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

Victor M. Chavez Valois[1], Reynaldo Castellanos Calvo[1], Amado Marin Toledo[1], Miguel Hernandez Padilla[1], Lilia Hernandez Salazar[1], Clotilde Prieto Ubaldo[1], and Norma Olaez Ahedo[1],

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[1]Activo 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

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Chávez-Valois, V.M., M.L. Clara-Valdés, J.I. Juárez-Placencia, I. Alor-Ortiz, M. Mata-Jurado, R. Villagrán-Yáñez, M. Guerrero-Tristan, and S. Ghosh, 2004, A new approach of the Tertiary plays in a multidisciplinary framework: Sureste Basin, Tabasco, México: AAPG Tulsa, Oklahoma, EUA, International Conference, October 24–27, Cancún, Mexico, 7 p.

Carmona, N.B., L.A. Buatois, M.G. Mangano, and R.G. Bromley, 2008, Ichnology of the lower Miocene Chenque formation, Patagonia, Argentia; animal-substrate interactions and the modern evolutionary fauna: Ameghiniana, v. 45/2, p. 377-392.

Lohr, T., C.M. Krawczyk, O. Oncken, and D.C. Tanner, 2008, Evolution of a fault surface from 3D attribute analysis and displacement measurements: Journal of Structural Geology, v. 30/6, p. 690-700.

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

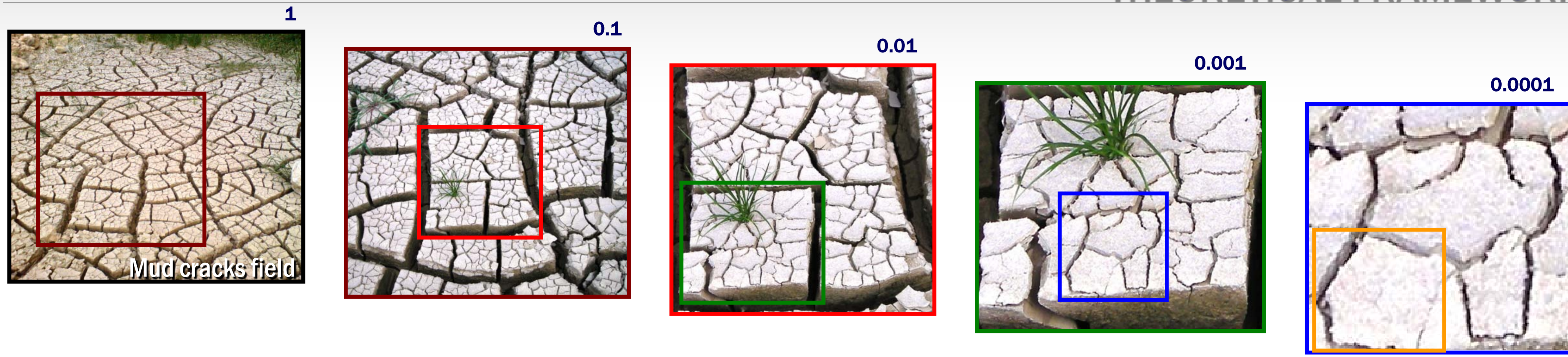
WORKFLOW

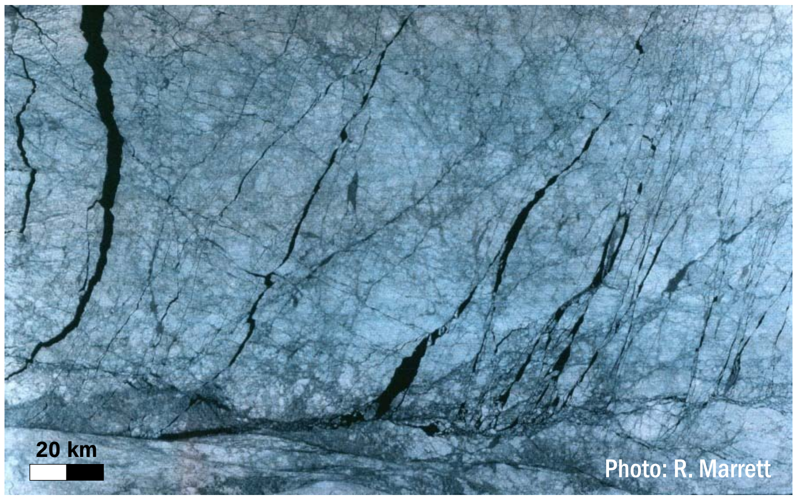
- Large Scale
- Medium Scale
- Small Scale

INTEGRATION OF INFORMATION

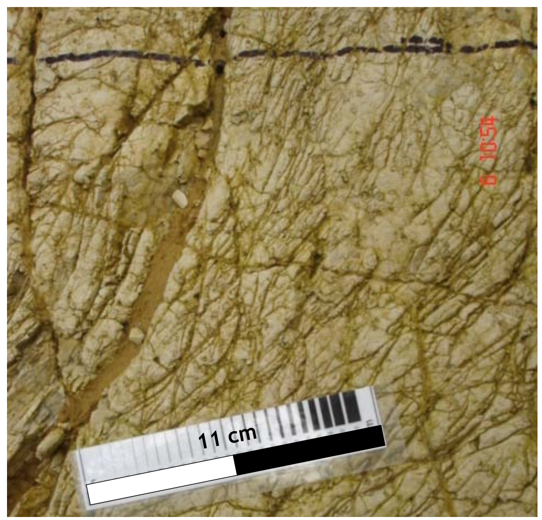
GOALS AND CONCLUSIONS

THEORETICAL FRAMEWORK





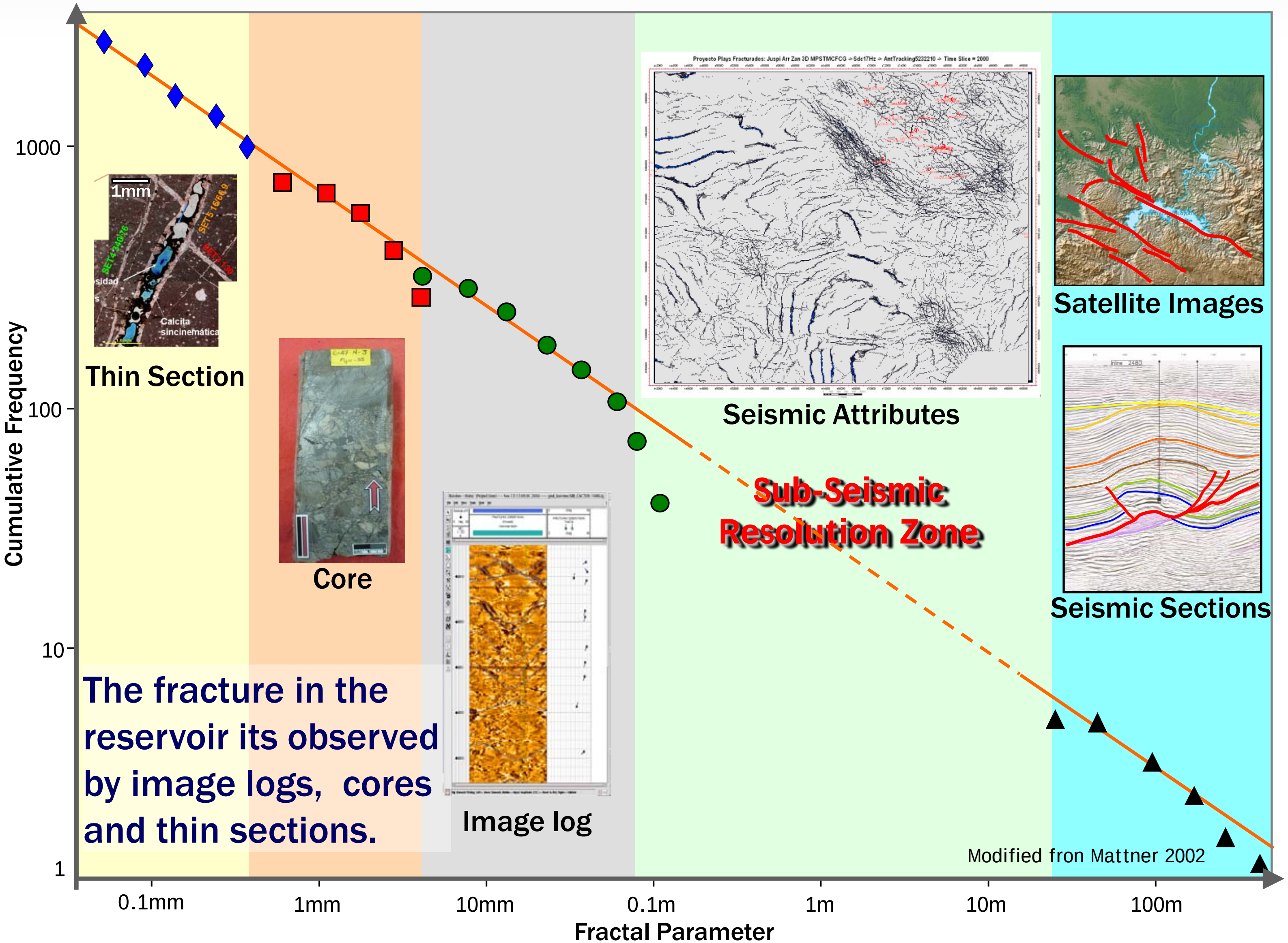
A FRACTAL is a semi-geometric object (not Euclidean) whose basic, fragmented or irregular structure, it repeats itself to different scales.



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.

SCALES OF FRACTURE ANALYSIS

The fractal dimension and the fracture analysis

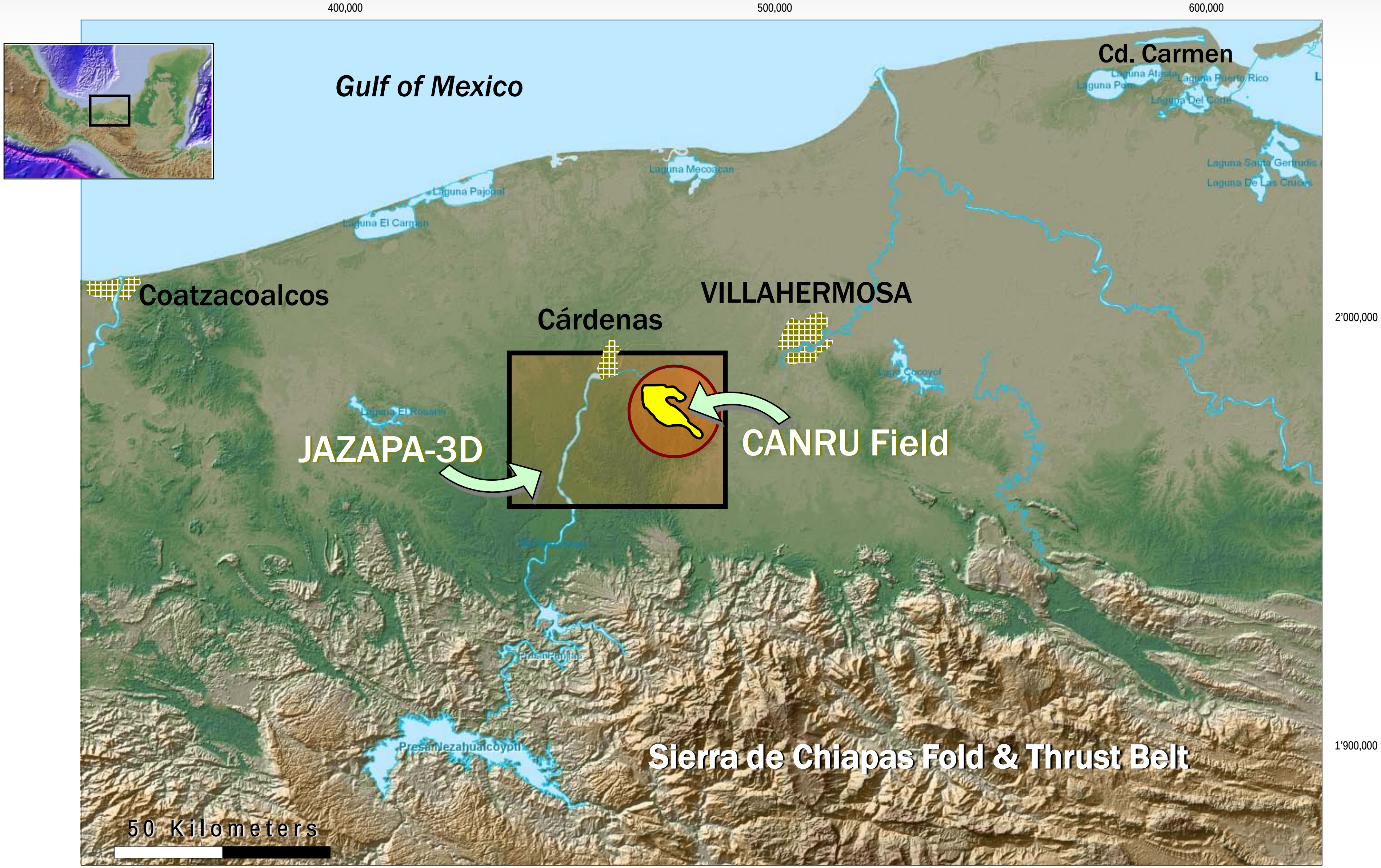


The large scale features (faults, folds, etc.), can be observed in surface by satellite images or in subsurface by seismic.

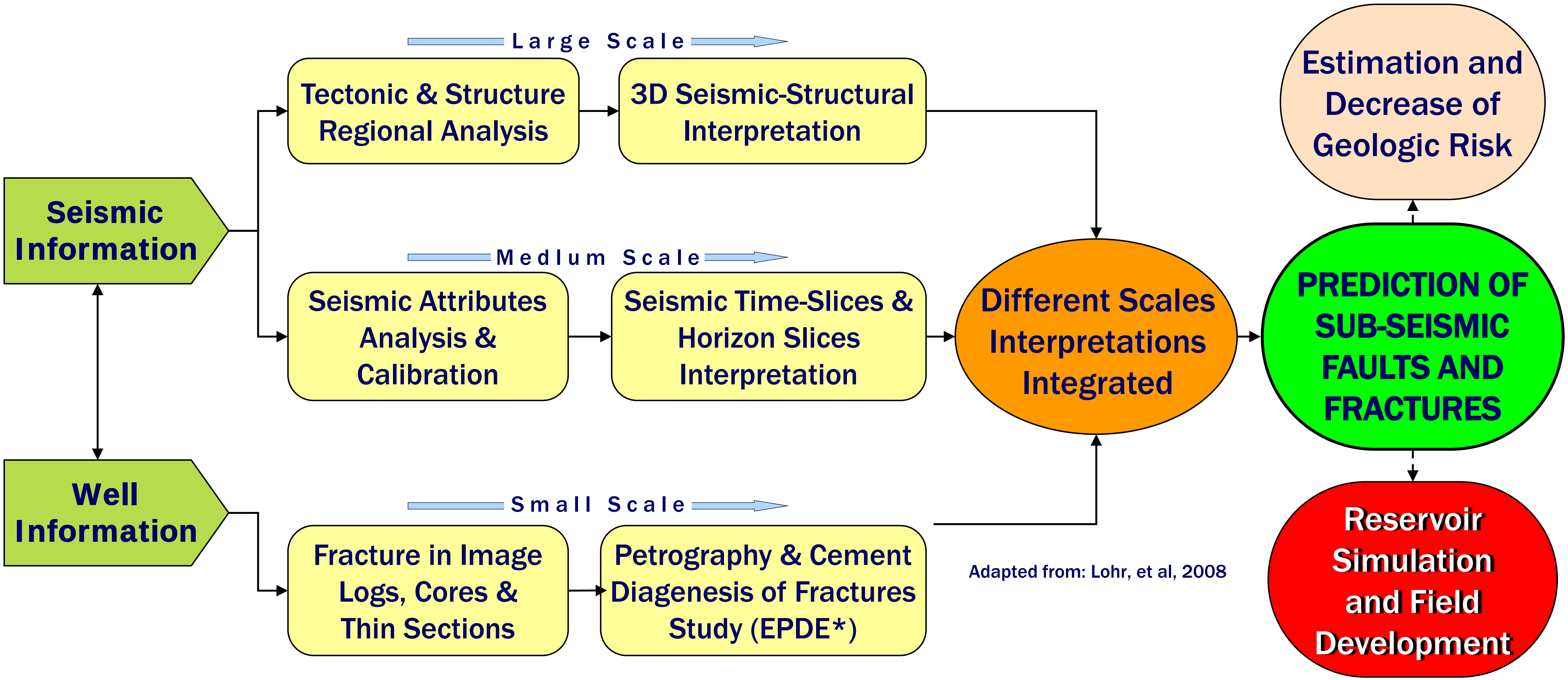
Integrating different analysis, from Regional scale to Microscopic scale, and besides using combined seismic attributes, we can delineate “Fracture Corridors” in “sub-seismic resolution zone”.

PEMEX
EXPLORACIÓN Y PRODUCCIÓN

AREA LOCATION



Our workflow integrates methodologies that include three different scales of analysis

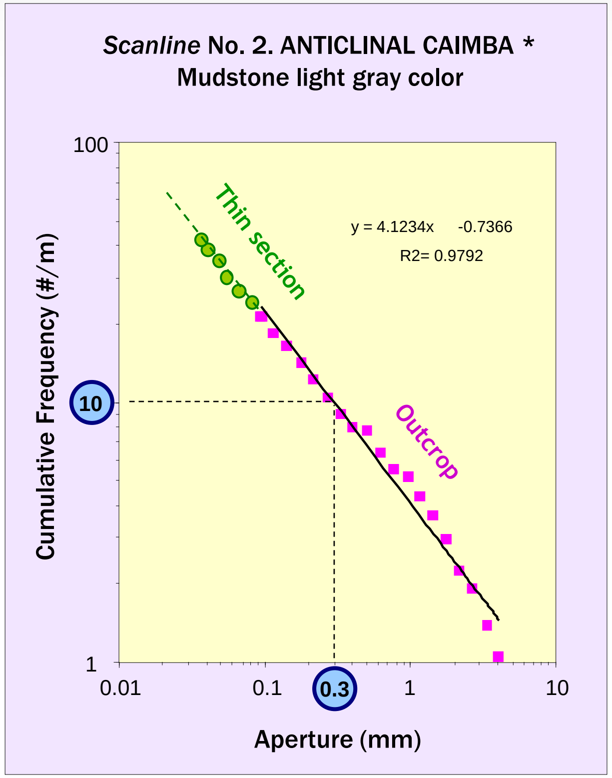


Adapted from: Lohr, et al, 2008

OUTCROP FRACTURE ANALYSIS*

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.



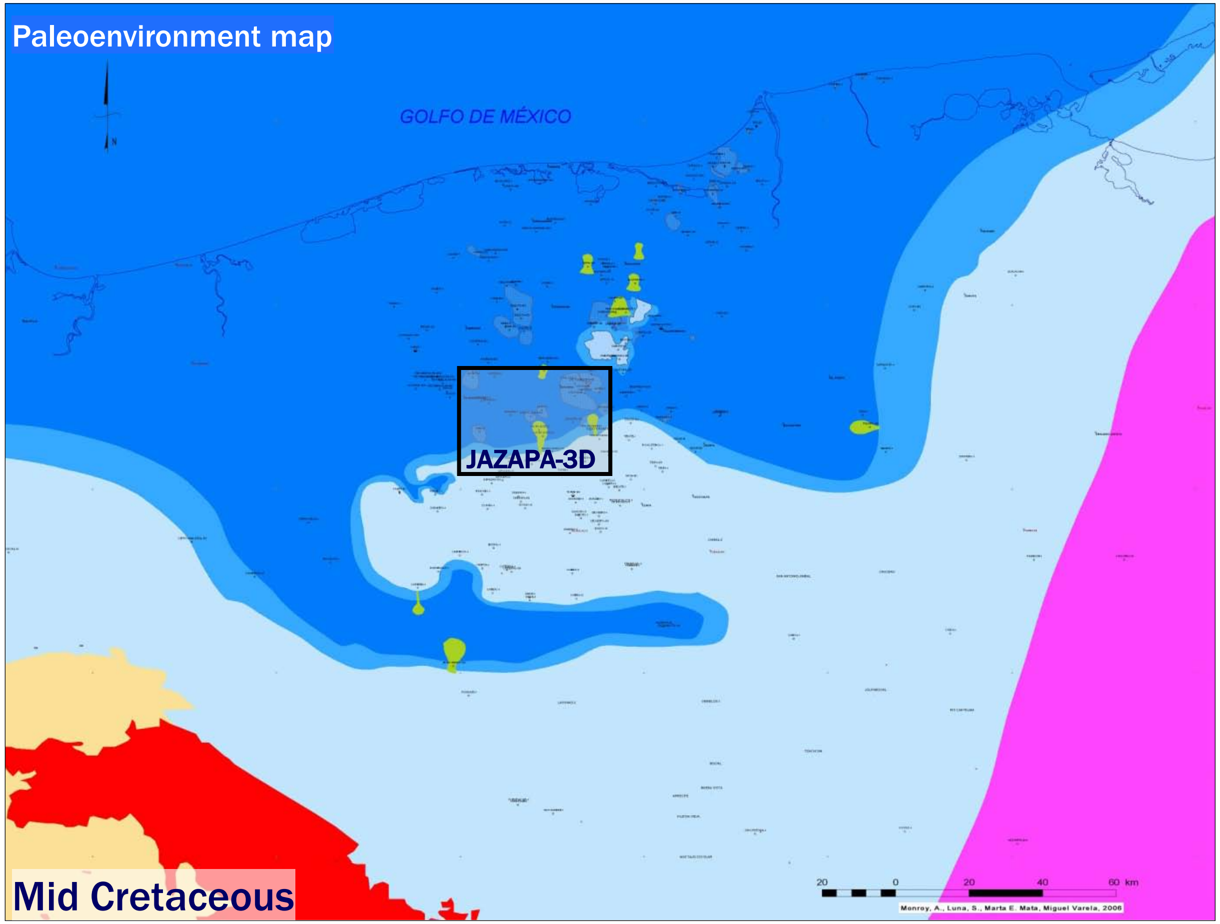
MULTIVARIABLE ANALYSIS *

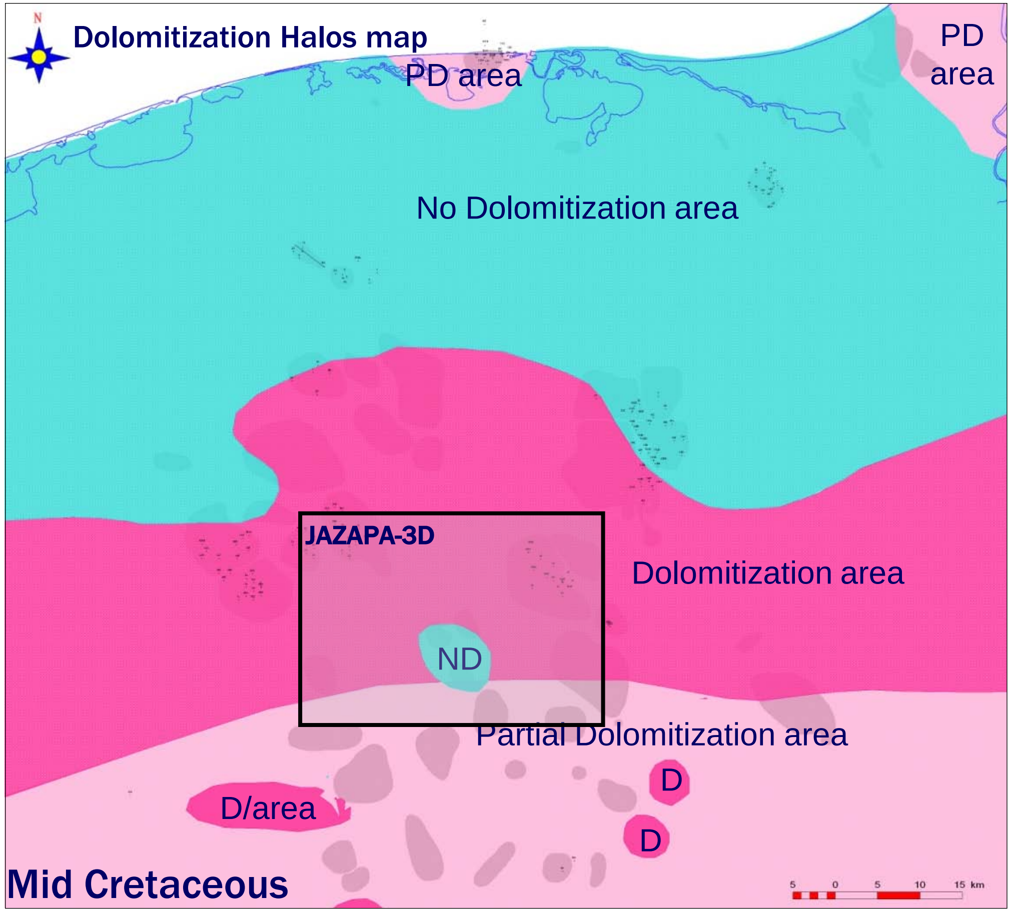
Geological controls vs. Fracture in Sierra de Chiapas

	Coefficient	*Typical error*	*Statistic t*	*Probability*	*Inferior 95%*	*Superior 95%*	*Inferior 95.0%*	*Superior 95.0%*
Interception	0.31	4.31	0.07	0.94	-8.52	9.15	-8.52	9.15
DOLOMITIZATION	10.82	4.22	2.56	0.02	2.16	19.48	2.16	19.48
AGE	6.71	5.81	1.16	0.26	-5.20	18.62	-5.20	18.62
DEP. ENVIRONM.	7.36	4.78	1.54	0.14	-2.44	17.16	-2.44	17.16
STRUCTURAL POSITION	5.37	3.95	1.36	0.19	-2.73	13.47	-2.73	13.47
POSITION/So	5.50	3.27	1.68	0.10	-1.21	12.21	-1.21	12.21
POROSITY	-4.72	3.49	-1.35	0.19	-11.87	2.43	-11.87	2.43

- (green) Fracture is directly related with dolomites and depositional environment.
- (red) Porosity is inversely proportional to fracture.
- (orange) Structural position and fracture is not conclusive.

LARGE SCALE



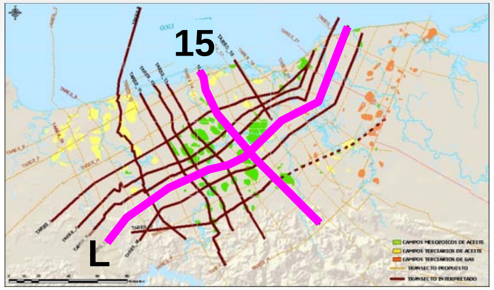


We integrated and validated Regional data including:

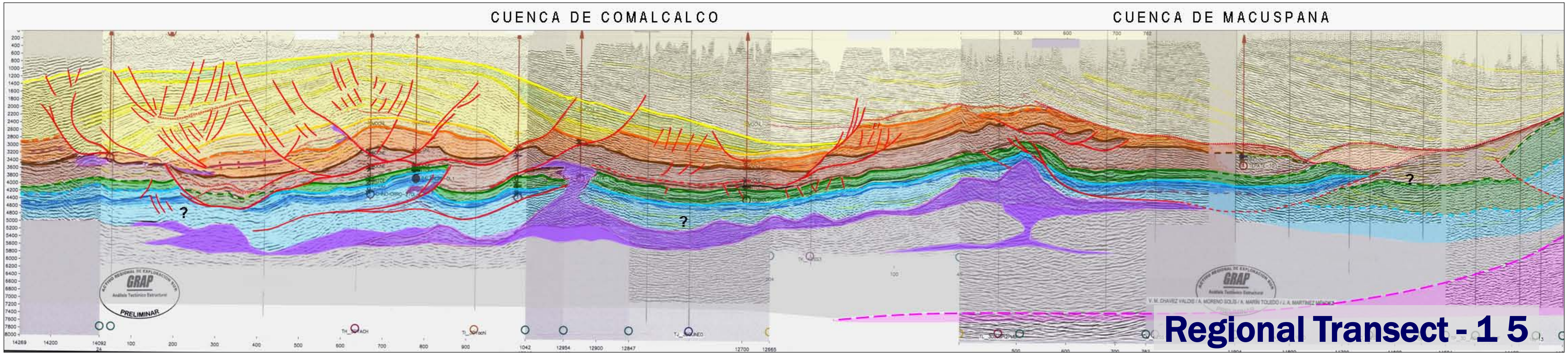
Sedimentary Facies Maps, Dolomitization Halos Maps, Sequence-Stratigraphy models, Plays Studies, etc.

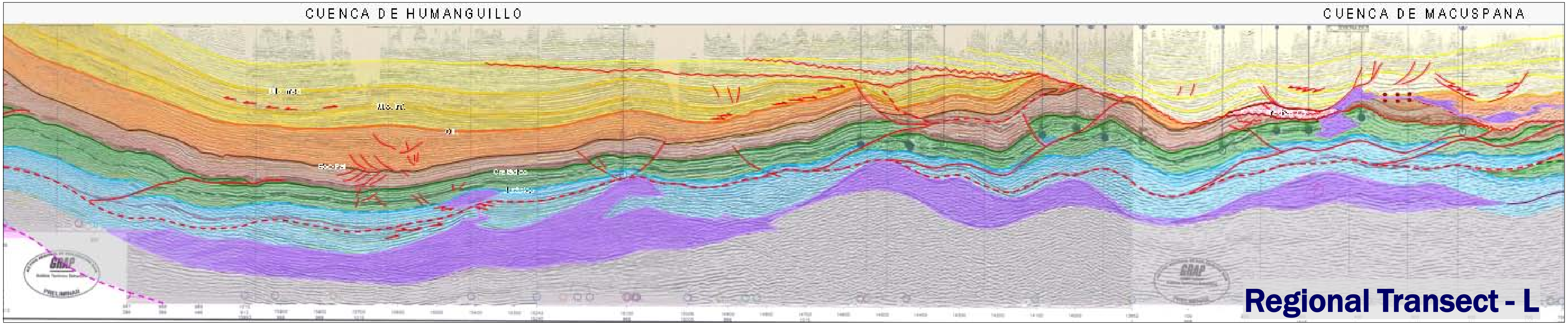
PEMEX
EXPLORACIÓN Y PRODUCCIÓN

LARGE SCALE



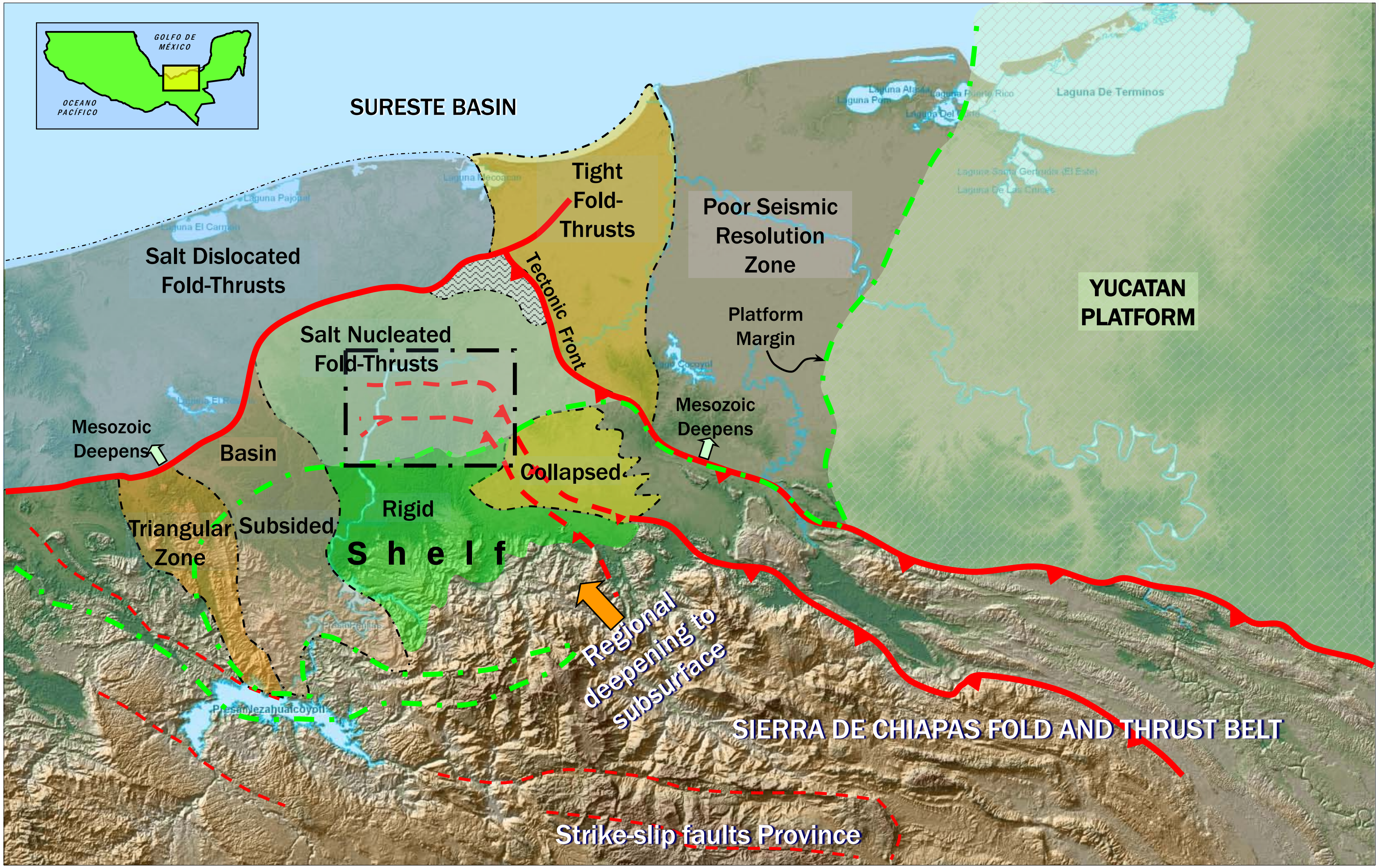
We have a Subsurface Regional Structure Model arisen from 15 Regional Seismic-Structural Transects, tens of 3D seismic cubes and hundreds of local random sections.





Chavez et al, 2006.

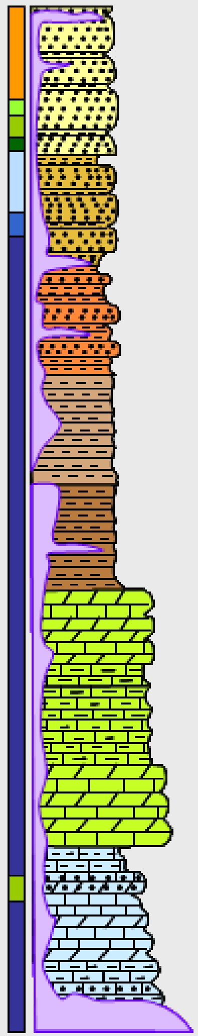
Subsurface Mesozoic Structural Domains



Synthesis of Cuenca del Sureste Tectonic-Sedimentary Framework

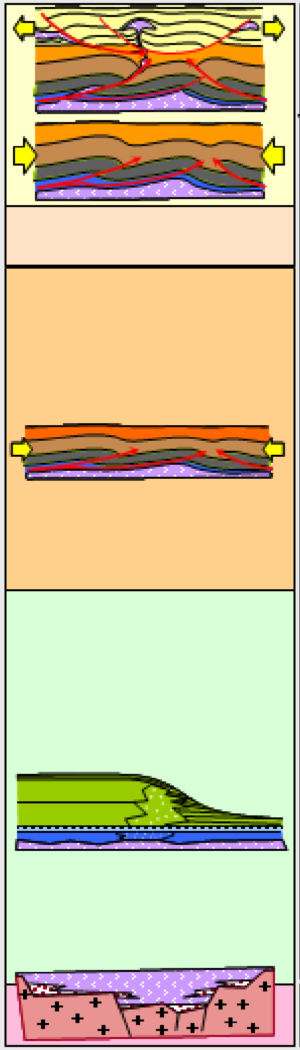
TIME: Q (HOLO., PLEI.); NEOGENE (PLIO.; MIOCENE: S., M., I.); PALEOGENE (OLIGOCENE: S., M., I.; EOCENE: S., M., I.; PALEOCENE: S., M., I.); CRETACEOUS (SUP., MED., INF.); JURASSIC (SUP., MED.)

COLUMN TYPE



RGRARS

STRUCTURE

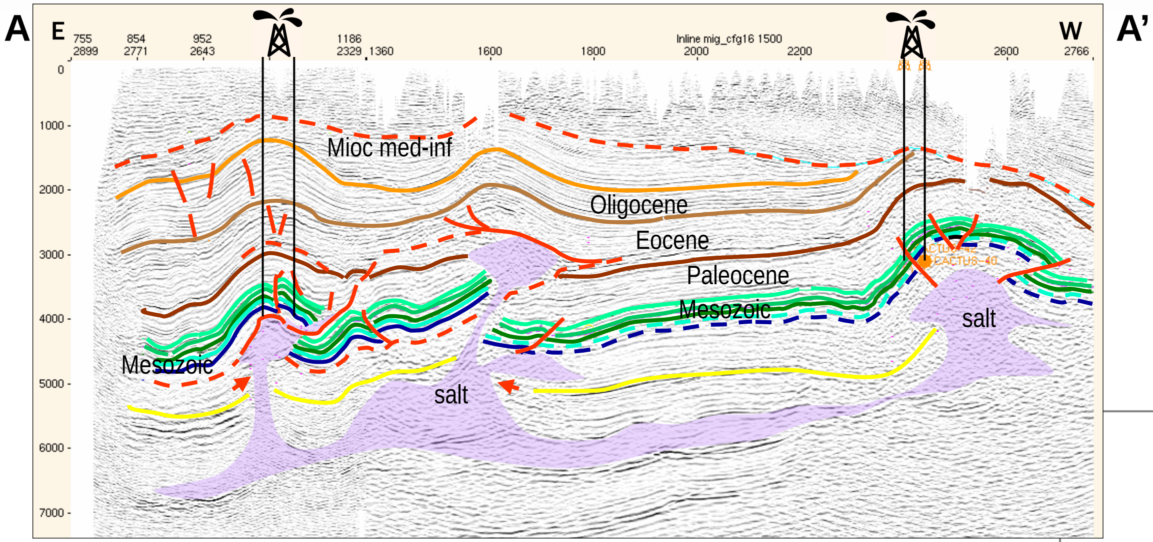


Movimiento de Masas de sal
Inundación de la Plataforma
Movimiento de Arcilla

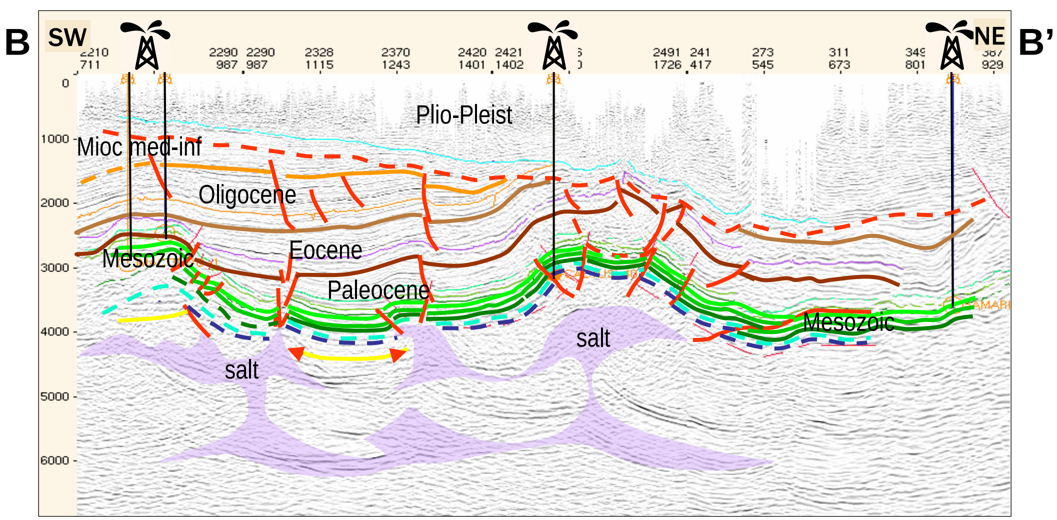
TECTONIC EVENT	TECTONOSEQUENCE
Passive Margin	Gravity Sliding, Thick siliciclastic accumulations and growth faults trigger allochthonous salt sheets advance and shale diapirism.
"Chiapaneca" Compression Stage	Main Deformation, Rise of Basement and Sierra de Chiapas. Siliciclastic shelves advance rapidly. Sequences shows sin-depositional deformation. Salt diapir amplification during shortening.
Intercompressive Stability	Tectonic impasse. Basinal terrigenous sequences, shales mainly. Salt buoyancy and evacuation.
"Laramidic" Compression Stage	First contractional event creates a Fold and Thrust Belt. Sedimentary regime change: Carbonate Platforms are drowned, the terrigenous sequences are extensive distributed. Development of channelized systems and turbidities fans which exhibit provenance from south. Salt piercement during contraction.
Thermal Subsidence & Post-Rift	Tectonic stability. Passive margin sequences, carbonate systems predominates, the facies evolve from transitional-shallow 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 seas transgression, this is the main source rock in the Basin. During Lower-Mid Cretaceous vast carbonate platforms with facies changes to open seas carbonates development. Since Upper Cretaceous starts the regional marine transgression and platforms flooding, with open seas shaly carbonates deposition. There are a few platform remnants. Salt tectonics vary from early passive to buoyancy.
Rifting Intracontinental	Sin-rift Sequences: Deposit of continental red-beds; evaporates and salt during flooding-desiccation alternate stages.

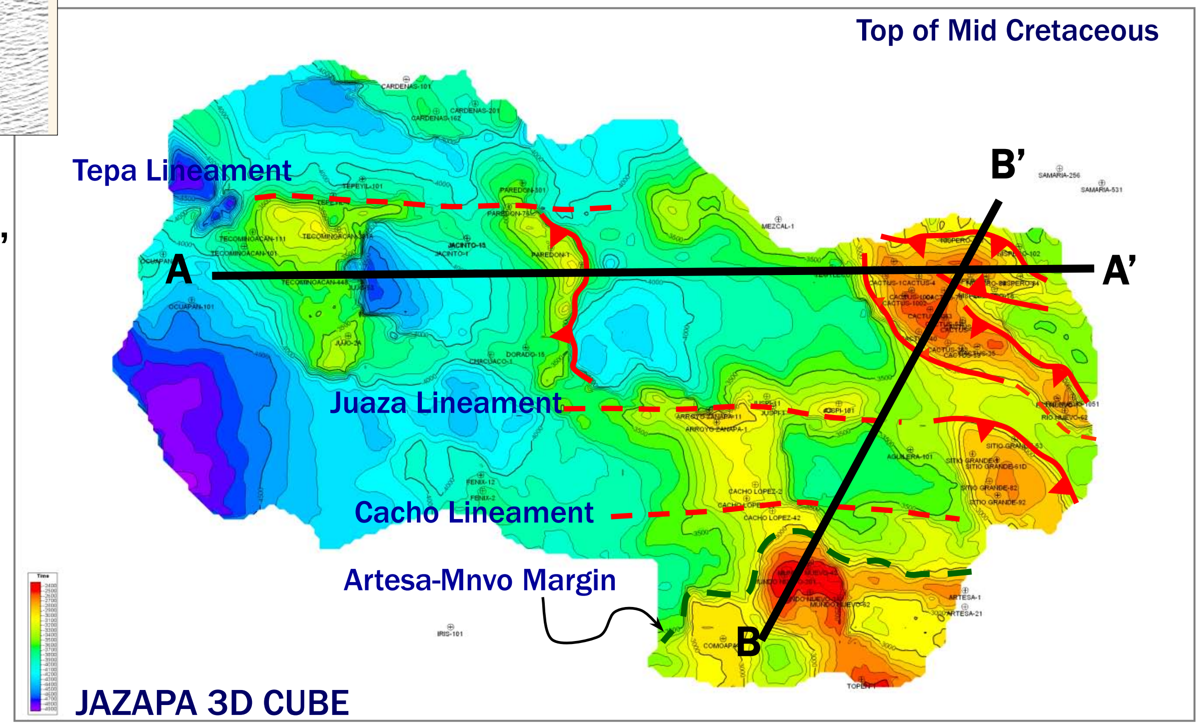
Victor M. Chavez Valois, 2002

MEDIUM SCALE



Seismic-Structural Interpretation of JAZAPA-3D Cube, and the top configuration of Mid Cretaceous (Cenomanian).

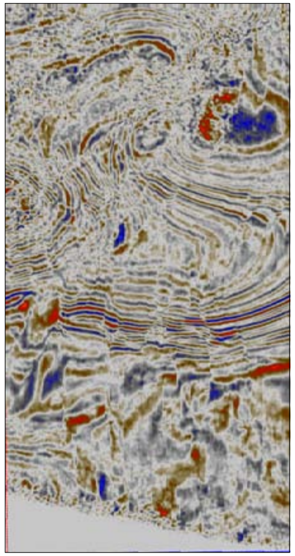




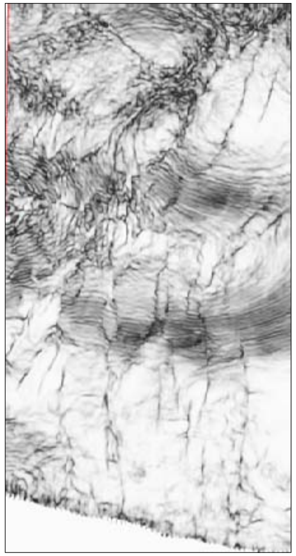
Seismic Attributes Calibration and Application to define Fracture Corridors

Workflow

Seismic Selection and Conditioning; signal-noise ratio. → Spectral Analysis of seismic record → Selection of Seismic attributes by objective: Structural vs. Stratigraphic ↔ Seismic Attributes Calibration ↔ Multi-attributes Analysis: Variance, Amplitude, Phase, Coherency, Edge, Azimut, Structure Cube, Spectral Decomp. ↔ Multiattribute-Ant-tracking Combination ↔ Horizon Slice, Time Slice, Flatten-Horizon → Interpretation

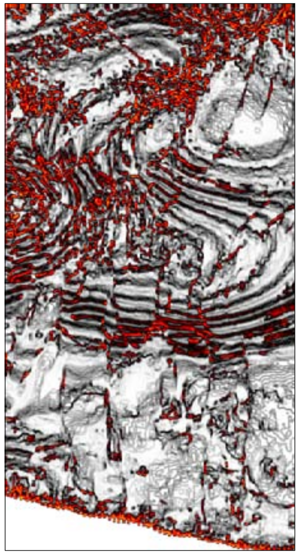


Amplitude



Structure Cube

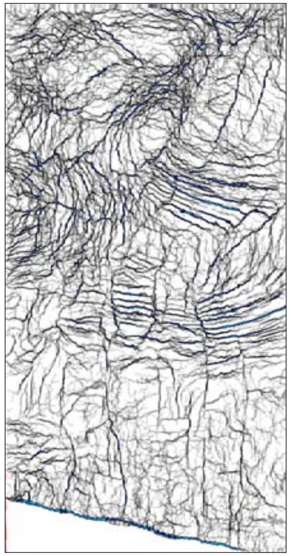
Spectral Dec. (Sdc)



Variance + Sdc

Phase + Sdc

Ant-track+Sdc



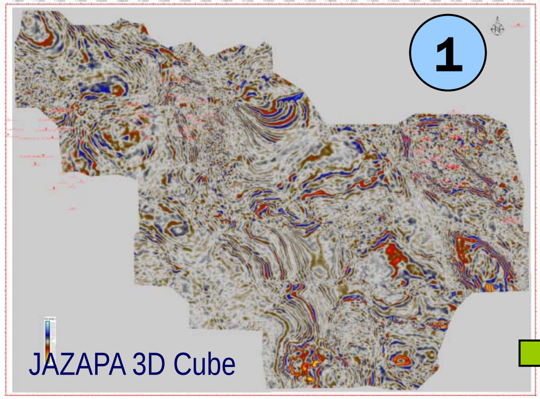
Ant-Track+Struct Cube

Analysis and Combination of Seismic Multi-Attribute to enhance linear anomalies structurally consistent related to corridors of fractures.

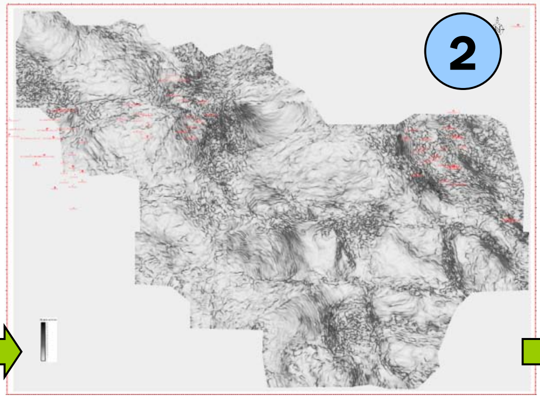
PEMEX EXPLORACIÓN Y PRODUCCIÓN

MEDIUM SCALE

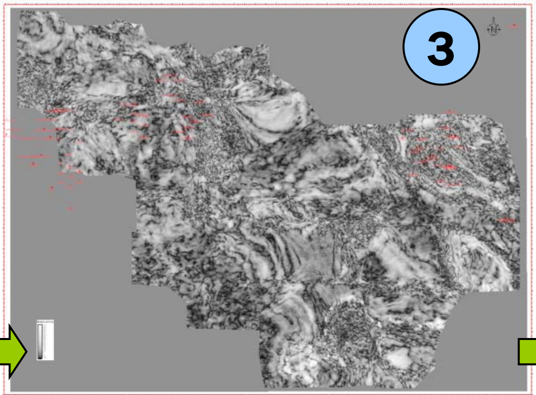
Interpretation Workflow



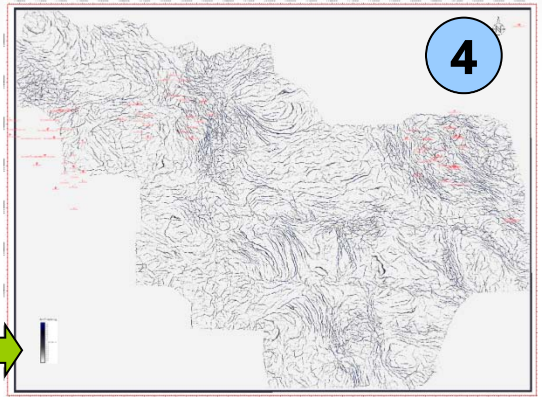
Amplitude



Structure-Cube

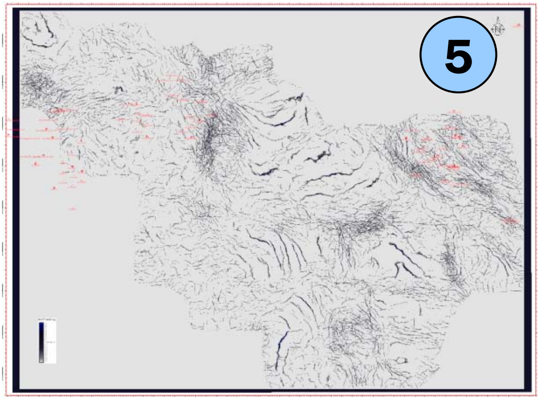


Spec. Decomp.



Structure Cube + Ant-tracking

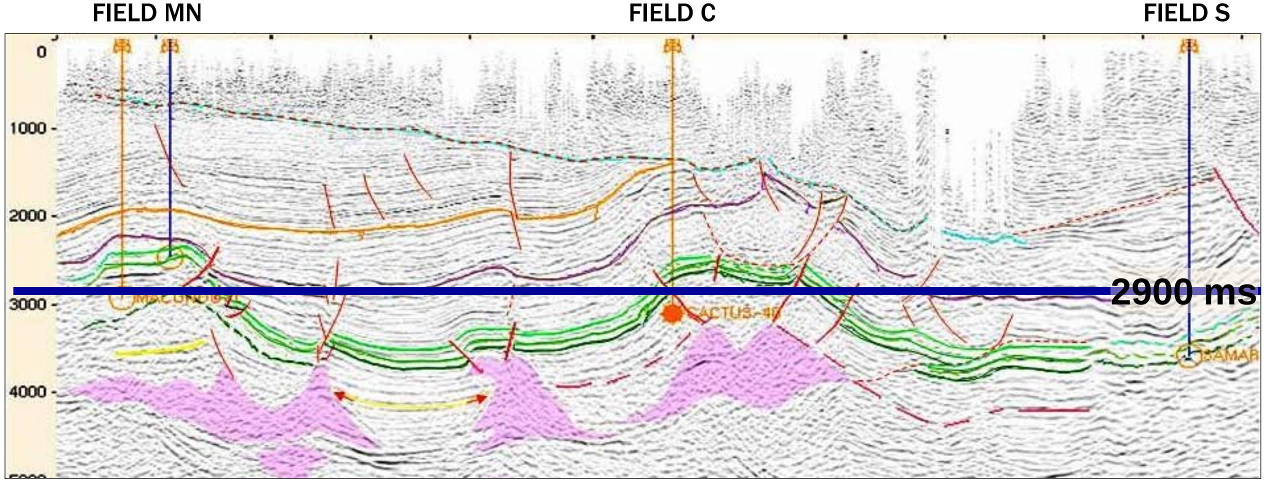
Step by step linear anomalies were highlighted both in time-slices & horizon-slices.



Spec. Descomp. + Ant-tracking

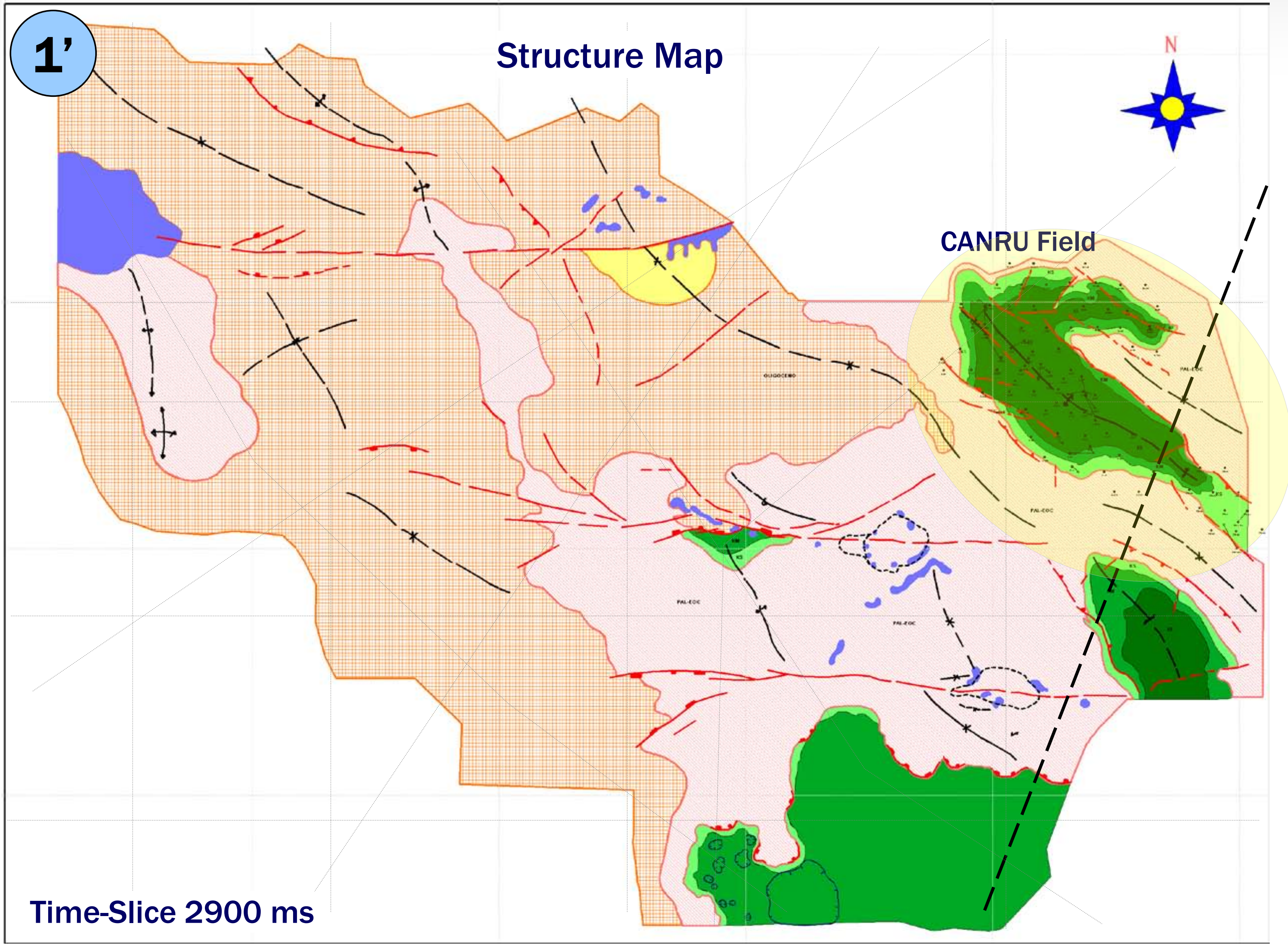
6

\+ Time-slices of the amplitude 3D cube was correlated with seismic sections.



1’

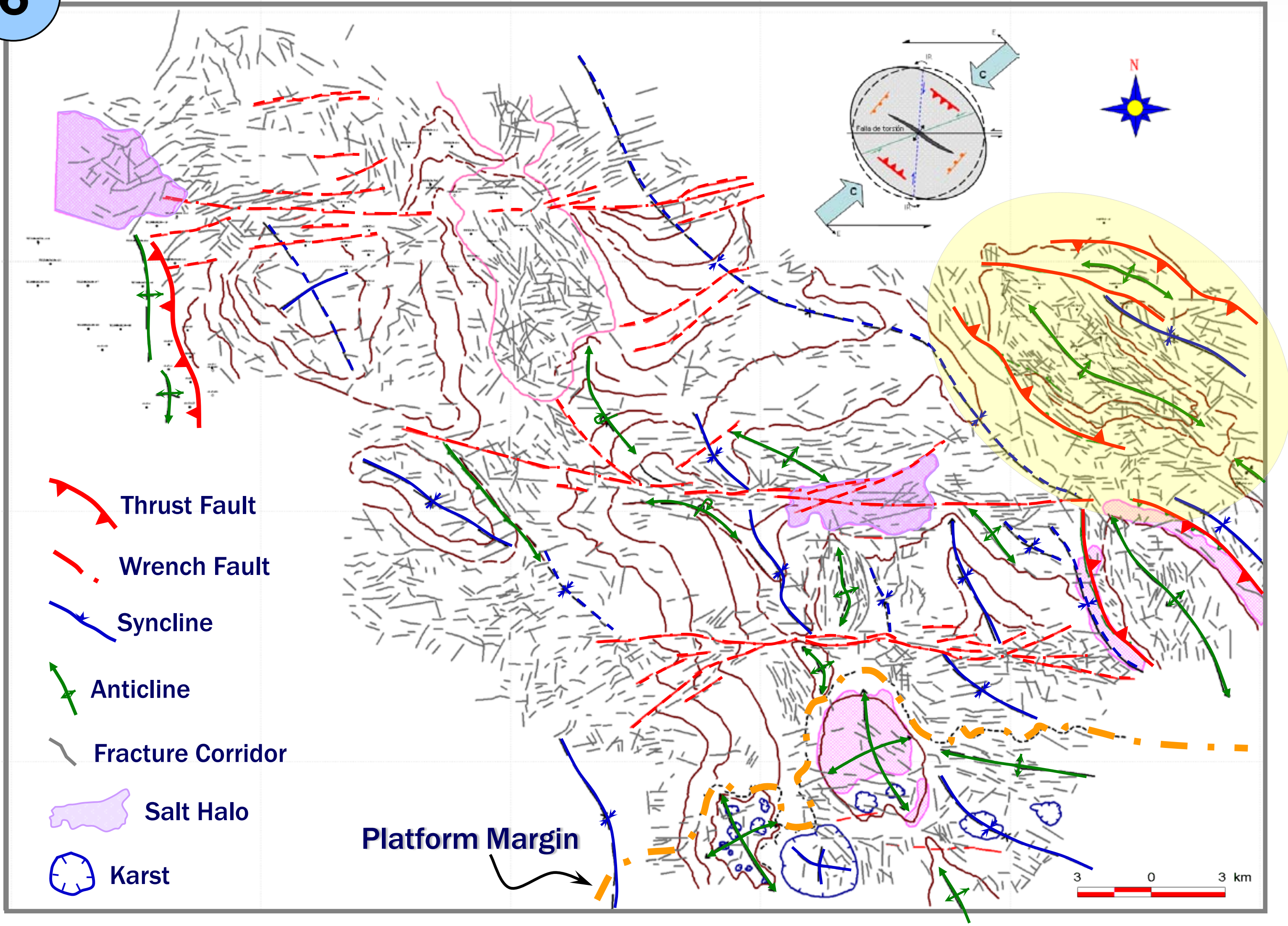
MEDIUM SCALE



Structure Map resulted from correlation between Amplitude 3D Cube and seismic sections. This is the example to 2900 mili-seconds in time.

6

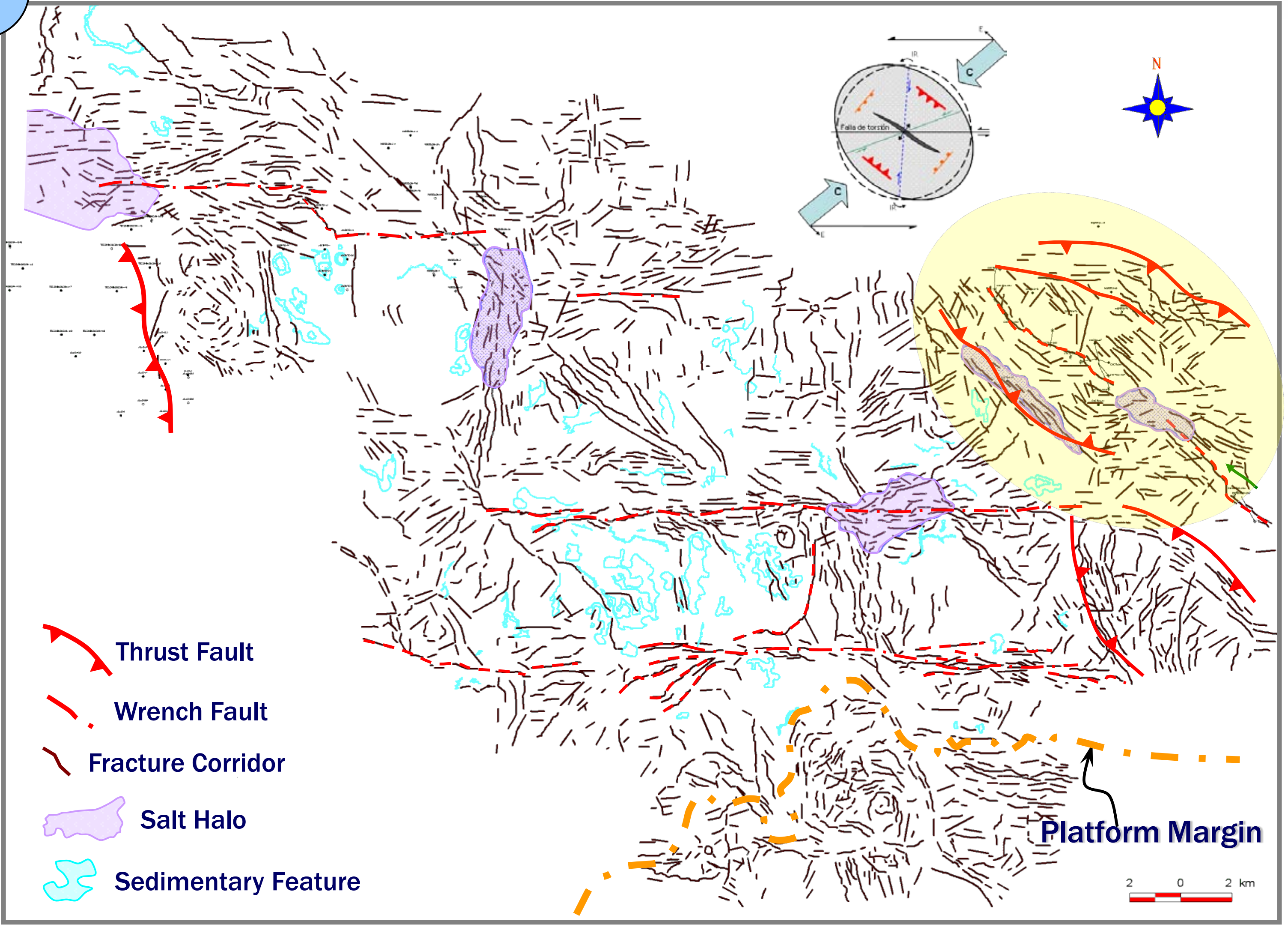
Linear Anomalies Map JAZAPA 3D Cube TS-2900 msec.



Major lineaments: Thrust Faults & Salt Evacuation related Faults.
Small lineaments correlative to fracture (“corridors”).
The interpreted elements are very geometrically consistent.

6

Linear Anomalies Map JAZAPA 3D Cube HS KM.

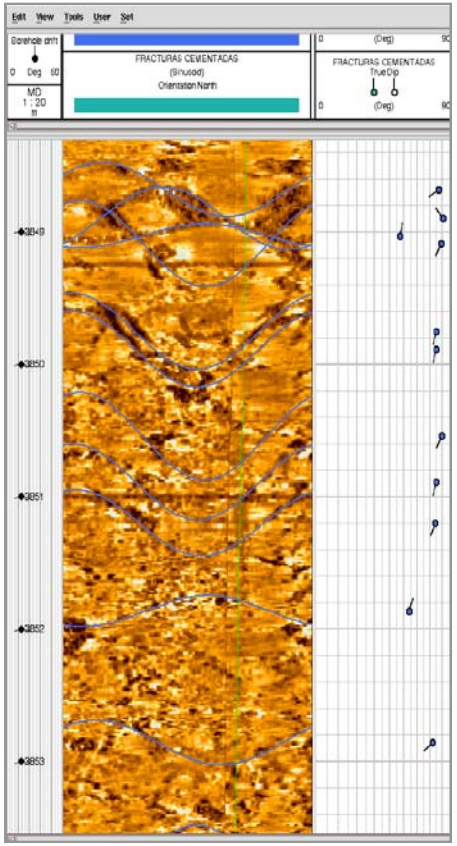


The HC's Fields are Thrust Faults related, Salt Halos are close related with Lateral Ramps (E-W oriented). The light blue areas appear sedimentary features.

The structural styles suggest mechanisms of compression coexisting with wrenching, the salt tectonics has a very important participation.

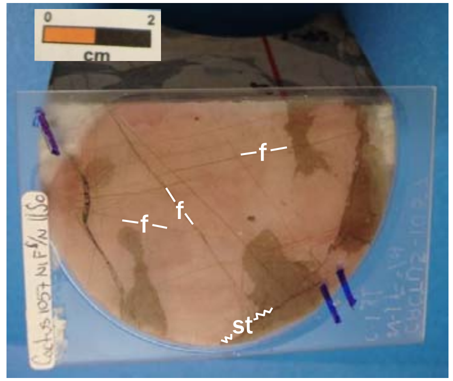
PEMEX
EXPLORACIÓN Y PRODUCCIÓN

Fracture characterization by Image Logs, Cores and Thin Sections

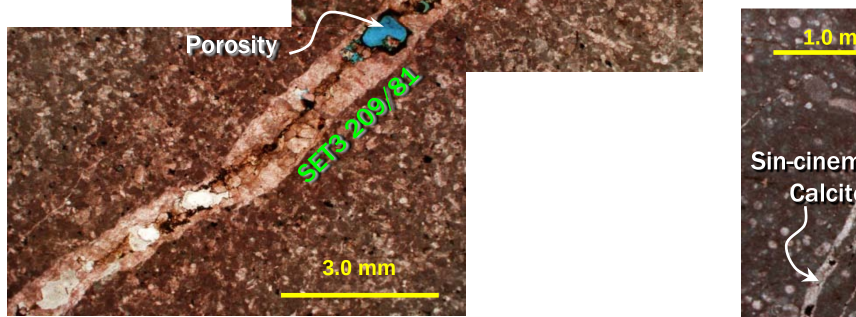


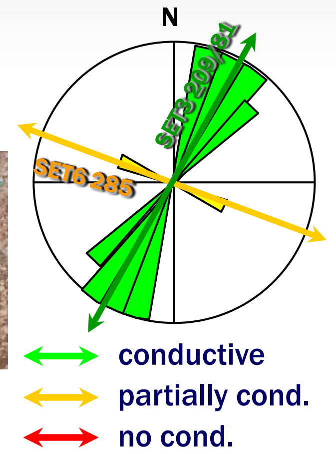
Well-1002 C-1B

Well-1057 C-1; KM

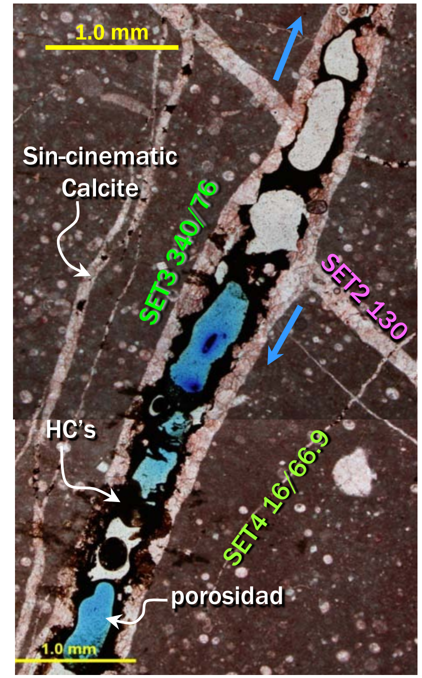


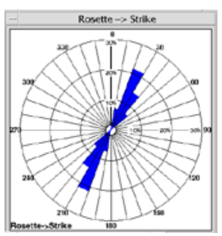
Well 1057 C-1





C-1057; Core-1



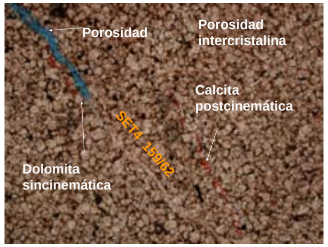


From logs and cores are differentiated impregnate and sealed fracture families. The Petrography & Cement Diagenesis of Fractures Study (EPDE) characterizes the fracture attributes as opening, orientation, conductivity, matrix-fracture connectivity, timing, etc., all of them are essentials for reservoir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

Petrography & Cement Diagenesis of Fractures Study vs. Mineralogical Facies* in CANRU Field

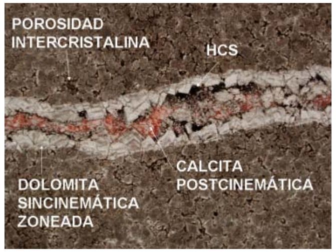
Matrix-Fracture Attributes

Lower Cretaceous | Mid Cretaceous | Upper Cretaceous

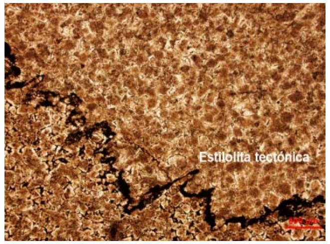


C-33 N1 KI4

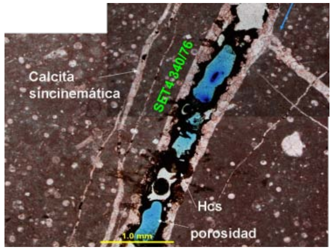
C-1002 N3 KI1



N-70 N2 KM



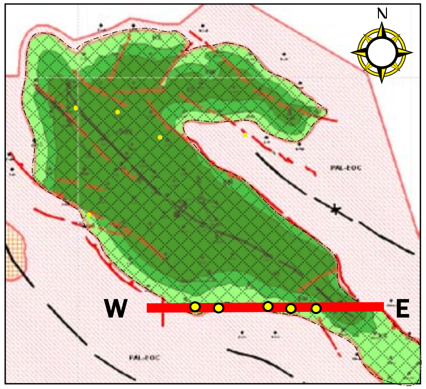
C-1063 N1 KM

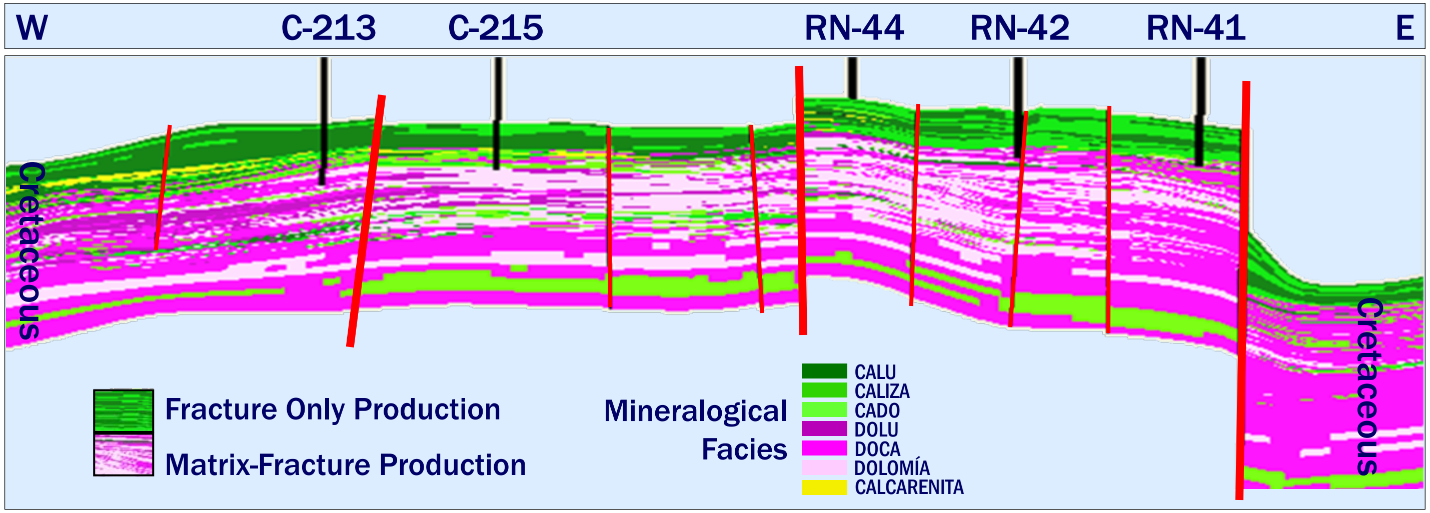


C-1057 N1 KM

C-57 N1 KS3

Matrix-Fracture Production | Fracture Only Production





PEMEX
EXPLORACIÓN Y PRODUCCIÓN

SMALL SCALE

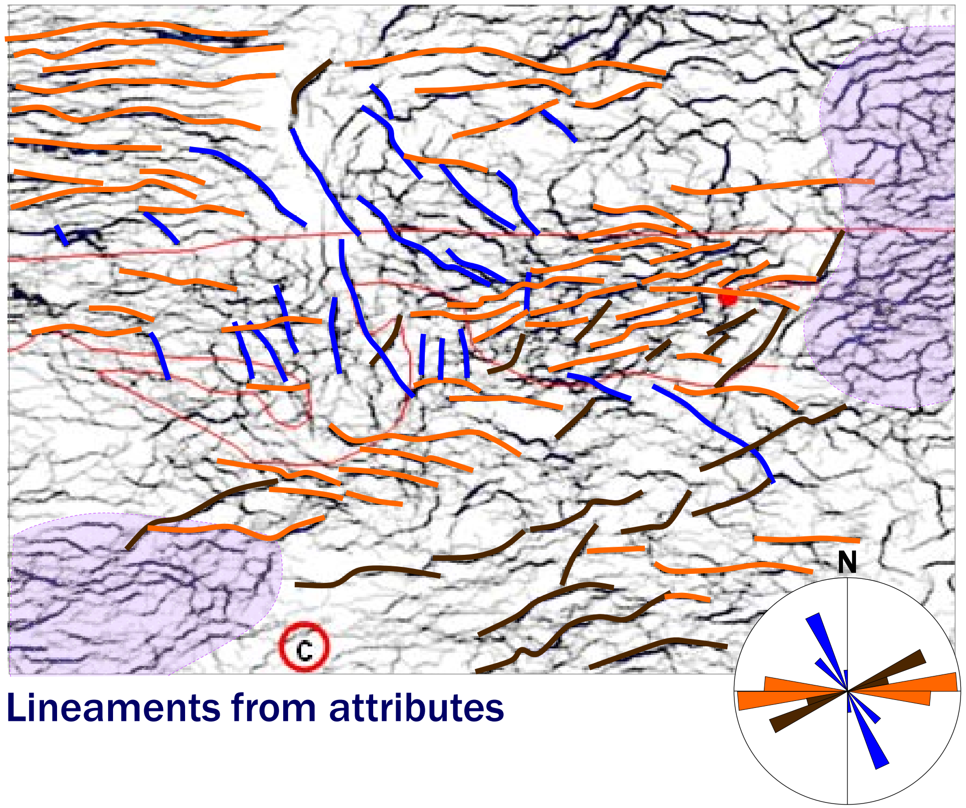
Matrix-Fracture Attributes and Conductive Quality

Matrix-Fracture Attributes; Mid Cretaceous; C Field							
Age	Well/Core	Set Number Strike/Dip	Fractures Number in Image Log	Number of Fractures in Core	Minimum Conductive Aperture Fracture (mm)	Matrix Porosity Quality	Lithology
MID CRETACEOUS	RN-1062/N3	64/77	12	40	>1.25	POOR	LIMESTONE
	N-118/N3	147	—	14	>0.75	REGULAR	DOLOSTONE
	N-80/N2	226/80	—	4	>0.05	REGULAR	MICRODOLOSTONE
	N-70/N1	46/70	—	11	0.8	POOR	LIMESTONE
	C-47/N2	197/83	14	13	>0.125	REGULAR	LIMESTONE
	C-1057/N1	87	3	49	>0.15	POOR	LIMESTONE
		130	—	85	0.17		
		340/76	—	58	0.8		
		16/67	—	58	0.1		
		278/87	3	49	0.07		
	C-1057/N2	51/56	3	12	0.025		LIMESTONE
		233/51	3	12	0.02		
	C-1006/N3	113	46	17	>0.10	REGULAR	MESODOLOSTONE
		5/80	33	31	>0.75		
	C-1063/N1	53/75	6	43	0.05	EXCELENT	MESODOLOSTONE
		277	10	44	0.01		

Fracture and Matrix Conductive Quality by Well; Mid Cretaceous				
Grade	Fracture Quality (Well)	Matrix Porosity Quality (Well)	Quantity of Fractures (Well)	Minim. Cond. Aperture Fracture (Well)
10	C-1057	C-1063	C-1006	C-1063
9	C-1006	N-70	N-70	C-1057
8	N-70	C-1006	C-47	N-80
7	N-118	N-80	RN-1062	C-1006
6	RN-1062	N-118	C-1063	C-47
5	N-80	C-1057	C-1057	N-118
4	C-47	C-47	N-118	N-70
3	C-1063	RN-1062	N-80	C-1062

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

Multiscale Fracture Systems Correlation



Lineaments from attributes

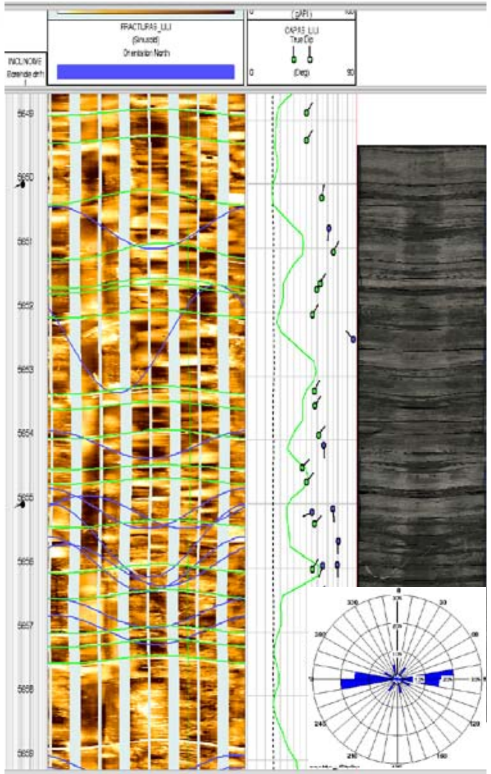
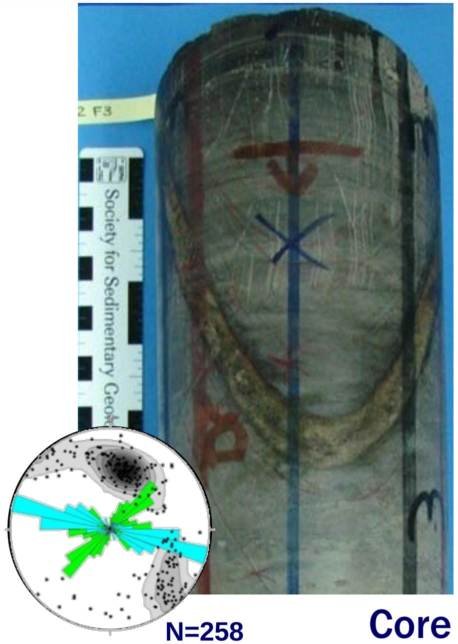
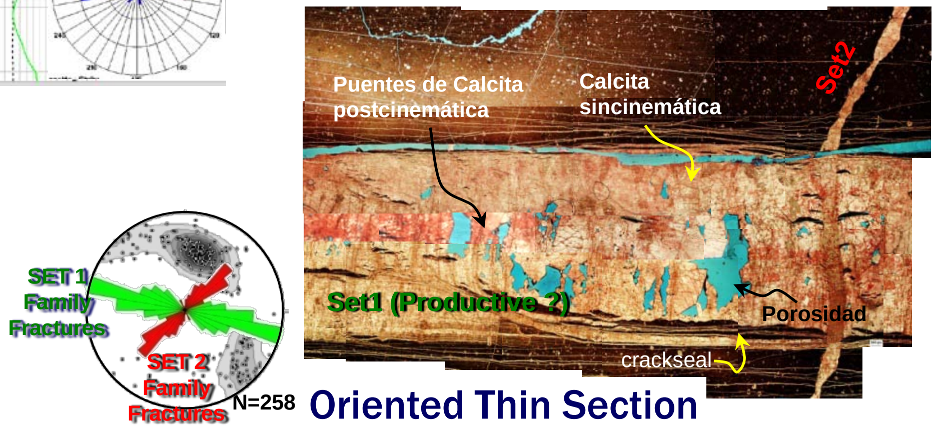


Image Log



Core

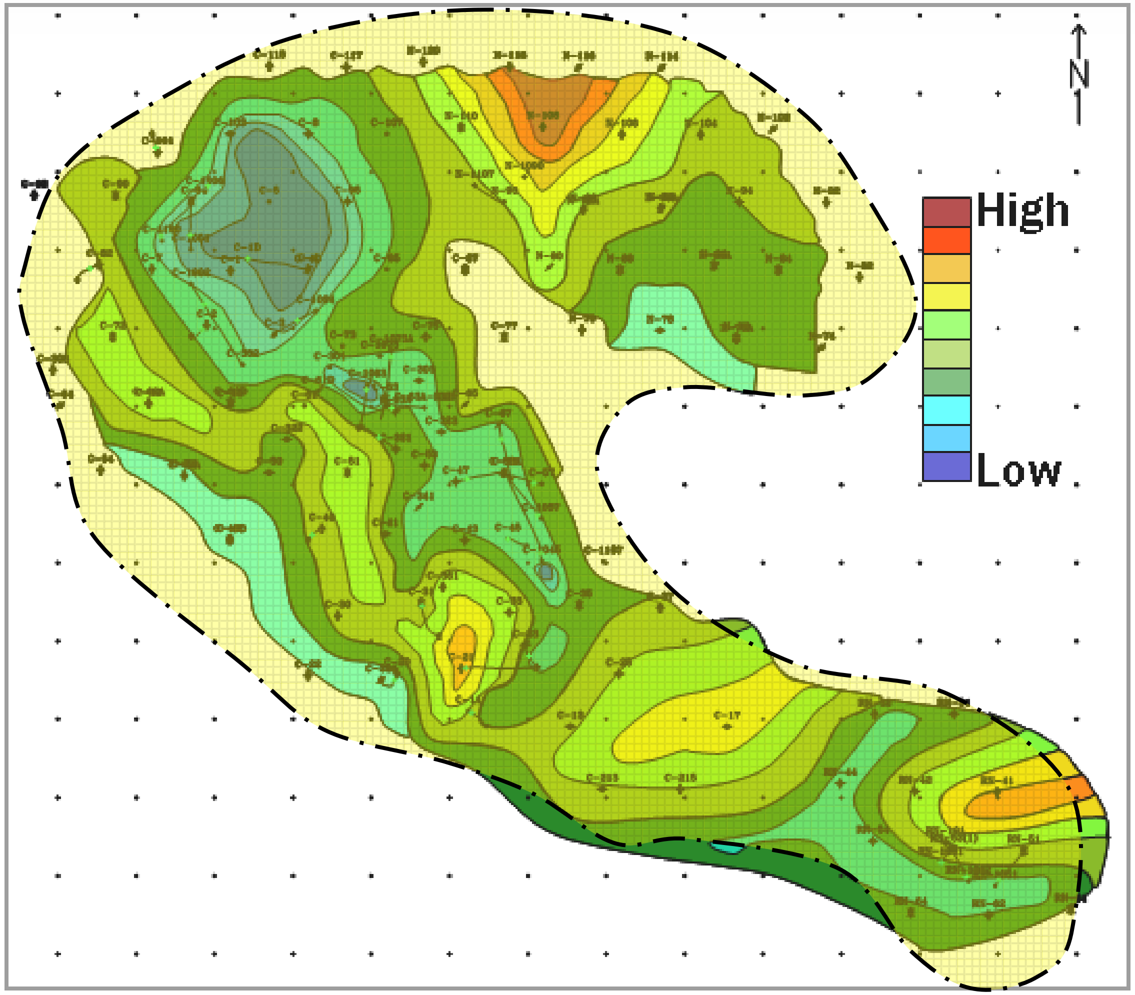


Oriented Thin Section

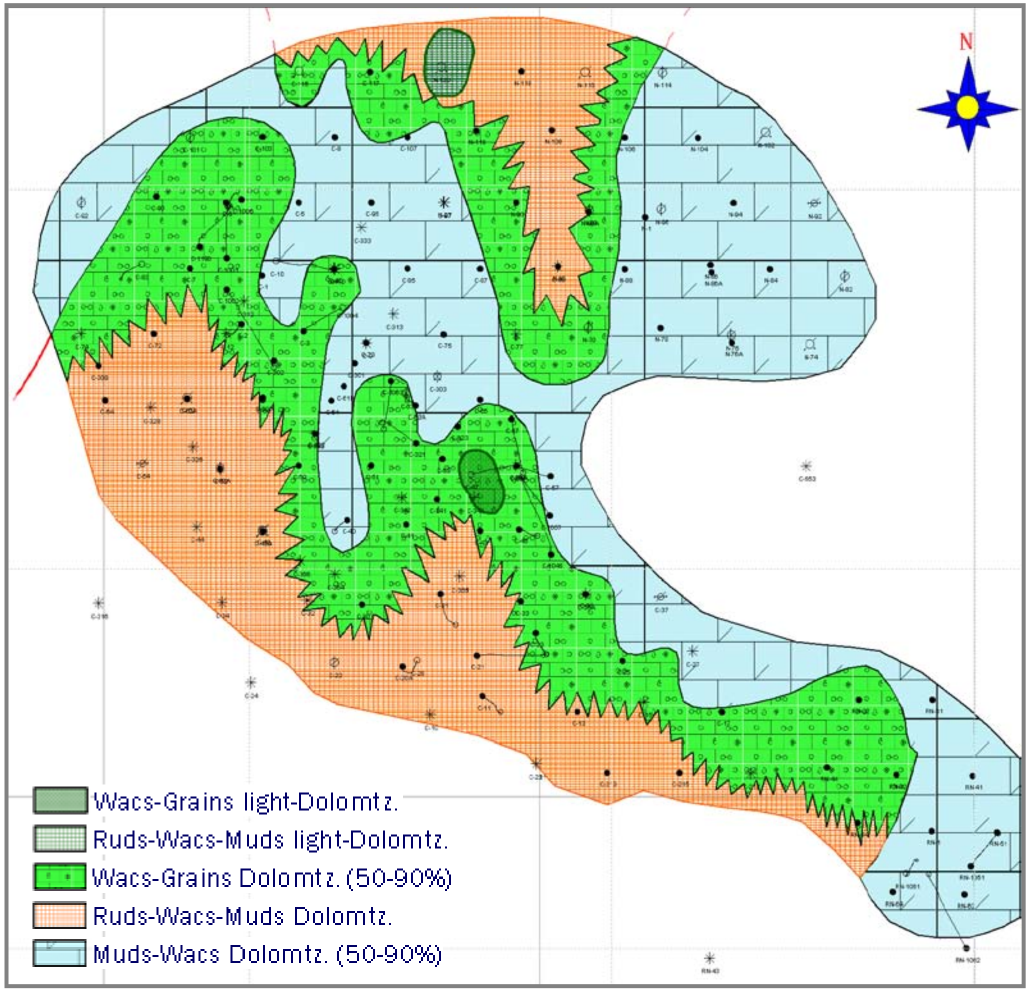
The lineaments interpreted on Time-slice /Horizon-slice are compared with those from Image Logs, Cores and Thin Section. There is a very close correlation between both macro-micro scales.

INTEGRATION OF INFORMATION

Cumulated-Normalized Production Map (MMBO/year)



Sedimentary Facies Map*

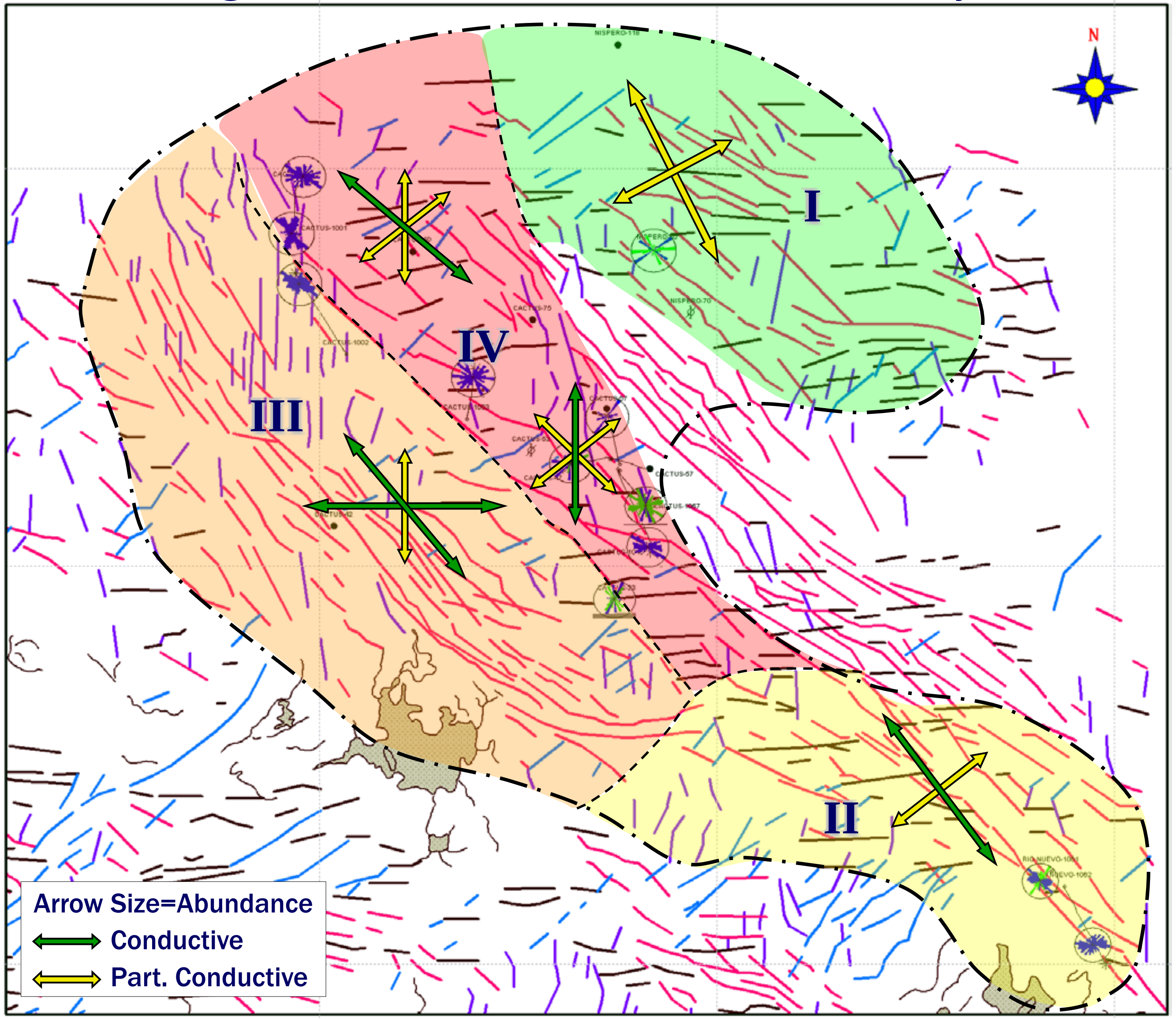


* From: Basañez – IMP; 2008

PEMEX
EXPLORACIÓN Y PRODUCCIÓN

INTEGRATION OF INFORMATION

Ranking of Cumulated-Normalized Production by Block



Cumulated-Normalized Production by Block/Well

Block	No. Wells	Q/block	% Block	Prom./ Well	Q norm/ Well %
I	12	16.45	28.03	1.37	35.2
II	13	14.30	24.36	1.10	28.3
III	19	20.24	34.48	1.07	27.5
IV	22	7.71	13.14	0.35	9
	66	58.70	100%	3.89	100%

Correlating the whole information we differentiate four different blocks ranked by production rates and conductive fracture directions.

GOALS

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.

CONCLUSIONS

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