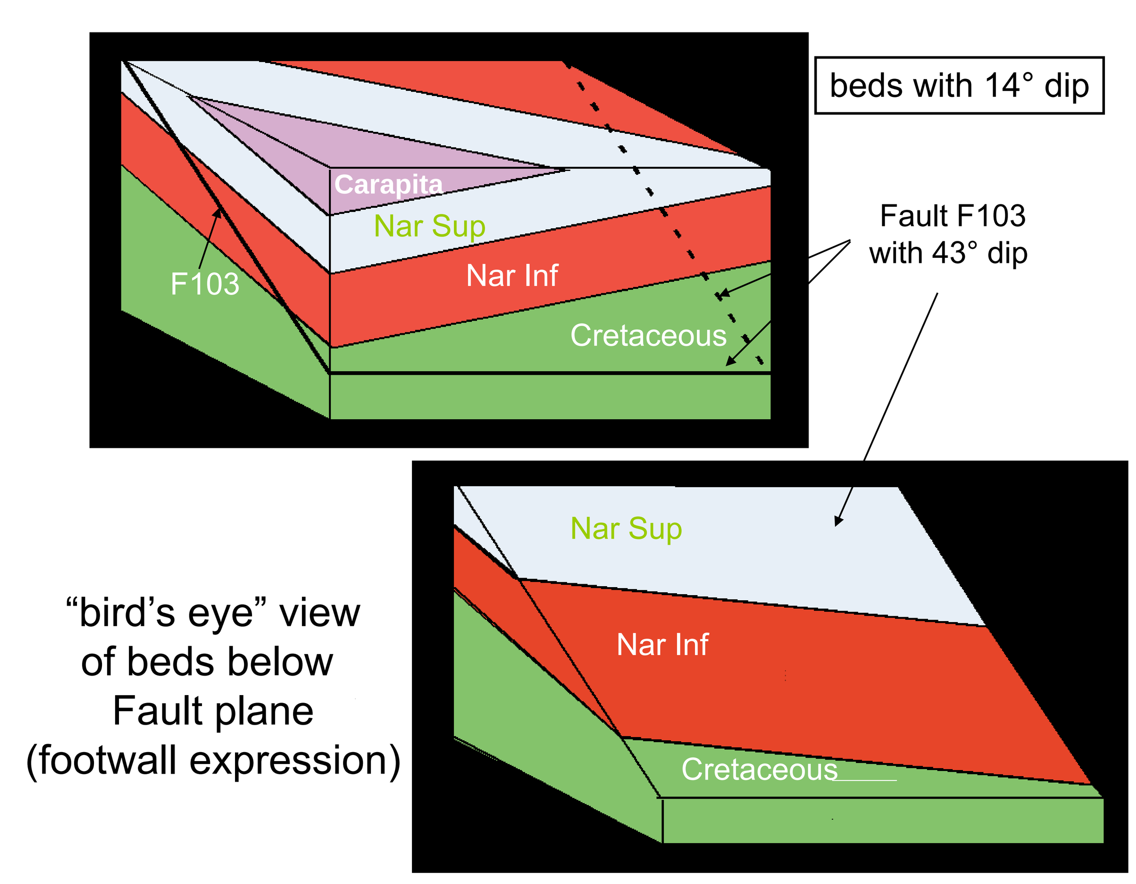
Map of top Cretaceous

Missing sections in Santa Barbara Central Block

Fault picks by F. Ruiz (stratigrapher)

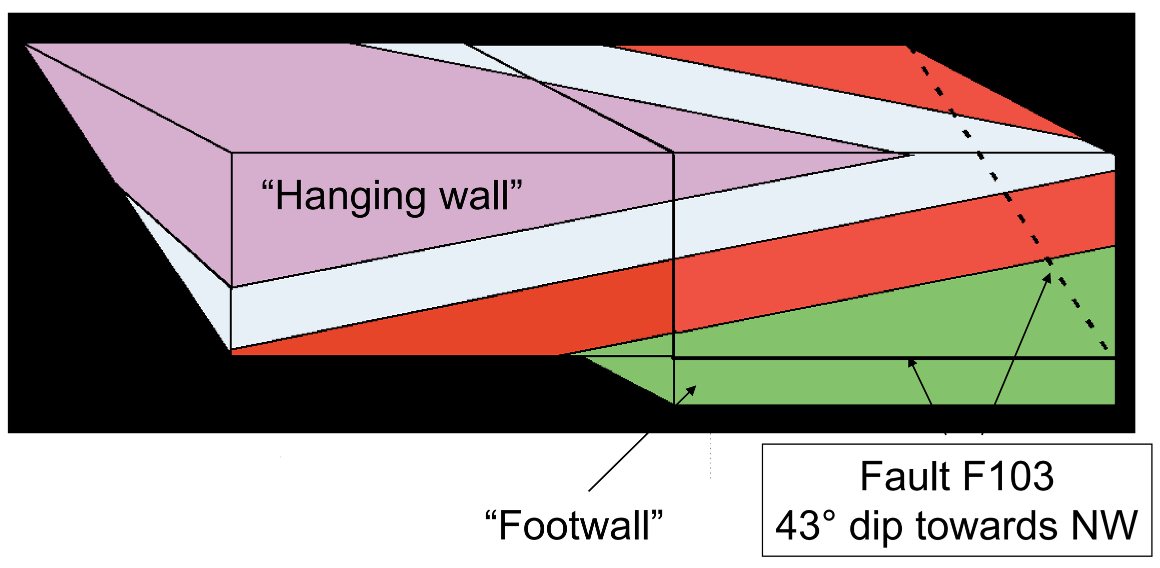


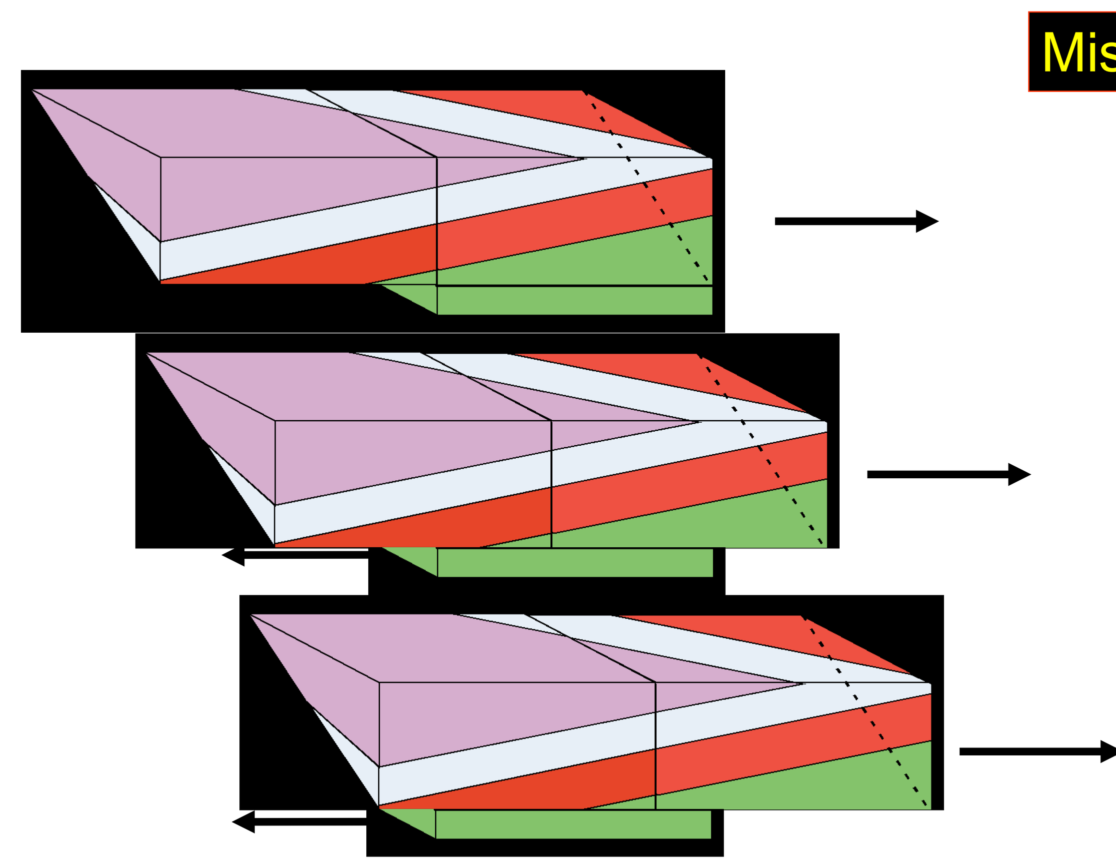
Schematic block diagram for Fault F103



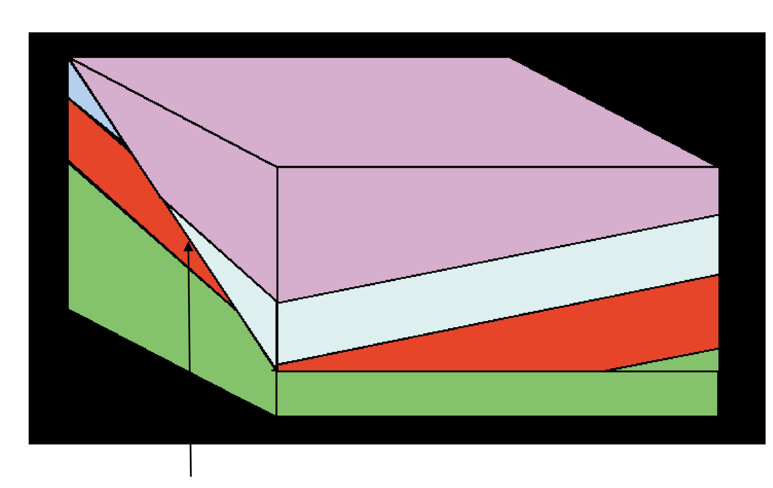
Lateral movement along Fault (simplification)

Beds with 14° dip towards NE





Missing sections associated with Fault F103



Learnings

Missing sections can be associated with reverse faults reactivated by oblique slip

This new interpretation ➔ new infill well to reach objective below the reverse fault

Best producer in the field > 8000 BOPD

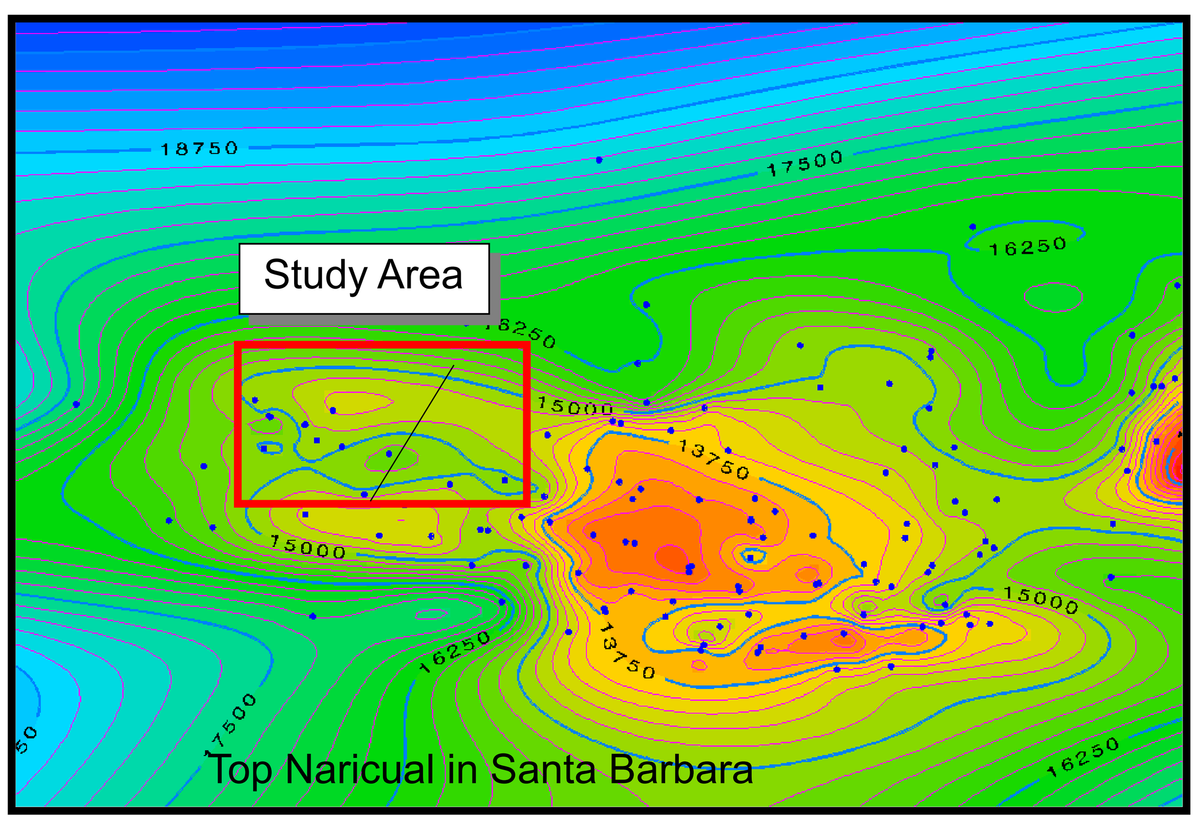
From many vertical faults to one low-angle fault and a big discovery

SANTA BARBARA FIELD

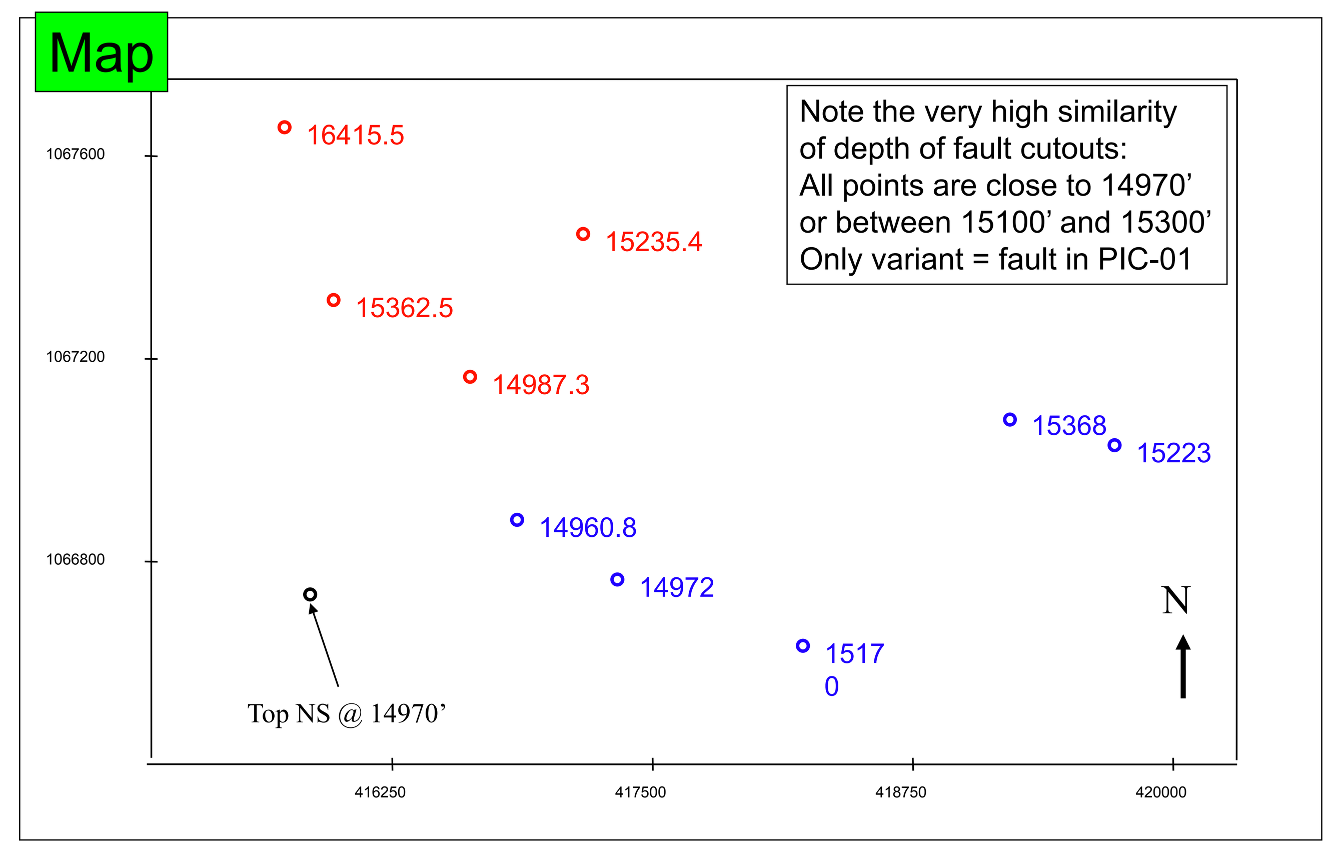
Observations:

One fault has been identified in every well
Each fault pick is in a narrow depth range

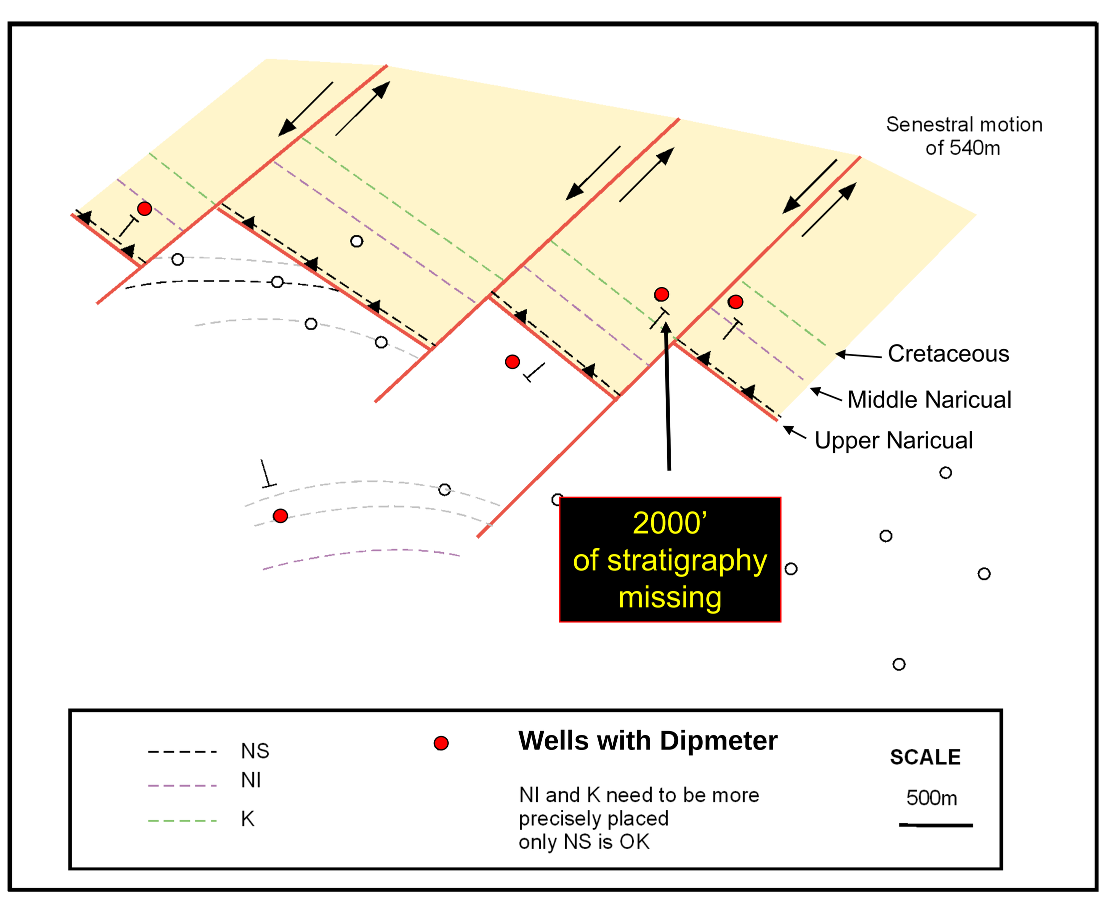
3D visualization shows planar alignment



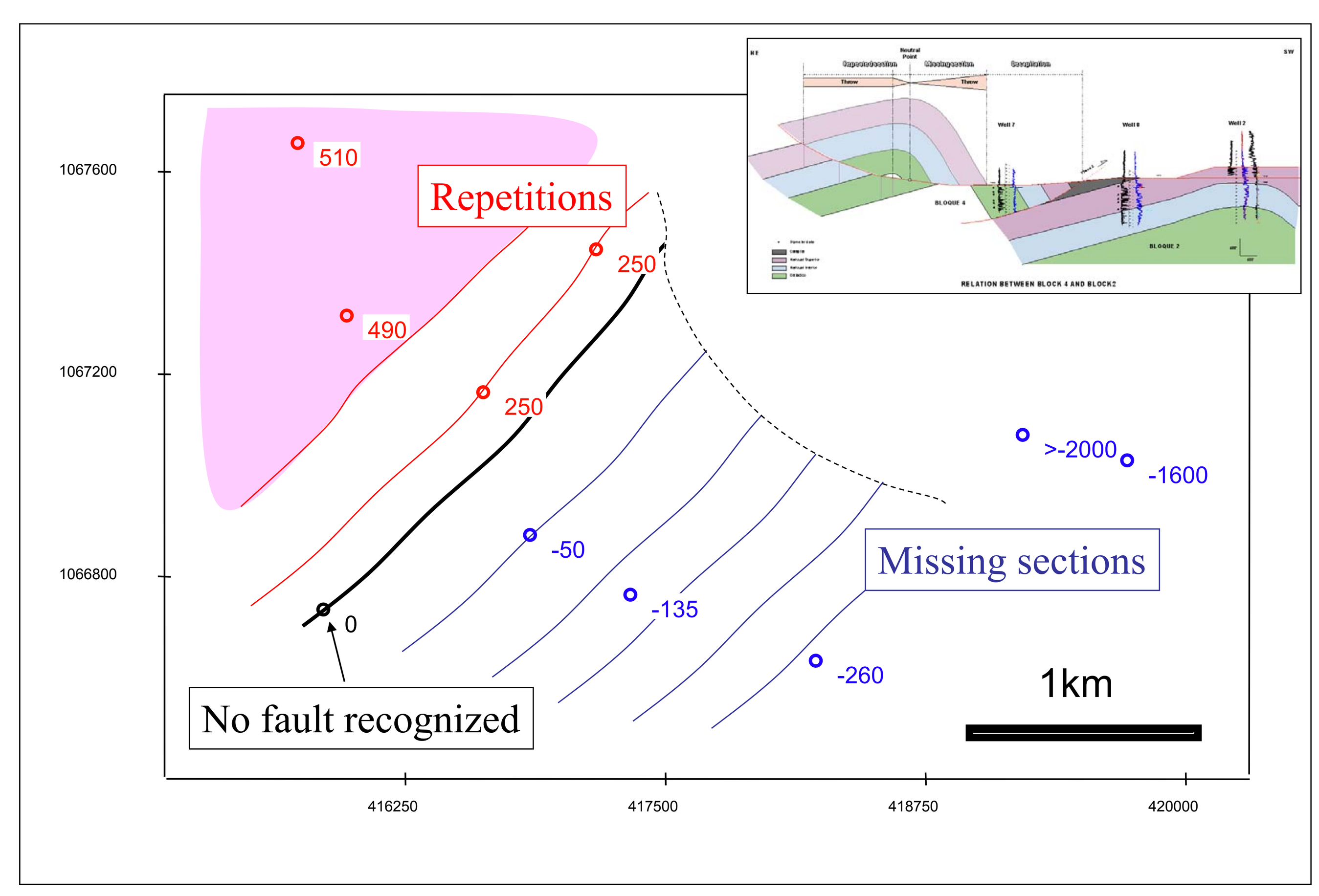
Depth of fault intersections



Bird's eye Map of low-angle fault

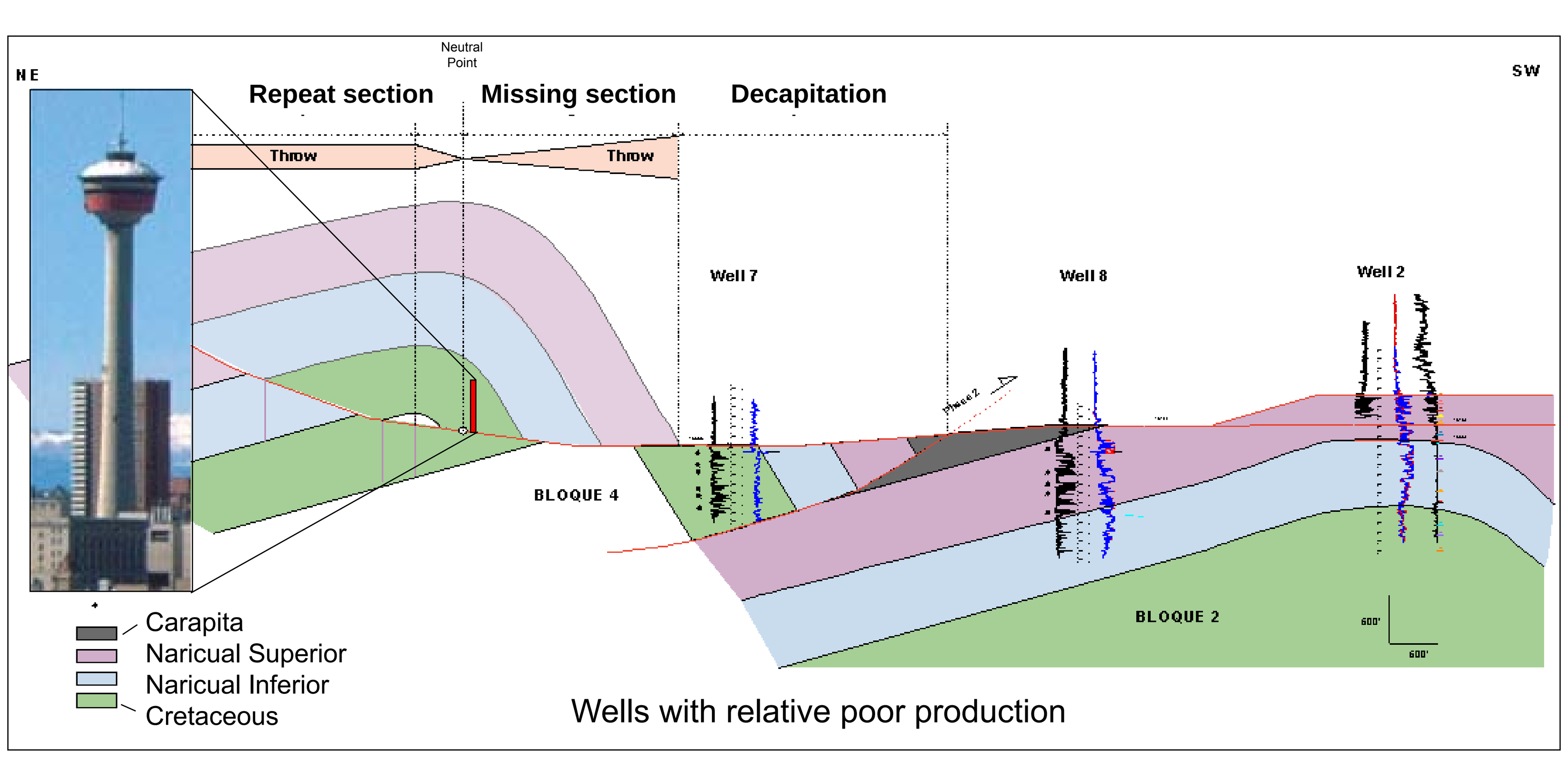


Fault throw Map



Decapitation and the hidden giant

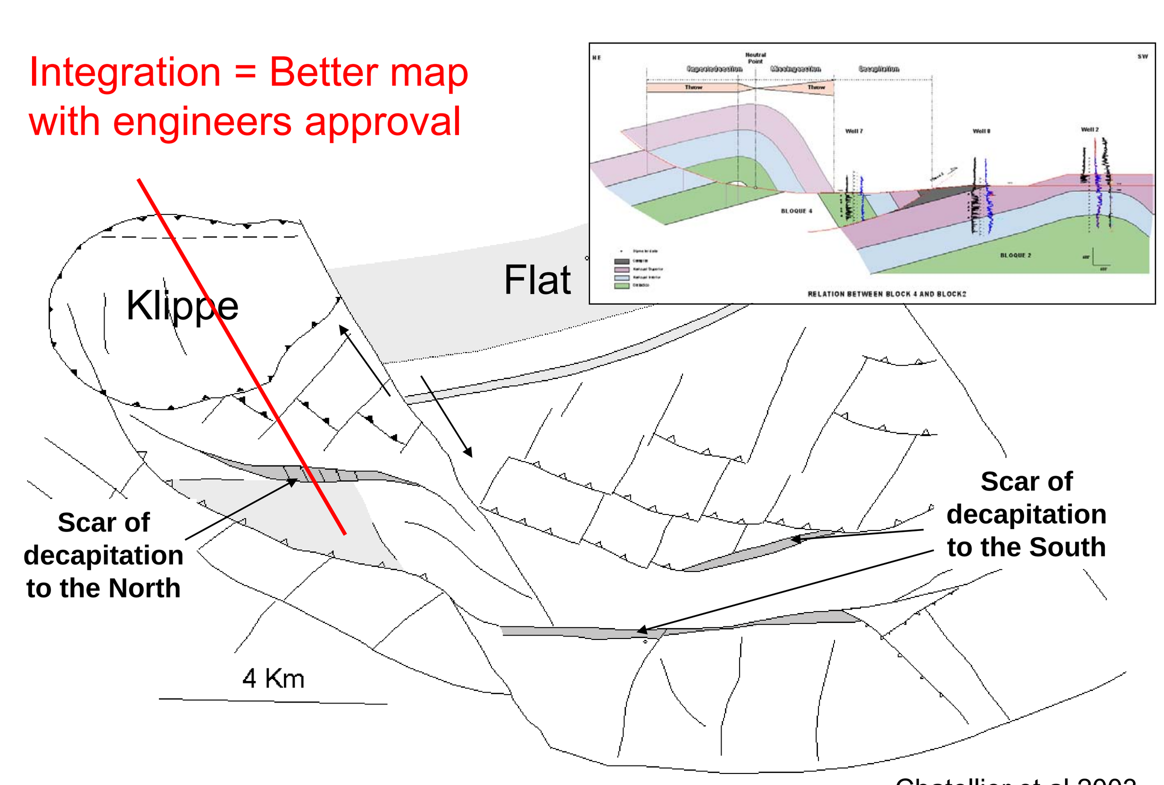
NE SW



Calgary tower as a scale

Modified after Chatellier et al 2002

Santa Barbara Structural Map



Chatellier et al 2003

Learnings

Low angle fault may have highly varying throws
from 3000' missing section to 500' repeat in Santa Barbara

Back thrust led to decapitation with backward motion towards thrust belt

Big discoveries can be made in unexpected locations

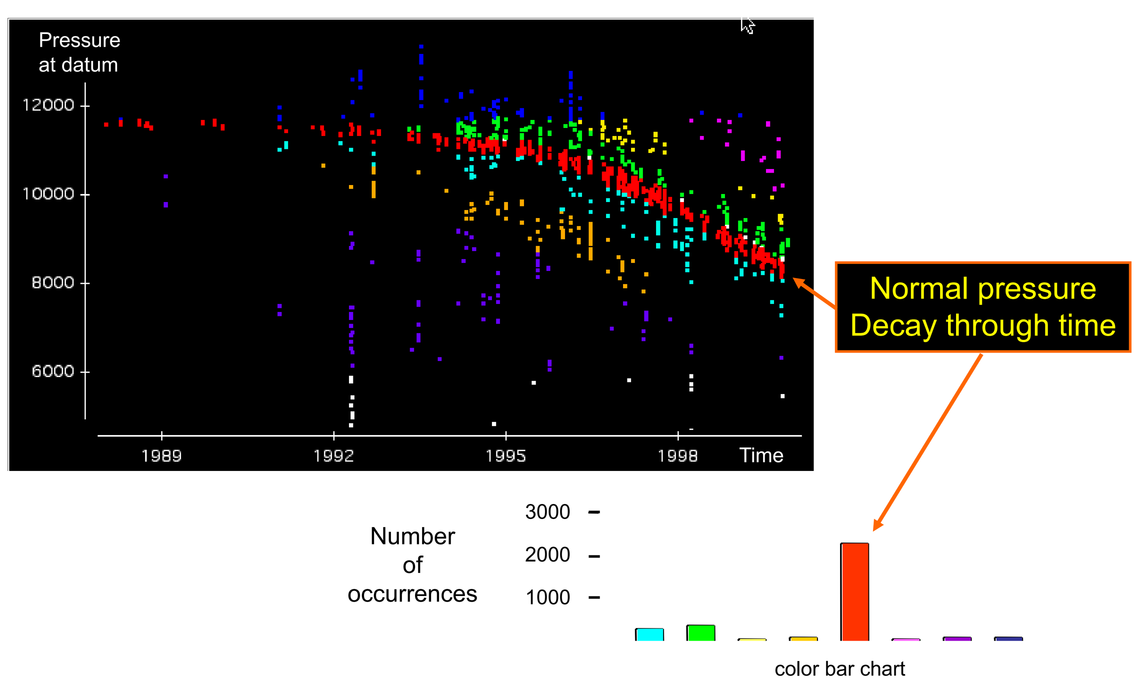
MULTIDISCIPLINARY INTEGRATION

SANTA BARBARA FIELD

Observations:

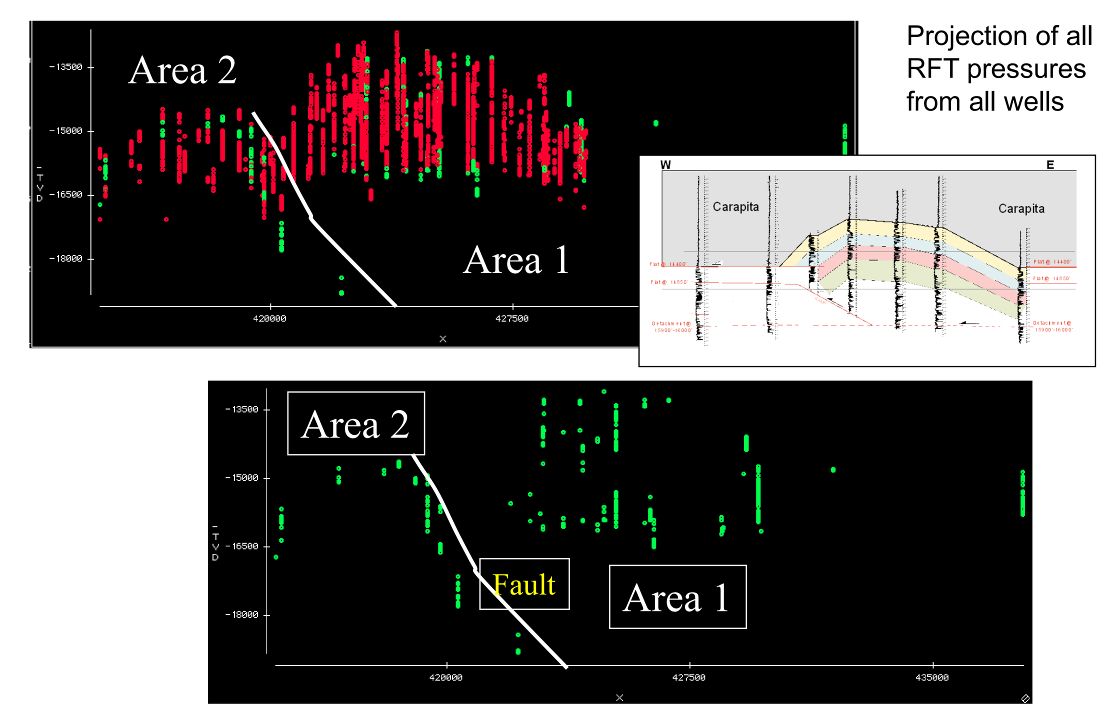
Numerous observations from various disciplines
Can help build a more reliable model

Pressures at datum through time

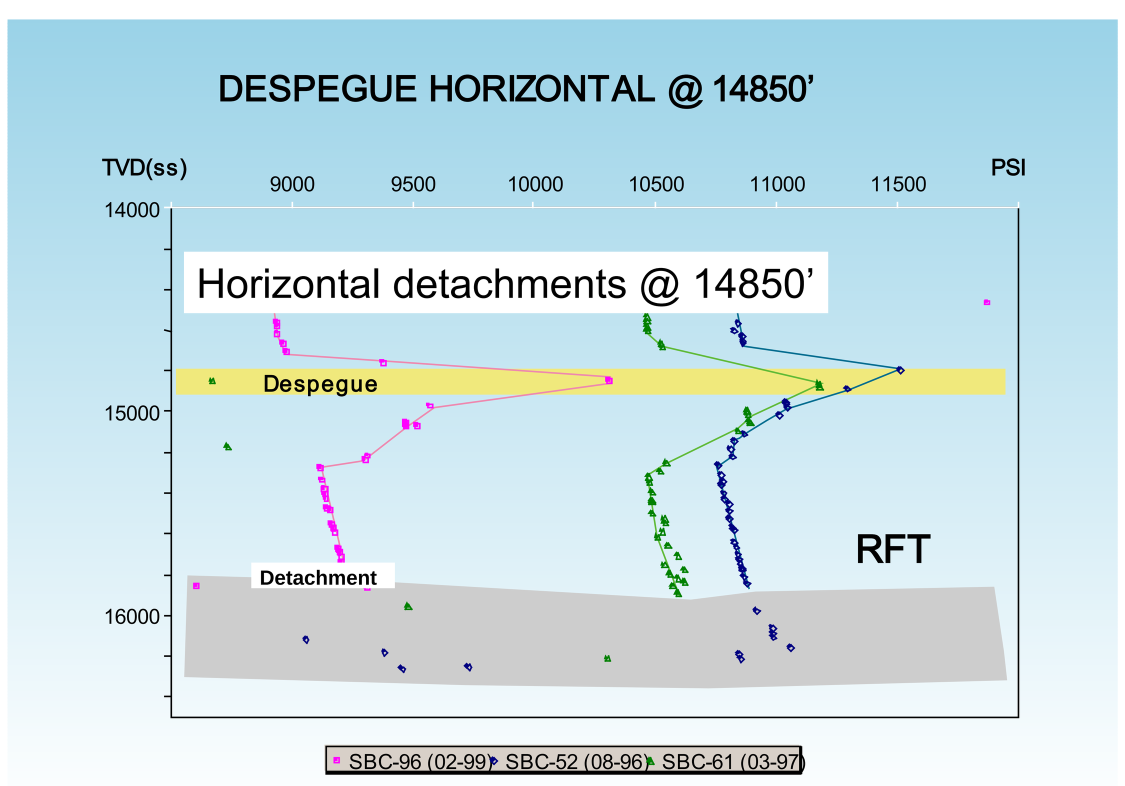


A view of normal pressures and slightly higher than normal

2-D view of pressures and fault bend fold

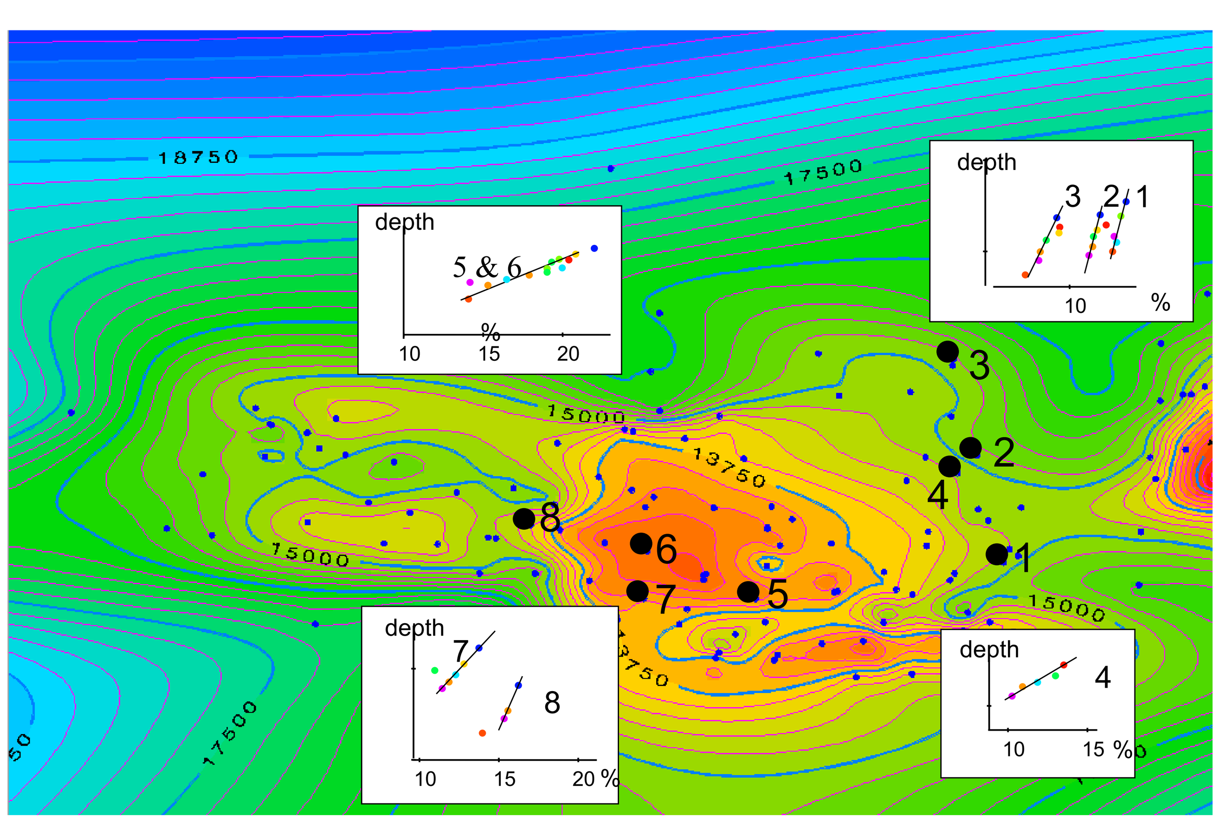


Best ever and only expression of this important fault



Abnormal, well defined and systematically repeated pattern of RFT pressures have proved to be ideal to identify major detachments

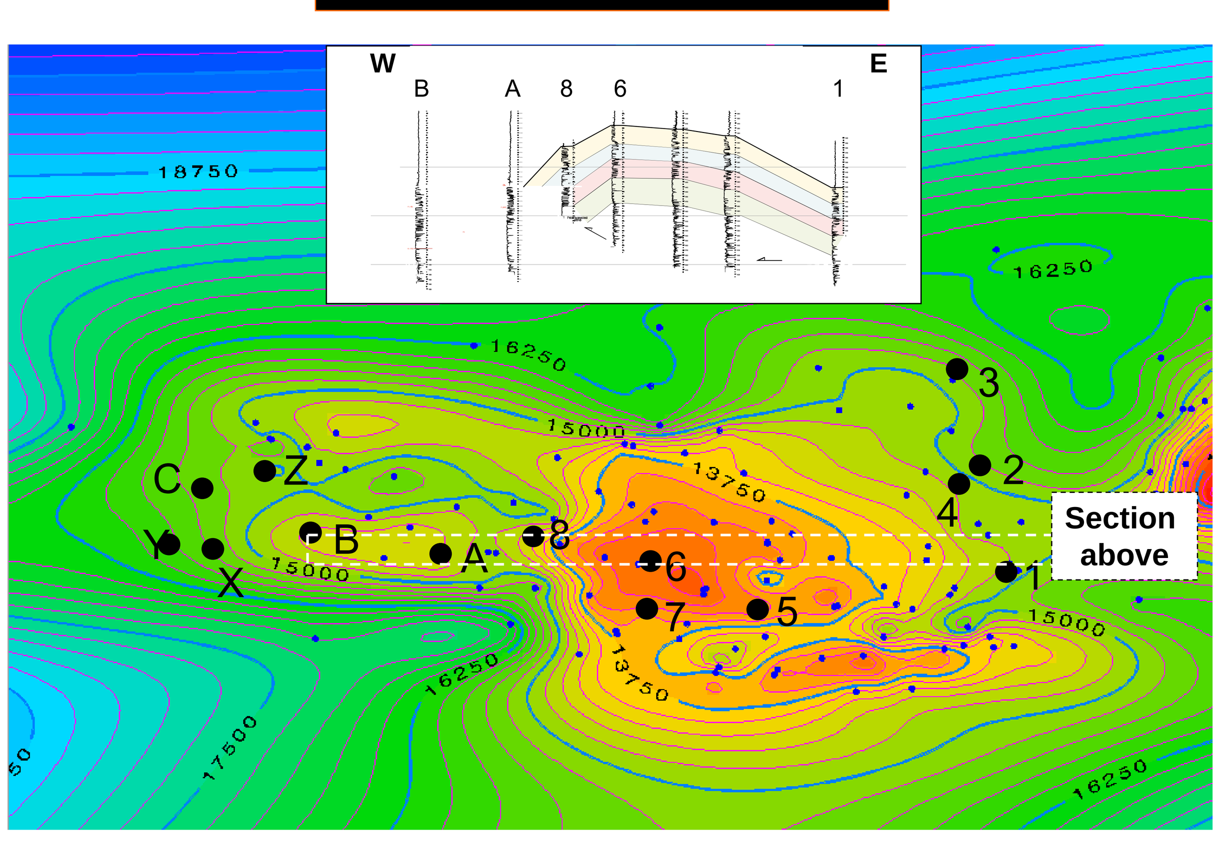
Porosity depth trends

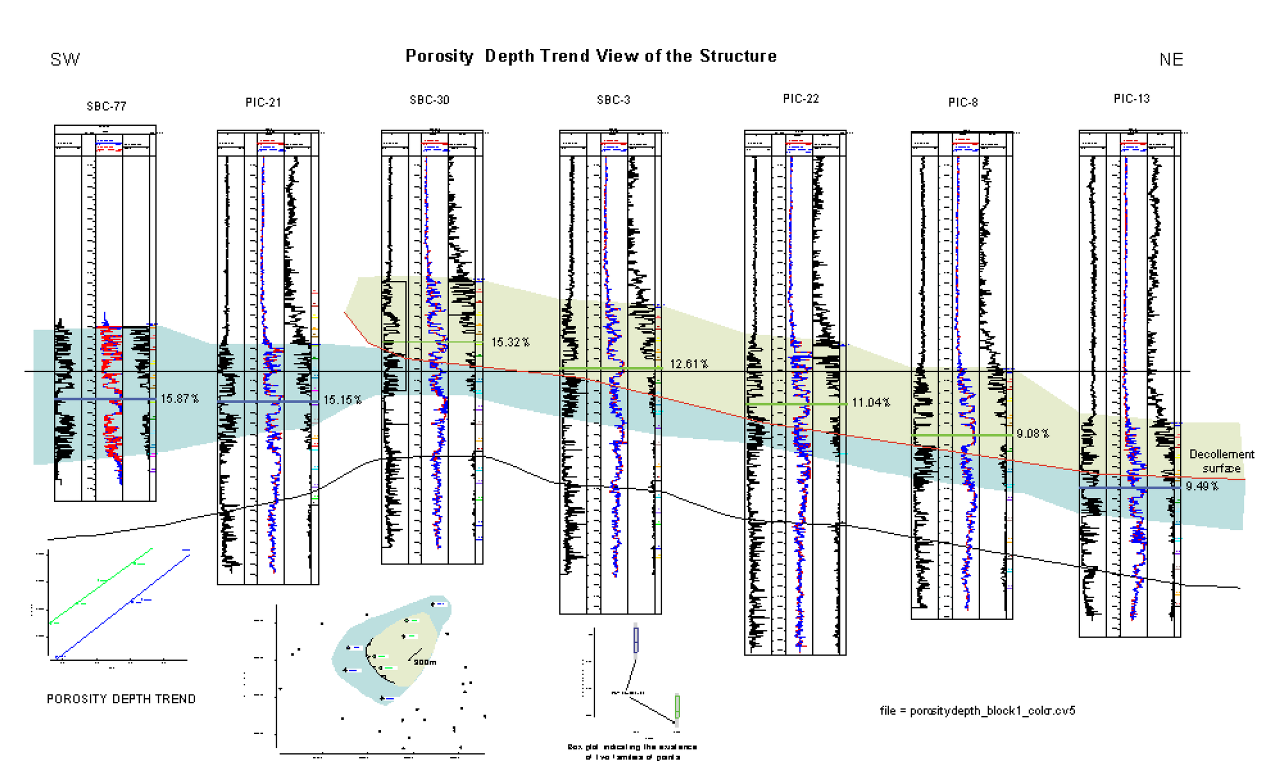


Field wide statistics led nowhere when trying to define a porosity depth trend

Map displays of porosity depth trends for individual wells provide a reliable and predictive view of porosity

Santa Barbara Field

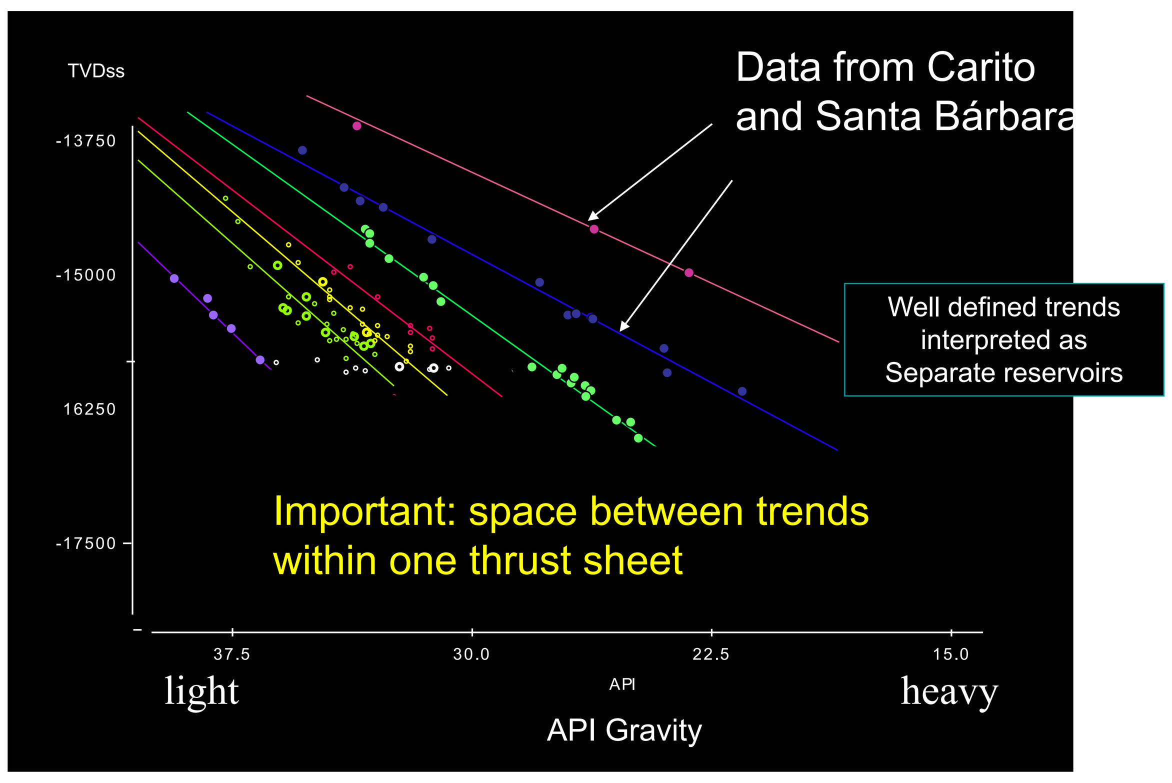


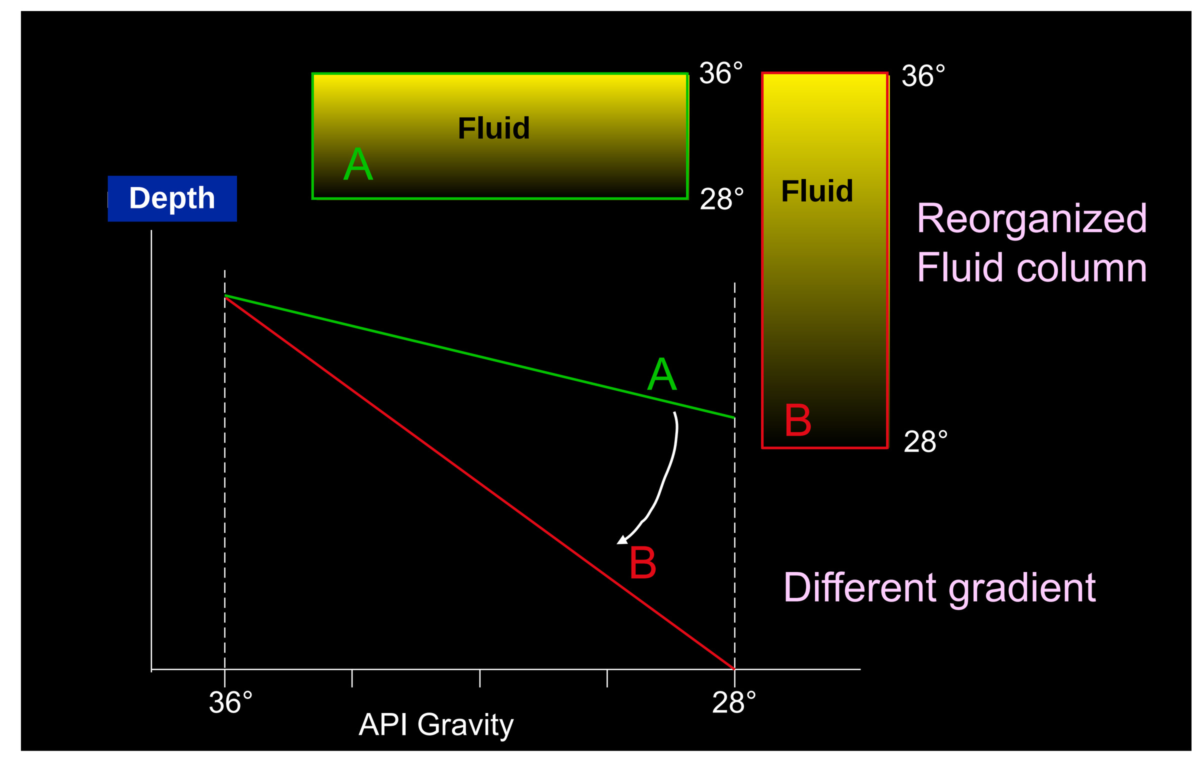


THRUSTS DEFINED BY FLUID CHEMISTRY

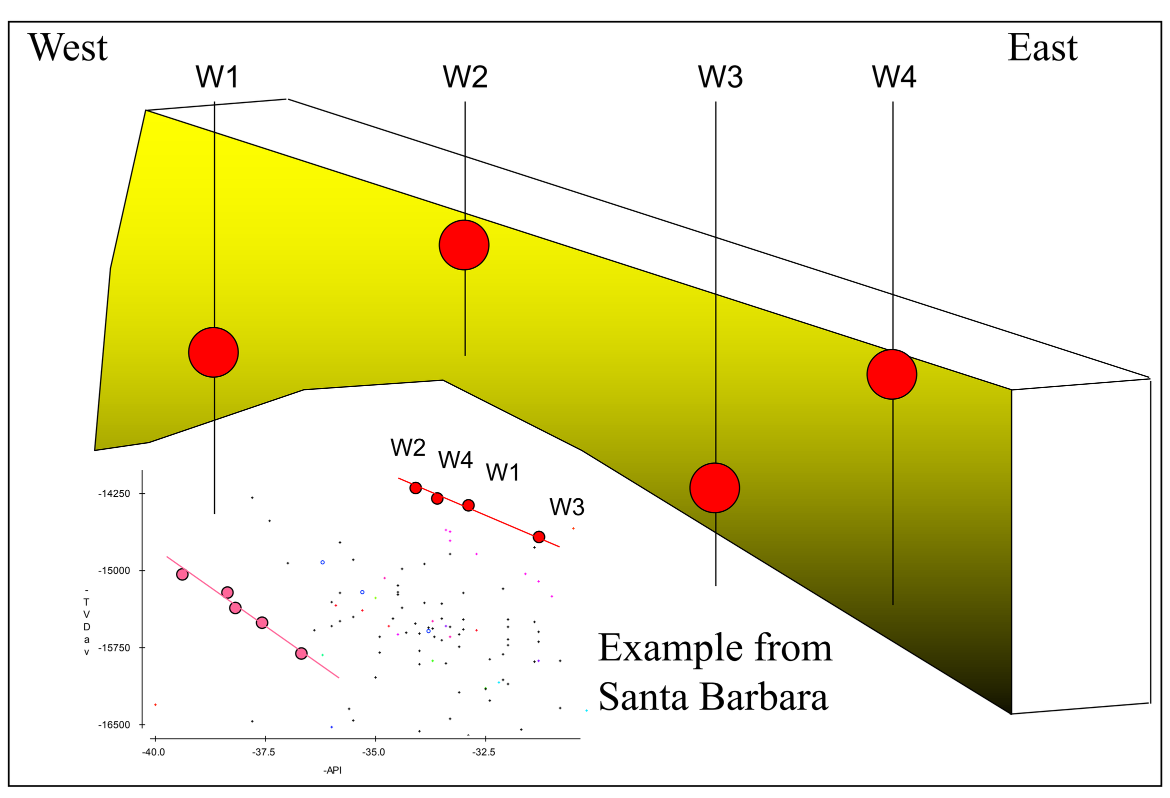
A different view of the CARITO FIELD

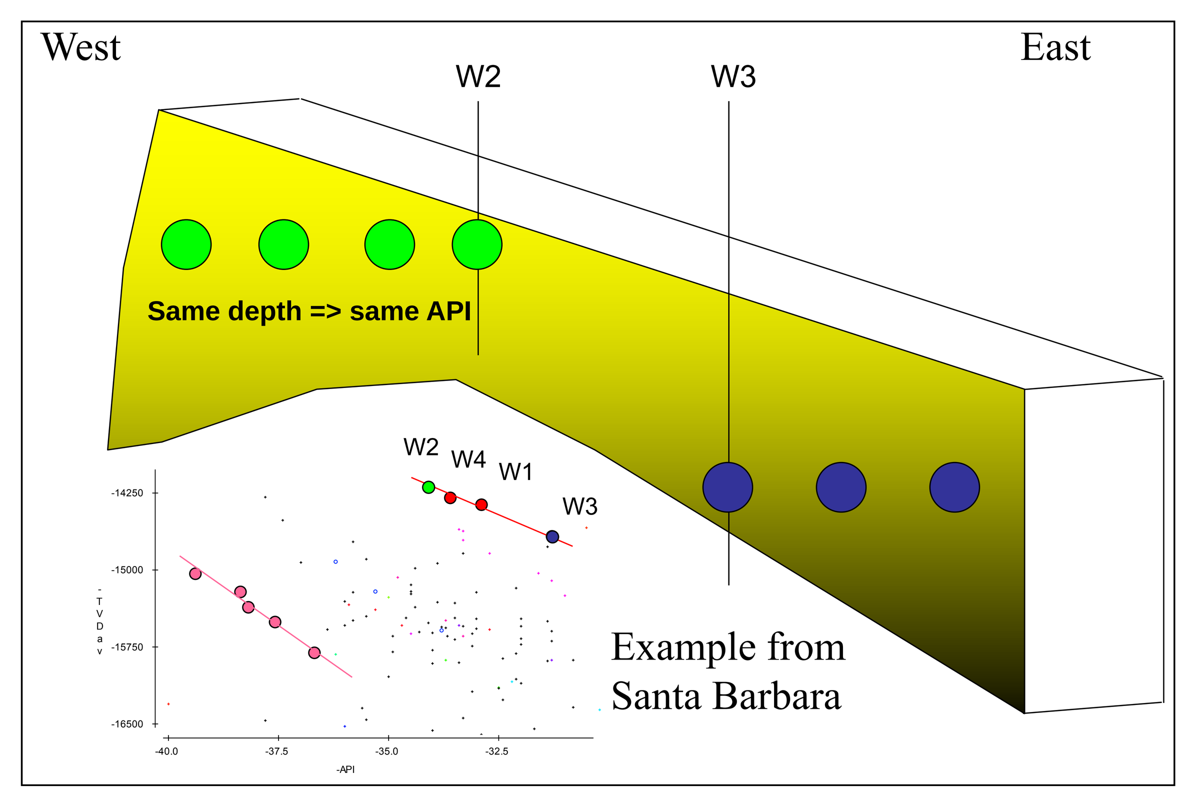
Understanding fluids leads to better understanding the complexity of the field

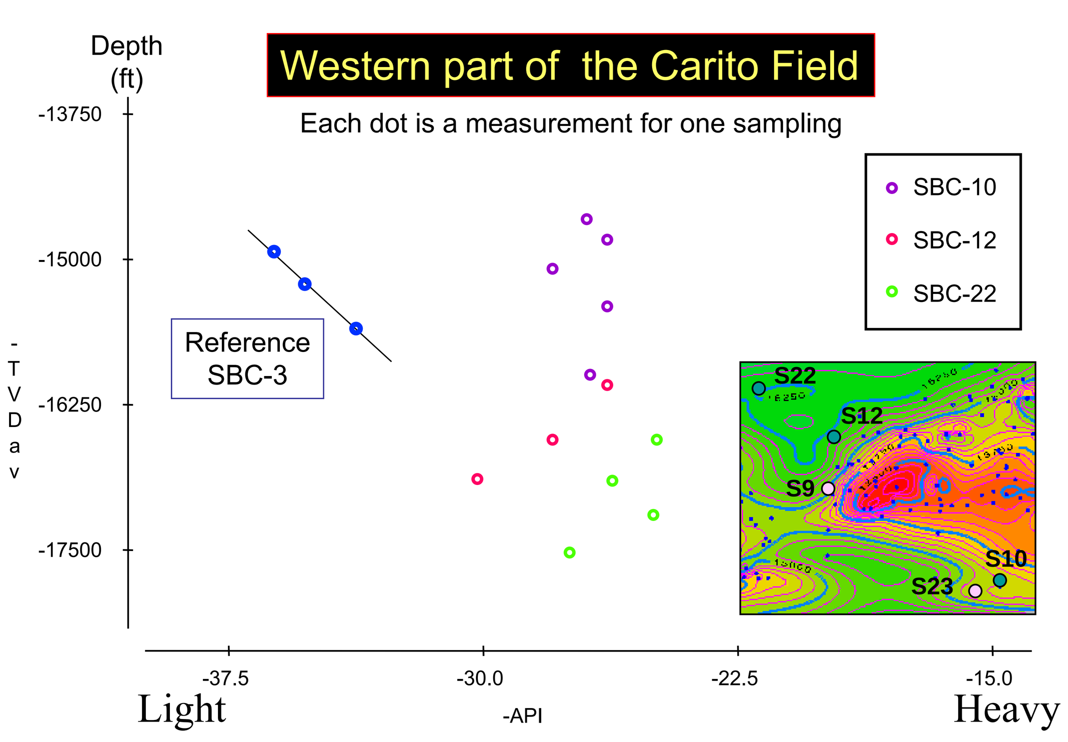




LINEAR TREND DEALING WITH FLUIDS





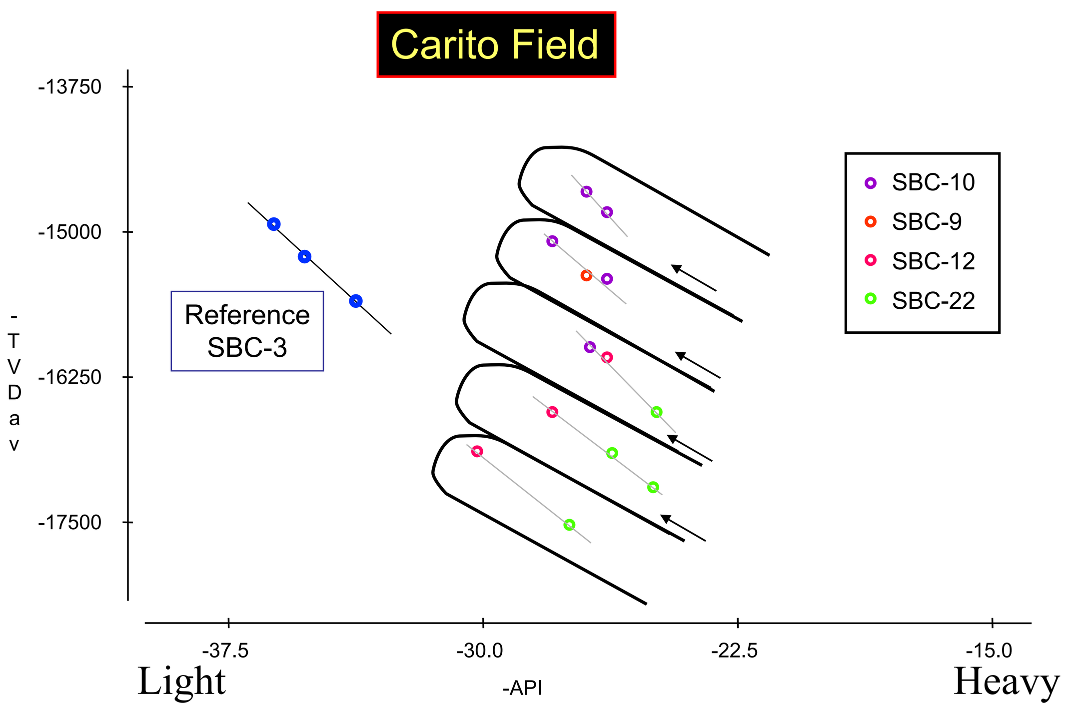


Many wells exhibit abnormal lighter oil with depths

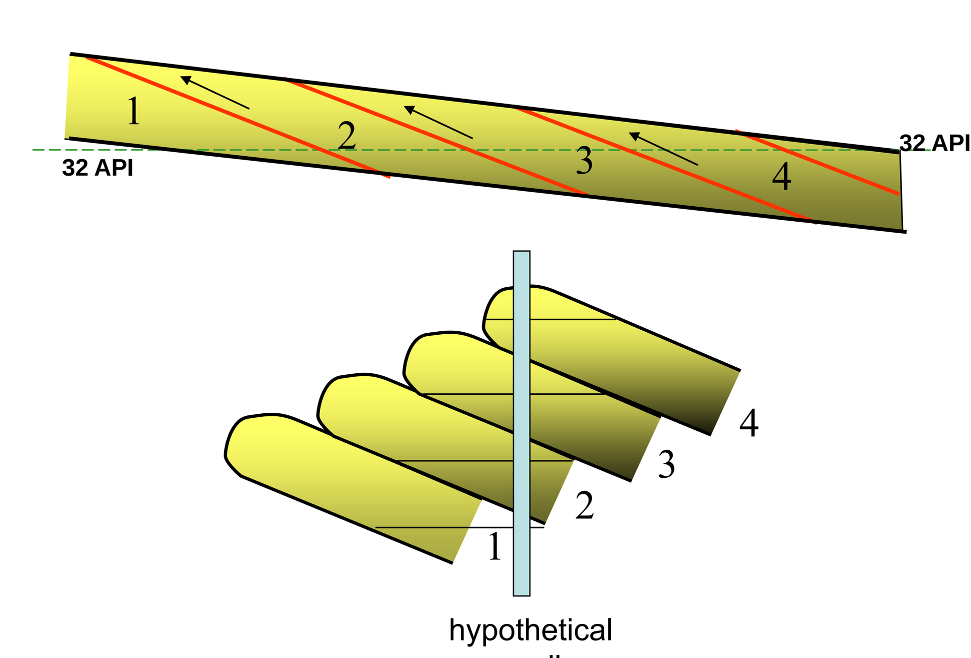
Traditional interpretation is that it is the result of numerous successive oil migrations

The new interpretation is that it is due to thrusting post-hydrocarbon migration

Carito Field



LIGHTER OIL WITH DEPTH



Learnings

The API gravity study has given the first and only acceptable structural interpretation of the western part of the Carito Field

Geochemists and structural geologists could not solve the problem alone

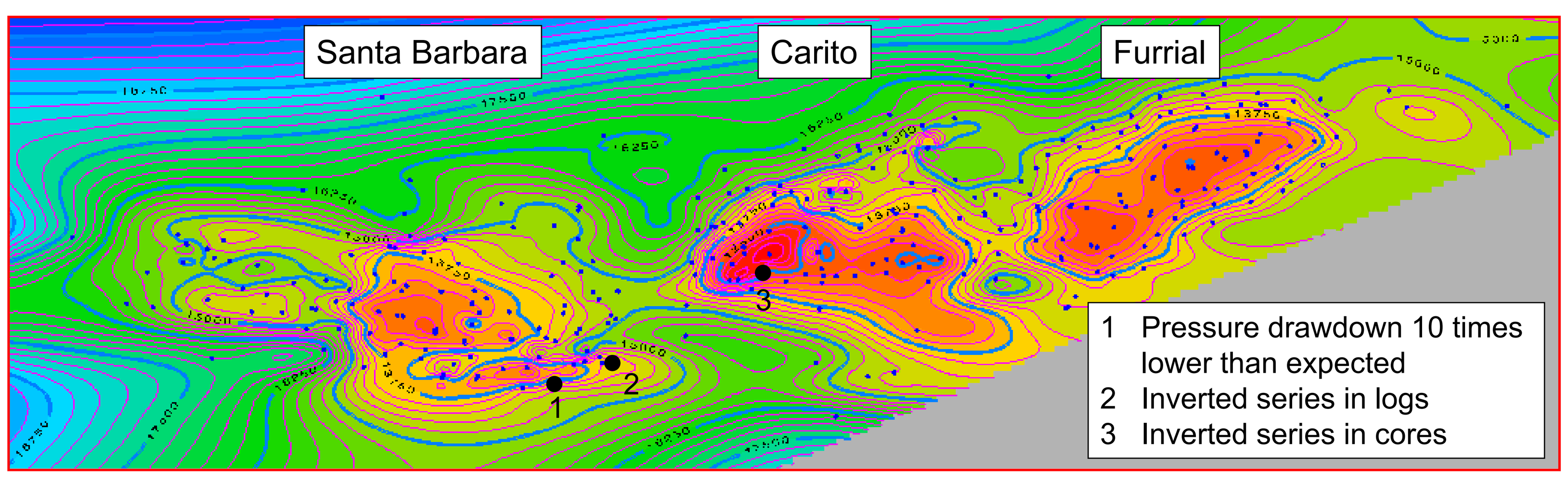
INVERTED SERIES

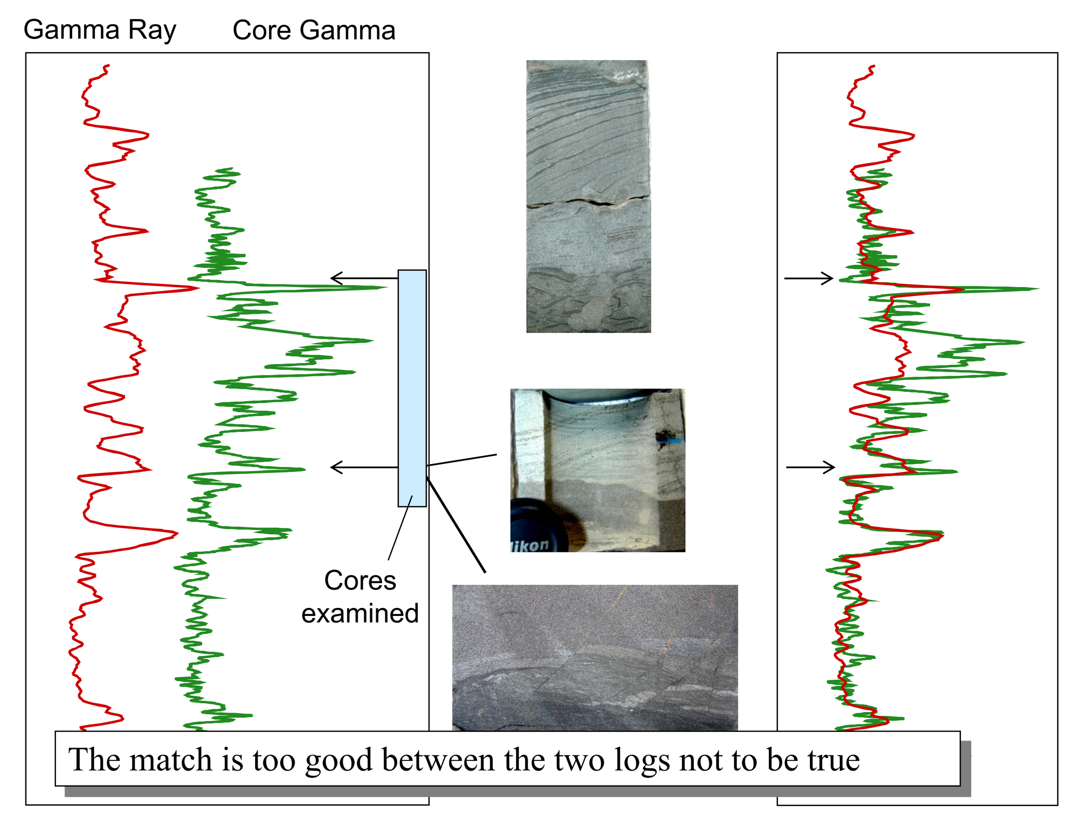
Rarely proposed or rarely recognized

Most major geological breakthrough have come from trying to resolve engineering enigmas.

An incredible producer rises a question. How can it be that at great depth well SBC92 produces with a pressure drawdown of 170 psi while normally it is about 1500 psi?

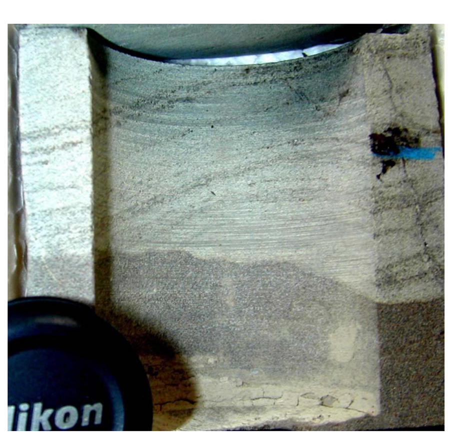
Solution = INVERTED SERIES



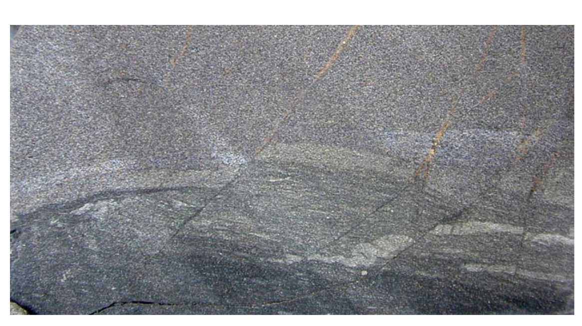


Different types of evidence of inverted series in cores

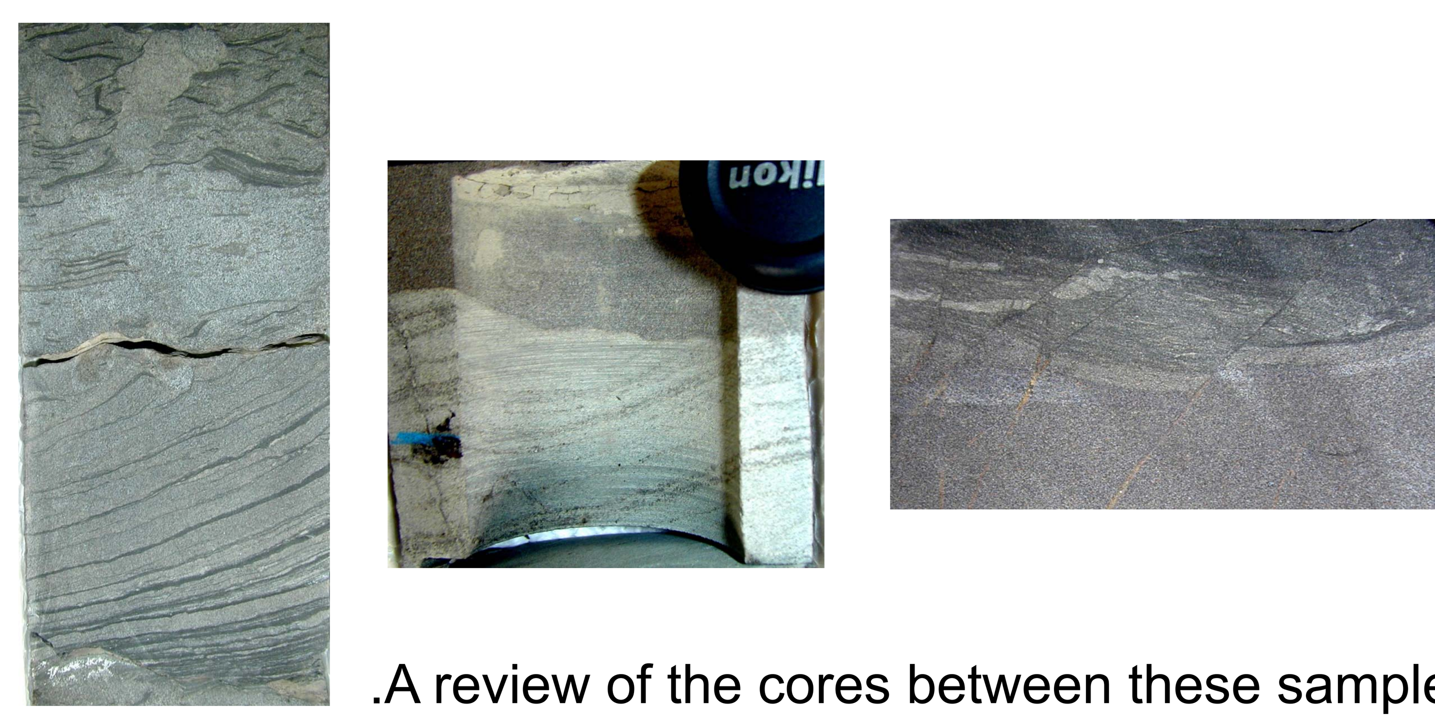
Mud drapes
15522´core 9



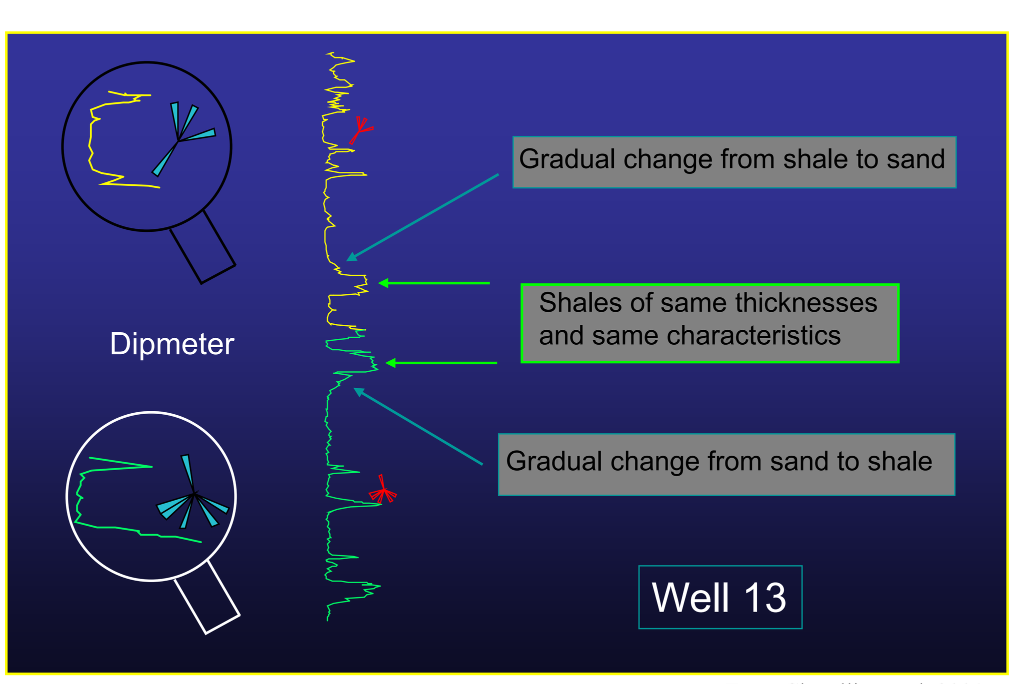
Truncation
15589.5'
core 11



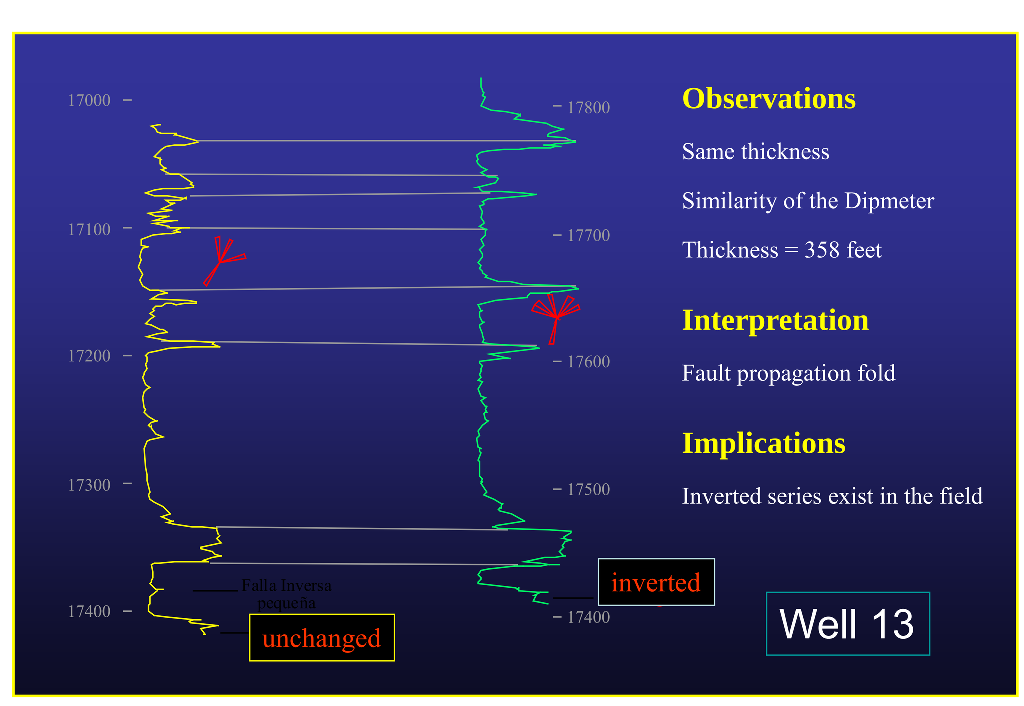
Small-scale faults
15590.5'
core 11



.A review of the cores between these samples has validated the hypothesis of having an inverted series and that we are not dealing with a few inverted samples caused by bad core handling.

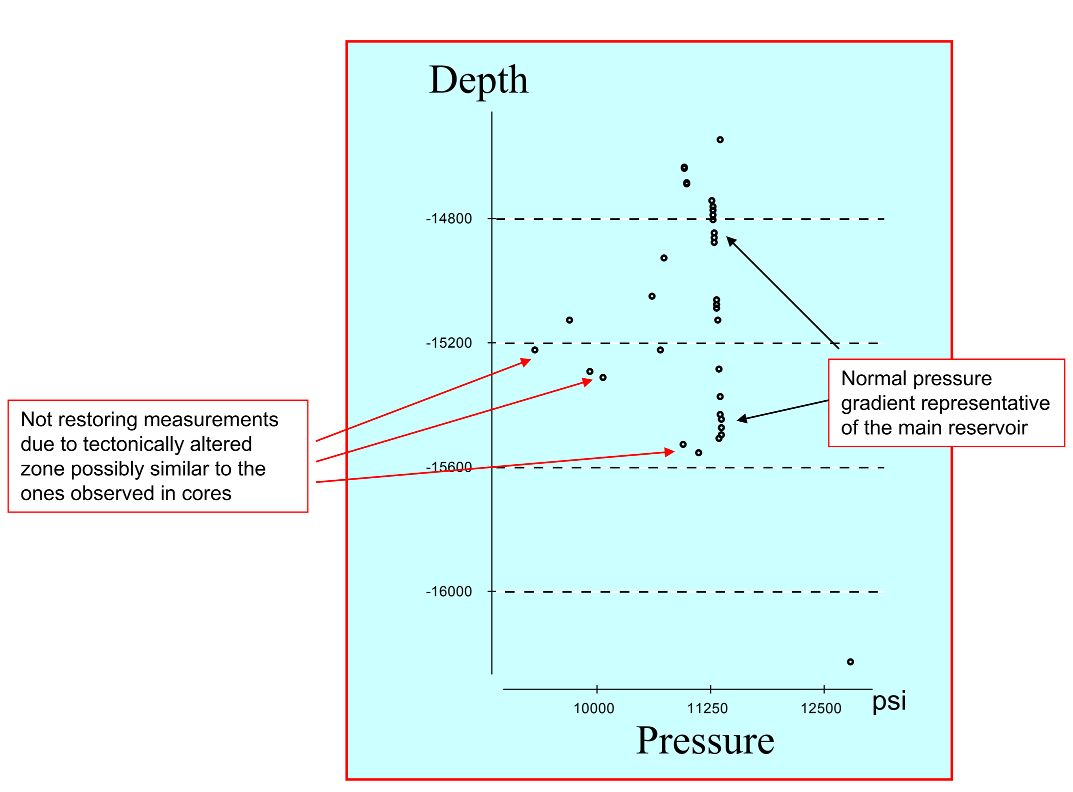


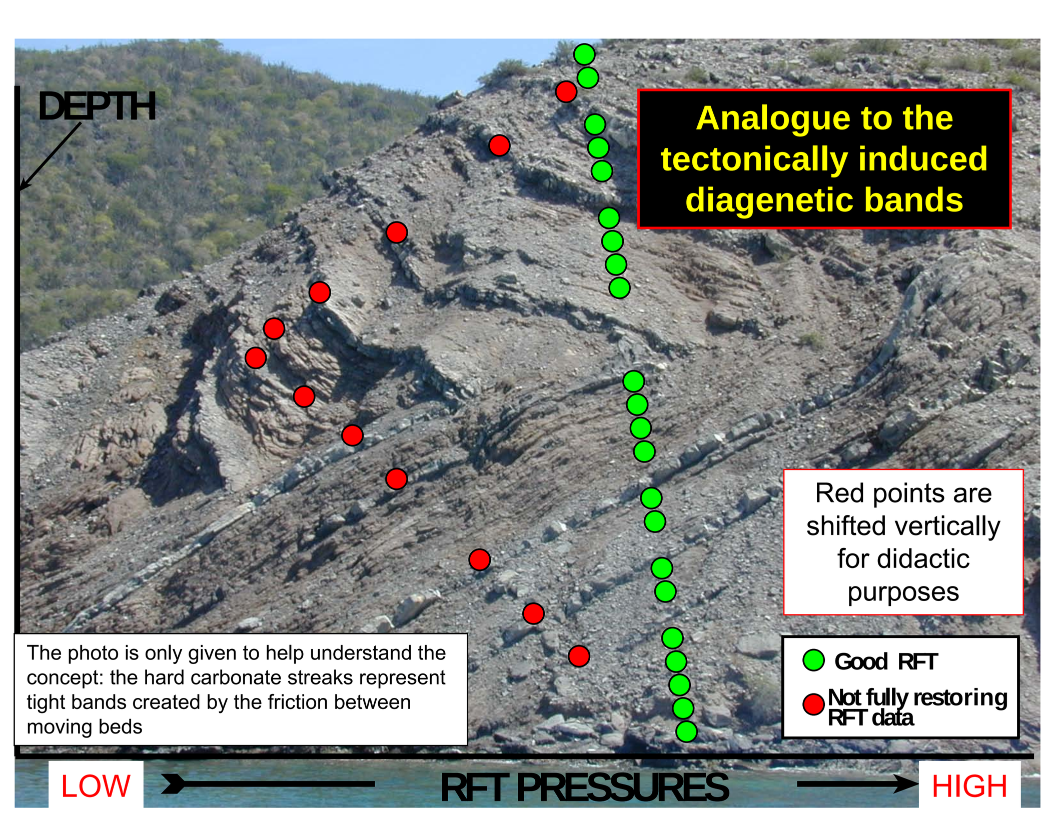
From Chatellier et al. 2001



From Chatellier et al. 2001

Recognition of inverted series in logs





Particular pattern of RFT pressures in inverted series

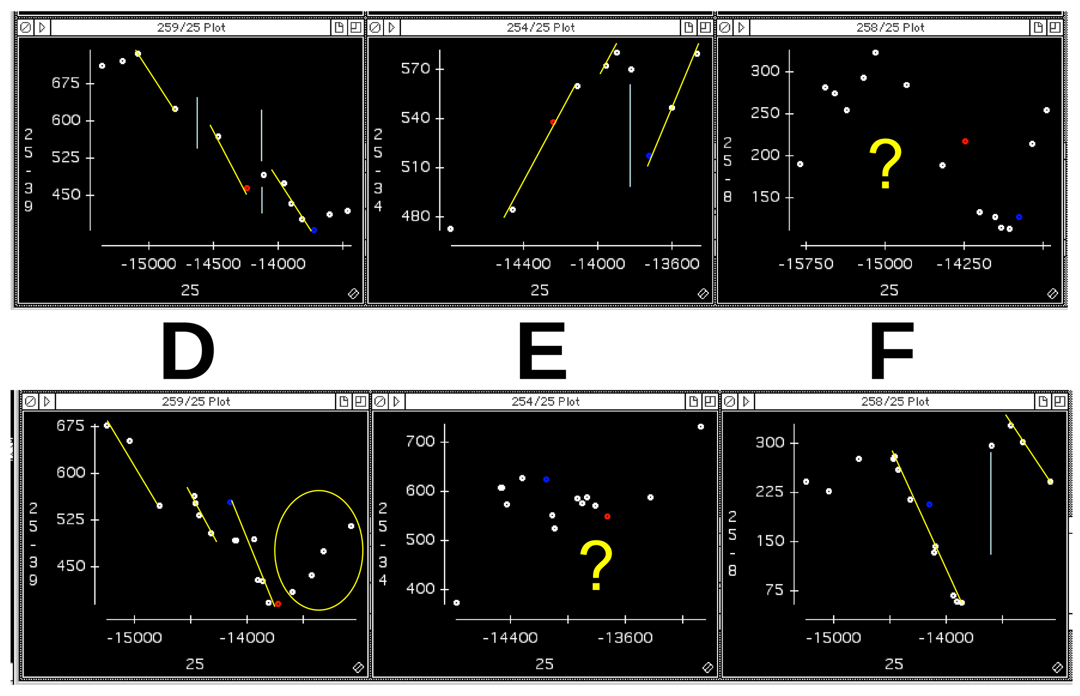
and outcrop analogue

GENERAL LEARNINGS FROM EL FURRIAL TREND

Correlations in complex terranes

CONTRACTOR 1
Conventional stratigraphy

CONTRACTOR 2
Sequence stratigraphy
50% more markers
than contractor 1



D and E coherent

F problematic

D and F acceptable

E problematic

Validating and comparing various correlations using the MBPA method
(Mutiple Bischke Plot Analysis)

Learnings

Each piece of work is worth studying

No one is always right

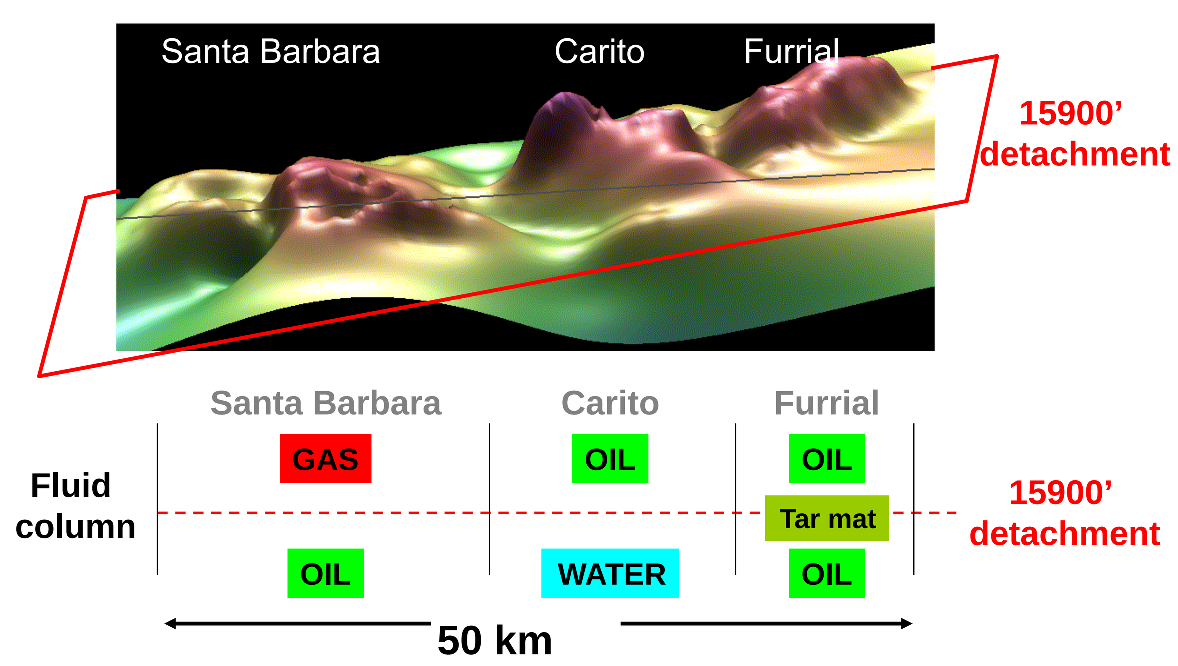
No tool is error proof

Graphically reviewing correlations speeds the process to a better solution

More layers do not necessarily mean better correlation

Geochemistry can help understand the link between fields

Variable expression of a mega-detachment

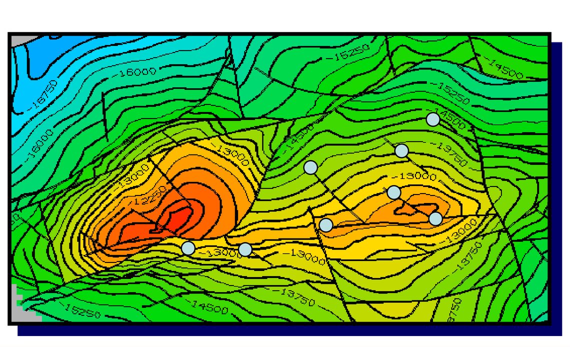


Learnings

Fluid changes at same depth in different fields are linked to the same very extensive detachment planes present in all three fields (Furrial, Carito, Santa Barbara)

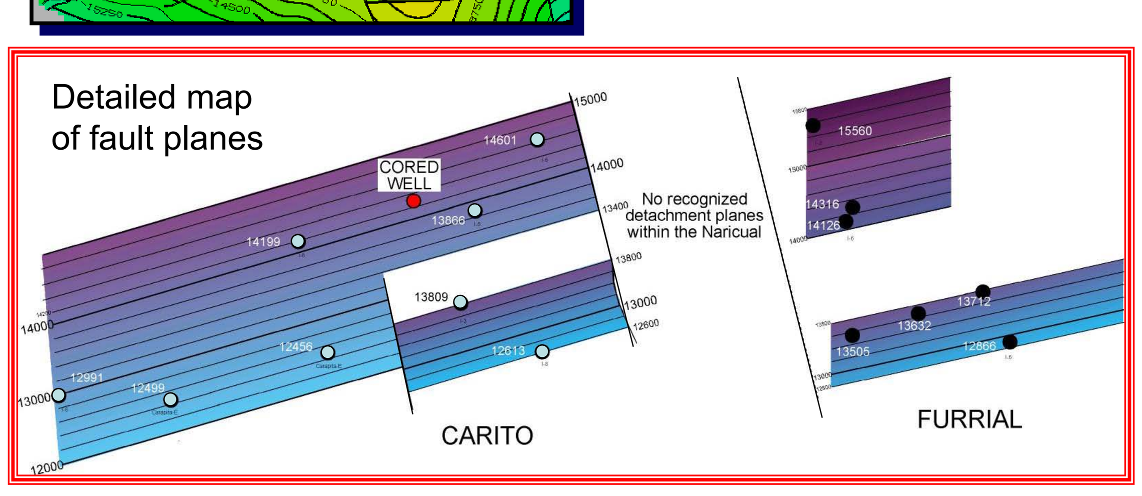
Think again if you have problems with normal faults

your missing sections may be associated with reactivated reverse faults



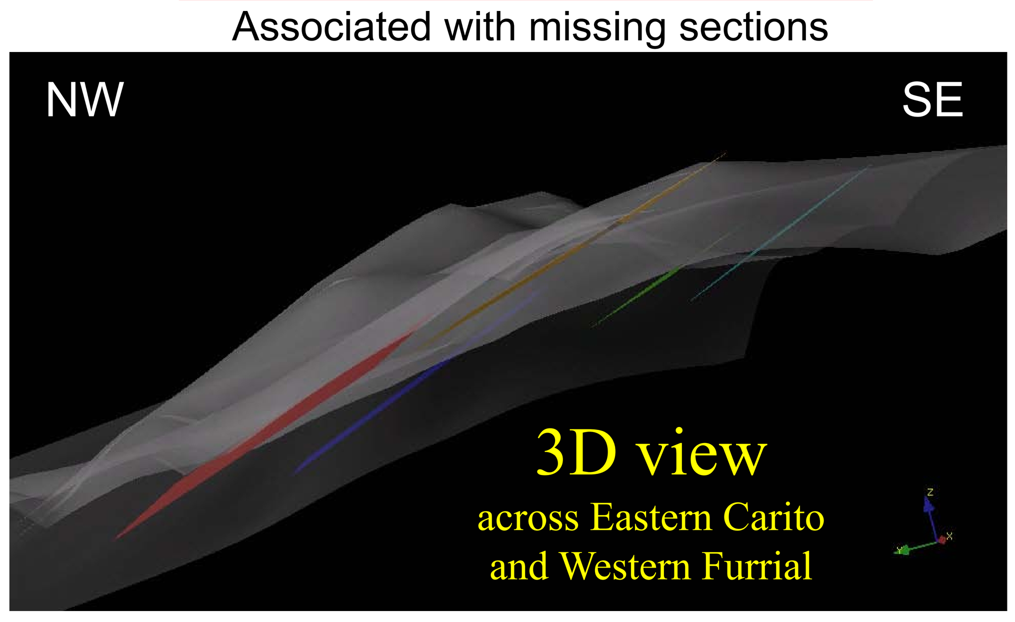
Two alternatives:

1. Normal faults
2. Low angle reverse faults



Low angle reverse faults

Associated with missing sections



Learnings

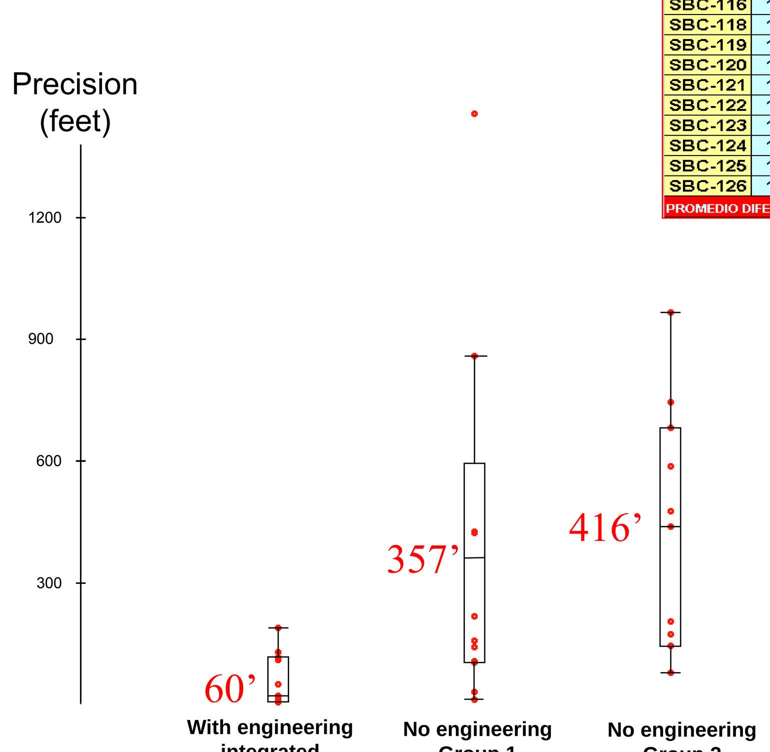
Reverse faults were interpreted from 2D and 3D seismics

Normal faults were interpreted by geologists because of missing sections

3D visualization confirms reverse faults

Multidisciplinary integration leads to better models

DRILLING vs PROGNOSIS



LOCS AÑO 2000 (TOPES FM. NARICUAL)

POZO	REAL	NUEVO MODELO	MODELO SUBSURFACE	MODELO OFICIAL
SBC-115	15106	15090	14360	13650
SBC-116	14247	14240	14170	14030
SBC-118	12940	12890	13380	13800
SBC-119	14005	14025	13320	13580
SBC-120	13521	13525	13350	13550
SBC-121	13360	13250	13950	13500
SBC-122	12957	12950	13100	12850
SBC-123	13104	13220	13180	13000
SBC-124	13127	13000	12650	12700
SBC-125	13689	13500	12720	13700
SBC-126	13245	13230	13040	13090
PROMEDIO DIFERENCIA		60.09	416.27	357.36

New tools and more integration have resulted in:

1) Better stratigraphy
2) Better structure
3) Better prediction
3) Faith in model

Learnings

A lot of money can be saved if you involve reservoir engineers from the very beginning of the geological modeling.

In Santa Barbara Reservoir engineering data led to the recognition of areas of high dips, detachments planes and inverted series.

References

Chatellier, J.Y., U. Azocar, and S. Olave, 2003, Deformation phases of the Furrial producing trend, Eastern Venezuela thrust belt: AAPG Annual Meeting Expanded Abstracts, v. 12; p. 29.

Chatellier, J-Y., Rueda, M.E., and Olave, S., 2002, Variable structural style along the Furrial Trend, implications for the development of these giant fields, Norte de Monagas, Venezuela (extended abstract): CSPG Annual Conference, Calgary, June 2002, 10 p. Web accessed 12 August 2009 http://www.cspg.org/conventions/abstracts/2002abstracts/extended/041S0115.pdf

Chatellier, J-Y., Hernandez, P., Porras C., Olave, S., and Rueda M., 2001, Recognition of fault bend folding, detachment and decapitation in wells, seismic and cores from Norte Monagas, Venezuela: Search and Discovery Article #40031 (2001). Web accessed 6 August 2009 (http://www.searchanddiscovery.net/documents/chatelier/index.htm).

Chatellier, J.Y. and O. Colmenares, 1997, Important links between tectonic and sedimentation in a strike-slip setting, *in* Memorias del Primero Congreso Latinoamericano de Sedimentologia, Soc. Venezolana de Geologo, Tomo I, November 1997, p. 201-210.

Gallango, O. and F. Parnaud, 1995, Two-dimensional computer modeling of oil generation and migration in a transect of the Eastern Venezuelan Basin, *in* A.J. Tankard, R. Suarez-Soruco, and H.J. Welsink, eds., Petroleum Geology of South American Basins: AAPG Memoir 62, p. 727–740.

Mijares, J., M. Silva, W. Maestracci, and E. Gil, 2004, Tectonic evolution and hydrocarbon migration synchronization in the Eastern Venezuela Basin; Tacata Area: Search and Discovery Article #10072 (2004). Web accessed 12 August 2009 http://www.searchanddiscovery.com/documents/2004/mijares/index.htm

Morales, M., E. Hung, and R. Bischke, 2005, Three dimensional interpretation of the El Furrial Trend, Eastern Venezuela Basin, Venezuela, *in* Seismic Interpretation of Contractional Fault Related Folds: AAPG Studies in Geology 53, p. 83-86.

Parnaud, F., I. Truskowski, Y. Gou, O. Gallango, J.C. Pascual, J. Di Croce, H. Passalacqua, and F. Roure, 1995, Petroleum geology of the Eastern Venezuela Basin, *in* A.J. Tankard, R. Suarez-Soruco, and H.J. Welsink, eds., Petroleum Geology of South American Basins: AAPG Memoir 62, p. 741–756.