Thinking and Methodology Leading to a Major Sweetspot in Tight Sands - A Deep Eocene Misoa Sands Discovery*

Jean-Yves D. Chatellier[1], Leon Freddy[2], Sabrina Sarzalejo[3], Renee Perez[4], Paul Hague[5], and Martin Wilpshaar[6]

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[1]Talisman Energy Inc, Calgary, AB, Canada (Jchatellier@talisman-energy.com)
[2]Partex Oil and Gas, Lisbon, Portugal
[3] Pacific Rubiales, Colombia
[4]University of Calgary, Alberta, Canada
[5]Sarawak Shell, Miri, Malaysia
[6]Wintershall, Netherlands

Abstract

The methodology and thoughts that led to the discovery of the giant “Tomoporo-Profundo” Field is reviewed to outline the power of a multidisciplinary integration associated with a 4-D diagenetic modeling. Our previous work in Lake Maracaibo demonstrated that very high porosity and permeability at great depth were likely linked to an early oil migration along a fault system. In Zulia Oriental, located east of Lake Maracaibo, deeply buried thick sandstones sequences are present but porosity is apparently absent.

The integrated work combined seismic with sedimentology, structural geology, and geochemistry. The data consisted of cores from a few wells and scattered 2D seismic lines. Vitrinite data was available for each of the 20 existing wells and gave us a good understanding of the basin burial history.

We generated predictive maps of various geological parameters for each horizon through time. Porosity evolution through time was calculated for each interval of interest in 9 hypothetical wells. One 2-D seismic line strongly indicates an early compression activity (late Eocene) in an area close to a major fault that extends to the west to a short lived oil kitchen (Oligocene). The porosity destruction by quartz cement growth was thought to have stopped with the hydrocarbons filling the structural trap; implying the possible existence of a deeply buried “island” of sandstones with some 25% porosity among otherwise very tight sandstones.

A 3-D seismic was acquired on the prospective area with a subsequent discovery of a giant oil field; the “Tomoporo-profundo” Field.

References

Chatellier, J-Y., Moreno, O., Zambrano, C., Mendez, M.J., Ruggiero, A., and Sarzalejo S., 1998, Correlation between vitrinite reflectance and sequence stratigraphy, examples from the Tertiary of Western Venezuela: Sixth Latin American Congress on Organic Geochemistry, October 1998, 5-page extended abstract.

Chatellier, J-Y., Mendez, M. J., Hague, P., and Navarro, A., 1998, Shale tectonics in Western Venezuela, implications on maturity study and on prospectivity: AAPG Salt Lake City, 1998, 4-page extended abstract.

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.

Chatellier, J-Y., Gil, N., Hernandez, P., Porras, C., and Ruiz, F., 2000, New structural model for the Santa Barbara Field and Furrial Trend, Norte Monagas, Venezuela (abs.): AAPG Annual Conference New Orleans, April 2000, p. A26

Chatellier, J-Y., and Perez, R., 2000, Timing of fluid flow, mass transfer and tectonic uplift revealed by modeling quartz and calcite precipitation (abs.): AAPG Annual Conference New Orleans, April 2000, p. A26.

Perez, R., Chatellier, J-Y., and Lander, R., 1998, Use of quartz cementation modeling to constrain burial histories of the Zulia Oriental region, Eastern Venezuela: Sixth Latin American Congress on Organic Geochemistry, October 1998, 5-page extended abstract.

Perez, R., Chatellier, J-Y., Lander, R., 1999a, Use of quartz cementation kinetic modeling to constrain burial histories. Examples from the Maracaibo Basin, Venezuela: Revista Latino Americana de Geoquimica Organica, v.5, p.39-46.

Perez, R., Ghosh, S., Chatellier, J-Y., and Lander, R., 1999b, Application of sandstone diagenetic modeling to reservoir quality assessment of the Misoa Formation, Bachaquero Field, Maracaibo Basin, Venezuela (abs.): AAPG convention San Antonio.

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a Deep Eocene Misoa Sands Discovery

Jean-Yves Chatellier,	Talisman Energy Inc, Canada
Freddy Leon,	Partex Oil and Gas, Portugal
Sabrina Sarzalejo,	Pacific Rubiales, Colombia
Renee Perez,	University of Calgary, Canada
Paul Hague,	Sarawak Shell, Malaysia
Martin Wilpshaar,	Wintershall, Netherlands

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  - Robert Lander — Quartz cement modeling
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    - Chatellier et al. 1998, 1999 and 2000

    - Perez et al. 1998, 1999a and 1999b

Talk Outline

How it started – the problem

Preliminary results and follow-up

Methodology

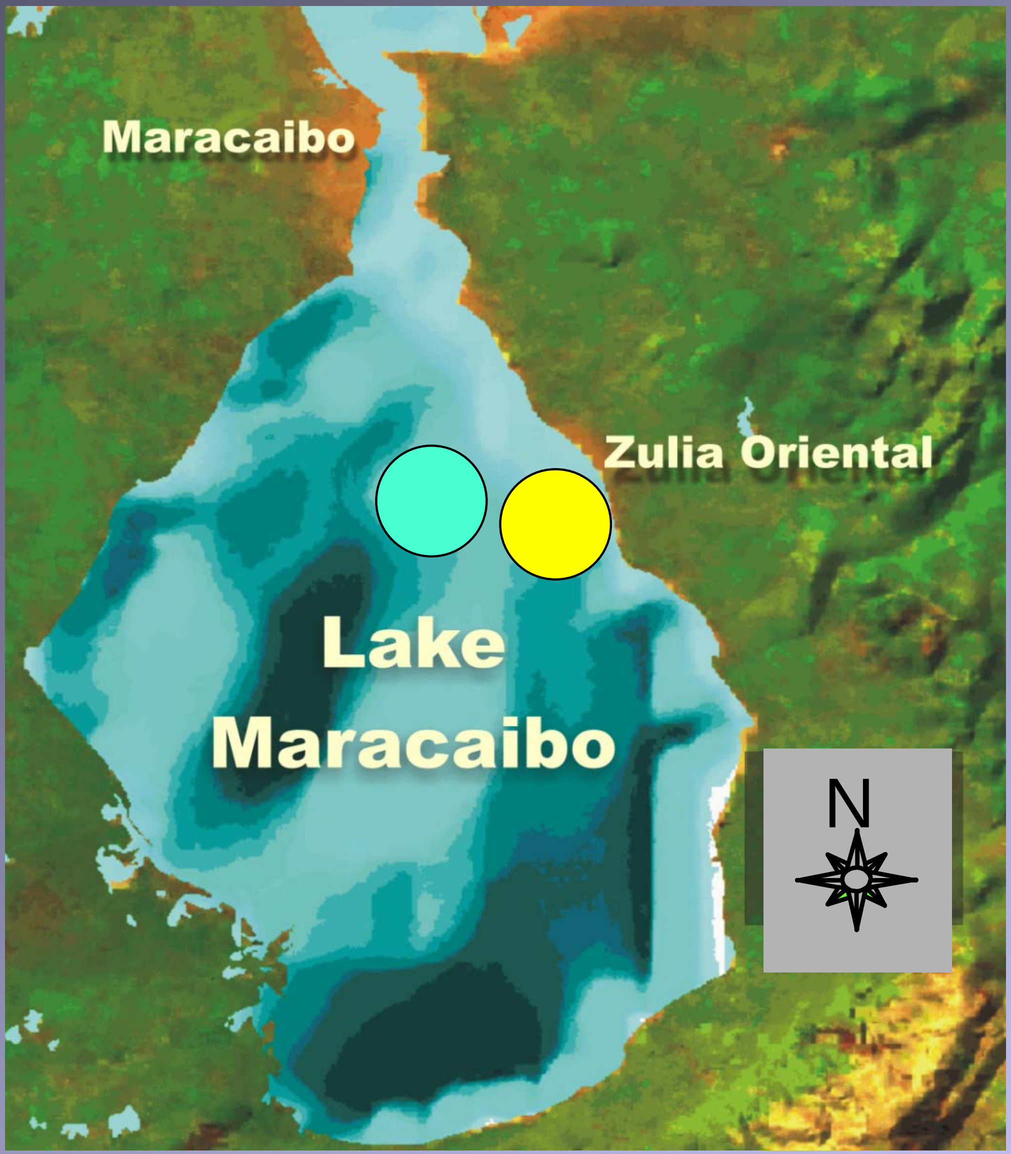
- Basin modeling
- Quartz cement modeling
- Integration with structure and geochemistry

Outstanding result

A Giant in Tight Sands

A Giant in Tight Sands

A Giant in Tight Sands



How it started

Deeply buried sands

Most sands are tight

Some very porous beds

Main Study area

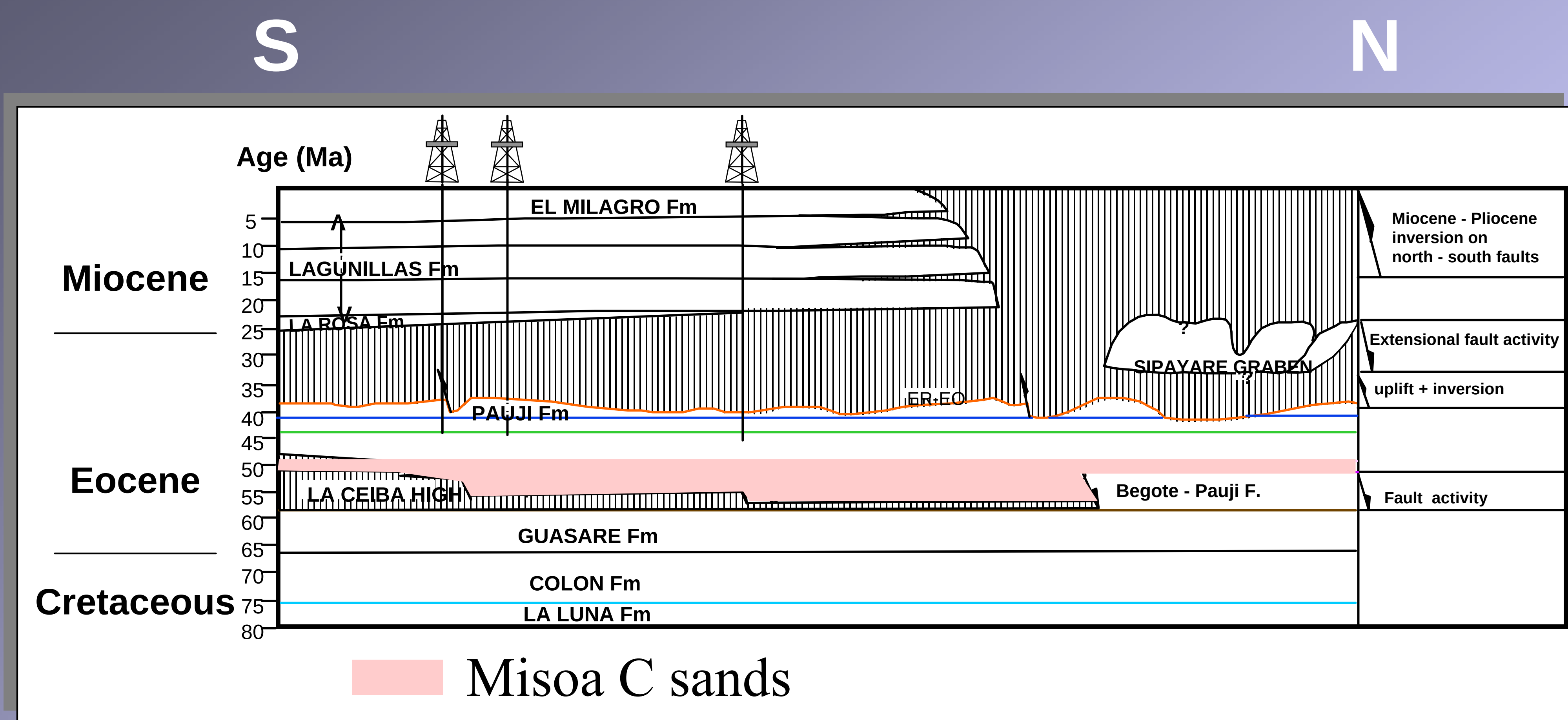
Bachaquero

Complement for analogy

Centro Lago

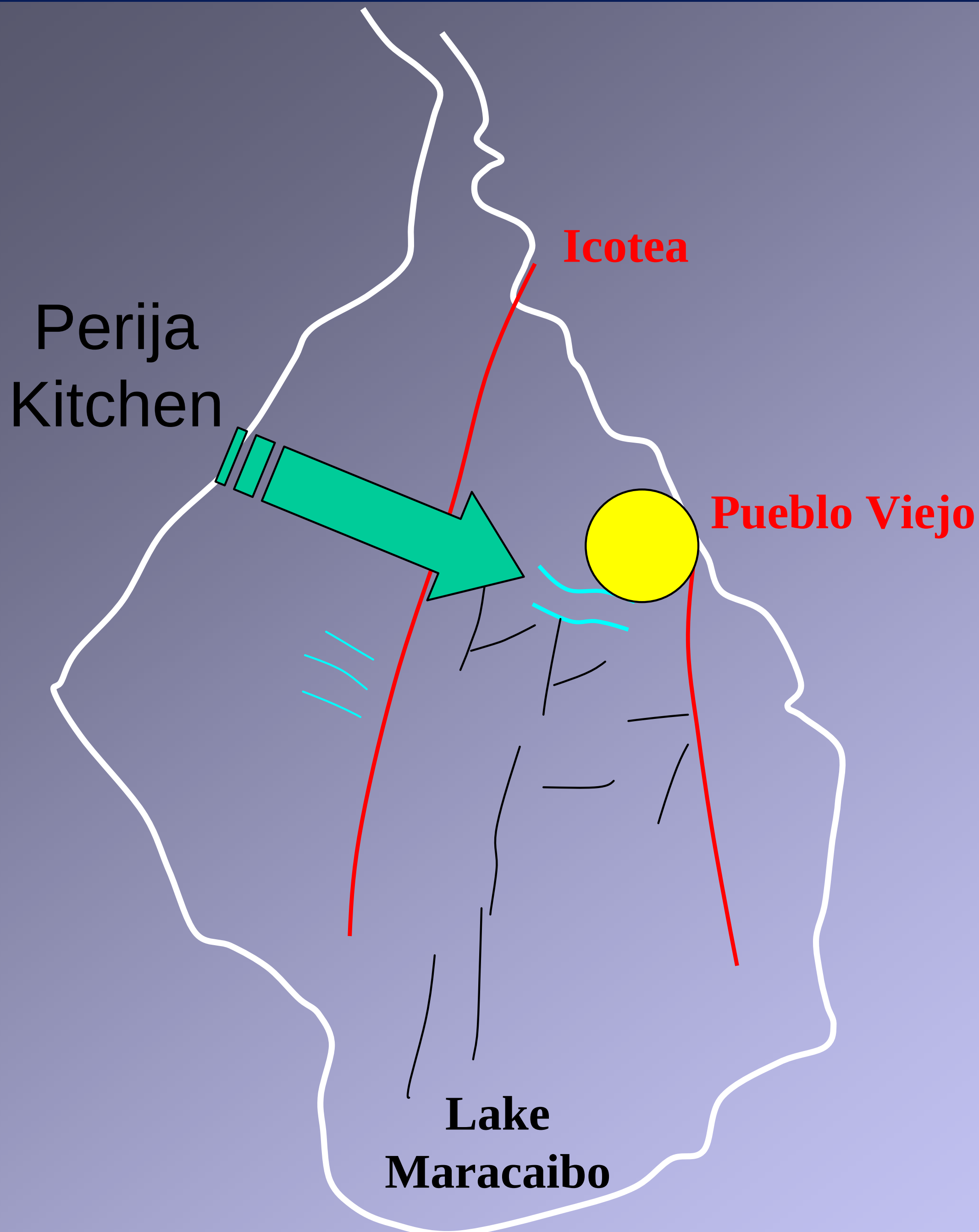
A Giant in Tight Sands

North-South Structural cross-section



The deeply buried Misoa C Sands remained “tight” until … Tomoporo

A Giant in Tight Sands



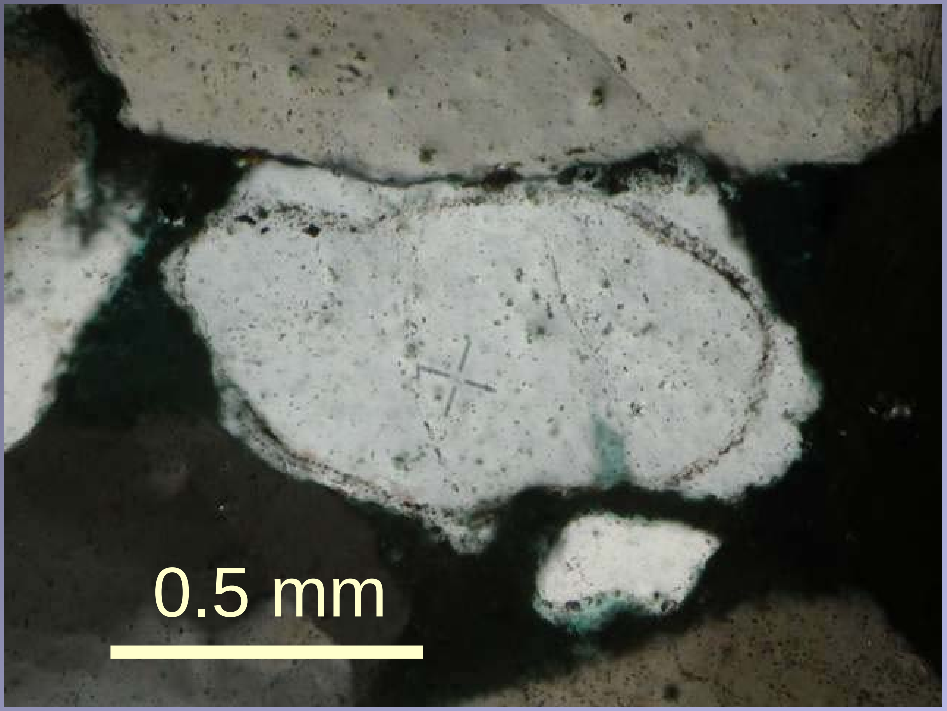
Deep Eocene
Diagenetic
Bachaquero Study

Main results:

A minor oil migration from the Perija Kitchen could only fill some of the deeply buried Misoa Sands

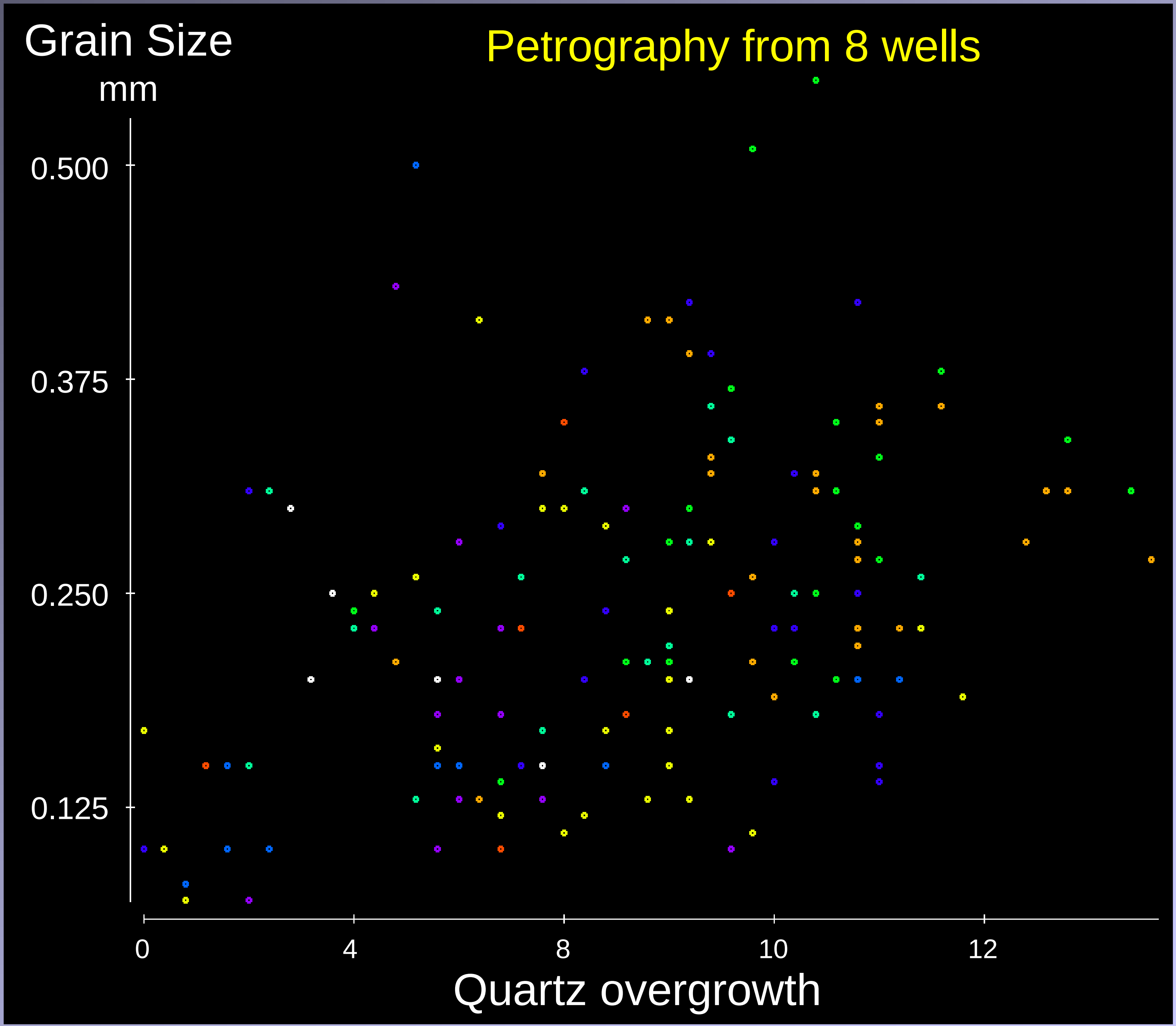
Preserving porosity

QUARTZ CEMENT from PETROGRAPHY

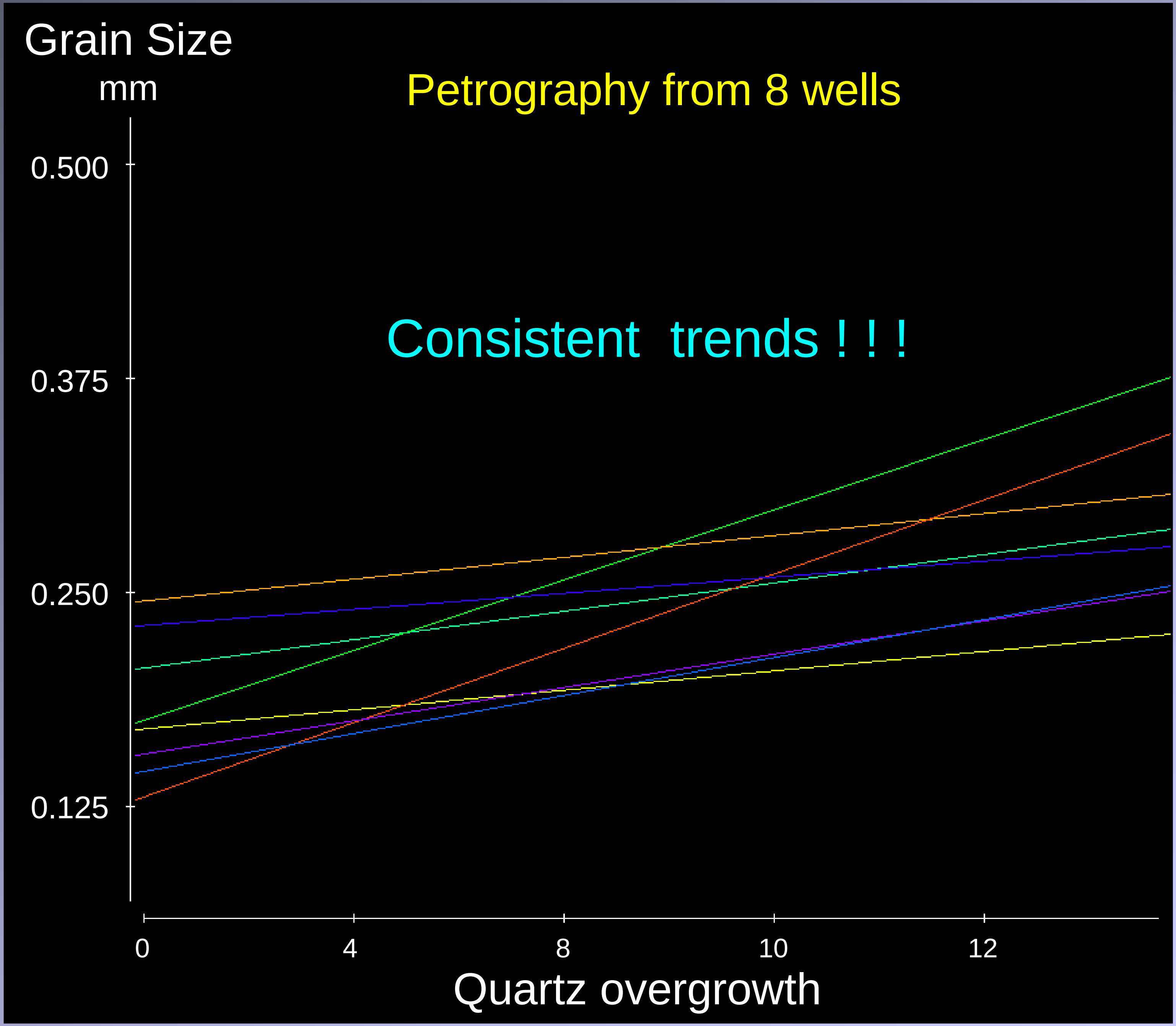


Outstanding quartz cement overgrowth with well defined ghost rim (residual insoluble particles)

A Giant in Tight Sands



A Giant in Tight Sands



Quartz cement

Petrography

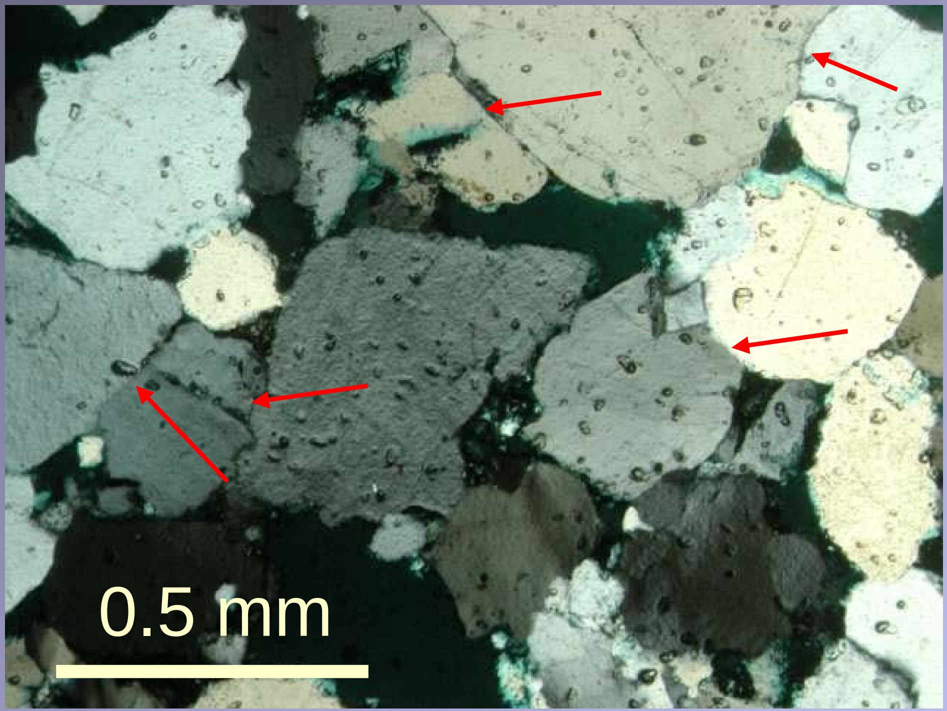
Versus

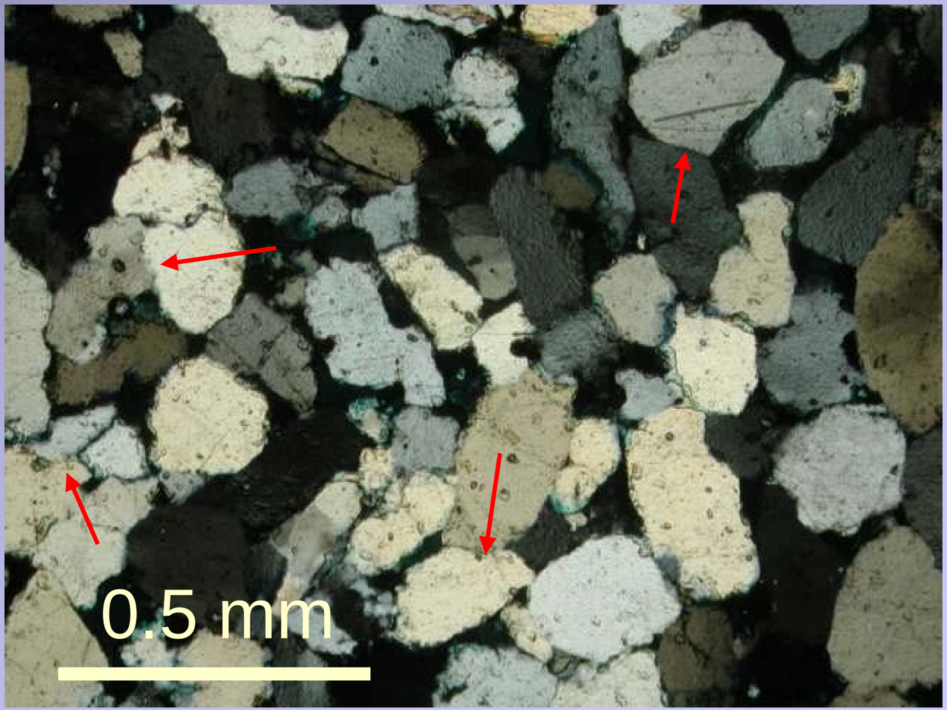
Cathodoluminescence

LIMITATION OF MICROSCOPY

Quartz cement hardly identified
in fine to very fine grained sandstones

!!!!! Finer grain ==> more quartz cement

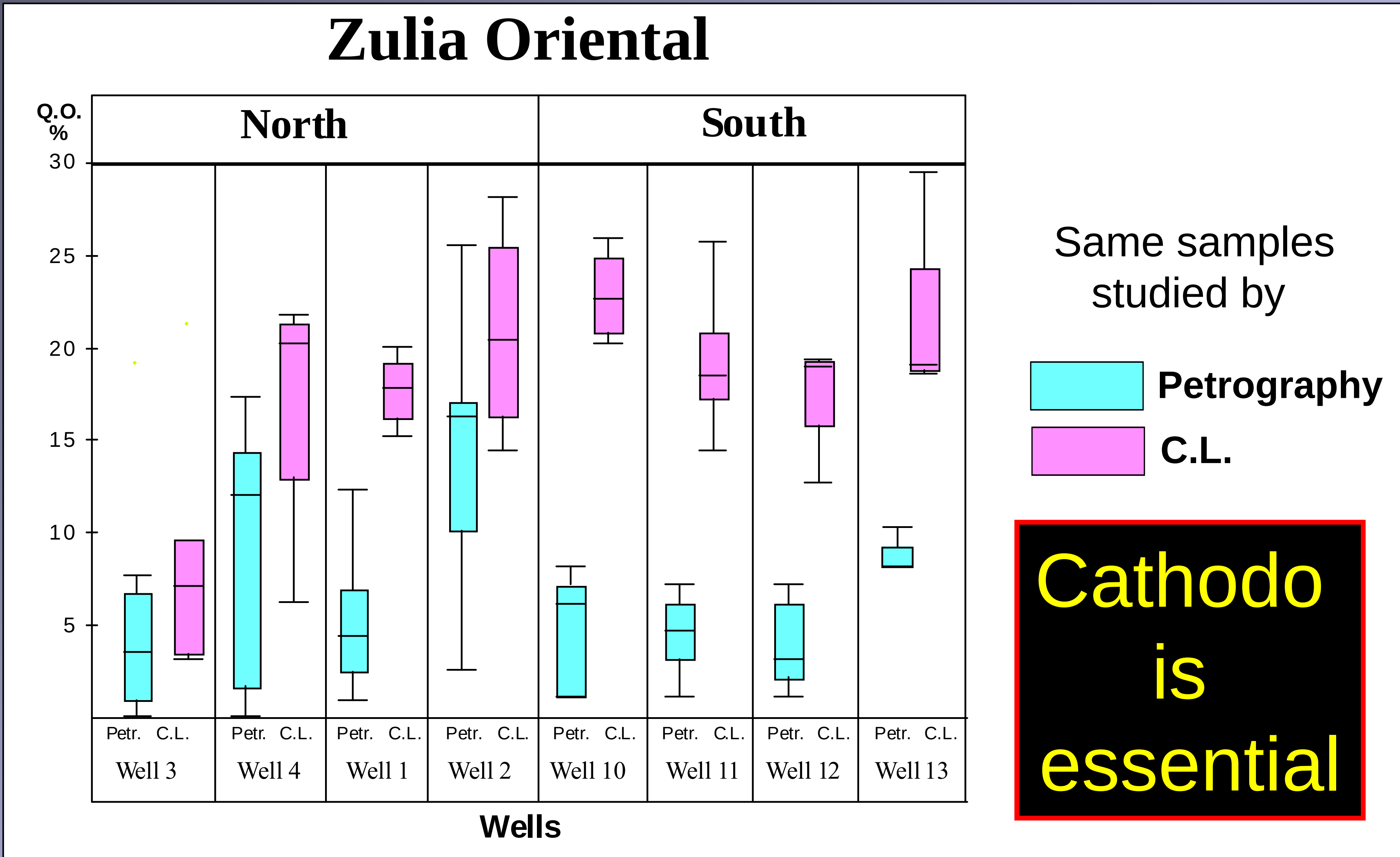




Location of quartz cementation

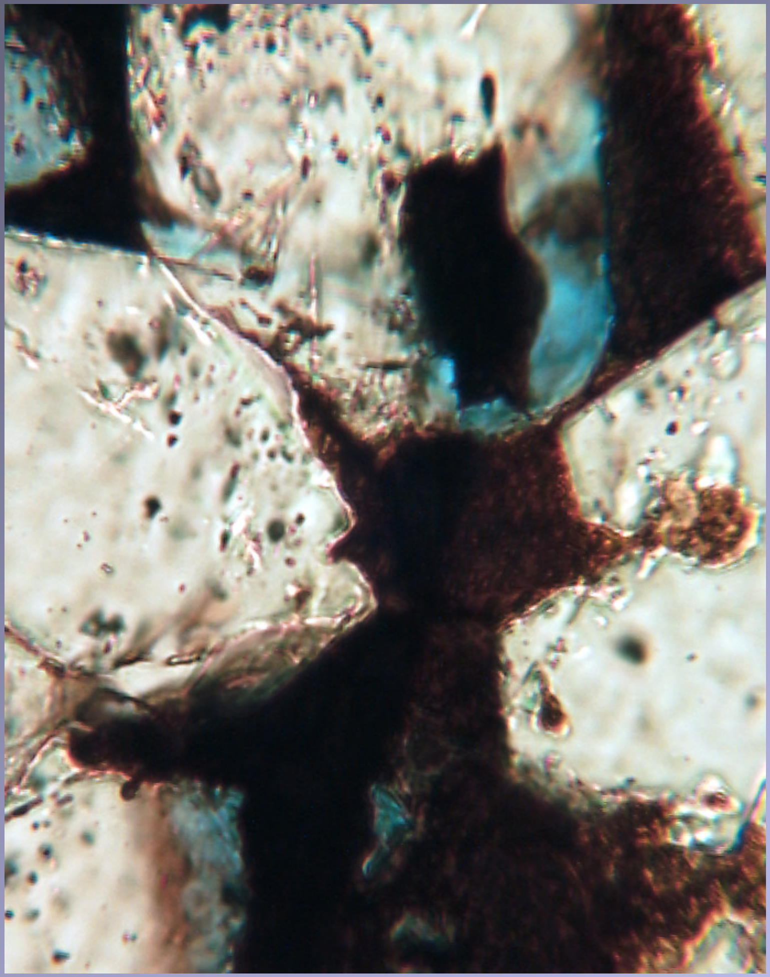
A Giant in Tight Sands

Petrography versus Cathodoluminescence

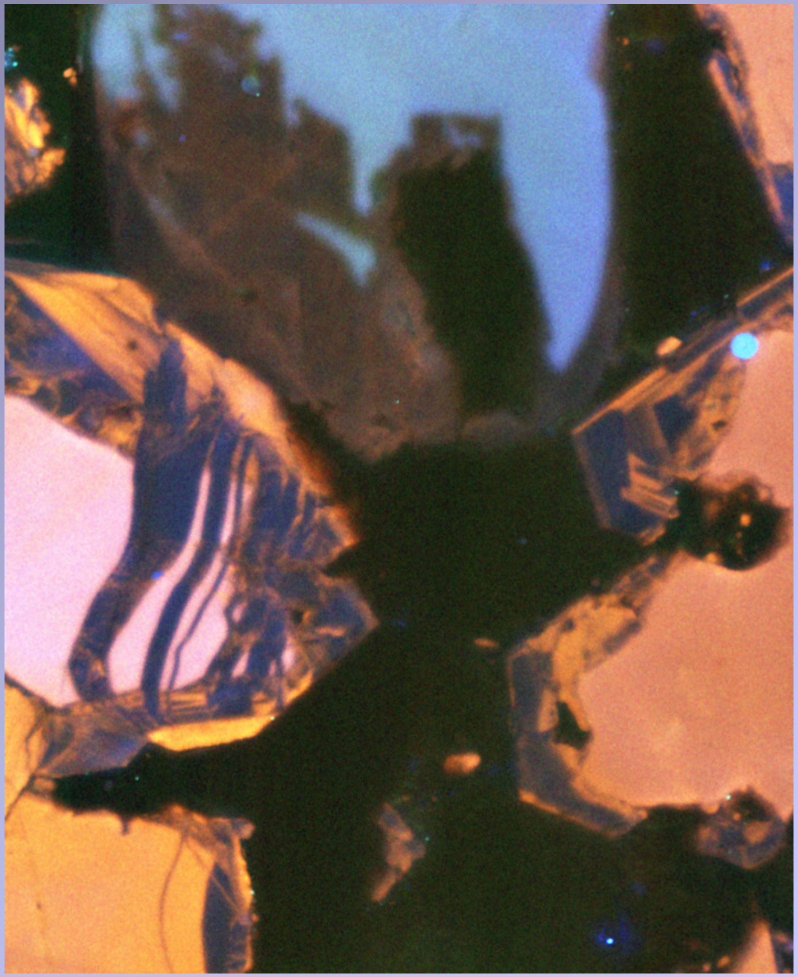


Cathodo is essential

Hot Cathodoluminescence



Microscopy



Cathodoluminescence

Courtesy University of Texas

A Giant in Tight Sands

Following-up

Zulia oriental

20 wells drilled in deep Eocene

All of them encountered very thick sands

All of the sands were tight

Tools and parameters needed

1. **Burial History**
   a) **Temperature > 80 degrees C**
   b) **Time**
2. **Petrography**
   a) **Grain size**
   b) **Composition**
   c) **Remaining Porosity**
3. **Cathodoluminescence**
   a) **Precise estimate of quartz cement**
   b) **Calibration of kinetics**

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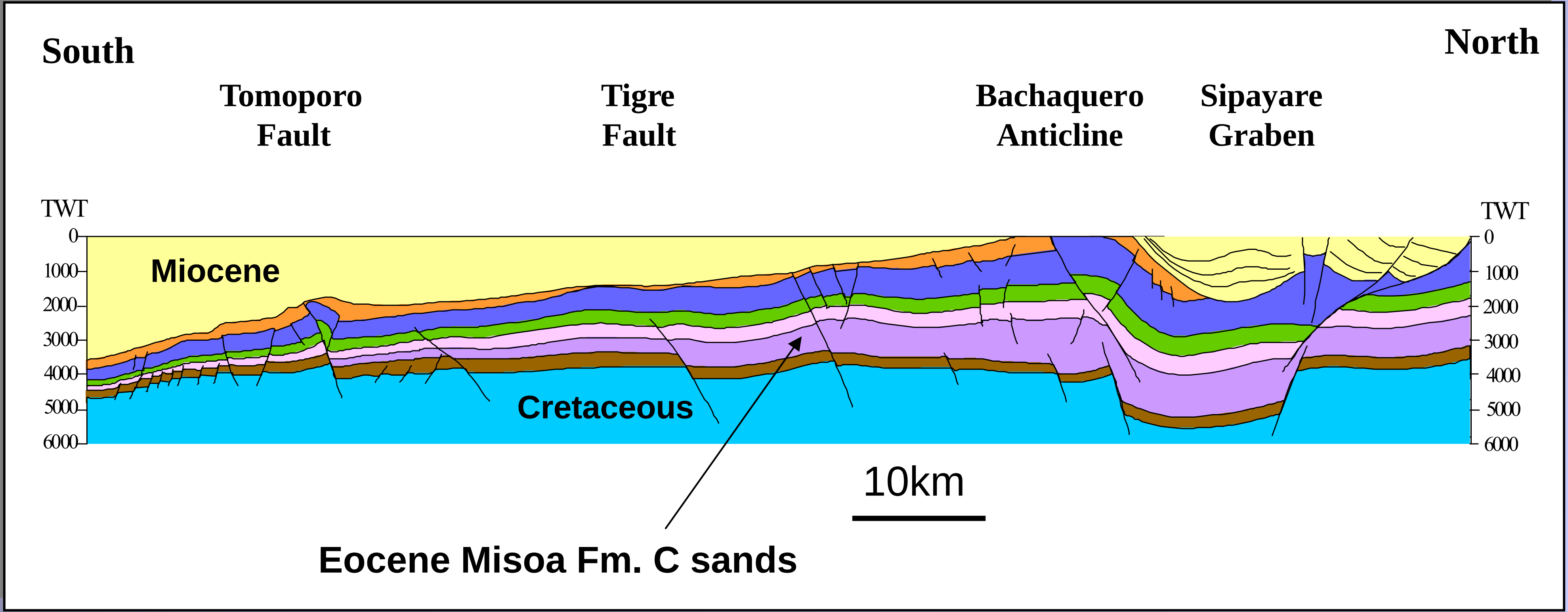
North-South Structural cross-section



Successive basin tilts led to intricate burial histories

FIRST TASK

Burial parameters

Vitrinite reflectance

First Problem:
overcooked basin

Vitrinite reflectance data indicates that Zulia Oriental is overcooked

A new seismic interpretation shed new light on the burial history of the area

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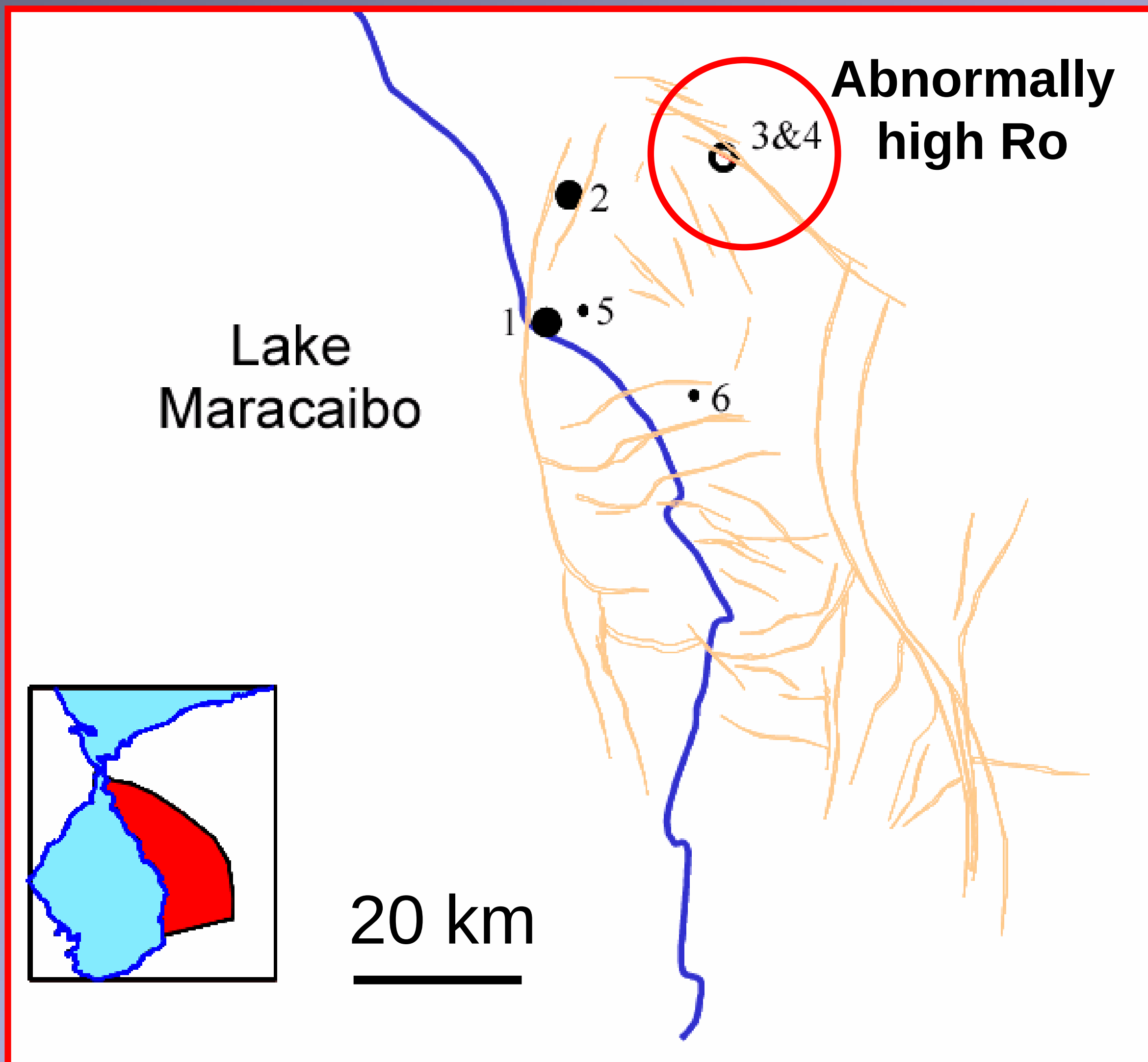
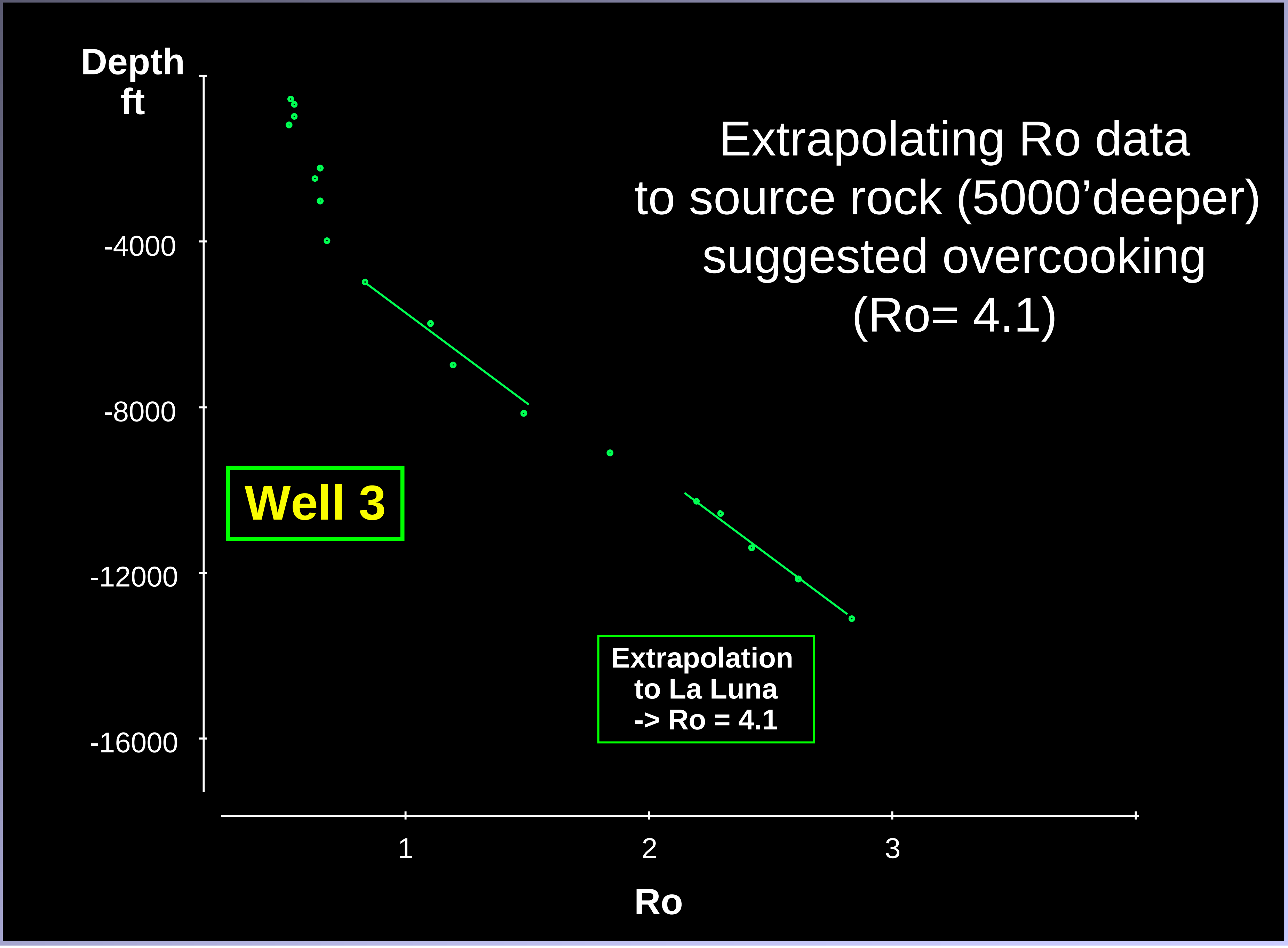
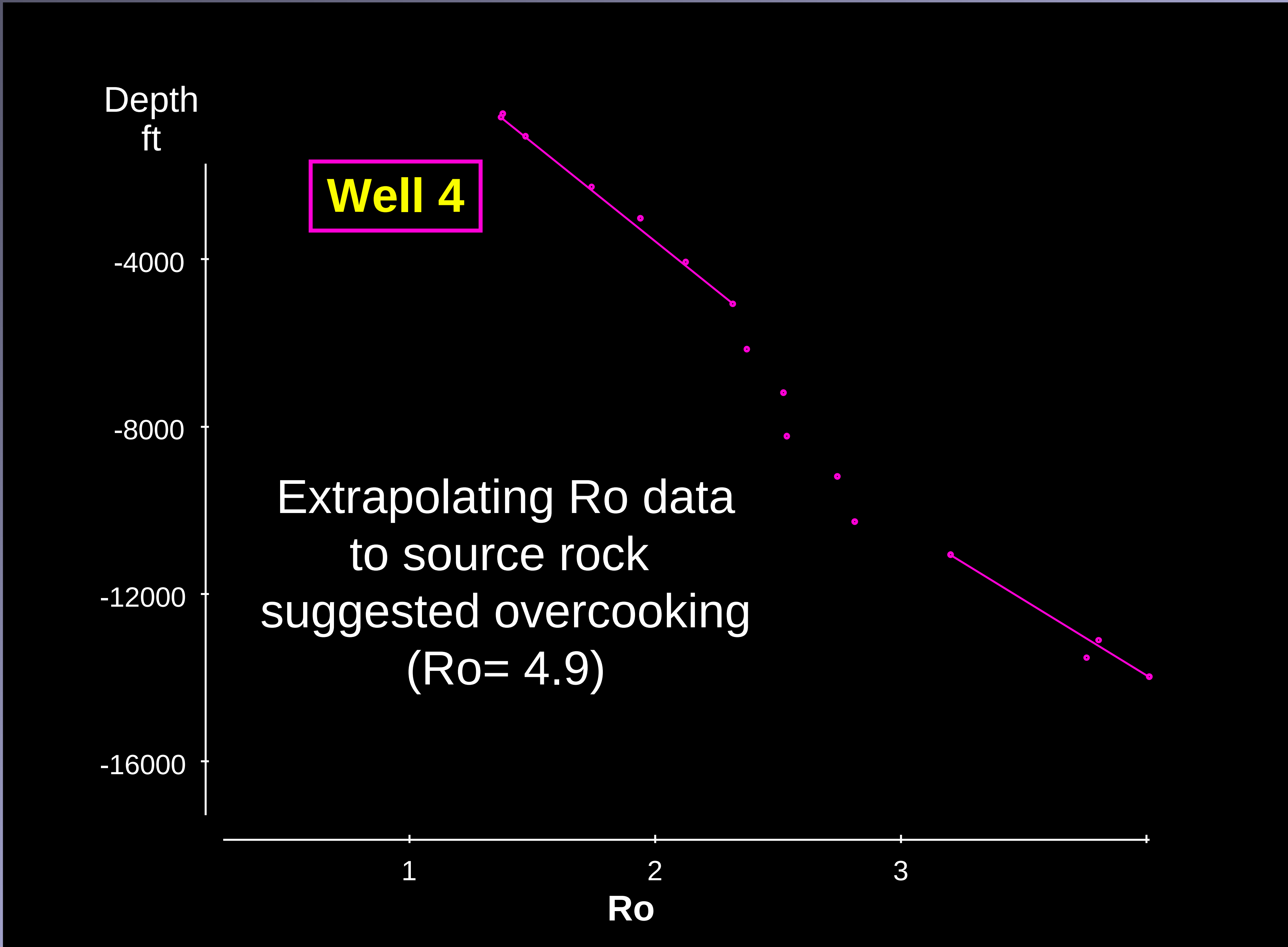
Revisiting the evidences of overcooking



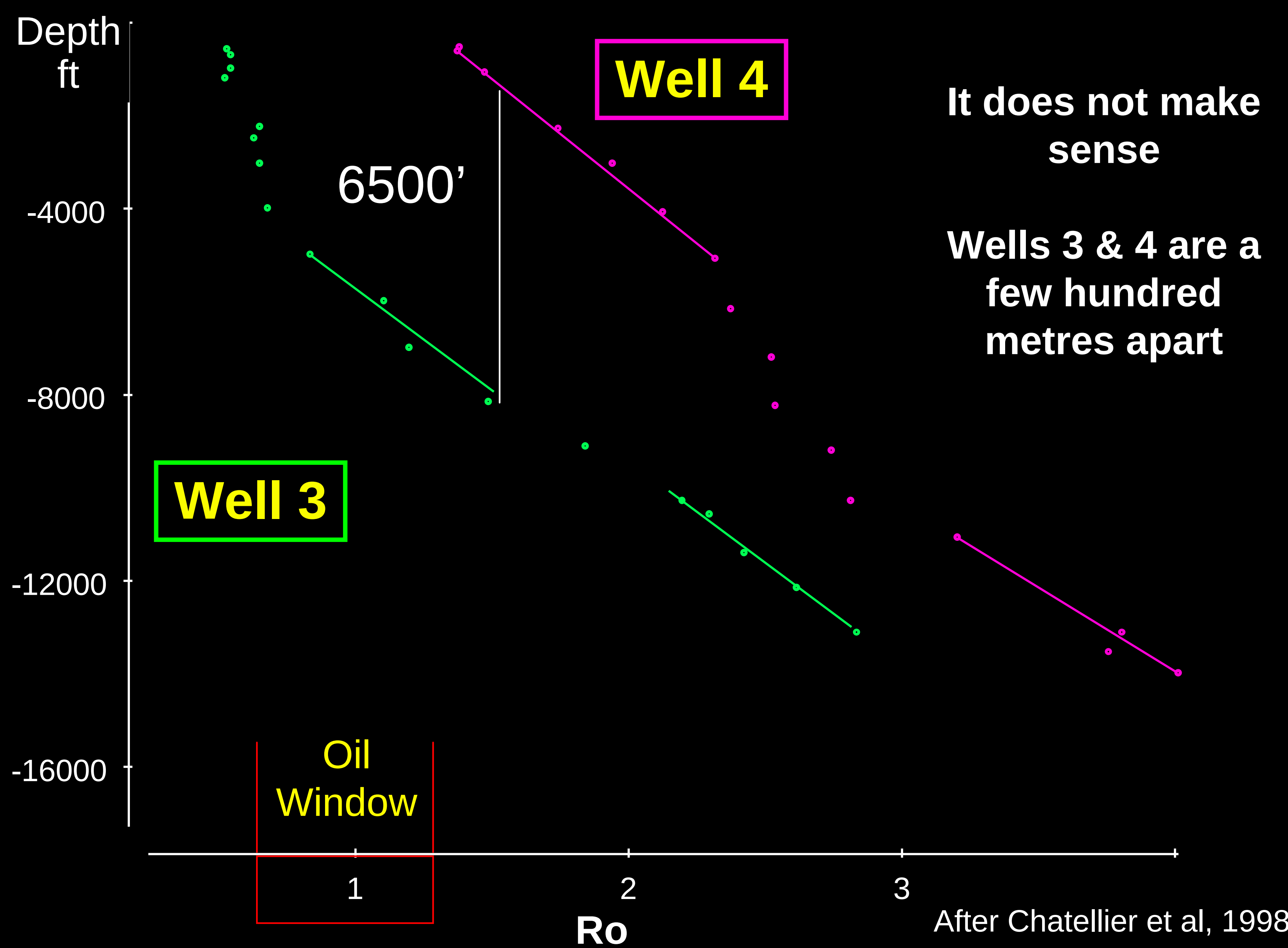
Evidence of overcooking, 1



Evidence of overcooking, 2



Inconsistencies



It does not make sense

Wells 3 & 4 are a few hundred metres apart

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Original interpretation was
6500 feet of erosion

New interpretation
shale tectonics

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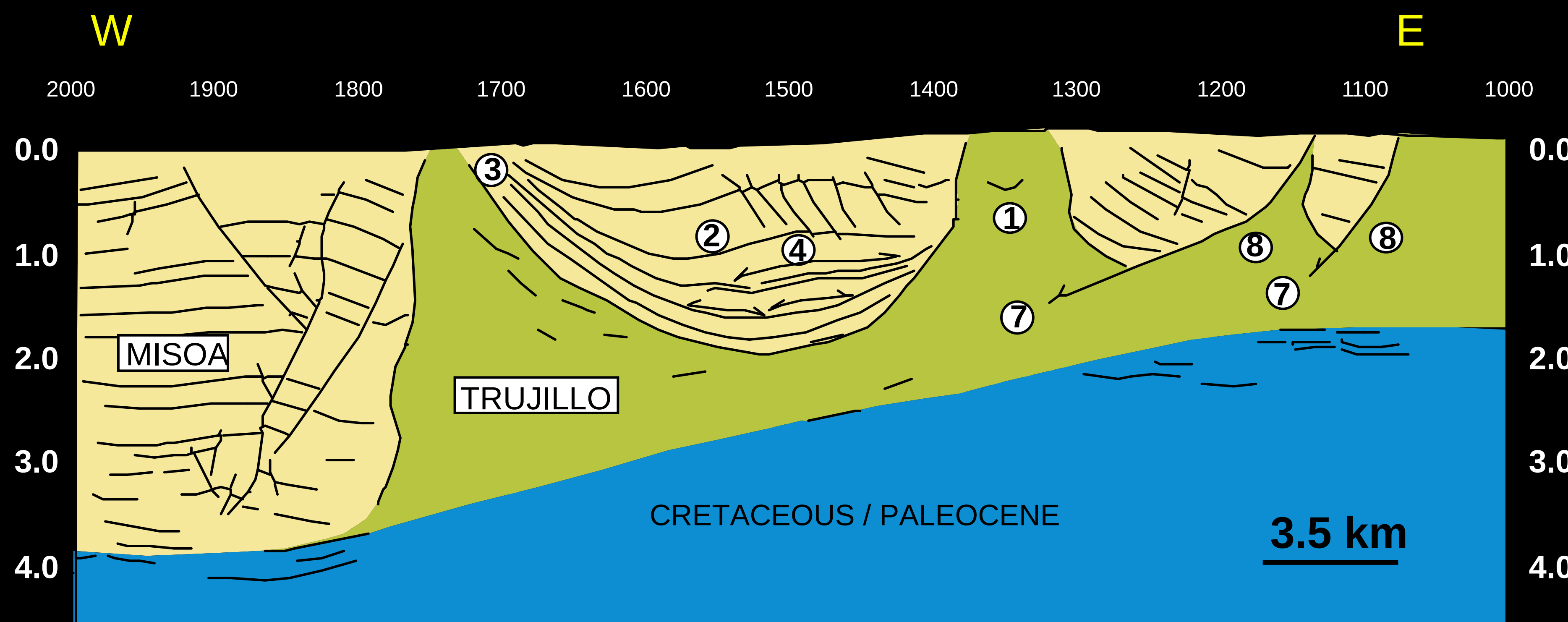
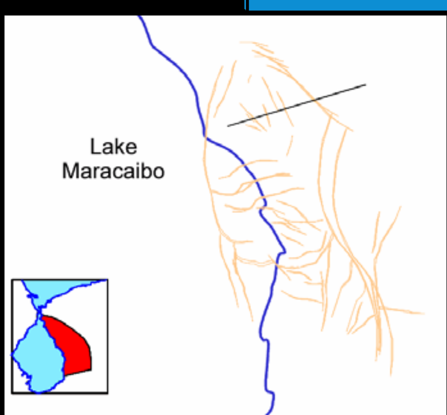
SHALE TECTONICS IN ZULIA ORIENTAL EXAMPLE





1. ‘Pull-down’ of seismic reflectors
2. ‘Withdrawal syncline’
3. ‘Draping’ of sediments over shale ridge
4. Vertically-stacked channels or turbidite fans
7. Listric normal faults
8. Shale ‘rollers’

After Chatellier et al., 1998

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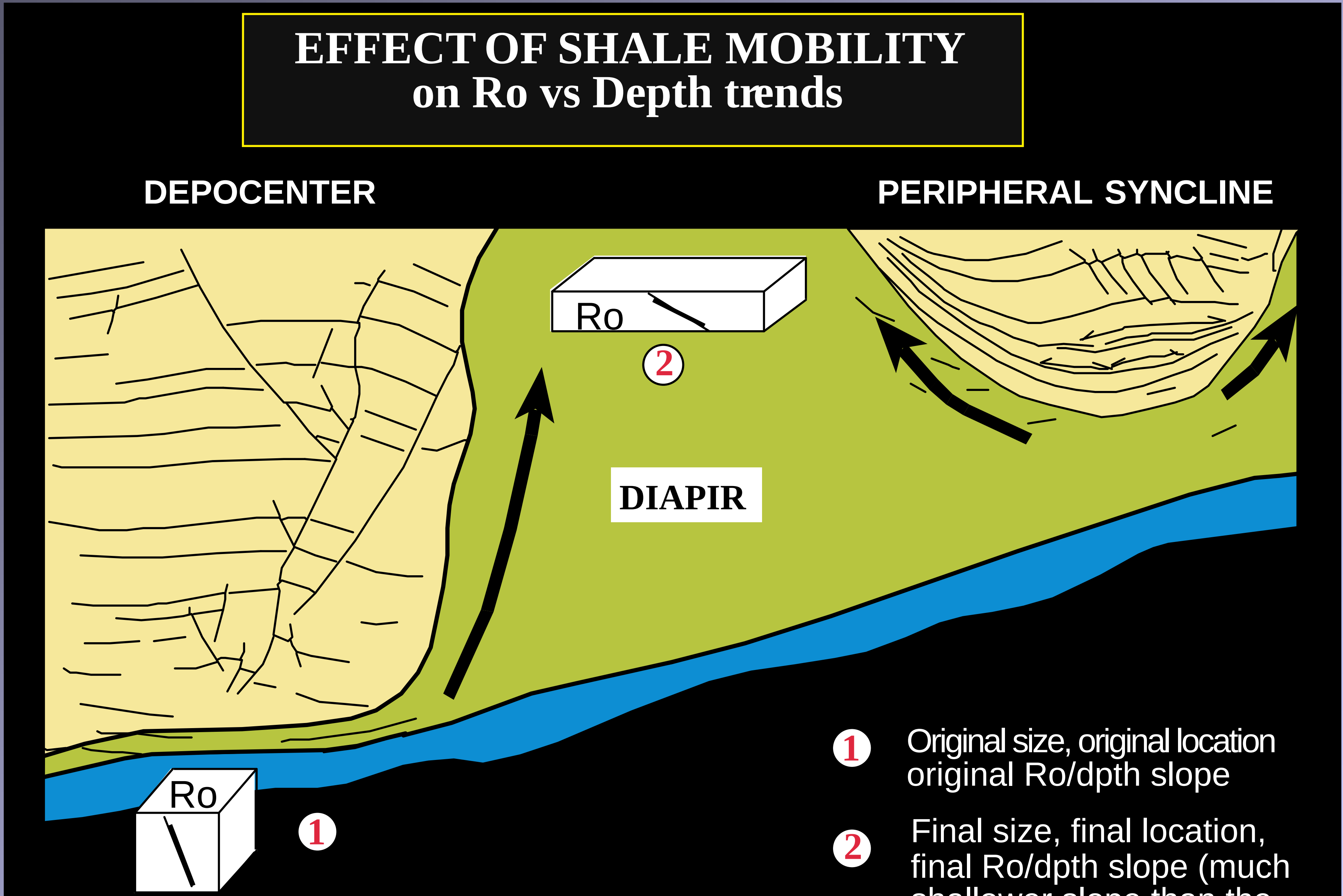

1. Original size, original location original Ro/dpth slope
2. Final size, final location, final Ro/dpth slope (much shallower slope than the original)

After Chatellier et al., 1998

Conclusions from Burial History

The area has much more potential than previously thought

Quartz cement Modeling

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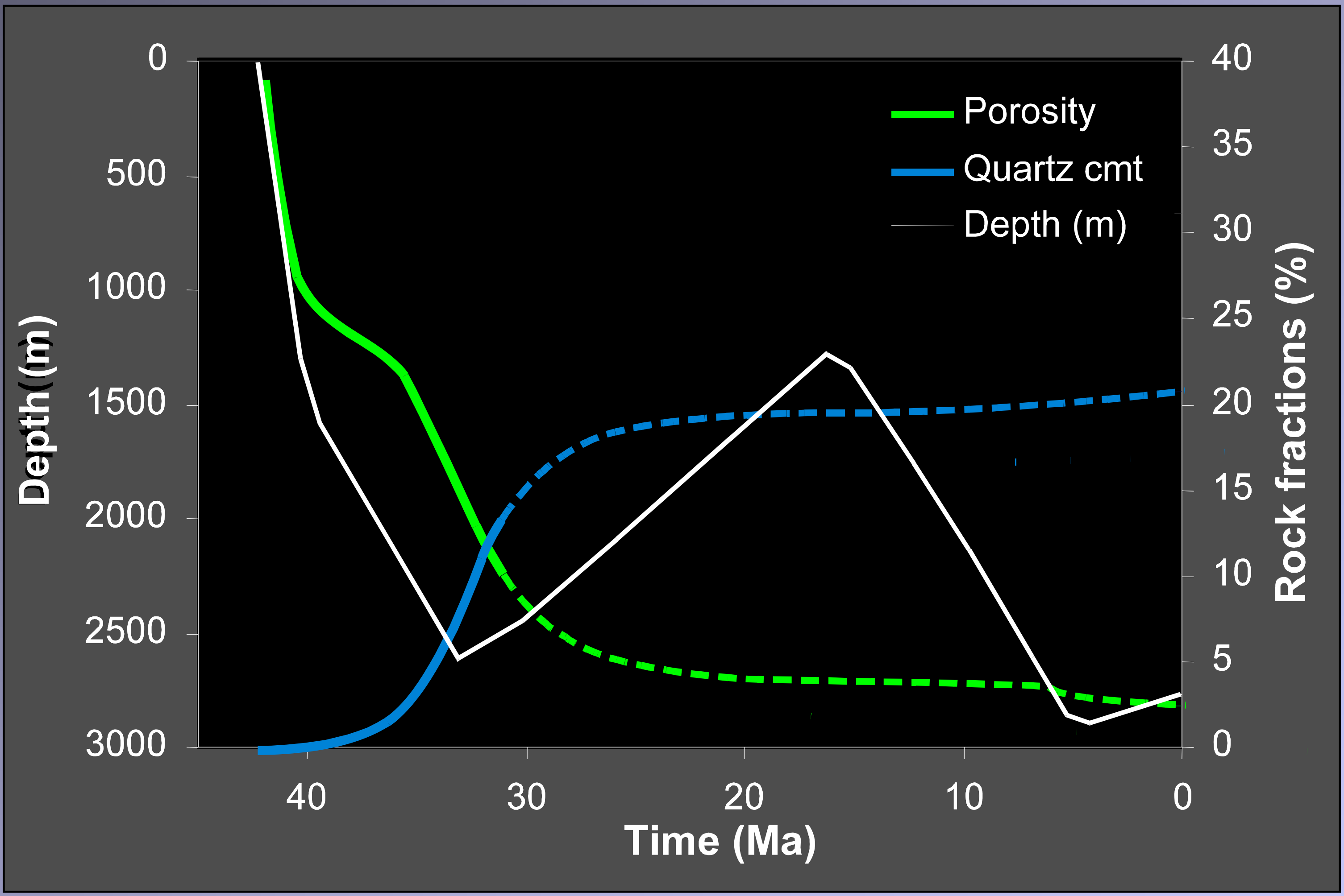
Simulation results



INPUT

Burial data:
Tº and time

Cathodo:
% Quartz cement

Petrography:
% Porosity

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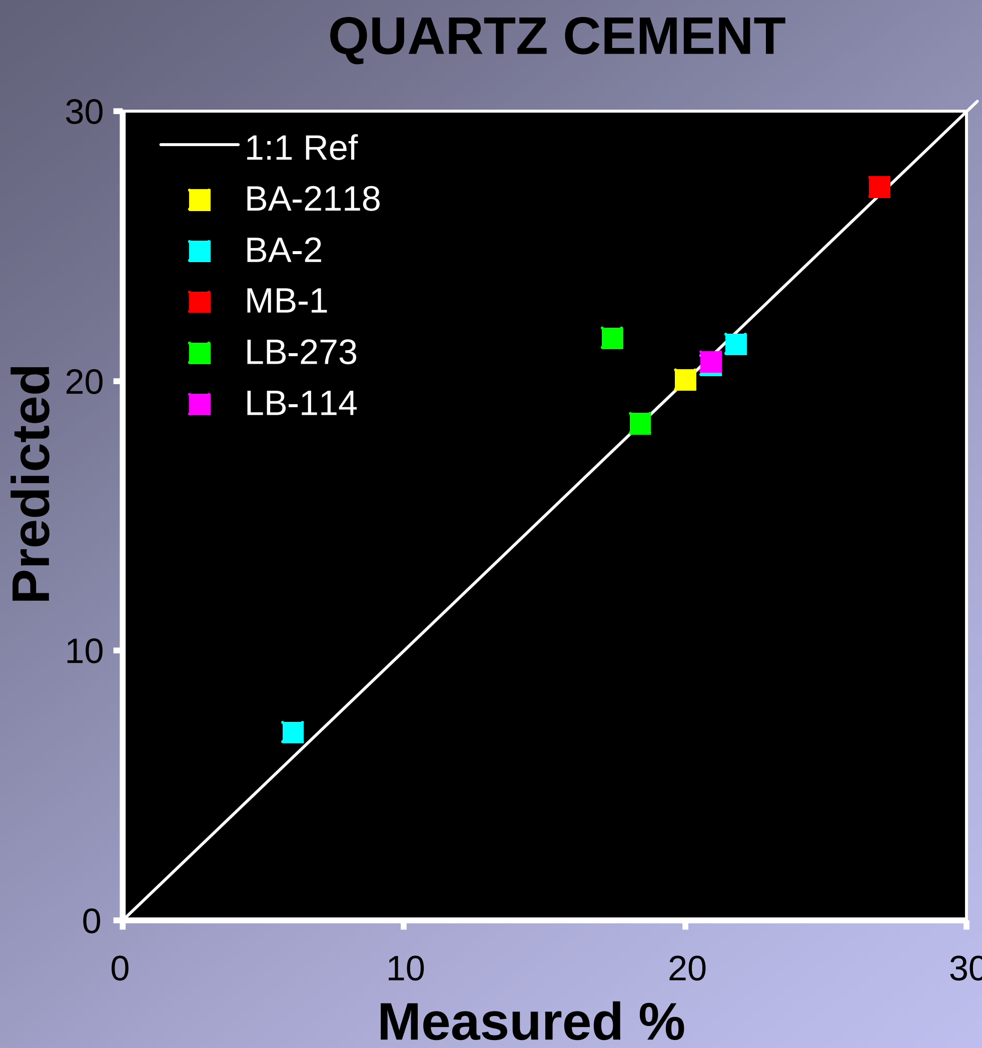
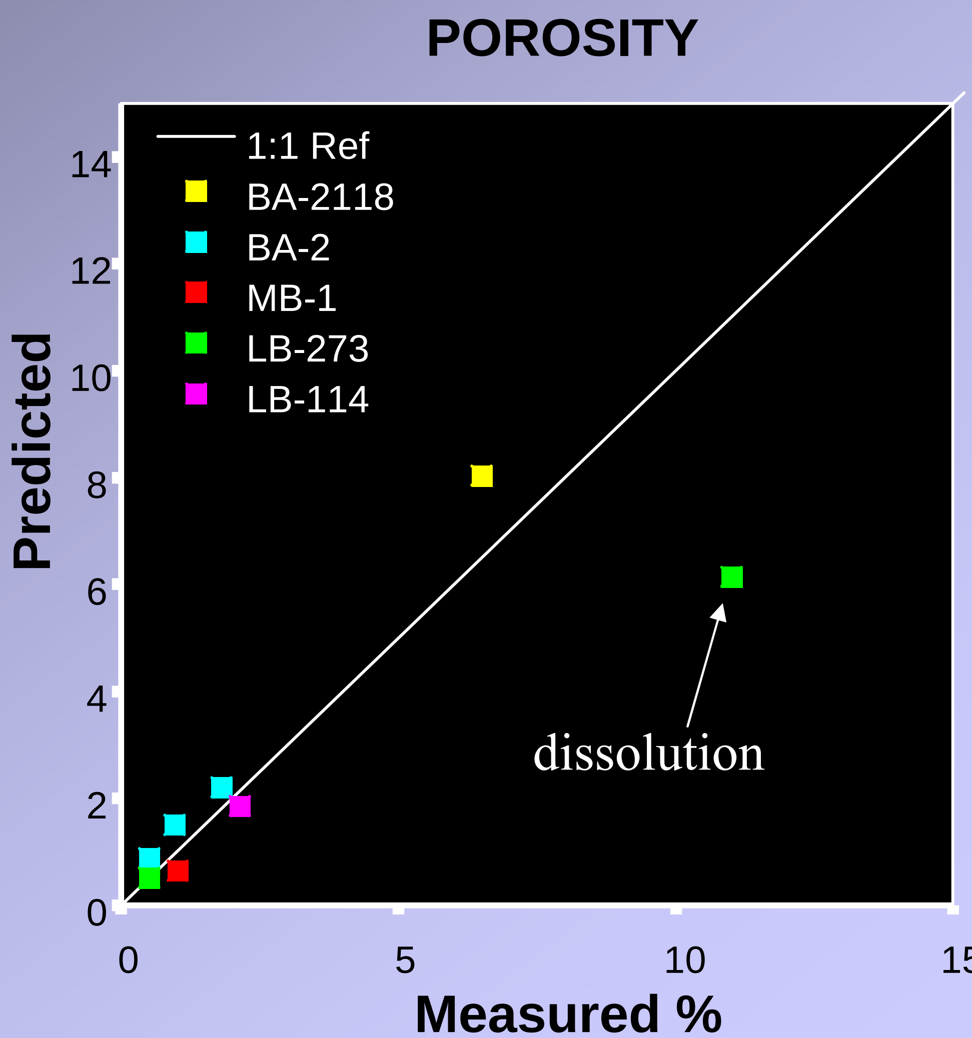
Quartz Calibration





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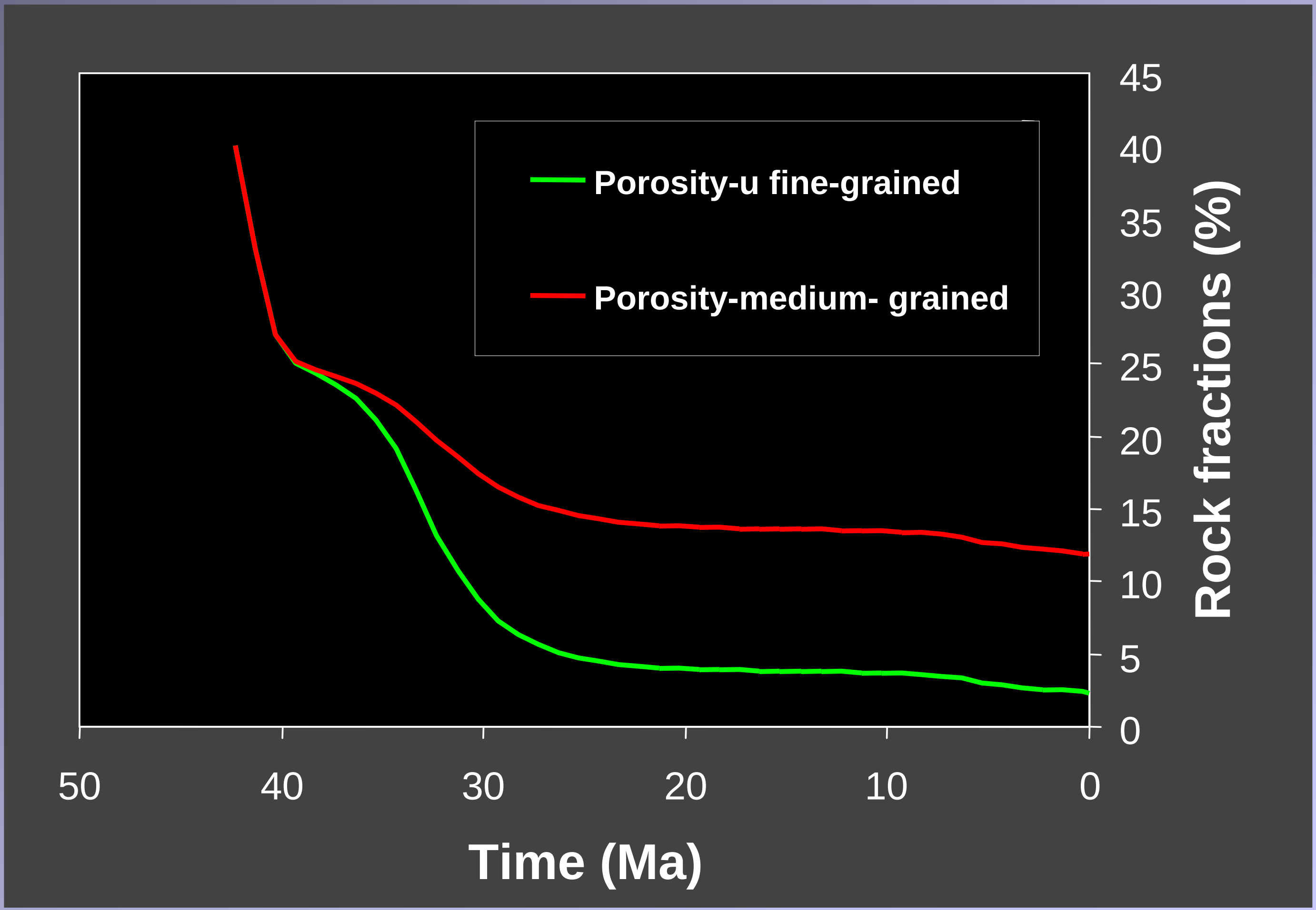
Effect of Grain Size on Well 5 Porosity



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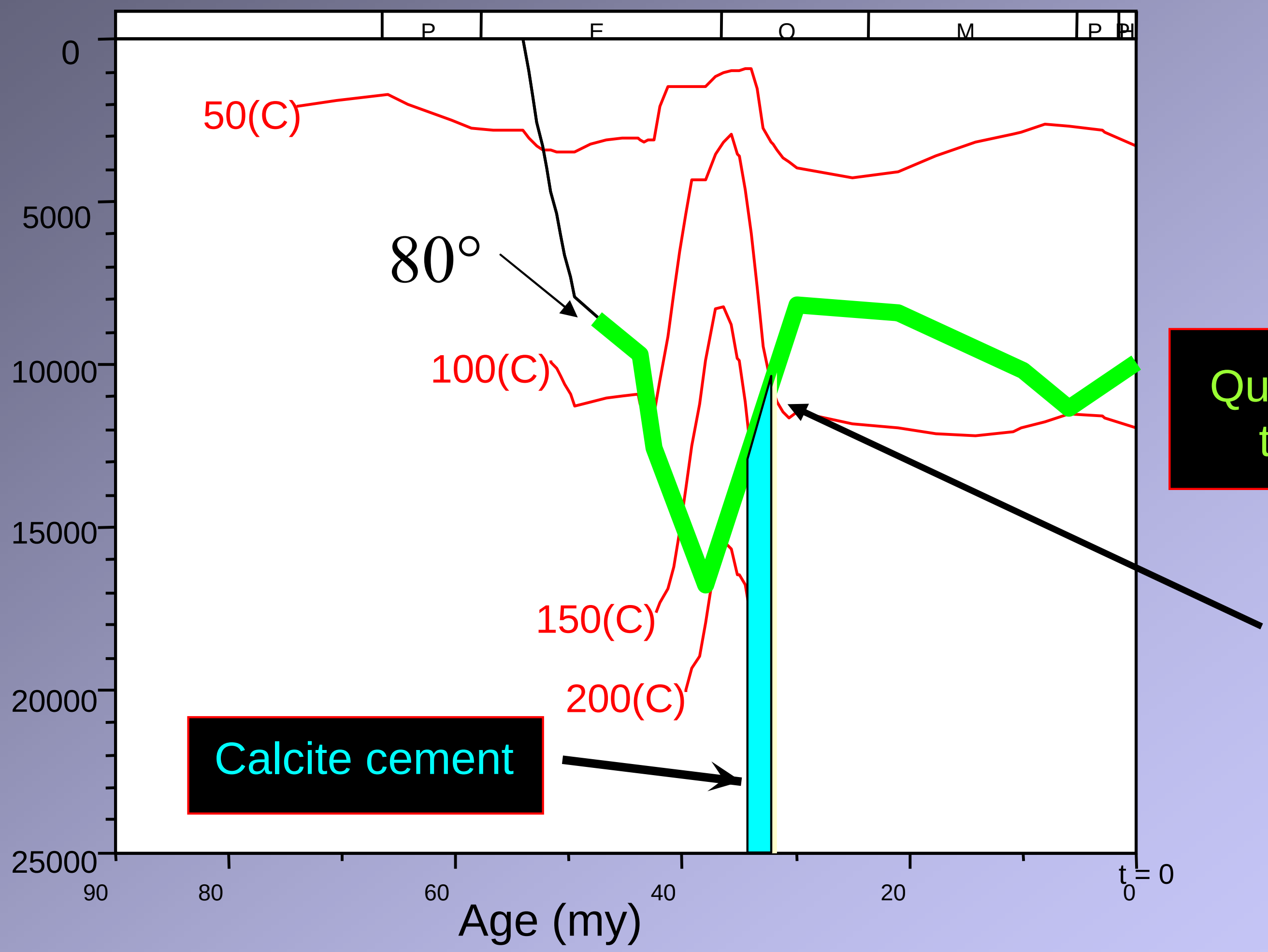
Timing of quartz and calcite cement



Well 1

Calcite cement
31-33 MY

Quartz Cement theoretical

End of Quartz cement precipitation

MODELING

- Modeling for wells with good burial history
  - (9 wells)
- Results
  - maps of porosity through time
- Integration with structure and geochemistry

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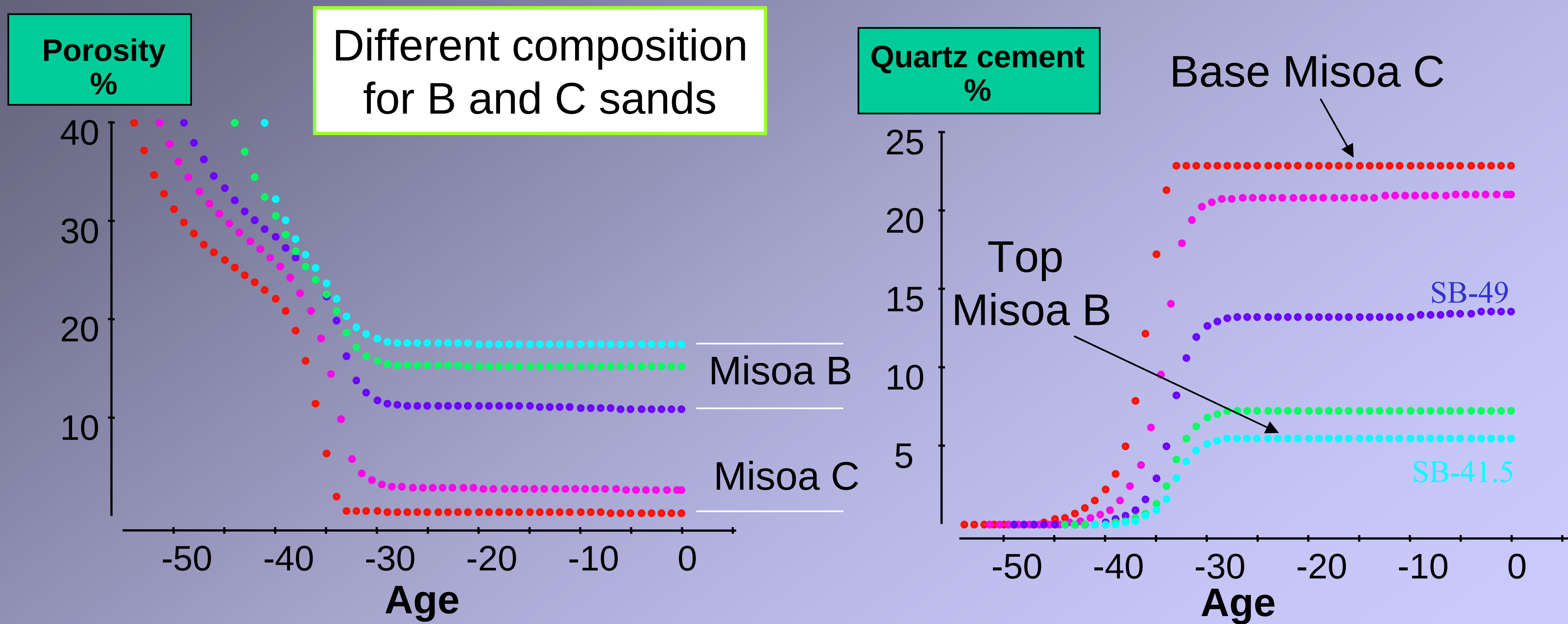
RESULTS FROM MODELING
Example from WELL 1



POROSITY

QUARTZ CEMENT

RESERVOIR QUALITY MAPS

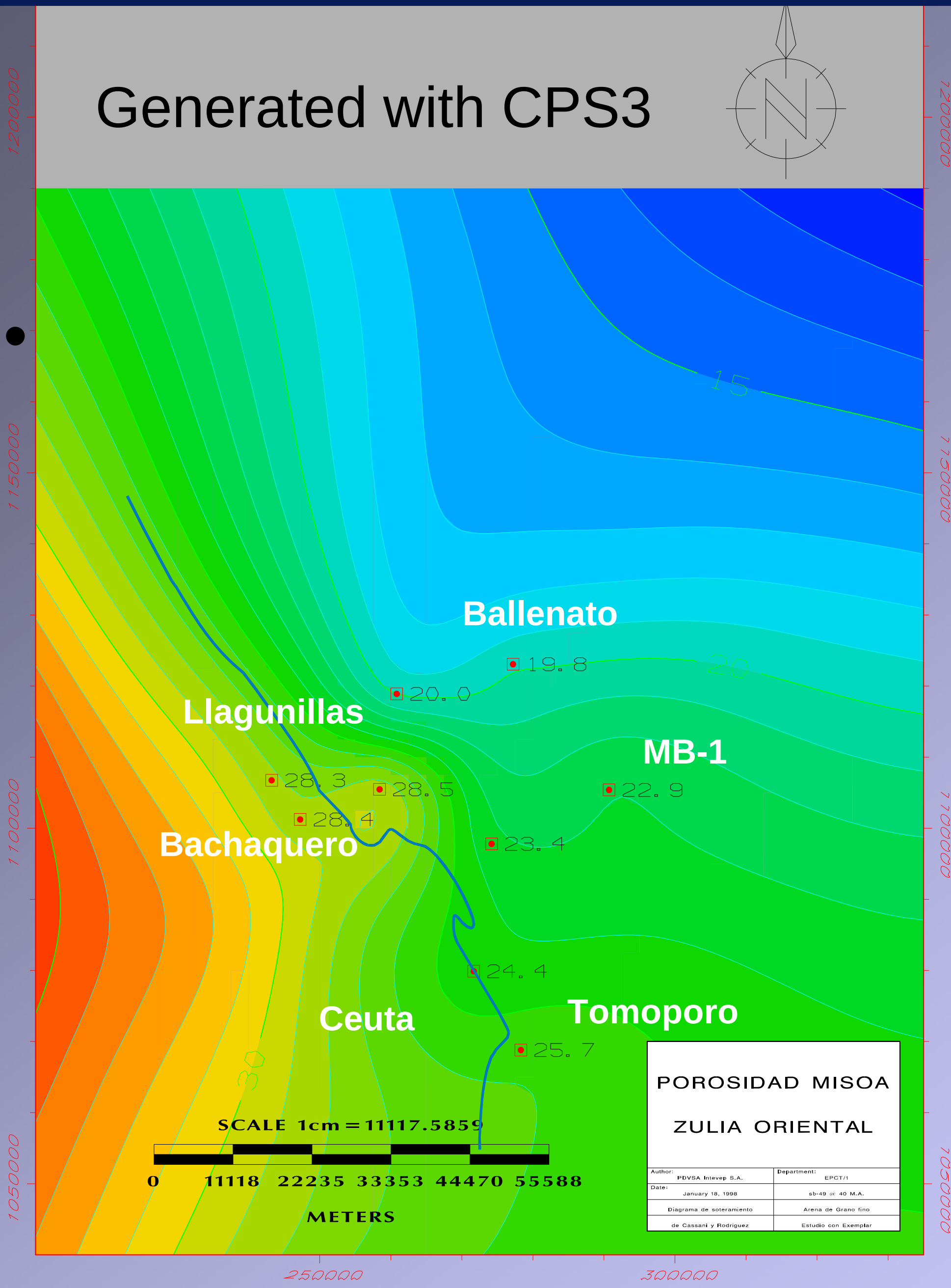
- **For sandstones with upper fine-grain size**
- **Maps of reservoir quality (porosity) for each horizon**
  - **top B sup**
  - **Top B inf**
  - **Top C sup**
  - **Top C inf**
  - **Base C inf**
- **Every 5 million years**
  - **45, 40, 35, 30, 25, 20, 15, 10, 5 MY and today**

PDVSA INTEVEP

ANALISIS DEL SISTEMA PETROLIFERO EN ZULIA ORIENTAL

PDVSA EXPLORACION

PROYECTO 4052

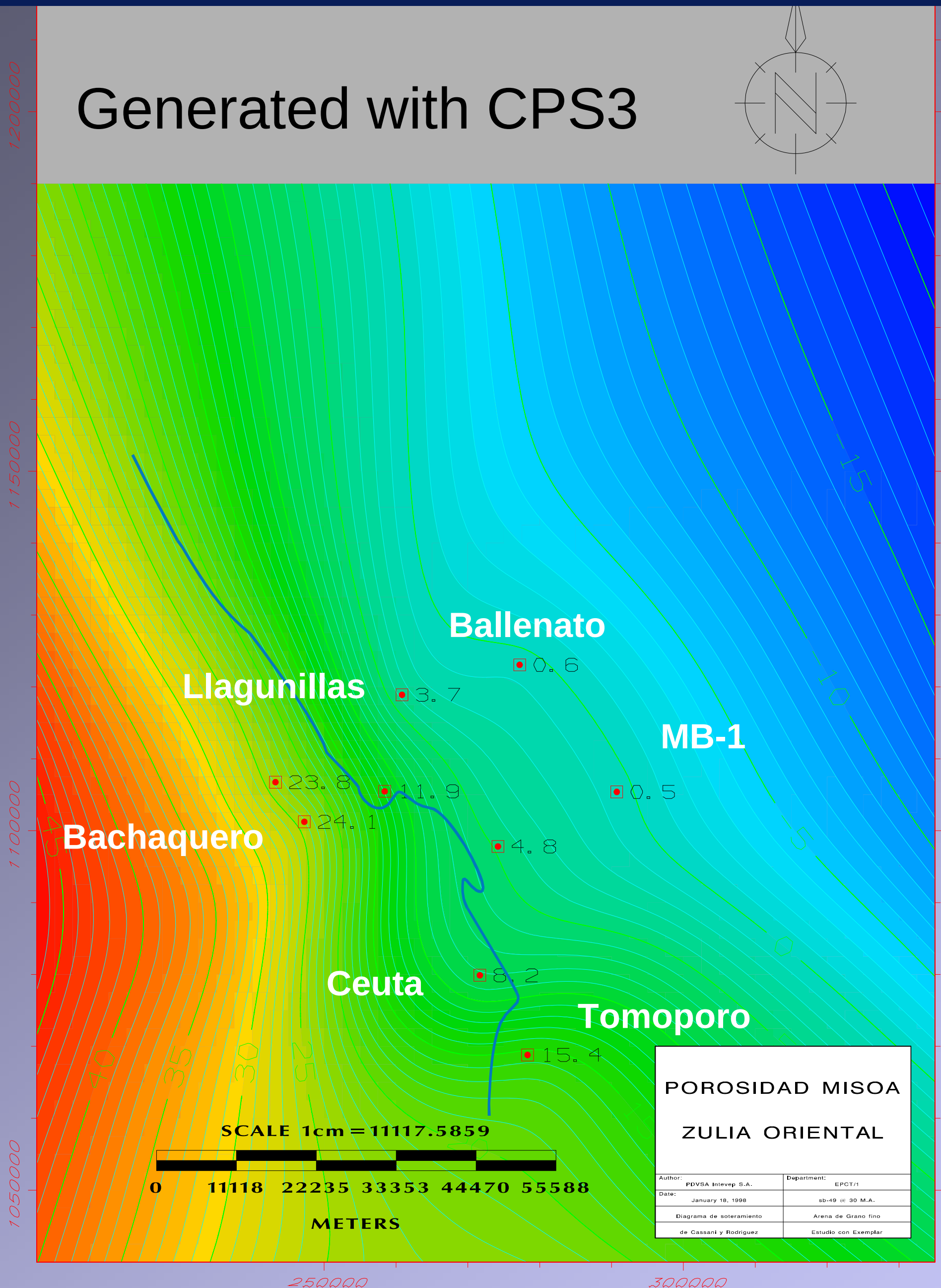


RESULTS FROM MODELING (1)

Top C Sands 40 Ma

Still good porosity in Zulia Oriental

19.8% to 26.4%



RESULTS FROM MODELING (2)

Top C Sands 30 Ma

Huge porosity loss in Northeastern part of Z.O.

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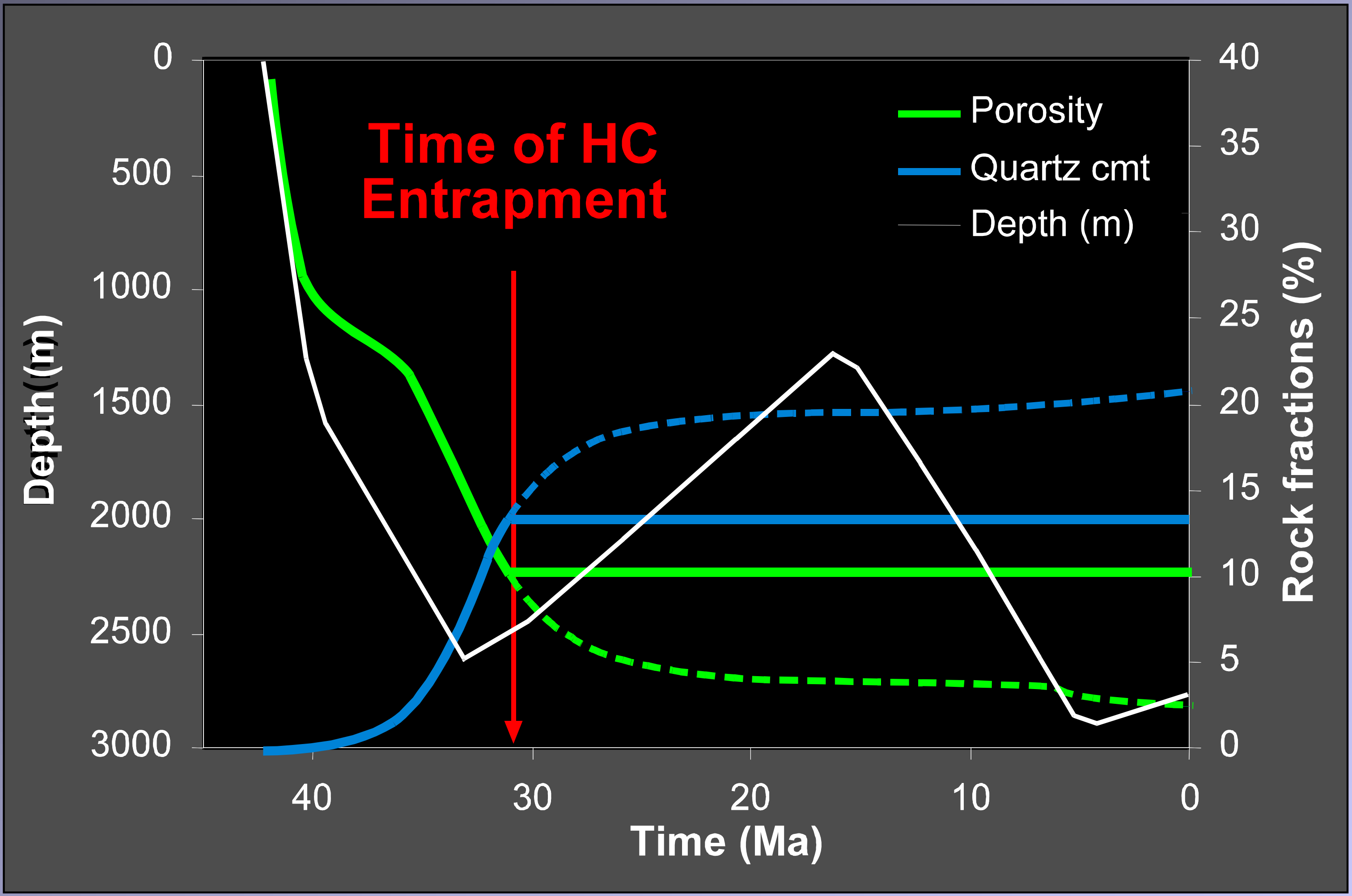
Why is hydrocarbon migration important?



OIL

EMPLACEMENT

STOPS

DIAGENESIS

==> preserve Reservoir quality

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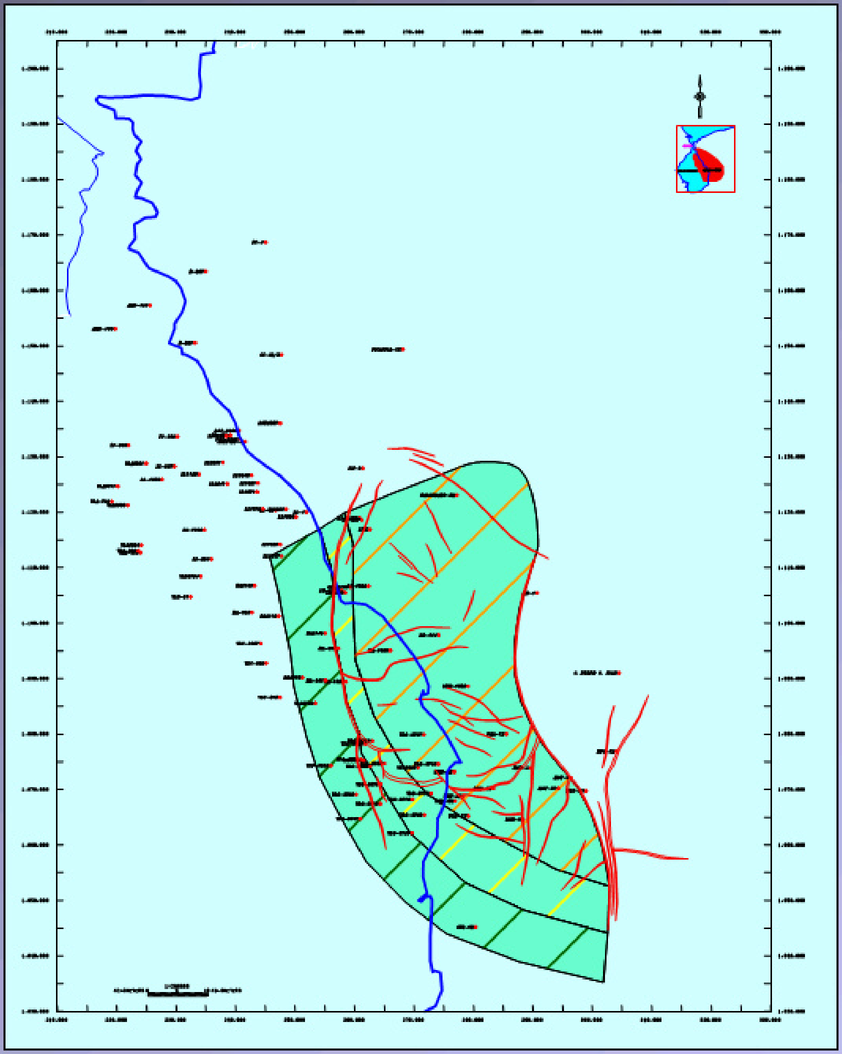
RESERVOIR QUALITY for 1st expulsion phase



Level studied = SB-49
Top of Misoa C sands

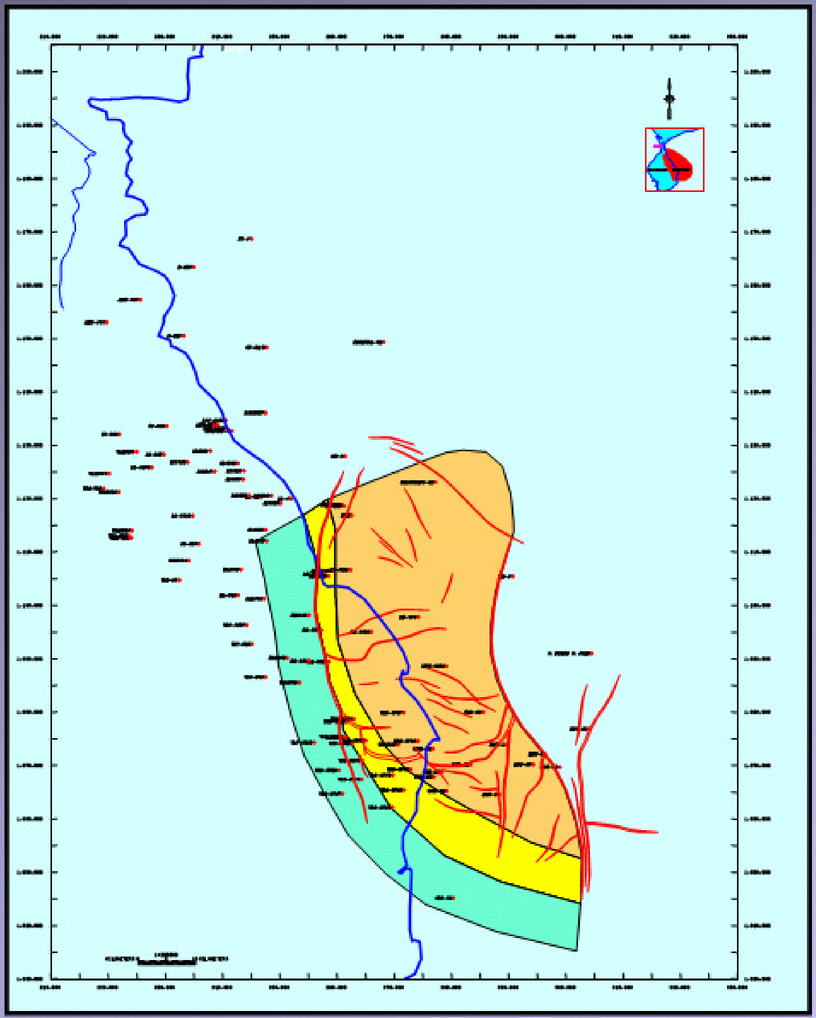
At time of 1st migration
all > 20% porosity

View @ 40 M.Y.

Combination 1st & 2nd migrations

- Porosity <10%
- Porosity 10%<<15%
- Porosity >15%

RESERVOIR QUALITY for 2nd expulsion phase



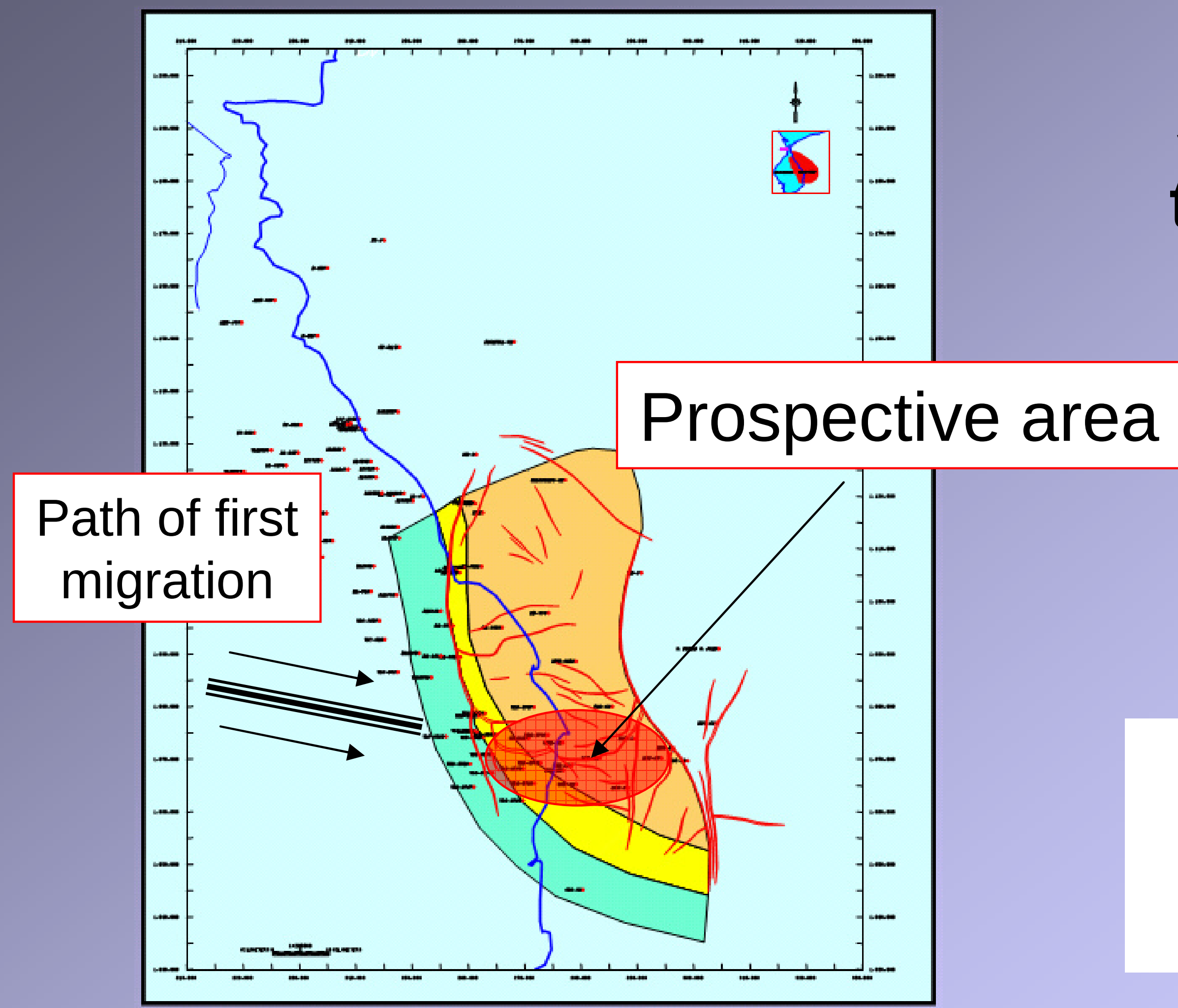
Level studied = SB-49
Top of Misoa C sands

Top of zone of interest (up to 900m thick)

View @ 10 M.Y.

- Porosity <10%
- Porosity 10%<<15%
- Porosity >15%

Looking for prospects



Searching for structures existing at time of first migration and on the migration path

View @ 10 M.Y.

- Porosity <10%
- Porosity 10%<<15%
- Porosity >15%

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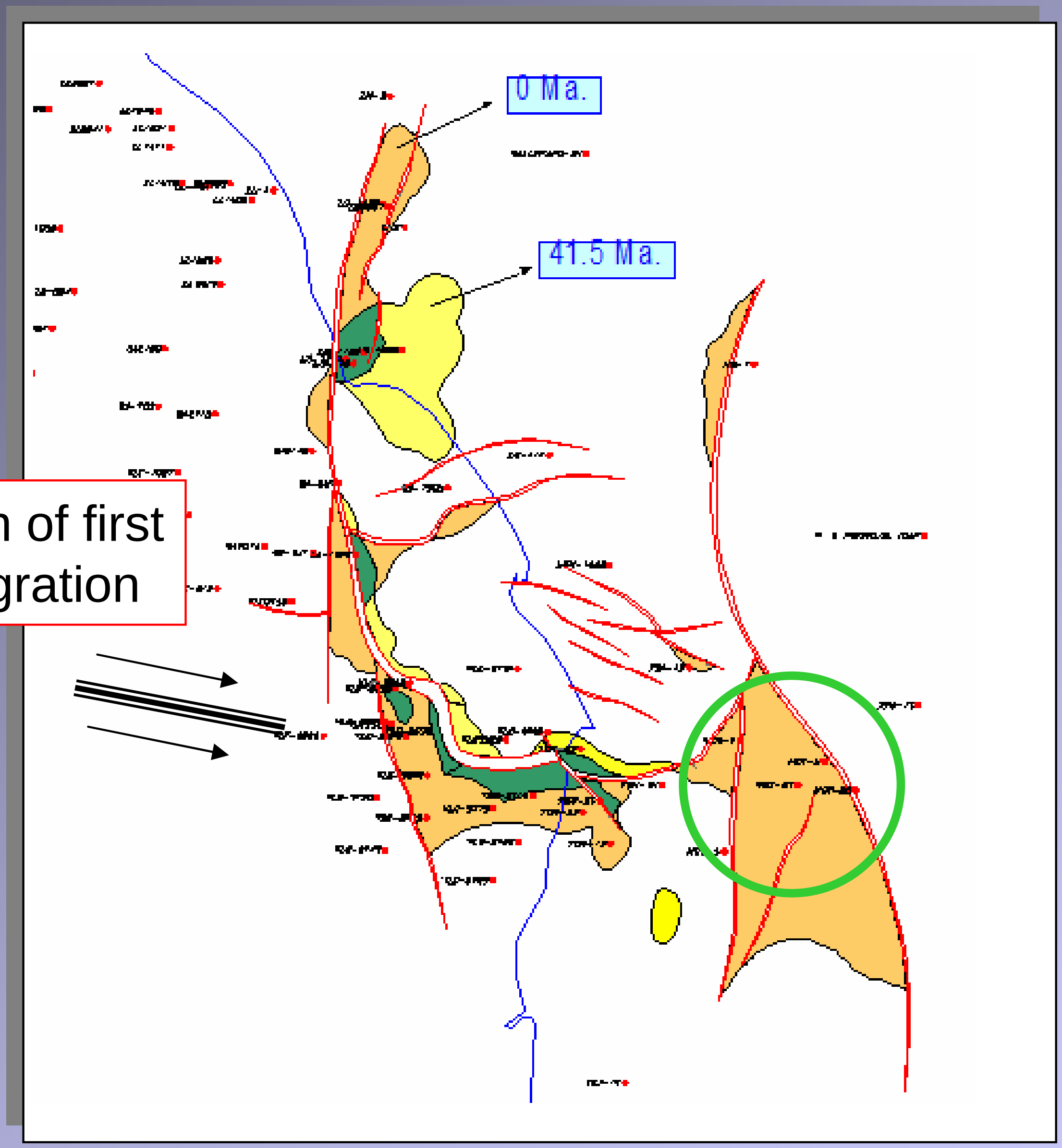
Path of first migration



CONCLUSIONS 1

- A simple diagenetic model did the job
    - Burial history
    - % Quartz cement from C.L.
    - Porosity from petrography
    - Composition from petrography
    - Grain size from petrography
- Added filters (change in grain size, calcite cement)
- Timing of migration is vital
    - Hydrocarbon emplacement stops diagenesis

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CONCLUSIONS 2

- Integration with the tectonic model
  - creation of traps
  - preservation of traps

- Integration with the migration history
  - e.g., 2 phases of migration
  - Structural trap in Tomoporo area at time of first migration
    - ➔ good porosity

- Final results
  - Location for new seismic
  - New drilling discovery well 17,400 barrels per day
  - “Tomoporo Profundo” Field >1 Billion bbls (official reserves)
  - **Biggest discovery in Venezuela since El Furrial Trend discovery**