

Organic Geochemical Patterns of Vaca Muerta Shale, Neuquen Basin, Argentina*

Ignacio E. Brisson¹, Martín E. Fasola¹, and Héctor J. Villar²

Search and Discovery Article #11302 (2020)**

Posted February 24, 2020

*Adapted from oral presentation given at AAPG 2019 International Conference and Exhibition, Buenos Aires, Argentina, August 27-30, 2019

**Datapages © 2020 Serial rights given by author. For all other rights contact author directly. DOI:10.1306/11302Brisson2020

¹YPF S.A., Buenos Aires, Argentina (ignacio.brisson@ypf.com)

²GeoLab Sur S.A., Buenos Aires, Argentina

Abstract

The Vaca Muerta (Late Jurassic-Early Cretaceous age) Shale bears a high-quality, oil-prone kerogen deposited under mostly anoxic, marine conditions that constitutes a world-class source rock with outstanding geochemical characteristics for the generation of petroleum (oil and gas) throughout the Neuquén Basin. The unit has been identified as the main source for most of the conventional hydrocarbon pools of the basin, but in the last ten years, it has acquired significance as an unconventional shale resource target for both oil and gas.

An extended database that comprises several tens of thousands of samples, from cuttings, cores, sidewall cores, and outcrops of the Vaca Muerta Formation from wells and sections along the entire basin was evaluated. This allowed formulating patterns of organic richness, hydrocarbon source quality, and distribution of free hydrocarbons in six reference areas of the basin. These reference areas are defined based either on the impact of the sedimentary rock on generated hydrocarbons or on the significant thermal maturity differences. More than 300 Vaca Muerta oils and organic extracts, and nearly 500 mud and production gas samples completed the dataset to assess the key features of the fluids occurring in the prospectable areas for shale oil and shale gas. Moreover, insights into the essential processes of the Vaca Muerta unconventional petroleum system including kerogen-related issues and basin-scale processes are discussed in terms of source rock kinetics, modeling of burial/exhumation histories, porosity development, and occurrence of overpressure.

The basin center stands out as the most attractive area for unconventional development to produce middle-to-light oil with low sulfur content along with gas condensate to the west. Surrounding the basin center, source rock displays similar characteristics but with overall lower thermal maturity. To the north, an area of middle-to-heavy, mostly sulfur-rich oils with minor gas, passes to an overall mid-maturity, middle-to-heavy, sulfur-rich oils predominance. Finally, the comparatively thin organic-rich intervals and low-to-middle thermal maturity of the southern sector of the basin restricts the unconventional prospectivity.

Selected Reference

Brisson, I.E., M.E. Fasola, and H.J. Villar, 2020, Organic geochemical patterns of the Vaca Muerta Shale, in D. Minisini, M. Fantin, I. Lanusse, and H. Leanza, eds., Integrated geology of unconventional: The case of the Vaca Muerta play, Argentina: AAPG Memoir 120, Chapter 11, *in press*.

Organic Geochemical Patterns of Vaca Muerta Shale Neuquen Basin, Argentina

Objectives: Discuss the geochemical characteristics of Vaca Muerta Fm. basinwide to help to understand Vaca Muerta as source rock and as a shale resource system



Ignacio E. Brisson¹, Martín E. Fasola¹ & Héctor J. Villar²

¹- YPF S.A. & ²- GeoLab Sur S.A.



GEOLAB SUR
GEOCHEMICAL LABORATORY

#664, 160-02A Vaca Muerta Play: An Integrated View

August 28th, 2019



PRESENTATION INDEX

01

DATABASE

02

ROCK
GEOCHEMISTRY

03

PETROLEUM
GEOCHEMISTRY

04

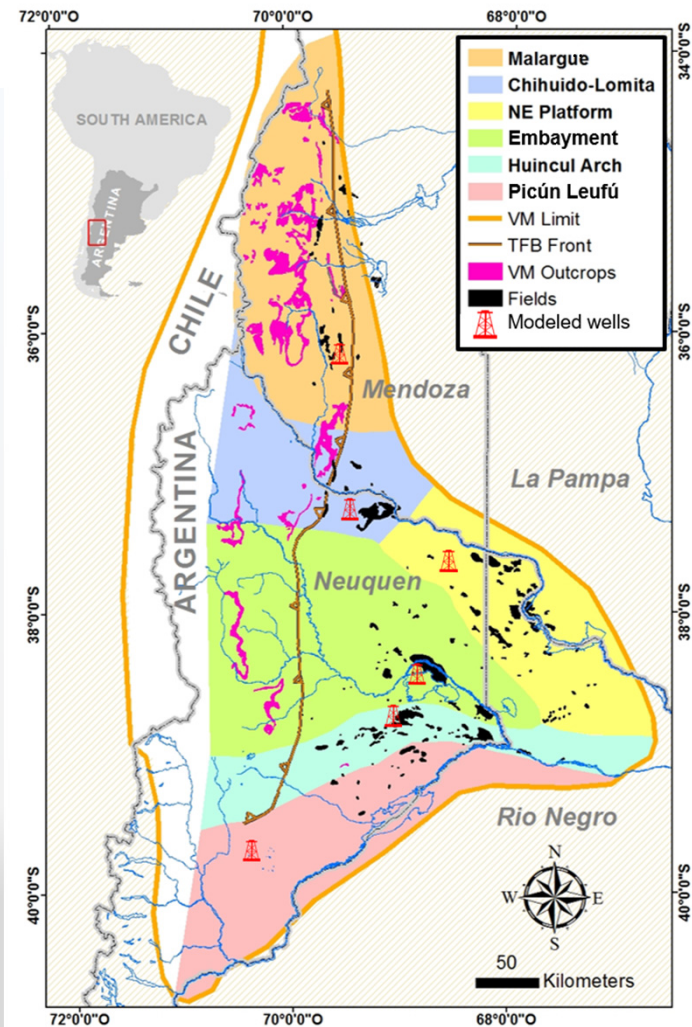
PETROLEUM
SYSTEM
MODELING

05

VACA MUERTA
SHALE PLAY

06

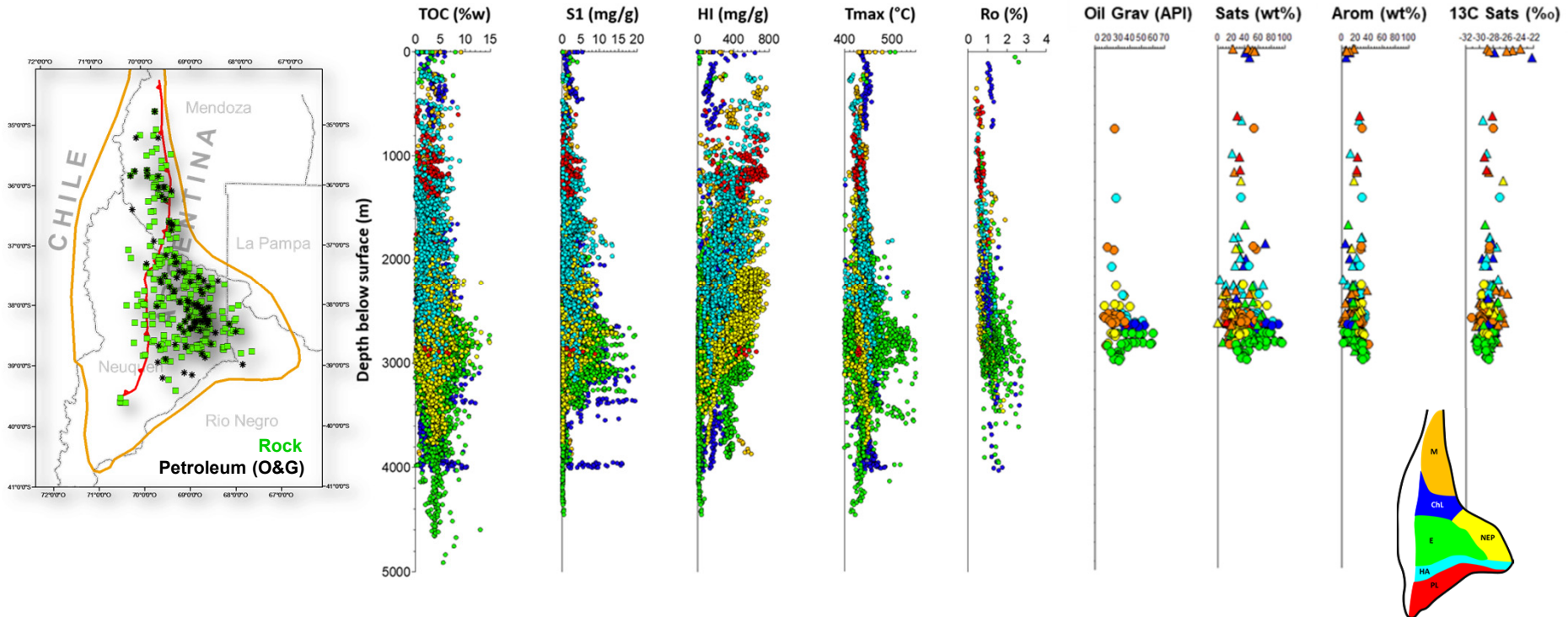
CONCLUSIONS



01- DATABASE

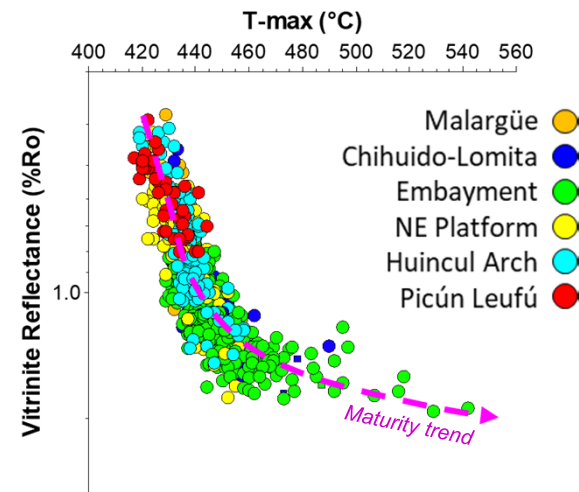
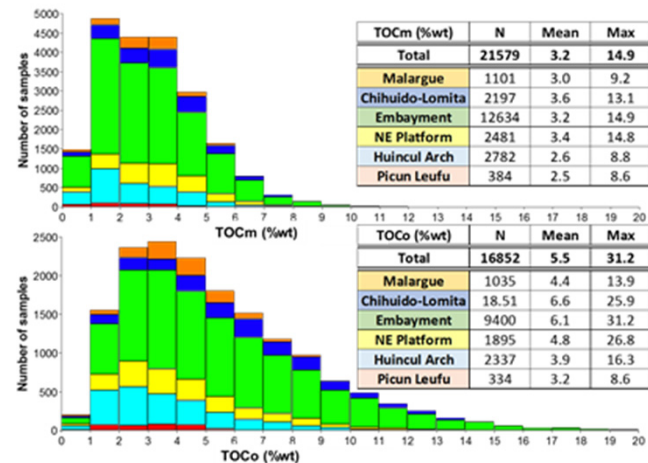
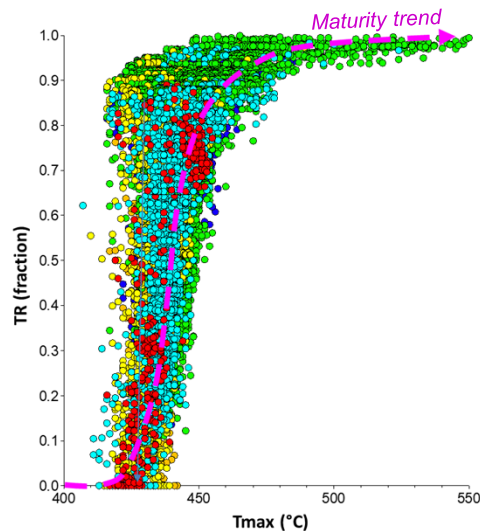
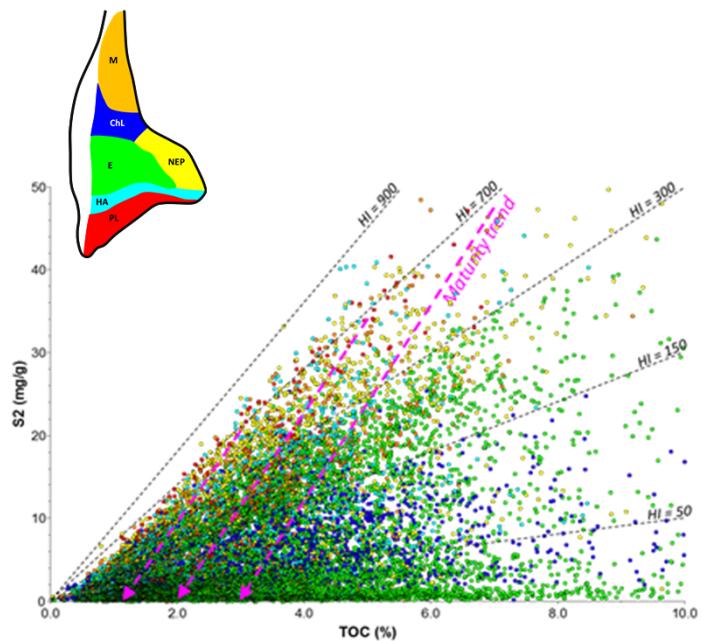
Strong geochemical data base distributed basinwide

- Rocks: ~35,000 samples (TOC, Pyrolysis, VKA, XRF, Isotopes, Kinetics, etc.)
- Oil, Gas & extracts: >300 wells (Density, Sulfur, GC, GC-MS, HTGC, Isotopes, etc.)



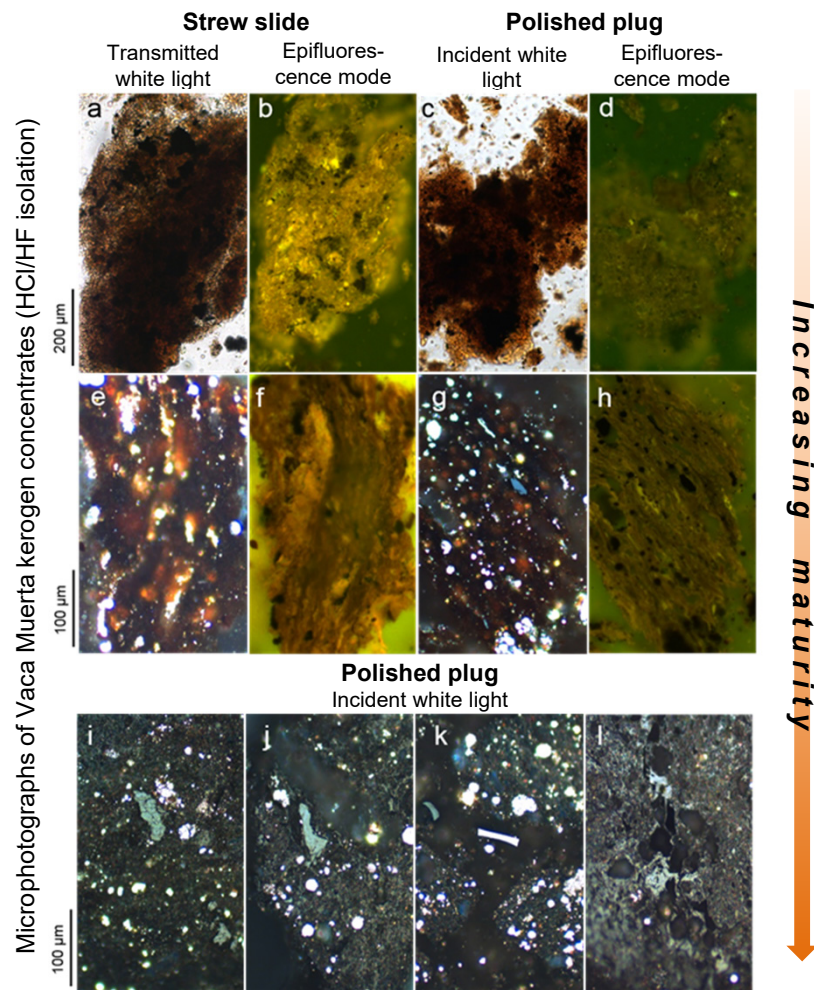
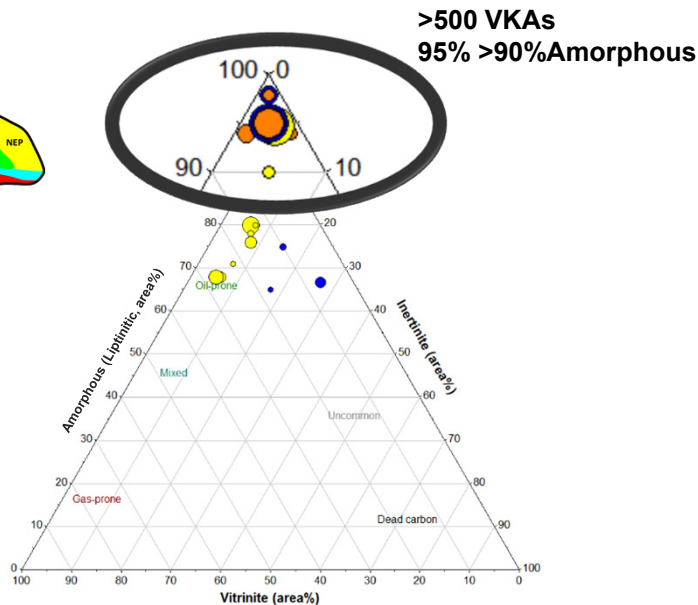
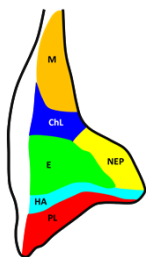
02- SOURCE ROCK GEOCHEMISTRY: RICHNESS, KEROGEN TYPE & QUALITY & MATURITY

- Whole Vaca Muerta (not only VM shale target)
- High present day and initial average TOC: 3.2 & 5.5%_{wt}
- High original HI: >600mg_{HC}/g_{TOC}
- Rapid transformation rate
- Tmax: good maturity indicator in the oil window



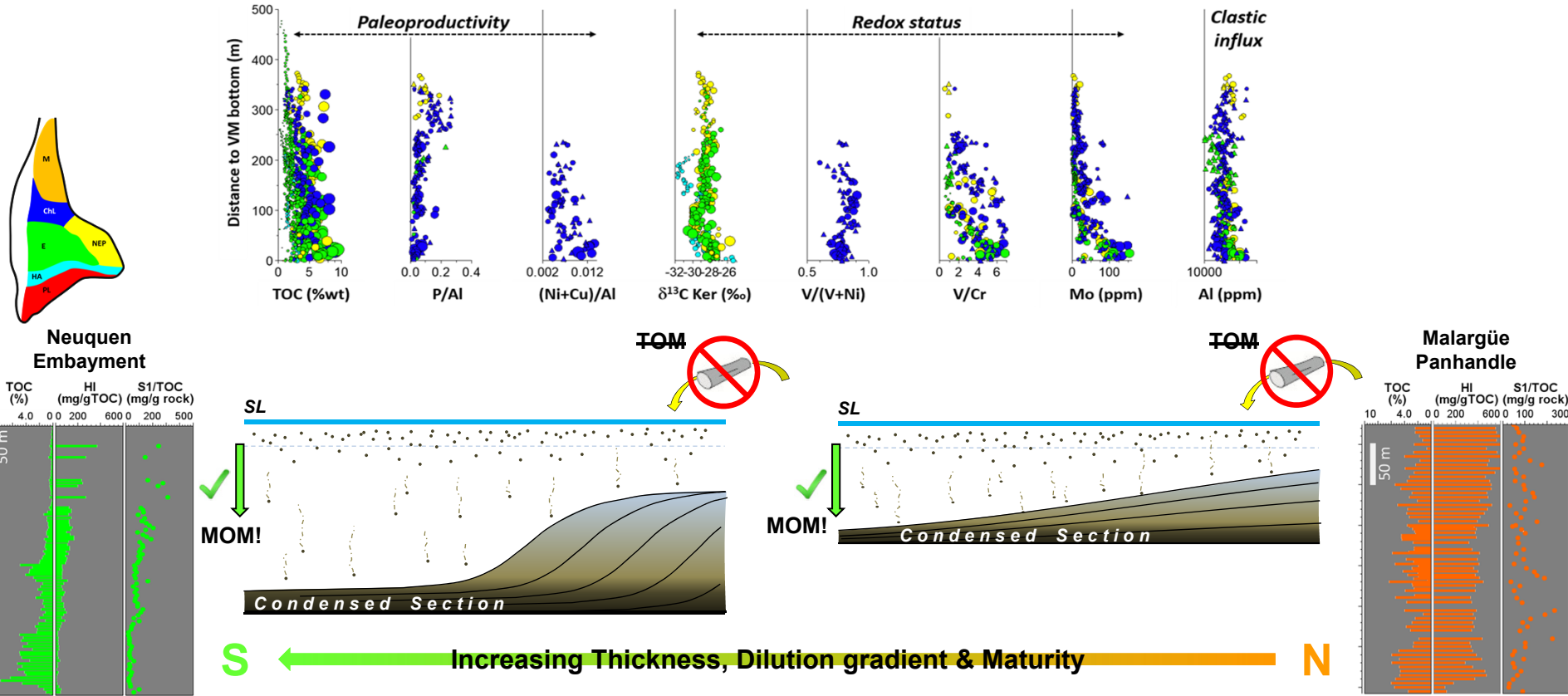
02- SOURCE ROCK GEOCHEMISTRY: ORGANIC MATTER COMPOSITION

- Kerogen predominantly Amorphous (Liptinitic)
- Homogeneous indigenous marine organic matter
- Scarce to absent Vitrinite to assess maturity
- No optically detectable variations across the basin and through time (Tithonian-Berriasian)



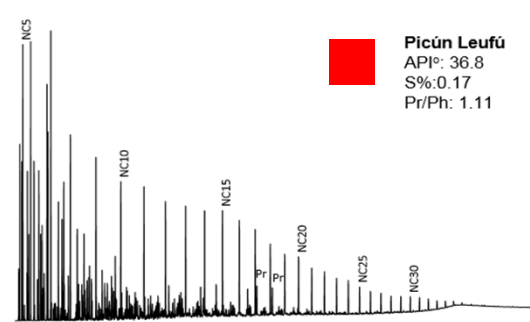
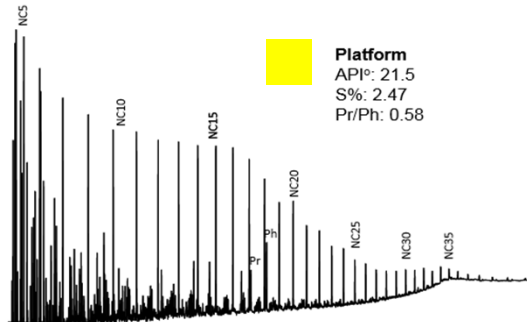
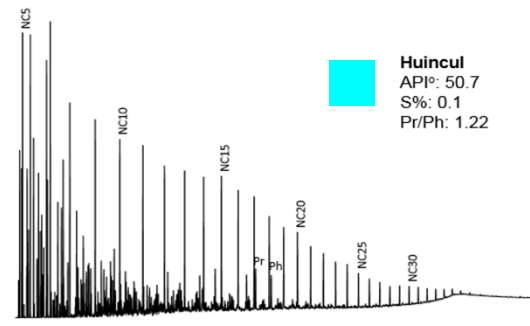
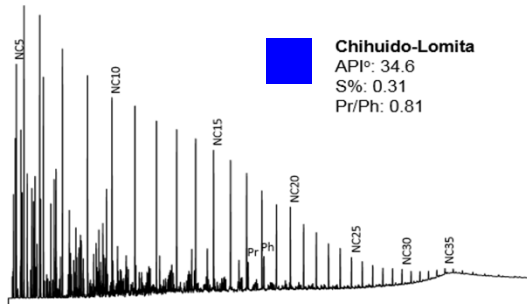
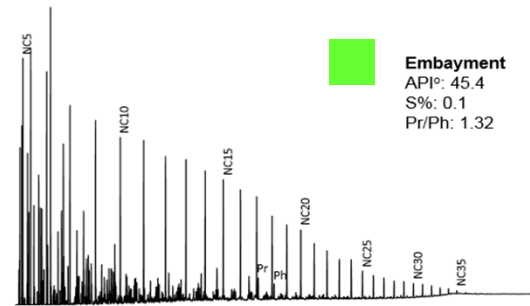
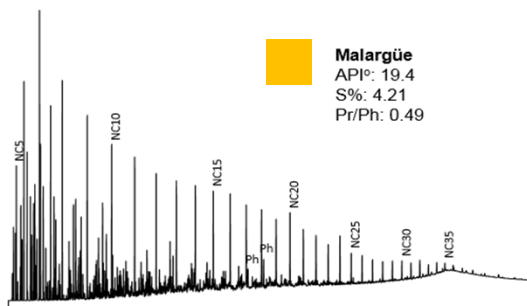
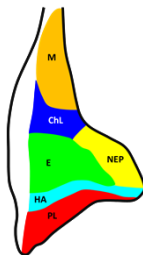
02- SOURCE ROCK GEOCHEMISTRY: ORGANIC MATTER DEPOSITION

- High bioproductivity basinwide and through time, high TOC at the base (condensed section)
- Sedimentation controlled richness and yield by dilution and reducing anoxia upward



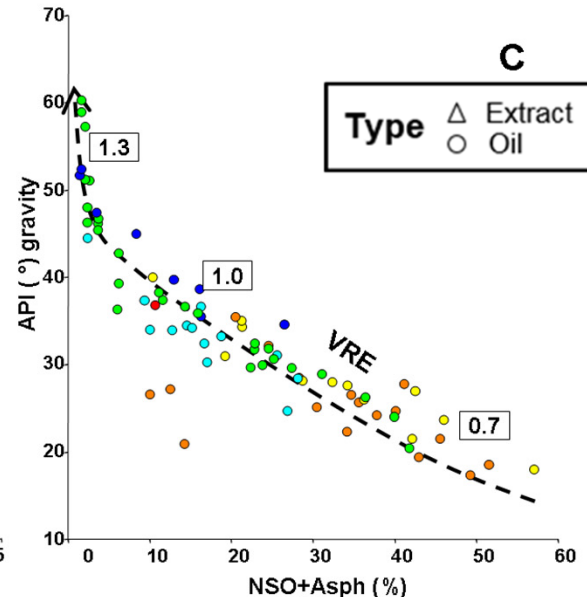
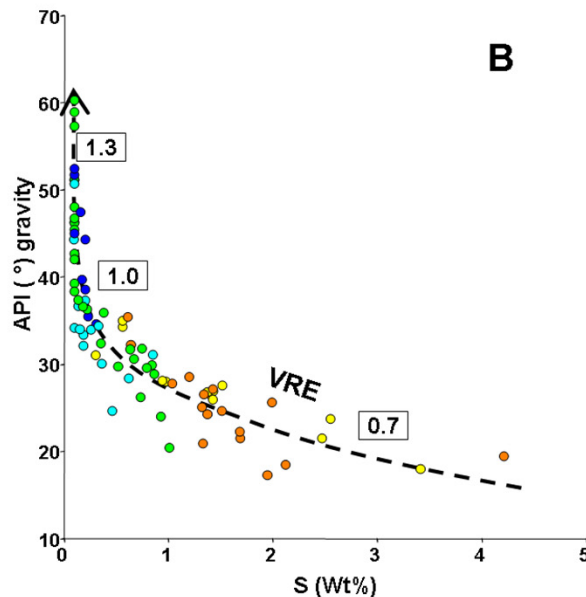
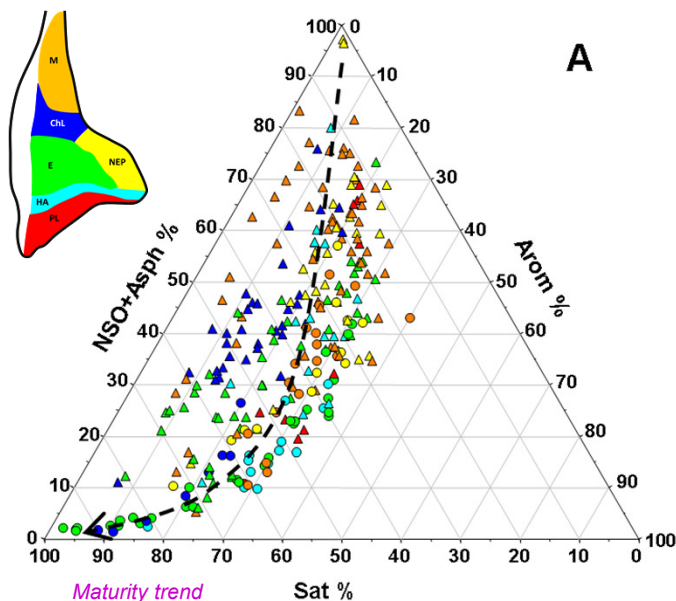
03- PETROLEUM GEOCHEMISTRY: OILS PROPERTIES & FINGERPRINTS

- Similar marine n-paraffins envelope
- API° range: 19-50
- %S: 0.1-4 (higher to the North)
- Pr/Ph: 0.49-1.32
- Highly to moderately anoxic



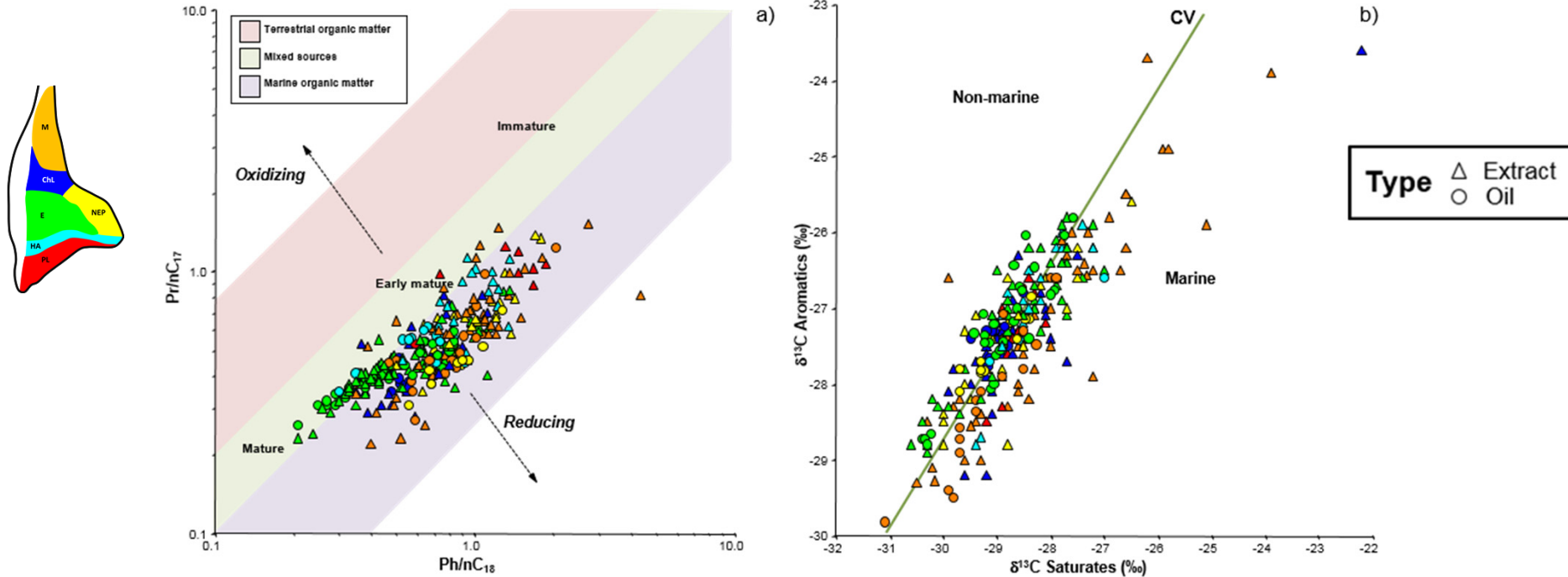
03- PETROLEUM GEOCHEMISTRY: OILS PROPERTIES & COMPOSITIONAL CHARACTERISTICS

- 86 oils + 230 rock organic extracts (“retained oils”) of Vaca Muerta
- Broad compositional range in oils (20-95% Saturates)
- Bulk composition and API gravity mostly controlled by thermal maturity



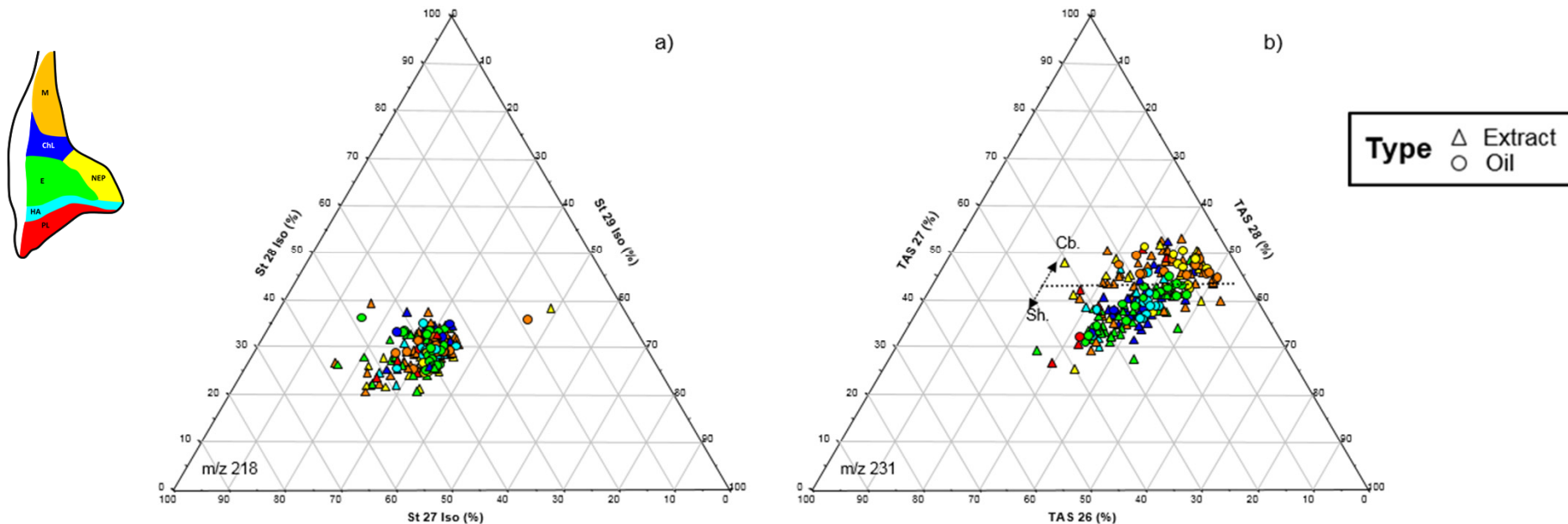
03- PETROLEUM GEOCHEMISTRY: ORGANIC MATTER DEPOSITIONAL ENVIRONMENT

- Bacterial-aquatic marine OM (nonwaxy) predominance



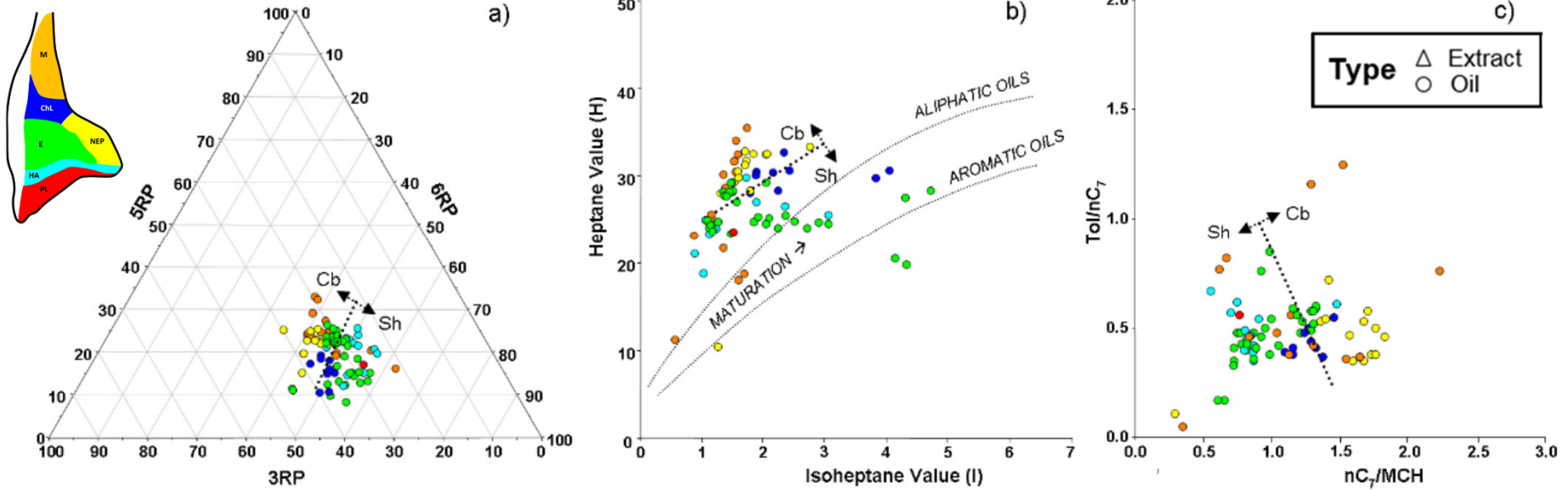
03- PETROLEUM GEOCHEMISTRY: ORGANIC MATTER DEPOSITIONAL ENVIRONMENT

- Bacterial–aquatic marine organic matter, with scarce-to-null terrestrial contribution
- Highly to moderately anoxic paleoenvironments



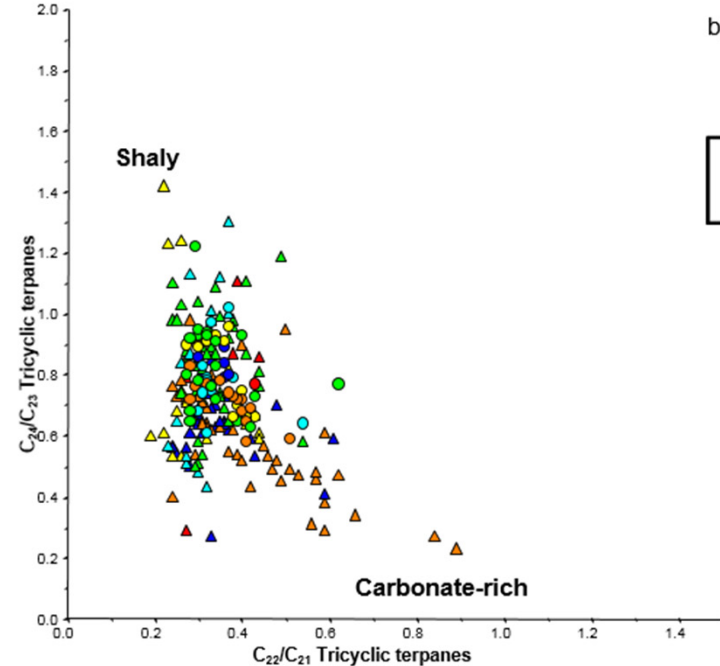
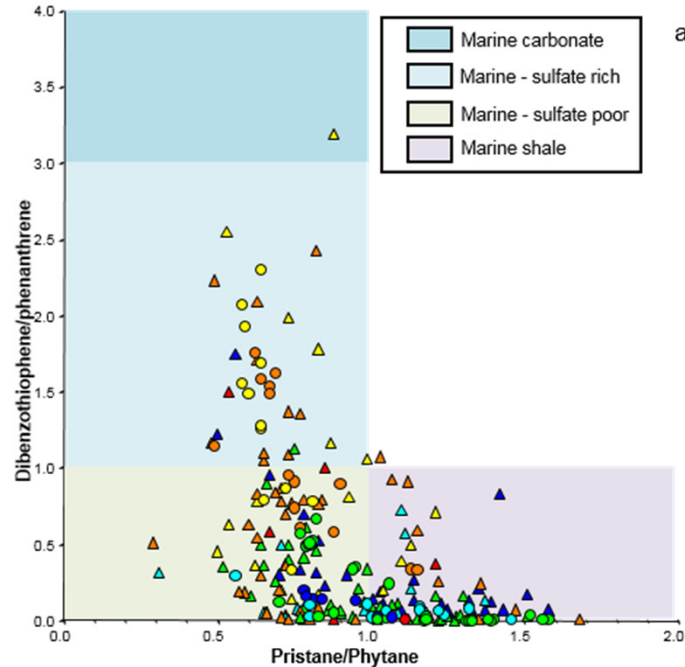
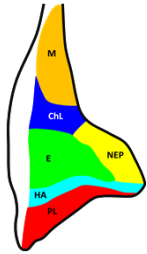
03- PETROLEUM GEOCHEMISTRY: LITHOLOGICAL CHARACTERISTICS (LIGHT HC PATTERNS)

- Mostly aliphatic oils
- Shaly-rich vs carbonate-rich sourced oils



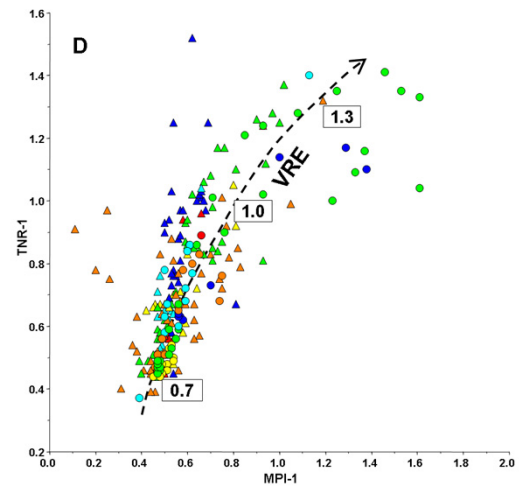
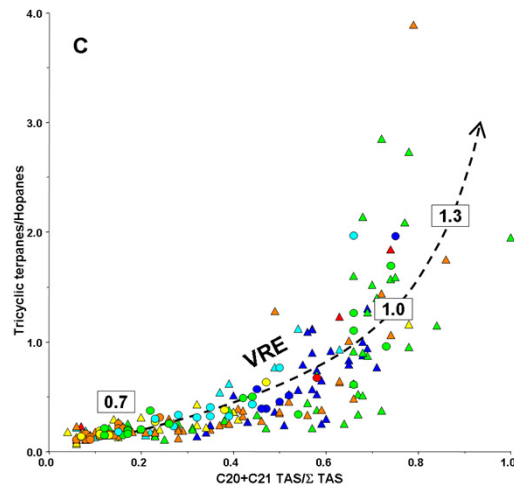
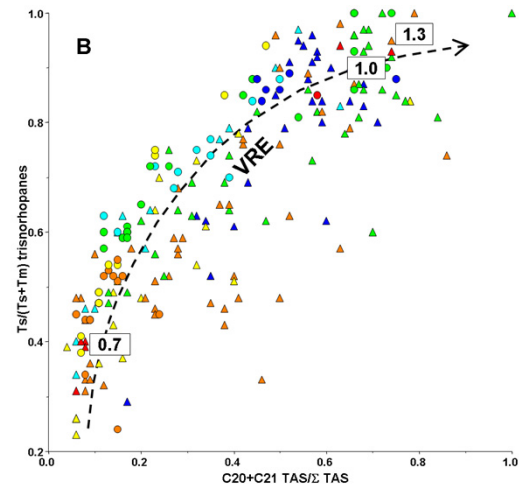
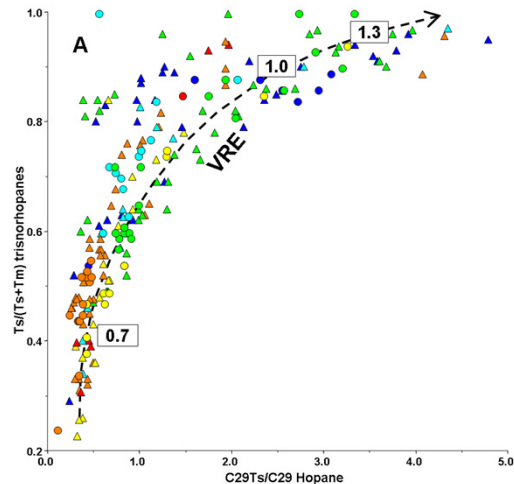
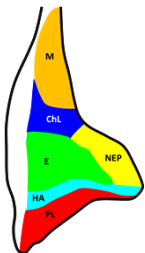
03- PETROLEUM GEOCHEMISTRY: LITHOLOGICAL CHARACTERISTICS (BIOMARKERS)

- Fluids of the central areas, differentiate from those of the periphery which show as carbonate-rich and more reducing.



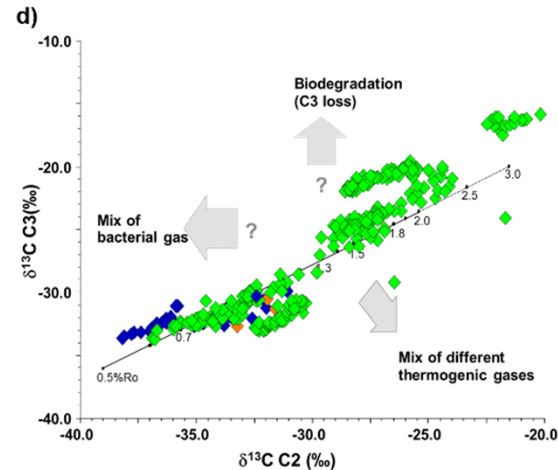
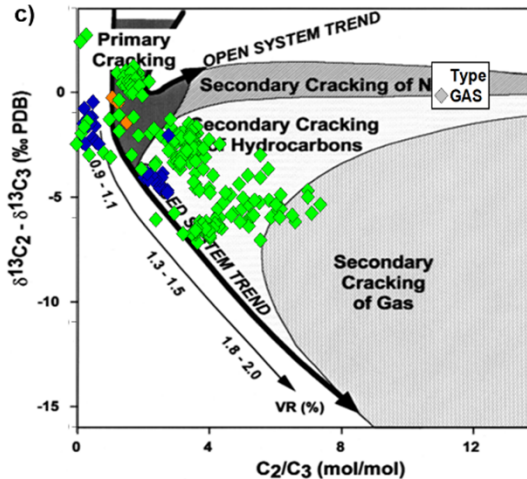
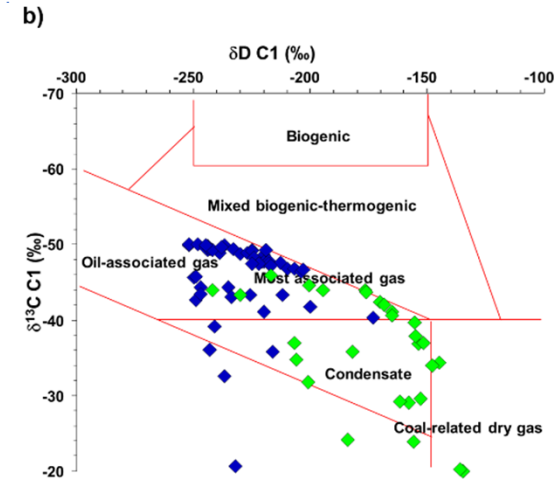
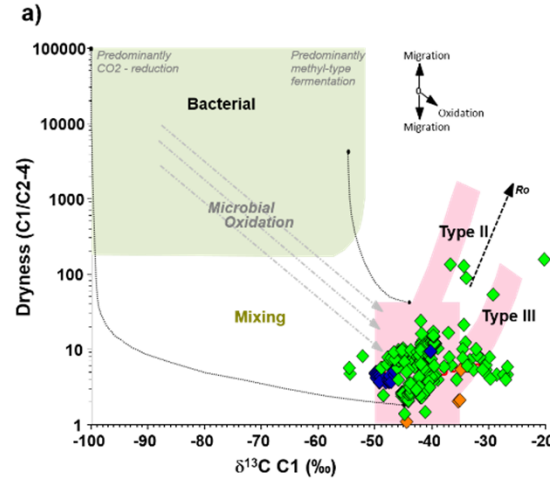
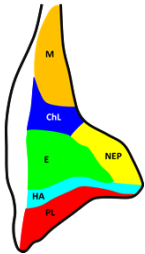
03- PETROLEUM GEOCHEMISTRY: THERMAL MATURITY

- Good correlation between GCMS and rock maturity indicators
- Trends as proxies to estimating maturity of the produced oils



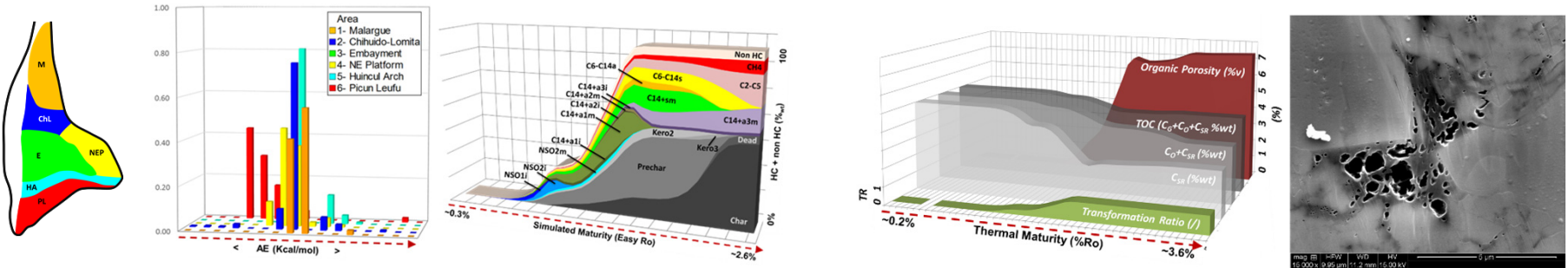
03- PETROLEUM GEOCHEMISTRY: GAS CHARACTERISTICS

- +500 samples from 30 wells (mud gas and production)
- Thermogenic marine origin (type II kerogen)
- Gases associated to oil and gas reservoirs
- Gas cracking recognized
- Very good match is observed between gas & rock maturity
- Excellent correlation with %TOC



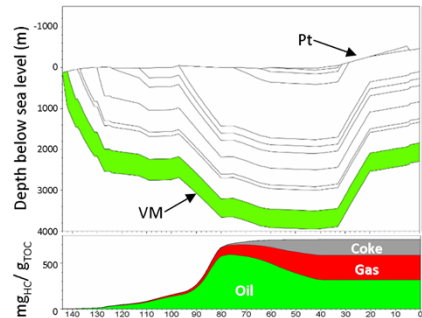
04- PETROLEUM SYSTEMS MODELING

- Basin NOT at maximum burial at present day: posthumous exhumation
- Different onset of oil generation by region
- Different kinetics by regions: rock interaction?
- Good to predict organic porosity development and to quantify hydrocarbon retention



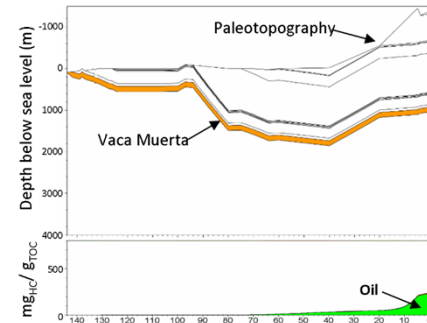
Embayment

S



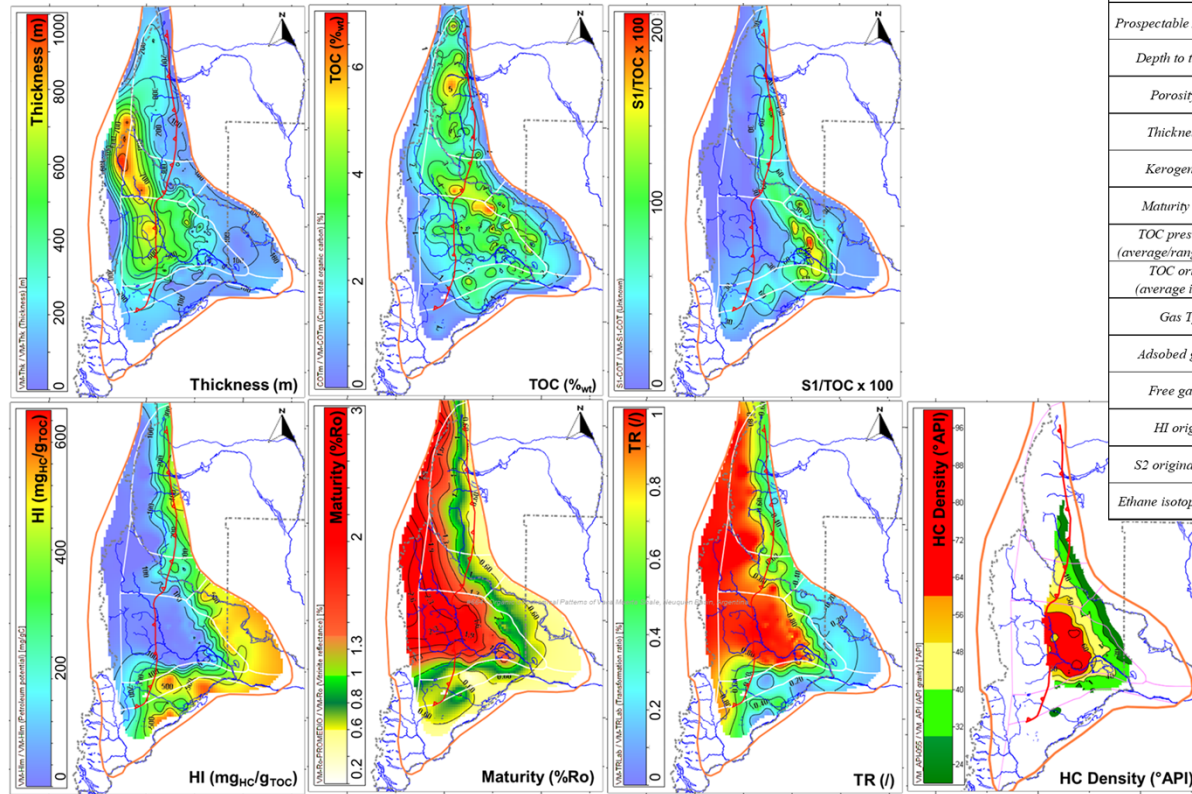
Malargüe

N



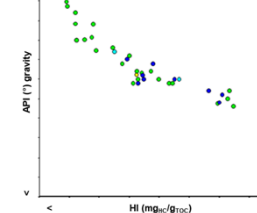
05- VACA MUERTA SHALE RESOURCE PLAY

- VM surpasses all the geochemical thresholds for a source rock shale play
- Values are in the order of most of the producing US shale plays



Parameters	SHALE PLAYS						
	Barnett	Haynesville	Marcellus	Eagle Ford	Woodford	Fayetteville	Vaca Muerta
Basin	Fort Worth	Salt	Appalachian	Eagle Ford	Arkoma	Arkoma	Neuquén
Age(Ma)	Mississippian	Late Jurassic	Devonian	Cretaceous	Devonian	Mississippian	Late Jurassic-Early Cretaceous
Prospectable Area (km ²)	13,000	23,000	250,000	5,000	20,000	23,000	30,000
Depth to top (km)	2.0 - 2.6	3.2 - 4.2	1.2 - 2.6	1.2 - 3	1.8 - 3.4	1.7	2.0 - 3.5
Porosity (%)	4.0 - 6.0	4.0 - 14.0	4.0 - 12.0	6.0 - 14.0	3.0 - 9.0	2.0 - 8.0	4.0 - 12.0
Thickness (m)	60 - 300	60 - 90	60	30 - 90	30 - 270	15 - 100	30 - 350
Kerogen Type	II	III	II - III	II-III	II	II - III	II - IIS
Maturity (%Ro)	0.85 - 2.1	1.2 - 2.4	0.9 - 5.0	0.8 - 1.6	0.7 - 4.0	2.0 - 4.5	0.8 - 3.0
TOC present-day (average/range in wt.%)	3.74 (3 - 12)	3.01 (0.5 - 4)	4.01 (2 - 13)	2.76 (2 - 8.5)	5.34 (3 - 12)	3.77 (2 - 10)	4.11 (2.0 - 14.9)
TOC original (average in wt.%)	5.92	7.79	8.2	4.24	9.33	5.74	6.78
Gas Type	Thermogenic	Thermogenic	Thermogenic	Thermogenic	Thermogenic	Thermogenic	Thermogenic
Adsorbed gas (%)	55	25	45	25	60	50-70	30
Free gas (%)	45	75	55	75	40	50-30	70
HI original	434	722	507	411	503	404	680
S2 original (mg/g)	25.65	55.51	40.33	17.42	46.91	23.18	46.11
Ethane isotopic rollover	Yes	Yes	Yes	Yes	Usually		Occasionally

Excellent Δ API vs HI_m correlation (only Hz wells production)

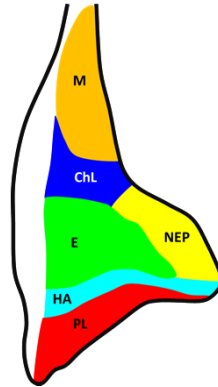


06- Conclusion-I: **VACA MUERTA ORGANIC GEOCHEMICAL PATTERNS, NEUQUEN BASIN**

- VM is an excellent source rock with high organic content and quality.
- No significant change in kerogen type is detected by pyrolysis or microscopy across the basin and time. However, GC and biomarker fingerprints show significant changes in depositional environment from shaly-moderately reducing to carbonate-anoxic.
- Organic richness, thickness, and thermal maturity increase basinward being the most attractive generation pools to the west.
- The dataset shows that the VM exceeds all the standard geochemical cutoffs for unconventional shale plays.
- The vast kitchen extention and the successful hydrocarbon production position the VM as a world-class shale resource system.
- The petroleum system modeling help to predict fluid types and to identify sweet spots based on retained volume within the source rock and organic porosity development.

06- Conclusion-II: VACA MUERTA ORGANIC GEOCHEMICAL PATTERNS, NEUQUEN BASIN

- The Neuquen Embayment is the most attractive area for unconventional development to produce middle-to-light oil with low sulfur content in addition to gas condensate to the west.
- The surrounding areas have similar characteristics and overall lower thermal maturity but can also host significant liquid and gas accumulation within the source rock.
- The Malargüe area shows comparable minor thickness, lower TOC, mid-maturity and predominantly sulfur-rich oils.
- The Picún Leufú area has only minor conventional production history related to the low source rock potential resulting from a thin organic-rich interval and low-to-mid-maturity.



Organic Geochemical Patterns of Vaca Muerta Shale Neuquen Basin, Argentina

Thanks for your attention

YPF



GEOLAB SUR
GEOCHEMICAL LABORATORY

