Fracture Systems Characterization: From the Regional Framework to the Reservoir, Sureste Basin, Chiapas-Tabasco, Mexico*

Victor M. Chavez Valois¹, Reynaldo Castellanos Calvo¹, Amado Marin Toledo¹, Miguel Hernandez Padilla¹, Lilia Hernandez Salazar¹, Clotilde Prieto Ubaldo¹, and Norma Olaez Ahedo¹,

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¹Activo de Exploración Sur, Pemex Exploracion y Produccion, Villahermosa, Mexico (vchavezv@pep.pemex.com)

Abstract

In the Sureste Basin huge quantities of oil are produced from fractured reservoirs. The main controls in the origin and development of fracture systems in the basin are structural deformation and diagenesis. Studies made separately, both in the Sierra de Chiapas outcrops and in the subsurface, demonstrate that the resulting fracture systems observed and controlled in outcrops are reproduced in subsurface conditions.

Throughout this work we integrate the whole studies made both in the Sierra de Chiapas outcrops and in the subsurface of Sureste Basin. Into this framework we adapted the workflow by Lohr et al. (2008). Our methodology includes three different scales of analyses: Large (we documented the main regional causes for the basin origin and evolution: tectonics, stratigraphy, sedimentation, and trap formation); Medium (we analyzed and calibrated seismic attributes and interpreted anomalies and lineaments from discontinuity seismic attributes); Small (we identified, analyzed and characterized fractures in image logs, cores and thin sections from many wells of a very important oil field in the basin).

We know from earlier studies that the fracture systems in the Sierra de Chiapas develop as a power law, and considering the concepts of fractals, we propose that the fracture systems documented by our analyses are the auto-similar expression of the lineal anomalies extracted and interpreted from seismic discontinuity attributes of Juspi-Arroyo Zanapa 3D-cube.
The documented fracture systems display a close geometric relationship with the structure and the main faults which limits the oil field in four different blocks (each with different production characteristics), on the other side, the fracture abundance is directly controlled by the dolomitization halos.

We identified eight different fracture families based on orientations and fracturing paragenesis, and we established the relative timing between them in base of their cut relationships. Finally we measured its minimum aperture value and the connectivity-conductivity relationships, these are very important input data for the reservoir simulation and characterization. When we are dealing with a fractured reservoir, the understanding of micro-macro fracture systems relationships is critical because it helps to calibrate oil reserves versus production and contributes to a better knowledge for its optimal administration.

Selected References


FRACTURE SYSTEMS CHARACTERIZATION:
FROM THE REGIONAL FRAME TO THE RESERVOIR, SURESTE BASIN,
CHIAPAS - TABASCO, MEXICO

VICTOR M. CHAVEZ VALOIS
REYNALDO CASTELLANOS CALVO
AMADO MARÍN TOLEDO
MIGUEL HERNÁNDEZ PADILLA
LILIA HERNÁNDEZ SALAZAR
CLOTILDE PRIETO UBALDO
NORMA OLÁEZ AHEDO
OUTLINE

THEORETICAL FRAMEWORK
FRACTURE ANALYSIS
STUDY AREA LOCATION
WORKFLOW
   Large Scale
   Medium Scale
   Small Scale
INTEGRATION OF INFORMATION
GOALS AND CONCLUSIONS
A FRACTAL is a semi-geometric object (not Euclidean) whose basic, fragmented or irregular structure, it repeats itself to different scales. Any fractal set follow an auto-similar pattern, in whom every part of a shape is geometrically similar to the everything (Mandelbrot, 1975). Its basic parameters (length, area, volume, mass, density, etc.) have mathematical relationship with the scale of observation by the power law.
The fractal dimension and the fracture analysis

The large scale features (faults, folds, etc.), can be observed in surface by satellite images or in subsurface by seismic.

Integrating different analysis, from Regional scale to Microscopic scale, and besides using combined seismic attributes, we can delineate “Fracture Corridors” in “sub-seismic resolution zone”.

The fracture in the reservoir is observed by image logs, cores, and thin sections.
Our workflow integrates methodologies that include three different scales of analysis:

**Large Scale**
- Tectonic & Structure Regional Analysis
- 3D Seismic-Structural Interpretation

**Medium Scale**
- Seismic Attributes Analysis & Calibration
- Seismic Time-Slices & Horizon Slices Interpretation

**Small Scale**
- Fracture in Image Logs, Cores & Thin Sections
- Petrography & Cement Diagenesis of Fractures Study (EPDE*)

**Prediction of Sub-Seismic Faults and Fractures**

**Estimation and Decrease of Geologic Risk**

**Reservoir Simulation and Field Development**

Adapted from: Lohr, et al, 2008
Fracture main controls in Sierra de Chiapas were defined from 144 outcrops.

The fracture sets consistently behave as a power law thru different orders of magnitude.

Fracture is directly related with dolomites and depositional environment.

Porosity is inversely proportional to fracture.

Structural position and fracture is not conclusive.
We integrated and validated Regional data including:

Sedimentary Facies Maps, Dolomitization Halos Maps, Sequence-Stratigraphy models, Plays Studies, etc.
We have a Subsurface Regional Structure Model arisen from 15 Regional Seismic-Structural Transects, tens of 3D seismic cubes and hundreds of local random sections.
Subsurface Mesozoic Structural Domains

SURESTE BASIN

- Salt Dislocated Fold-Thrusts
- Mesozoic Deepens
- Triangular Zone
- Subsided
- Salt Nucleated Fold-Thrusts
- Basin
- Collapsed
- Rigid

SURESTE BASIN

- Tight Fold-Thrusts
- Shelf
- Regional deepening to subsurface
- Strike-slip faults Province
- SIERRA DE CHIAPAS FOLD AND THRUST BELT

SURESTE BASIN

- Poor Seismic Resolution Zone
- Platform Margin
- Mesozoic Deepens
- Fold-Thrusts
- Shell Salt Nucleated Fold-Thrusts
- Rigid Salt Dislocated Fold-Thrusts

SURESTE BASIN

- YUCATAN PLATFORM
- OCEAN PACIFICO
- GOLFO DE MEXICO
- SIERRA DE CHIAPAS FOLD AND THRUST BELT
Synthesis of Cuenca del Sureste Tectonic-Sedimentary Framework

**Time**  | **Column Type**  | **Tectonic Event**  | **Structure**  | **Tectonosequence**
---|---|---|---|---
Jurassic  | INF. |  |  | Tectonic stability. Passive margin sequences, carbonate systems predominate, the facies evolve from transitional to marine-deep marine. From Middle to Upper Jurassic deposits from transitional to open shelf carbonates. In Tithonian rich organic matter carbonates are deposited during an important sea transgression, this is the main source rock in the Basin. During Lower-Mid Cretaceous vast carbonate platforms with facies changes to open shelf carbonates development. Since Upper Cretaceous starts the regional marine transgression and platforms flooding with open shelf shaly carbonates deposition. There are a few platform remnants. Salt tectonics vary from early passive to buoyancy.
| SUP. |  |  |  | Sin-rift sequences: Deposit of continental red-beds, evaporates and salt during flooding-desiccation alternate stages.
Cretaceous  |  |  |  | First contractual event creates a Fold and Thrust Belt. Sedimentary regime change: Carbonate Platforms are drowned, the terigenous sequences are extensive distributed. Development of channelized systems and turbidities fans which exhibit provenance from south. Salt piercement during contraction.
Pliocene  |  |  |  | Gravity sliding. Thick siliciclastic accumulations and growth faults trigger allochthonous salt sheets advance and shale diapirism.
Pliocene  |  |  |  | Intercompressive Stability
Pleistocene  |  |  |  | "Chiapaneca" Compression Stage
Quaternary  |  |  |  | Movement of the Platforma
Pleistocene  |  |  |  | Laramide Compression Stage
Miocene  |  |  |  | Thermal Subsidence & Post-Rift
Palaeocene  |  |  |  | Rifting Intracratonic
Seismic-Structural Interpretation of JAZAPA-3D Cube, and the top configuration of Mid Cretaceous (Cenomanian).
Analysis and Combination of Seismic Multi-Attribute to enhance linear anomalies structurally consistent related to corridors of fractures.
Time-slices of the amplitude 3D cube was correlated with seismic sections.

Step by step linear anomalies were highlighted both in time-slices & horizon-slices.
Structure Map resulted from correlation between Amplitude 3D Cube and seismic sections. This is the example to 2900 mili-seconds in time.
Major lineaments: Thrust Faults & Salt Evacuation related Faults. Small lineaments correlative to fracture (“corridors”). The interpreted elements are very geometrically consistent.
The HC’s Fields are Thrust Faults related, Salt Halos are close related with Lateral Ramps (E-W oriented). The light blue areas appear sedimentary features.

The structural styles suggest mechanisms of compression coexisting with wrenching, the salt tectonics has a very important participation.
Fracture characterization by Image Logs, Cores and Thin Sections

From logs and cores are differentiated impregnate and sealed fracture families. The Petrography & Cement Diagenesis of Fractures Study (EPDE) characterizes the fracture attributes as opening, orientation, conductivity, matrix-fracture connectivity, timing, etc., all of them are essentials for reservoir simulation.
### Petrography & Cement Diagenesis of Fractures Study vs. Mineralogical Facies* in CANRU Field

#### Matrix-Fracture Attributes

<table>
<thead>
<tr>
<th>Mineralogical Facies</th>
<th>Lower Cretaceous</th>
<th>Mid Cretaceous</th>
<th>Upper Cretaceous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C-33 N1 KI4</td>
<td>C-1002 N3 KI1</td>
<td>C-1057 N1 KM</td>
</tr>
<tr>
<td>Calcarenite</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Calcita</td>
<td></td>
<td></td>
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<tr>
<td>Dolomitica sincinematica</td>
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<td></td>
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<tr>
<td>Dolomitica postcinenmatica</td>
<td></td>
<td></td>
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<tr>
<td>Intergranular porosity</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

#### Matrix-Fracture Production

- C-213
- C-215

#### Fracture Only Production

- RN-44
- RN-42
- RN-41

*From: Carmona et al., IMP; 2008*
Matrix-Fracture Attributes and Conductive Quality

Very important input data to Reservoir Simulation and Characterization are the related with the Fracture Abundance of Conductive Families, their Minimum Apertures and its Matrix-Fracture interaction.
The lineaments interpreted on Time-slice /Horizon-slice are compared with those from Image Logs, Cores and Thin Section. There is a very close correlation between both macro-micro scales.
Cumulated-Normalized Production Map (MMBO/year)

Sedimentary Facies Map*

- Wacs-Grains light-Dolomtz.
- Ruds-/Wacs-Muds light-Dolomtz.
- Wacs-Grains Dolomtz. (50-90%)  
- Ruds-/Wacs-Muds Dolomtz.
- Muds-Wacs Dolomtz. (50-90%)
Correlating the whole information we differentiate four different blocks ranked by production rates and conductive fracture directions.
This Methodology is oriented to understand the fracture systems in three different approaches

**EXPLORATORY:**
✓ To predict fracture systems even in not proven areas.
✓ To estimate/to diminish the fracture plays geological risk.
✓ To support exploratory wells near to fields or intermediate locations into a field.

**FIELD DEVELOPMENT:**
✓ The data obtained by our methodology will improve the naturally fracture fields simulation & characterization.
✓ To drill wells in the best direction looking for conductive fracture families.
✓ To take lower risk decisions during field development and administration activities.
✓ Visualizing and proposing areas of field extension.

**MATURE FIELDS REVITALIZATION:**
✓ The searching of remaining reserves in not drained areas understanding conductive preferential systems.
✓ Contributing to programs of secondary and improved recovery.
We are convinced that this methodology contributes to better results since:

✓ The Geological phenomena that originate the fractures must govern any study on Fracture Reservoirs.

✓ From the geological controls on fracture (tectonics, stress-strain relationship, mechanical stratigraphy, fracture stratigraphy, etc.) there depend the variables related to flow of fluids.

✓ The rocks “hard” data (cores, cuttings), must be a *sine qua non* condition to study and understand the fracture systems in any reservoir.

✓ The results of fracture studies in a particular area, must not be applied as a kitchen recipes to other area or reservoir, since any difference in any geological control can contribute different results.

✓ The geological characterization of any fracture reservoir only will work for this reservoir particularly
Thanks