San Andres Play in the Northwest Shelf of the Permian Basin: A New Insight on Its Petroleum Systems from Oil Geochemistry*

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Abstract

The San Andres Formation is the most prolific reservoir of hydrocarbons in the Permian Basin of west Texas and eastern New Mexico, with a hydrocarbon production that has exceeded 3.9 billion bbl in the Northwest Shelf. In this region, the San Andres Fm. represents a series of regressive cyclic deposits of shallow-water carbonates and evaporates that prograded southward across a broad, low-relief, shallow-water shelf. The main reservoir facies are subtidal porous dolostones; these successive porosity zones are offset basinward and occur in increasingly younger strata to the south. The trapping mechanism for the San Andres play in the Northwest Shelf results mainly from porosity pinch-outs defined by an increase in the anhydrite content or in the degree of the dolomitization. The source for this play has been proposed to be Wolfcampian basinal clastics in the northern Midland Basin. This author has also proposed that the biodegradation from anaerobic sulfate-reducing bacteria could explain the association of highly sulfurous and aromatic oil in the anhydrite-rich reservoirs of the Northwest Shelf. In this study, a number of oils and core extracts have been analyzed and the results have shown high sulfur, very low pristine/phytane ratios, and relatively normal alkane and isoprenoid distribution in the whole oil gas chromatographic traces. The integration of these geochemistry results together with data from public databases and a geological model of the depositional environment indicate that a carbonate-rich (Type IIs or Class A) source rock could explain the characters found in the oils. Moreover, the increase in the aromatics could also be explained by a process of evaporative fractionation from oils trapped in stratigraphic traps and updip migration of a gassier and lighter phase. Finally, Basin and Petroleum Systems Modeling has also been applied to analyze the timing of generation and charge, and the generated volumes for the different potential source rock intervals of Permian age. A detailed understanding of the source rock facies that have charged the San Andres reservoirs in the Northwest Shelf and the integration into a BPSM are critical steps in the regional evaluation of the oil signatures and, eventually, in the assessment of the differences in the productivity of the fields.

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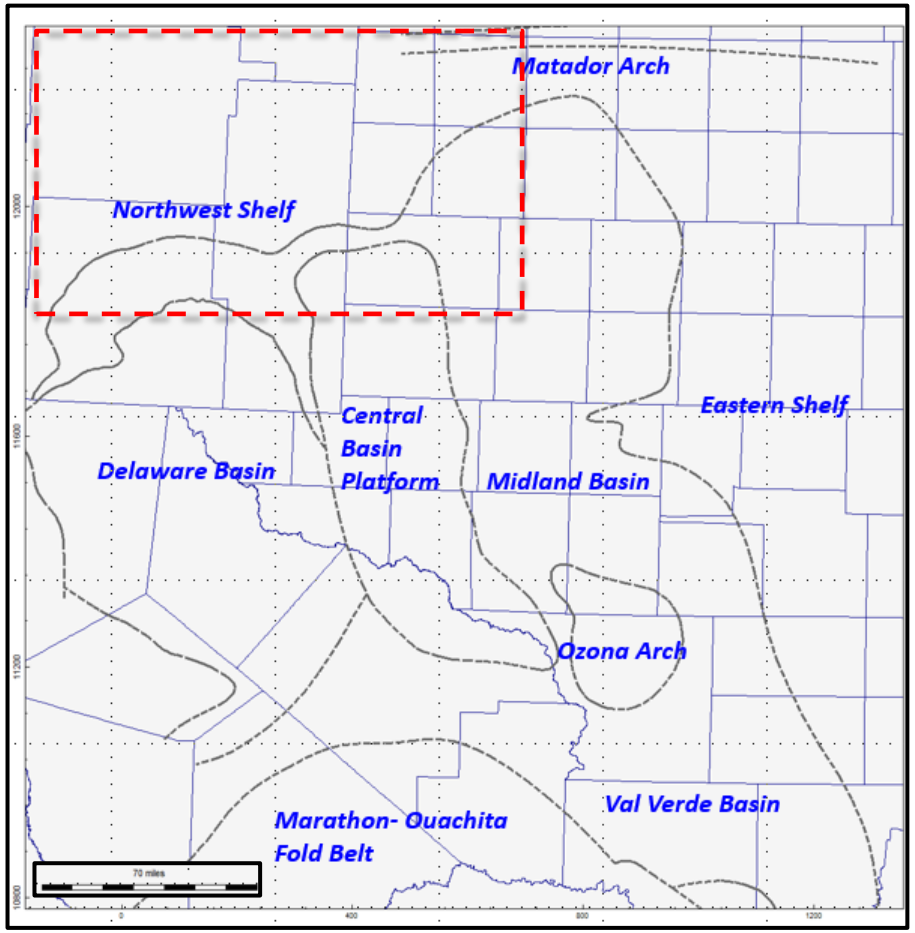
SAN ANDRES PLAY IN THE NORTHWEST SHELF OF THE PERMIAN BASIN: A NEW INSIGHT ON ITS PETROLEUM SYSTEMS FROM OIL GEOCHEMISTRY

LUCIA RODRIGUEZ AND CHANGRUI GONG

INTRODUCTION

- The San Andres Formation is the most prolific producer in the Permian Basin (Stoudt and Raines, 2004)

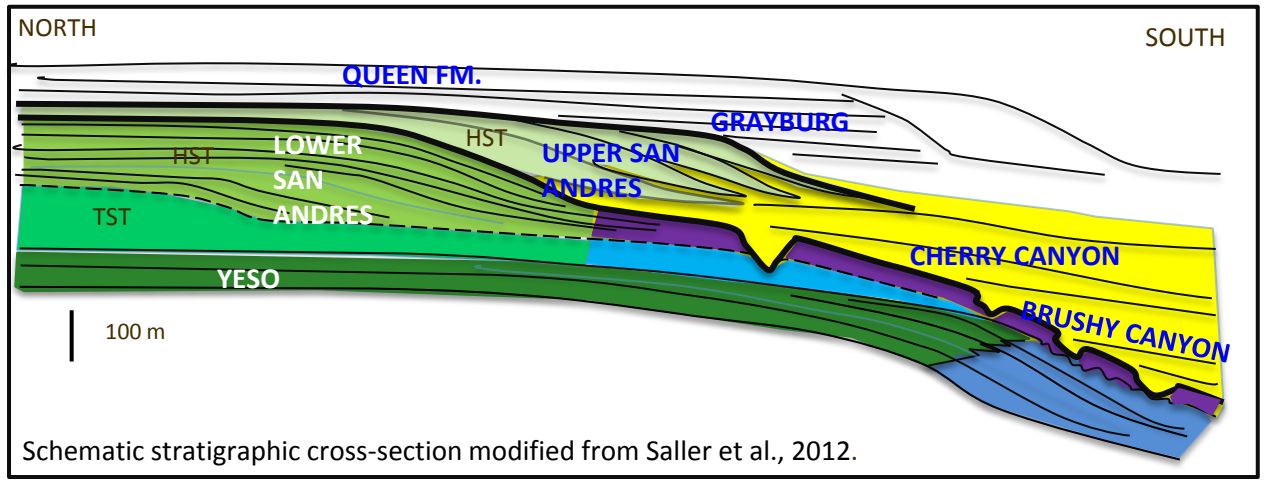
- Purpose of study:
  - Analyze oil San Andres geochemistry to determine organofacies and maturity
  - Understand charge and build a better predictive model
  - Evaluate secondary processes and compartmentalization
  - Implications for prospectivity and development



Major subdivisions and boundaries of the Permian Basin in West Texas and southeast New Mexico

SAN ANDRES PLAY NW SHELF ELEMENTS

- Reservoir:
  - Dolomitized carbonate lithofacies of outer-to inner-ramp
  - Latest Leonardian-Mid Guadalupian
- Source rock:
  - Previous works: Wolfcampian organic-rich shales (Ramondetta, 1982)
  - In this study: Mid-Late Permian carbonate/marls source rocks
- Primary trapping mechanism is stratigraphic
- Hydrocarbon peak generation occurred during Early Triassic
- Tilting of the western margin of the Permian Basin during Early Paleogene (Ewing, 2013)



Schematic stratigraphic cross-section modified from Saller et al., 2012.

System	Epoch/Series/ Stage	Delaware Basin	NW Shelf New Mexico
PERMIAN	Ochoan	Dewey Lake	Dewey Lake
		Rustler	Rustler
		Salado	Salado
		Castile	Castile
	Guadalupian	Bell Canyon	Tansill
			Yates
		Cherry Canyon	Seven Rivers
			Queen
		Brushy Canyon	Grayburg
			Upper San Andres
		Cutt-off	Lower San Andres
	Leonardian	Bone Spring	Glorieta
			Yeso Group
			Abo
	Wolfcampian	Wolfcamp	Wolfcamp

Stratigraphic column from Wolfcampian to Guadalupian (Dutton et al., 2005)

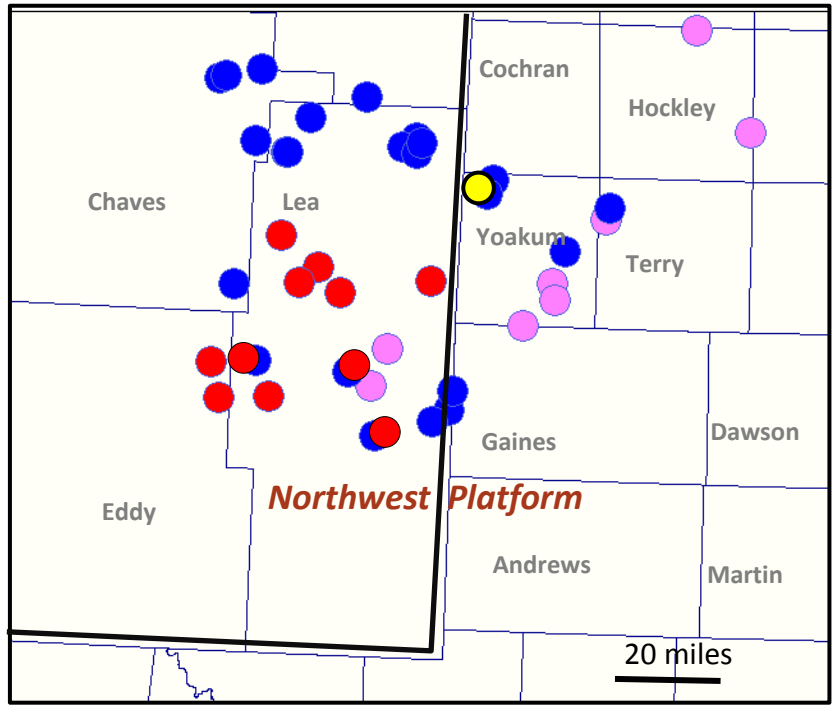
DATASET AND METHODOLOGY

Dataset

- Oil geochemistry data from produced oils from Apache and GeoMark database
  - Bulk data (API gravity and % Sulfur content)
  - WOGC (Whole Oil Gas Chromatography)
  - GCMS/ biomarker data
- Oil geochemistry from core extracts on 1 well

Methodology

- Geochemistry data grouped by reservoir age
- Interpretation of the regional character of the oils
- Evaluation of San Andres data:
  - Integration with petroleum systems model
  - Evaluation of secondary processes
  - Interpretation of the fingerprinting data from core extracts



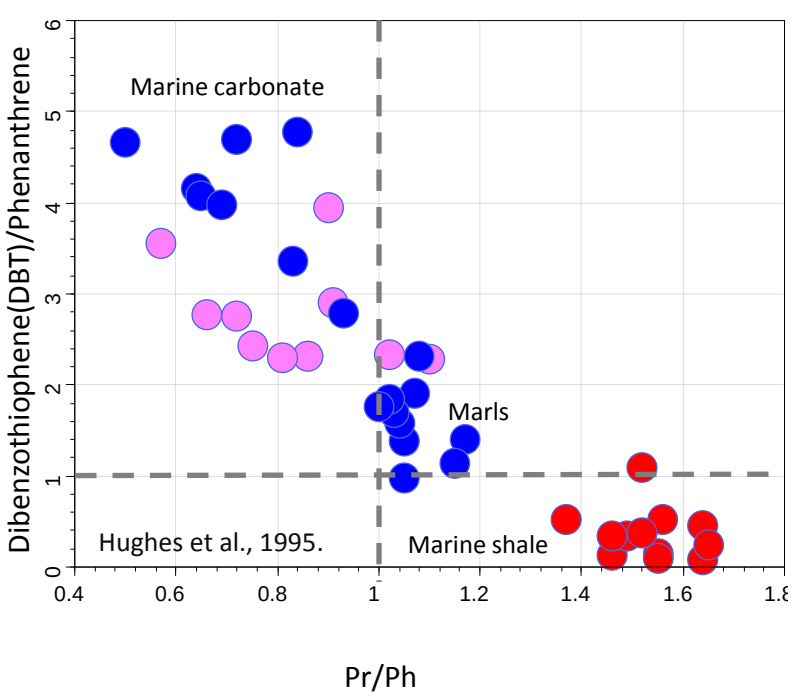
Oil samples color-coded by reservoir age

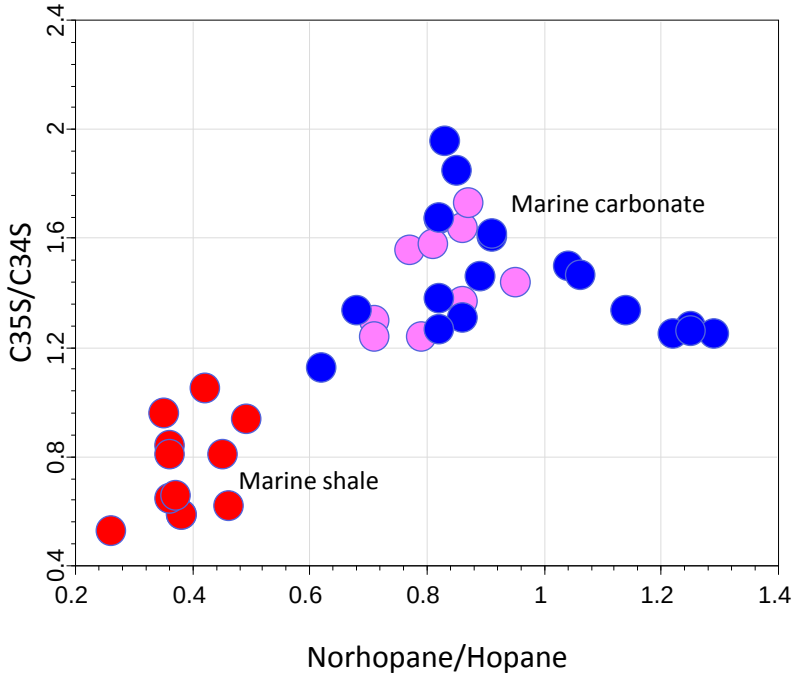
- Latest Leonardian-Mid Guadalupian (**San Andres**, Grayburg)
- Mid-Late Leonardian (Yeso Group, Clear Fork, Glorieta)
- Wolfcampian-Early Leonardian (Wolfcamp, Abo)
- Core extracts

ORGANOFACIES

- Oils in Guadalupian and Leonardian reservoirs show
  - High DBT/P
  - Low-intermediate Pr/Ph
  - High norhopane/hopane ratios and C35/C34 hopanes
  - Supported by:

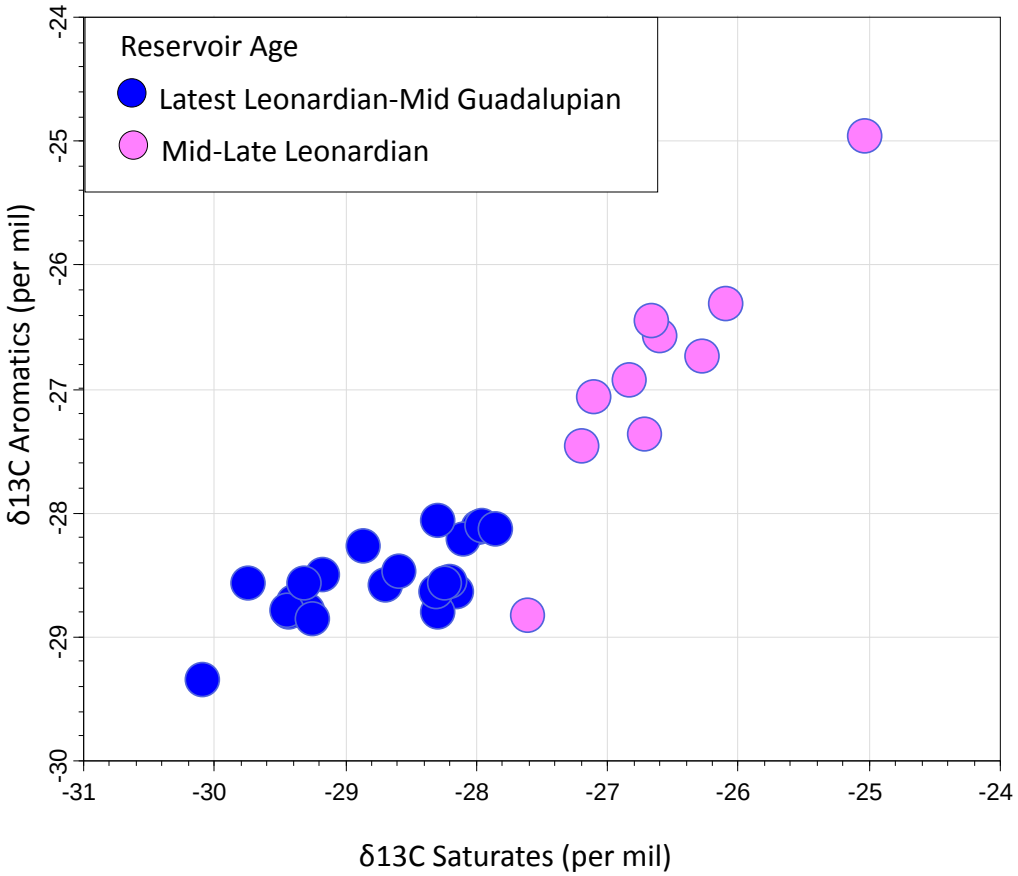
    Abundant C24 tetracyclic terpane
- Oils derived from a marine carbonate/marl source rock
- Wolfcampian are derived from marine shale source rocks

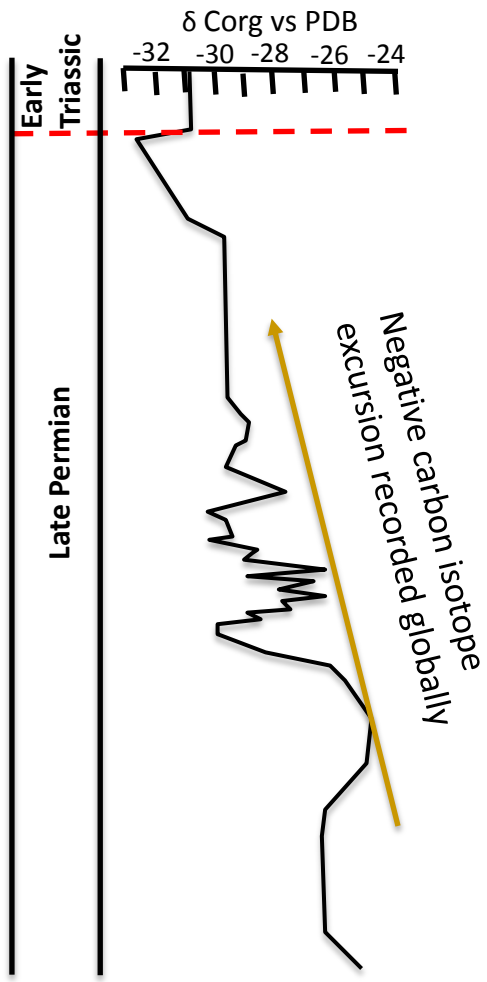




Reservoir Age
- Latest Leonardian-Mid Guadalupian
- Mid-Late Leonardian
- Wolfcampian-Early Leonardian

CARBON ISOTOPES

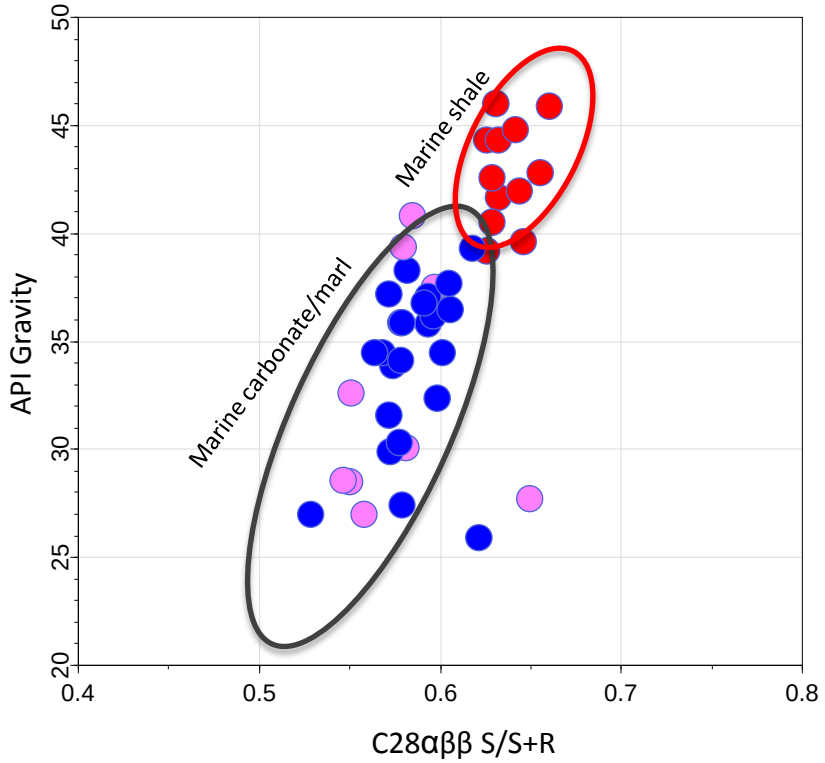


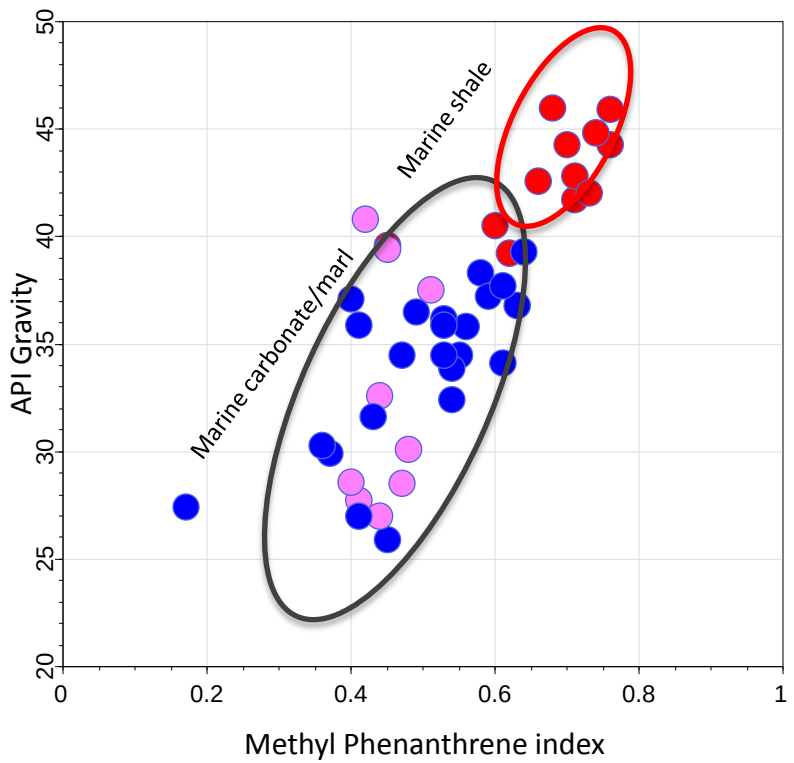


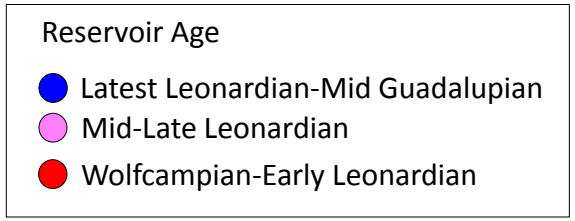
Kraus et al. 2013

- Oils in Latest Leonardian –Mid Guadalupian reservoirs are isotopically lighter than in Mid Leonardian reservoirs
- Reasons:
  - Subtle variations of facies
  - Negative carbon isotope excursion documented in the Late Permian (Chen et al., 1984; Kraus et al., 2013).
- This could suggest migration from Late Permian source rocks.

THERMAL MATURITY

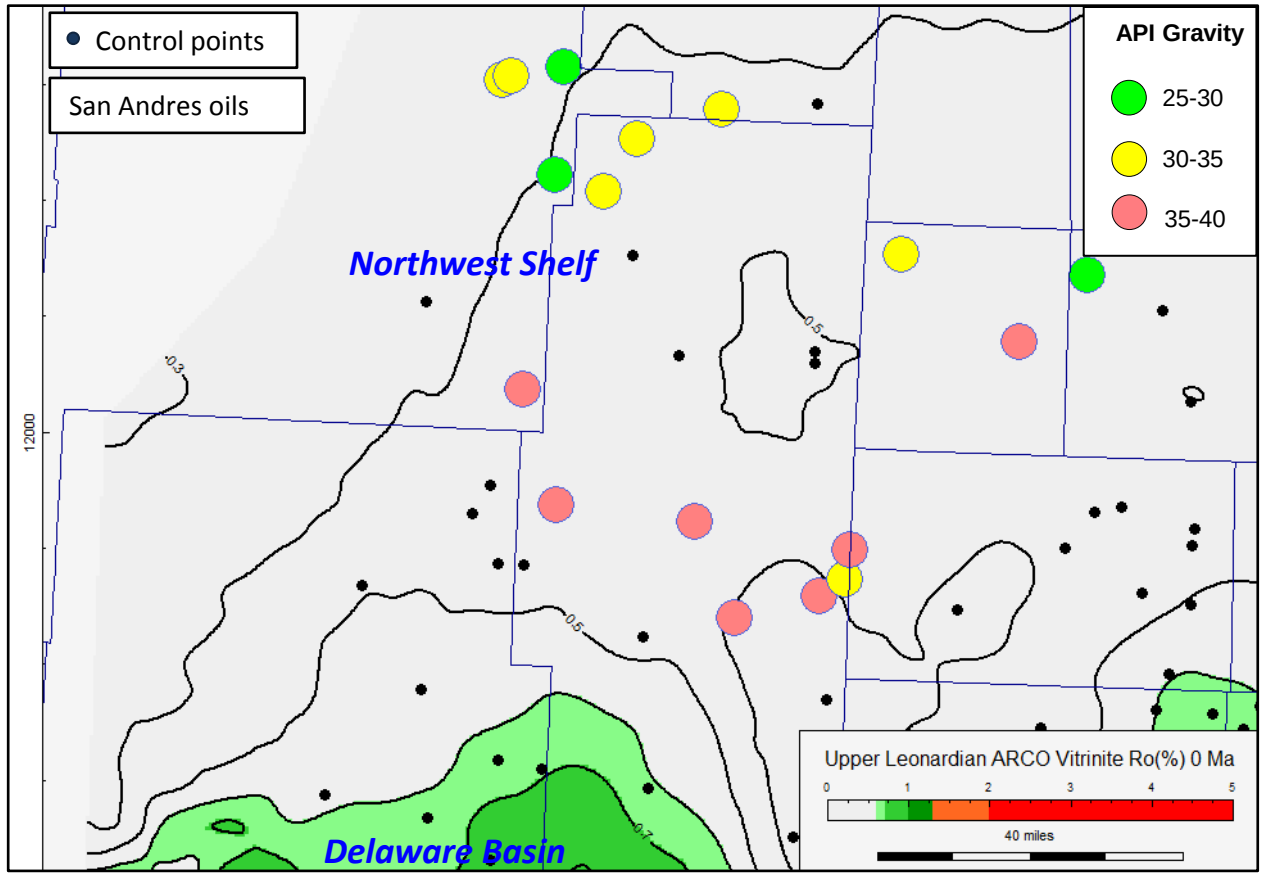






- API gravity consistent to maturity parameters
- For Guadalupian reservoired oils, this range of cumulative API corresponds to maturities between 0.55-1.1 %VRo (Kinex modeling)

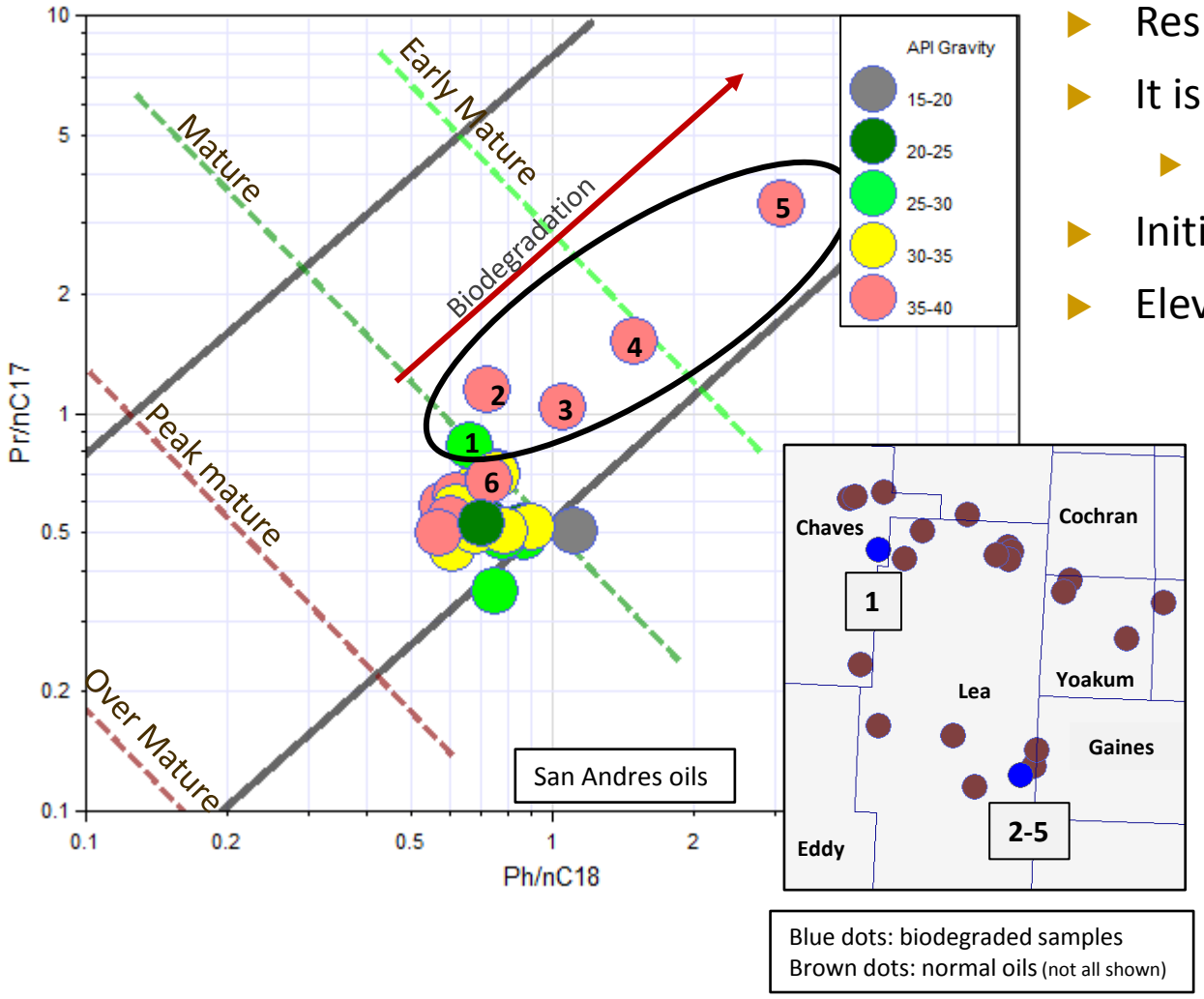
MATURITY SUGGESTS DEEPER CHARGE



Upper Leonardian maturity map

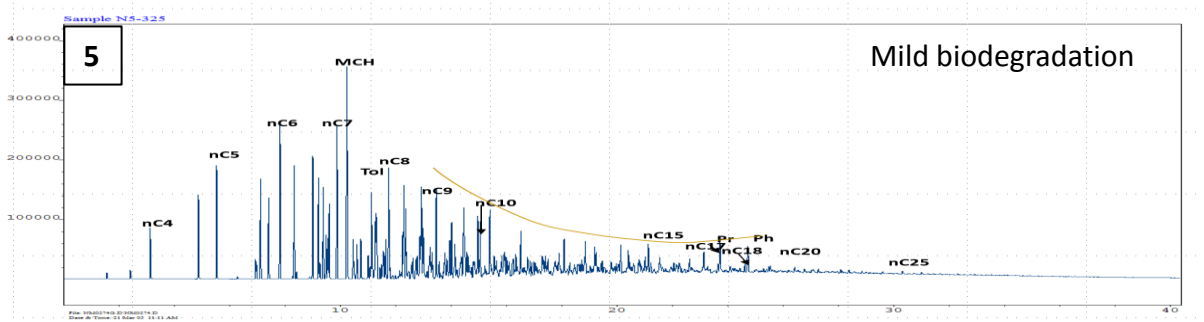
- Maturity of the San Andres oils is higher than the maturity of Mid-Upper Permian rocks.
- Vertical migration from Wolfcampian source rocks not supported by geochem data.
- Most likely scenario, long distance migration from deeper parts of the basin.
- Long distance migration expected in a homoclinal ramp, consistent regional gradient

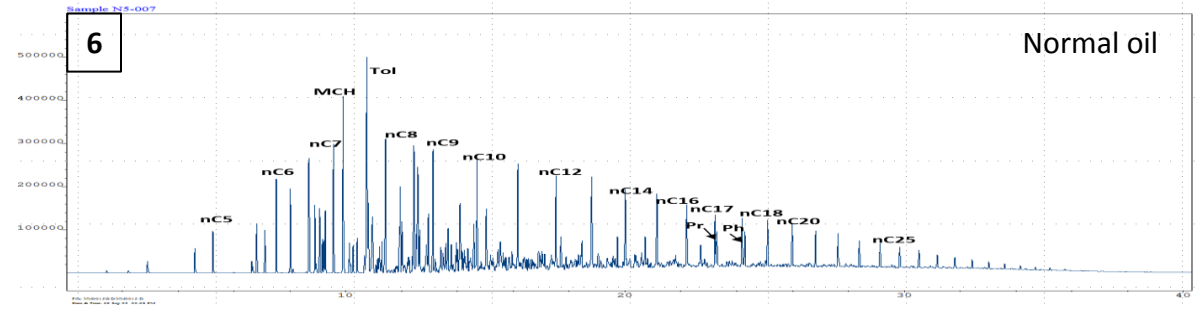
BIODEGRADATION IS NOT WIDESPREAD



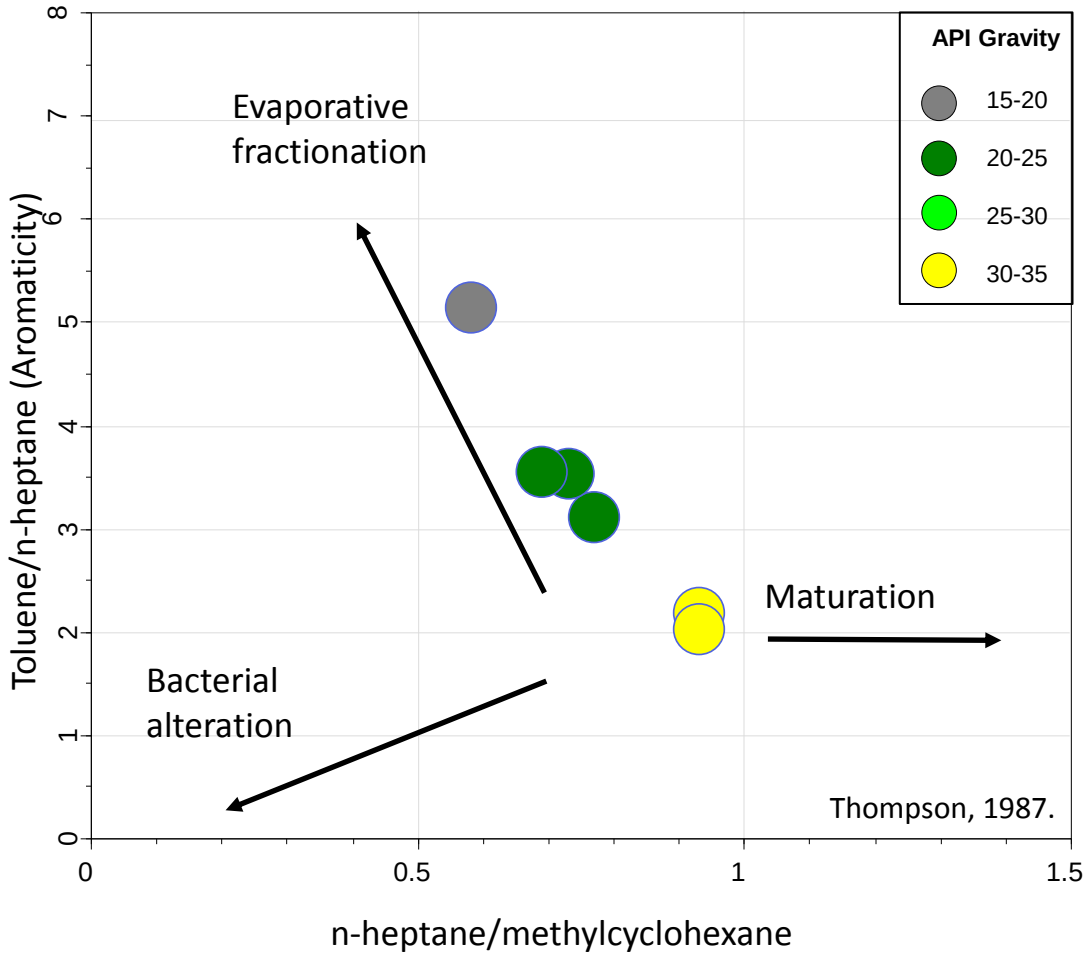
Blue dots: biodegraded samples
Brown dots: normal oils (not all shown)

- Res temp around 120° F, biodegradation can be expected:
- It is not a widespread process:
  - High isoprenoid to normal alkanes ratios in 4 oils of around 35 API gravity
- Initial charge biodegraded with later charge (light ends preserved)
- Elevated UCM observed in one sample (sample 1)



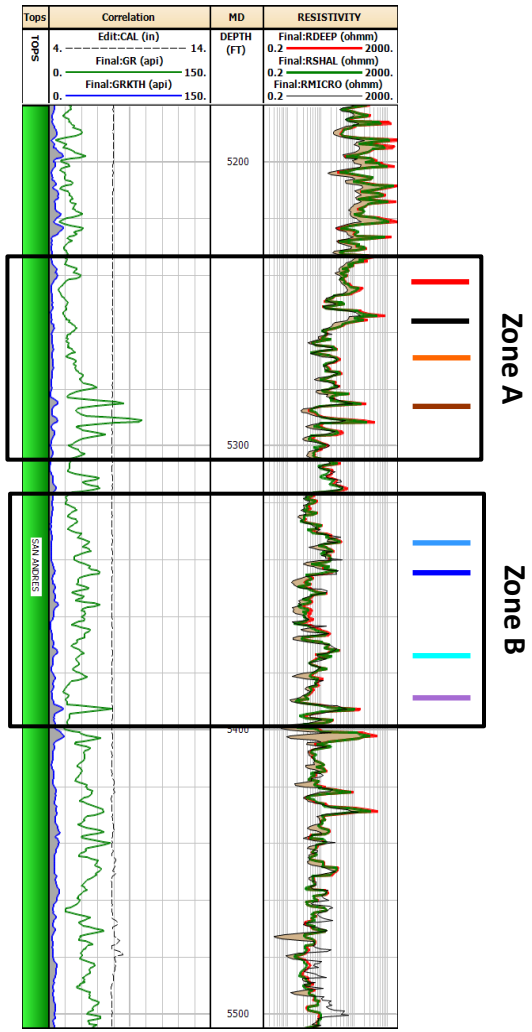


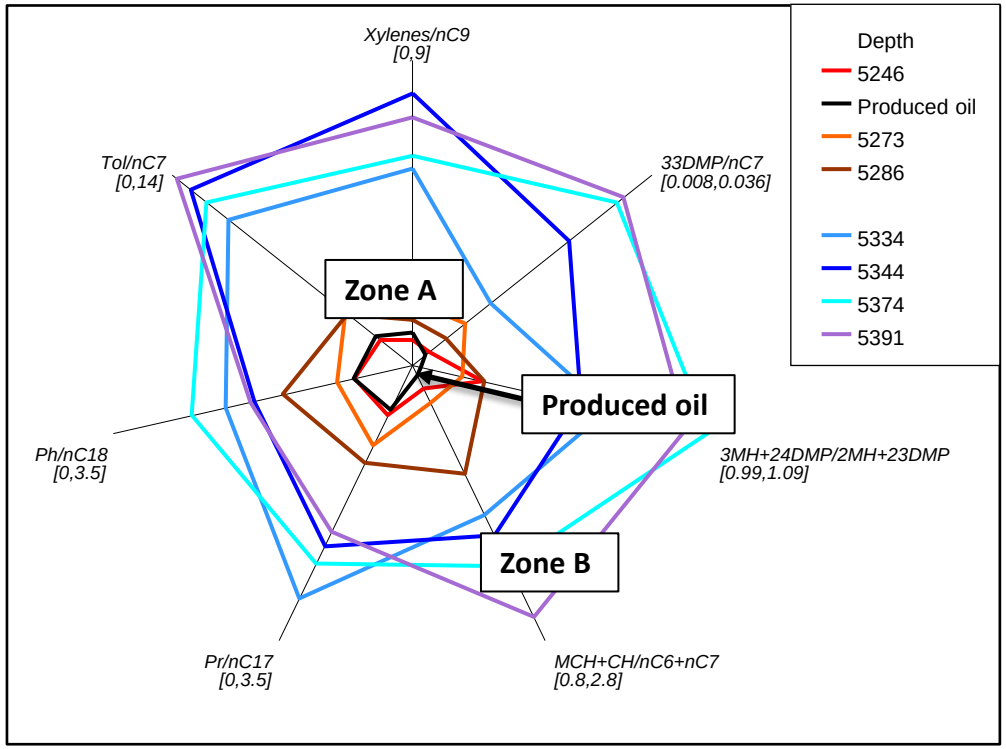
HIGH AROMATICS IN UNTOPPED SAMPLES



- Untopped samples from San Andres oils
- Not water-washing:
  - Oils are enriched in most water-soluble compounds (light aromatic hydrocarbons)
- Evaporative fractionation:
  - Two phases are unseen in most cases but degasification could have occurred if seal was breached and charge was lost

COMPARTMENTALIZATION

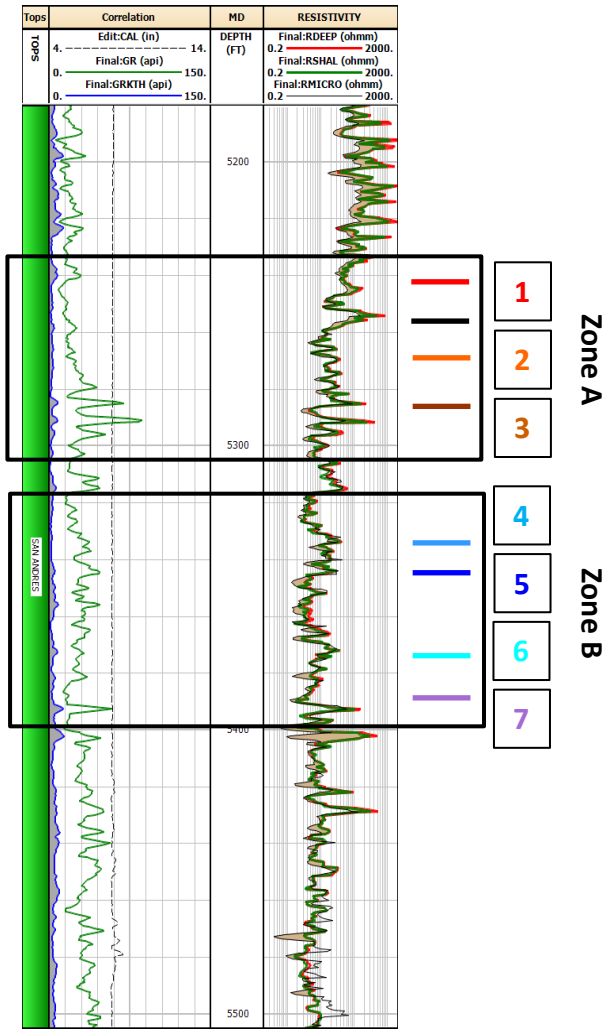


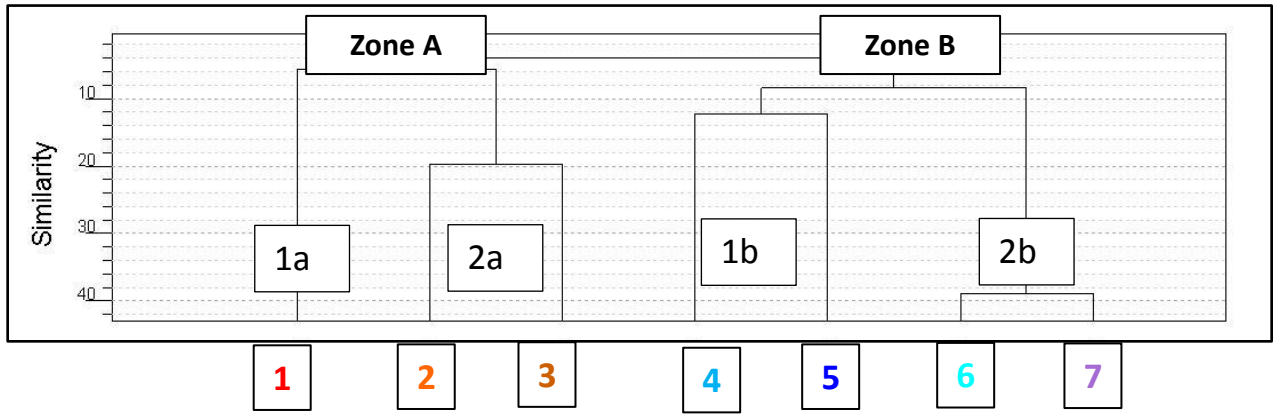


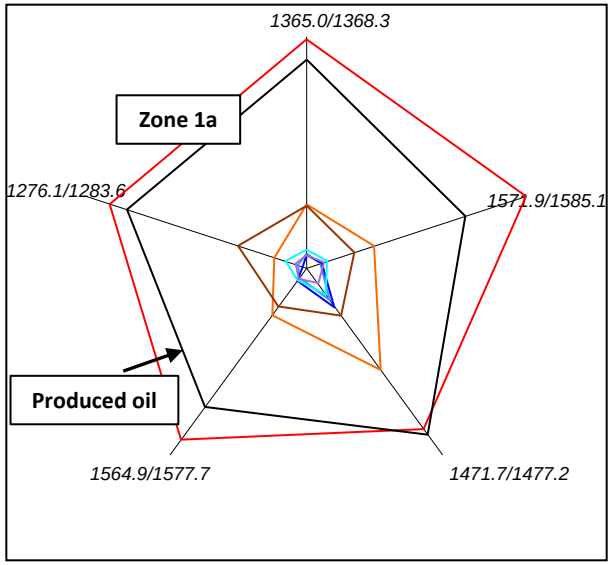
Carbon disulfide core extracts

- Heterogeneous facies in San Andres Fm
- Compartmentalization is expected
- High-resolution WOGC on core extracts and a produced oil sample from a Hz well nearby used to understand:
  - Presence of compartments
  - Drainage height
- Two distinct oil groups have been recognized, in agreement with core description

COMPARTMENTALIZATION







- Additional intra-paraffin peak ratios (N: 105) were used to confirm the grouping of core extracts in two main zones
- Main contribution to produced oil comes from zone A, subzone 1a
- Important results when defining landing zones and optimal stimulation treatment

CONCLUSIONS

- Oil geochemistry data from Guadalupian and Leonardian reservoired oils indicate a carbonate source rock (Type IIs or Class A)
- Wolfcampian-Early Leonardian reservoired oils are of different organofacies and maturity; different petroleum systems
- Most likely scenario for the San Andres Play in NW Shelf: long-distance migration from deeper parts in the basin from Mid-Late Permian marine carbonate source rocks
- Biodegradation in San Andres oils is not a widespread process
- Evidence of vertical compartmentalization from fingerprinting of San Andres core extracts (implications on drainage height and recovery)

RECOMMENDATIONS

- Oil-source rock correlation from Mid-Late Permian source rocks (Bone Spring carbonates/Yeso shelf margin/Delaware Mountain Group) extracts deeper in the basin should be undertaken.

- Biodegradation is not widespread, but observed in some cases. Better understanding of the controls.

- High aromaticity. Additional studies to better explain evaporative fractionation and regional extent.

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