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

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Search and Discovery Article #10202 (2009)
Posted August 14, 2009

*Adapted from poster presentation at AAPG Annual Convention, Houston, Texas, April 9-12, 2006

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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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A recent very large discovery in Tacata Triangle Zone. After Mijares et al. 2004, the blue lines are only to enhance some of the seismic features. The variability along El Furrial trend, as shown in Santa Barbara and Carito, can be observed. From Morales et al. 2005, 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

Furrial Fault interpretation

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

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

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

2-D view of pressures and fault bend fold

A view of normal pressures and slightly higher than normal

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

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
THRUSTS DEFINED BY FLUID CHEMISTRY
A different view of the CARITO FIELD

Understanding fluids leads to better understanding the complexity of the field

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

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.

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

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

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

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

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


