

La Geoquímica en la Evaluación de Recursos de *Shale-oil* y *Shale-gas*

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Los recursos potenciales de *Shale* en Argentina

Argentina Basins

Geological and Geochemical Keys of the Potential Shale Resources

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(1)



Patagonia
Exploración s.a.



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Six productive petroliferous basins include **eleven source rock units** with potential for unconventional oil and gas:

- **Five** marine source rocks
- **Six** lacustrine source intervals, one of them just mentioned due to reduced areal distribution and limited knowledge.

Key features to be presented:

- Map of regional distribution and thermal maturity
- Total Organic Carbon (TOC%) content
- Rock-Eval pyrolysis (kerogen type)
- Visual Kerogen Analysis (VKA)
- Source Quality/Thermal Maturity (Oil – Gas – Mixed)
- Thickness range
- Depth range

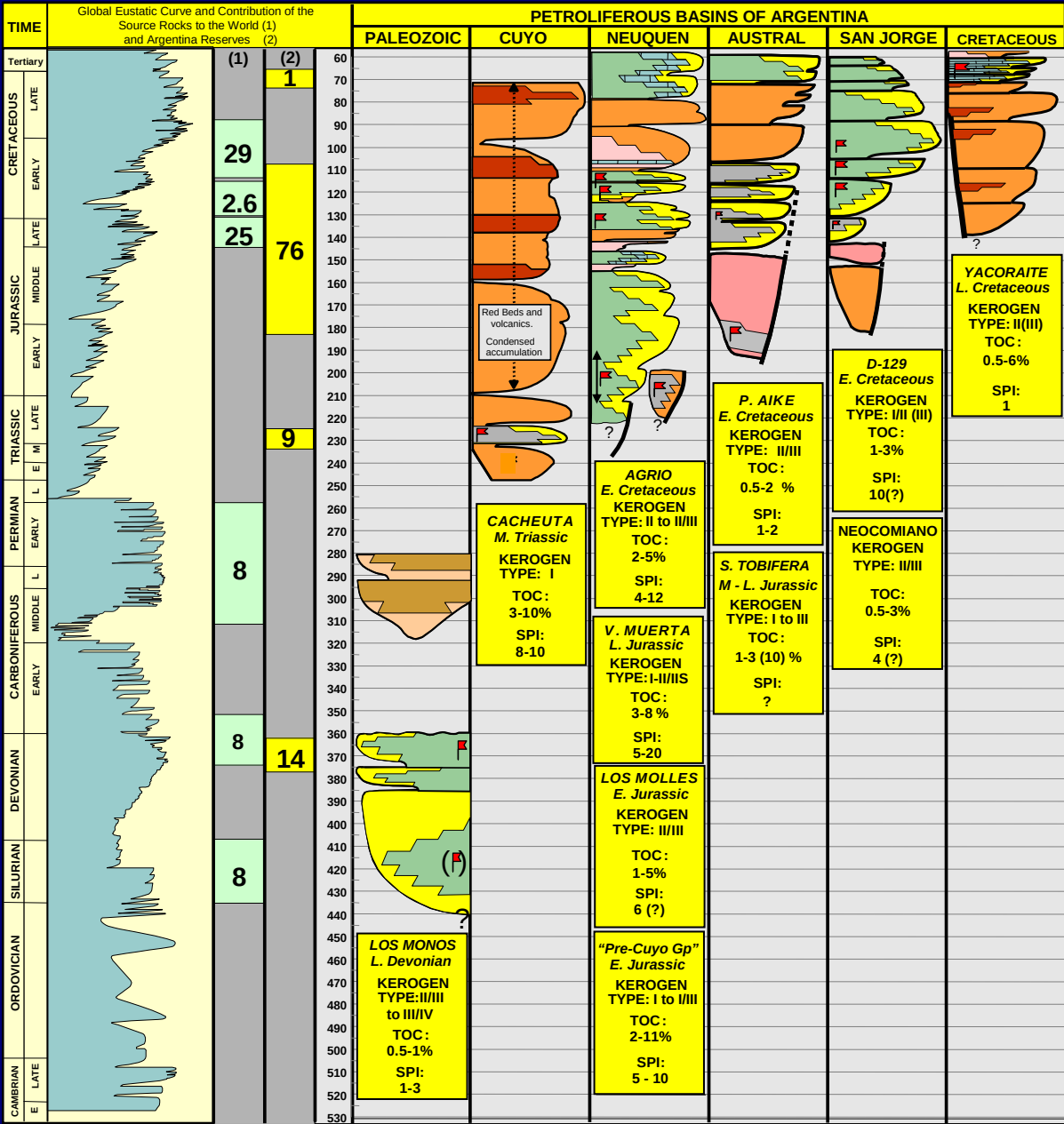
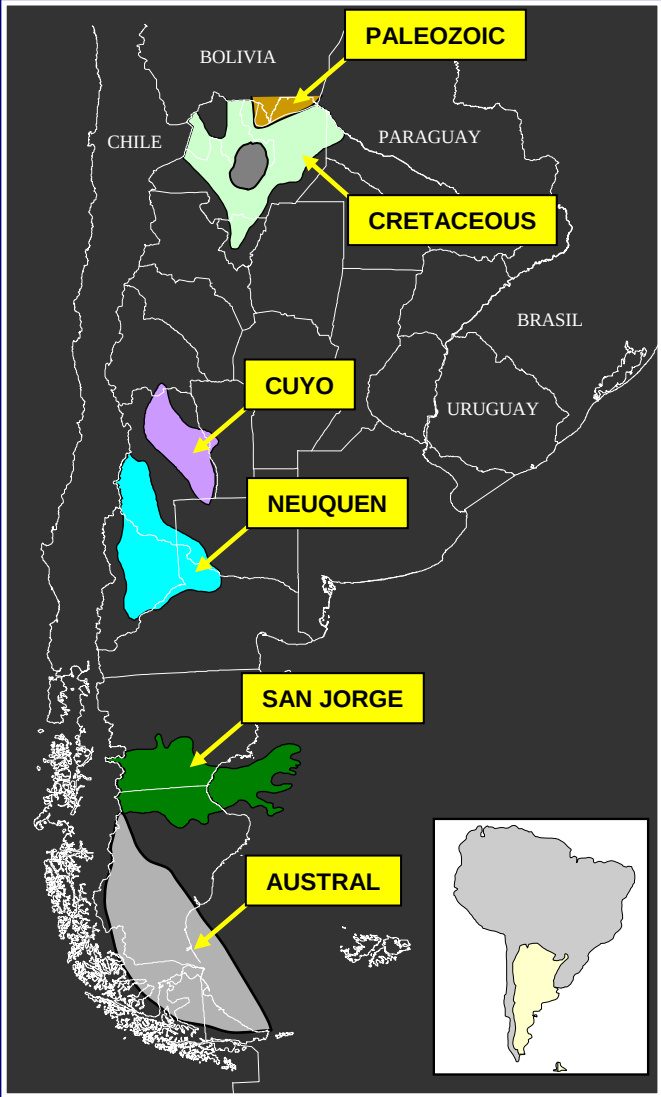
Other properties such as mineralogy, porosity, permeability, rock mechanics, fluid content, and adsorption capacity are excluded from this presentation since their public knowledge is very limited or inexistent

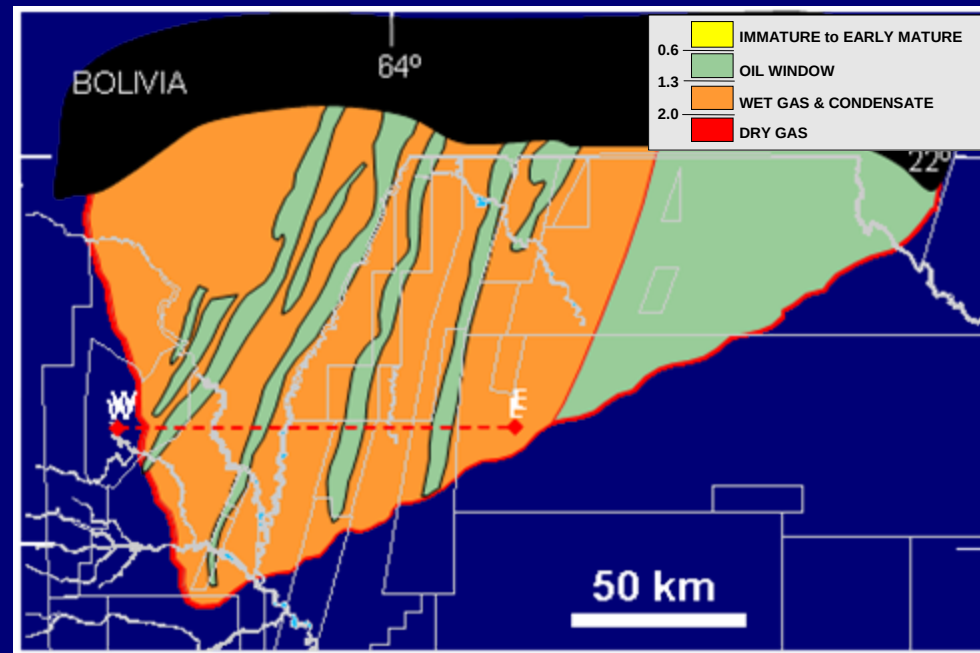
Data obtained from 1990-2010 public domain literature

Petroliferous Basins of Argentina

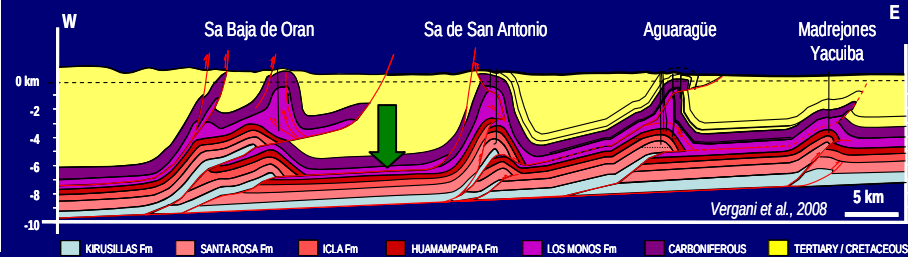
Stratigraphy of the Source Rocks

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Accumulated mainly during Late Devonian under marine conditions within an underfilled foreland system



TOC: 0.5-1.0%, rarely over 1.5%

Kerogen Type: II/III to III/IV

VKA: algal-amorphous, with variable terrestrial contribution

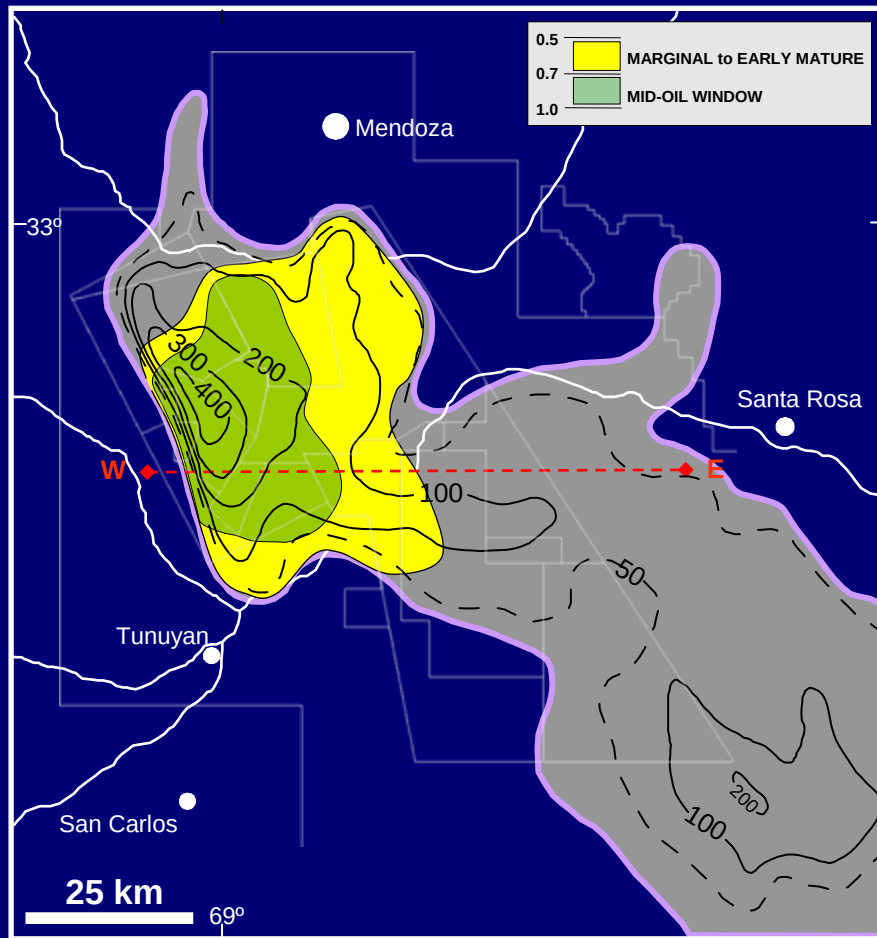
Source Quality/Maturity: poor to mediocre, dominantly gas-prone, compensated by its significant thickness and wide areal distribution

Thickness: 500 to 1000 m

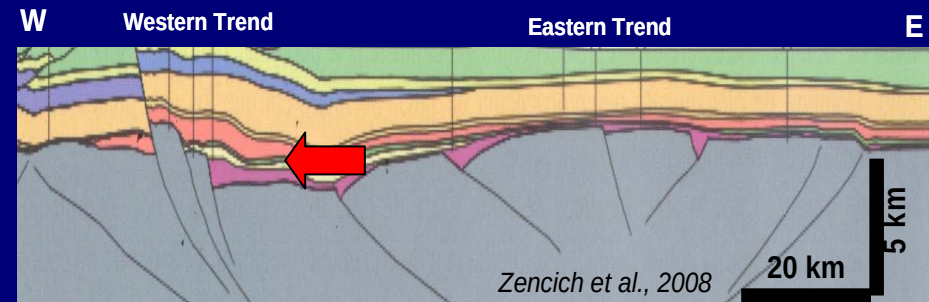
Cuyo Basin

Cacheuta Fm (Triassic)

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Deposited in deep lakes, with main depocenters coinciding with the axis of important asymmetric troughs, developed on top of a collapsed Late Paleozoic orogen



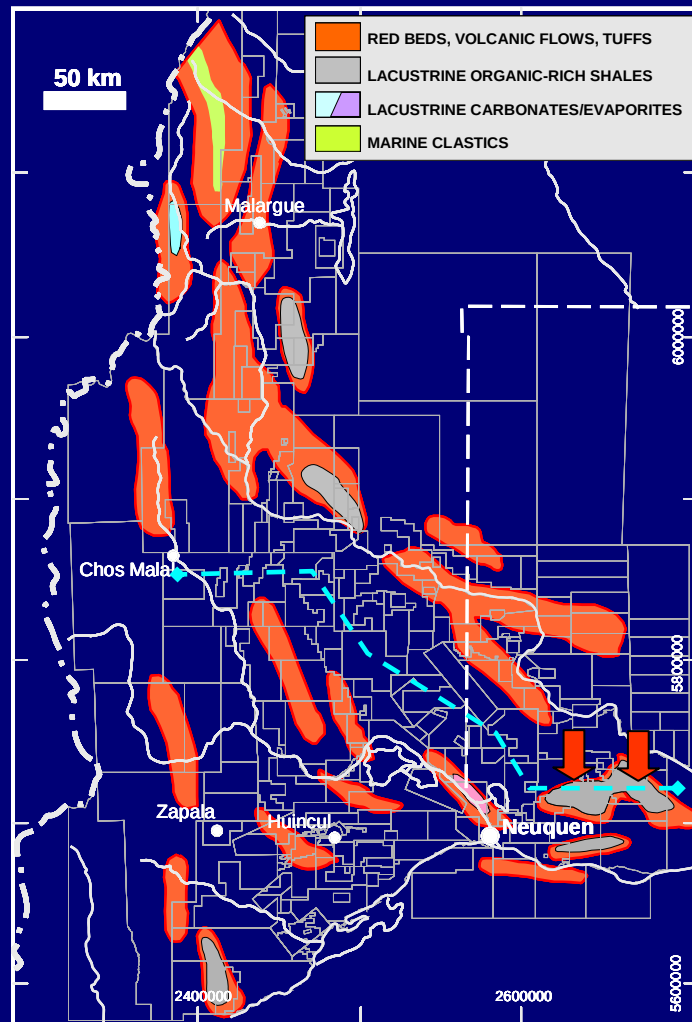
TOC: 3-10%

Kerogen Type: I

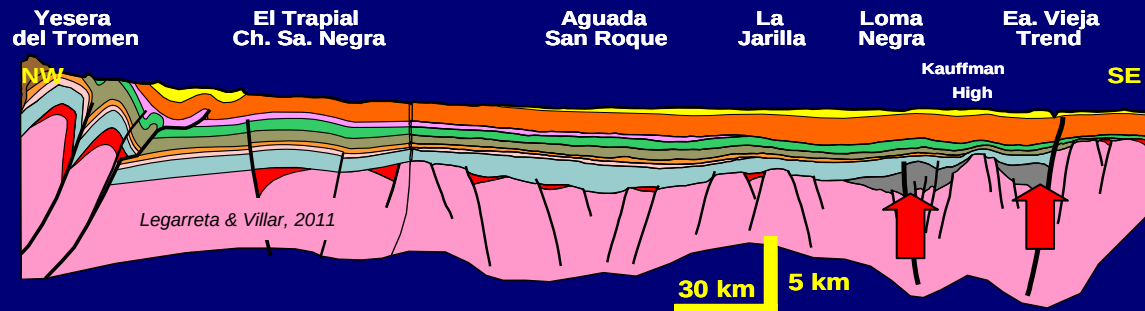
VKA: algal (*Botryococcus*-rich)-amorphous, with minor terrestrial contribution

Source Quality/Maturity: Overall low thermal maturity of the source rock at a basin scale, balanced by an excellent generating capability of the Tupungato kitchen. Waxy oils; nearly no gas production

Thickness: 50 to 400 m



Organic-rich shales were documented within few geographically constrained half-grabens, accumulated within deep lakes with restricted bottom conditions



TOC: 2-11%

Kerogen Type: I to mixed I/III

VKA: algal-amorphous, variable contribution of terrestrial plants

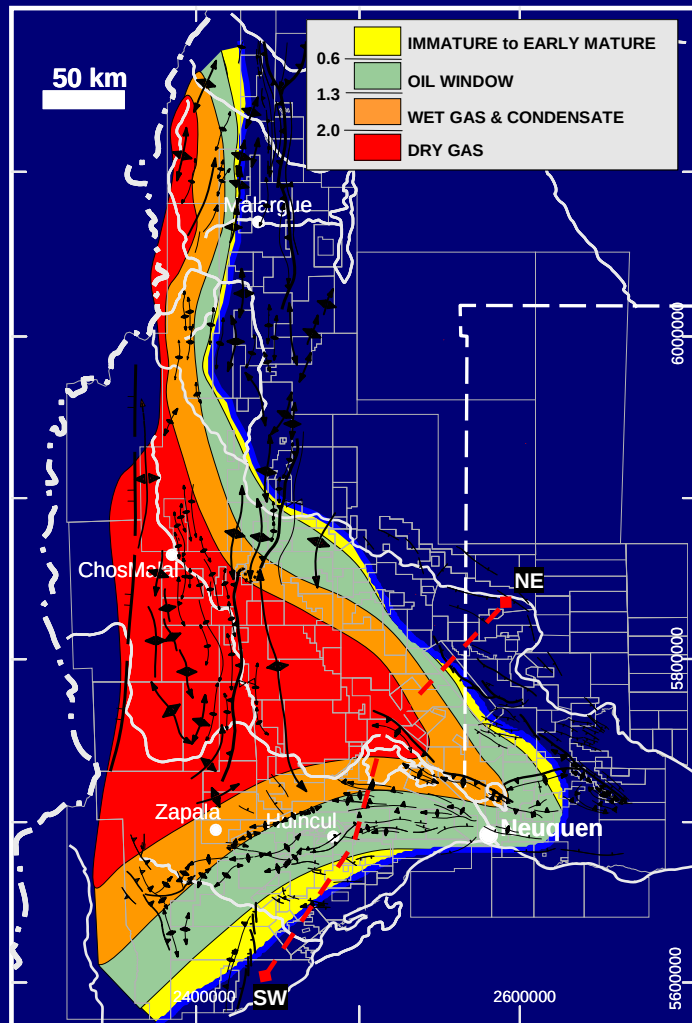
Source Quality/Maturity: highly variable in each depocenter, mostly oil-prone; very variable maturities, from marginally mature to late mature

Thickness: 50 to over 1100 m, variable in each depocenter

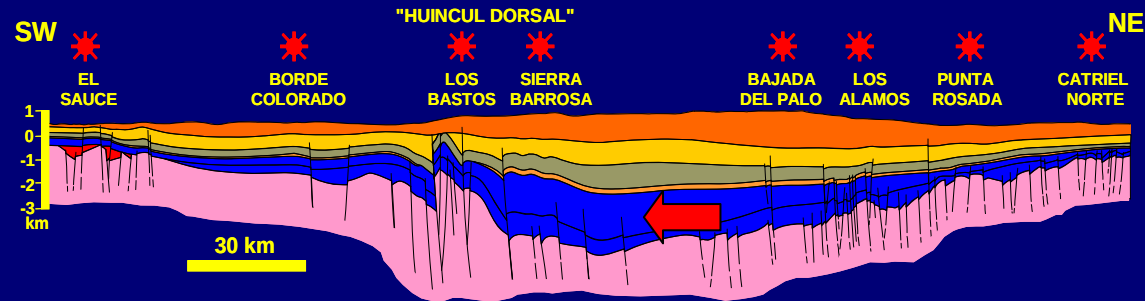
Neuquén Basin

Los Molles Fm (Early Jurassic)

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Organic-rich shales accumulated during first basinwide marine flooding, locally affected by an irregular sea-bottom topography associated with the initial rifting of the basin



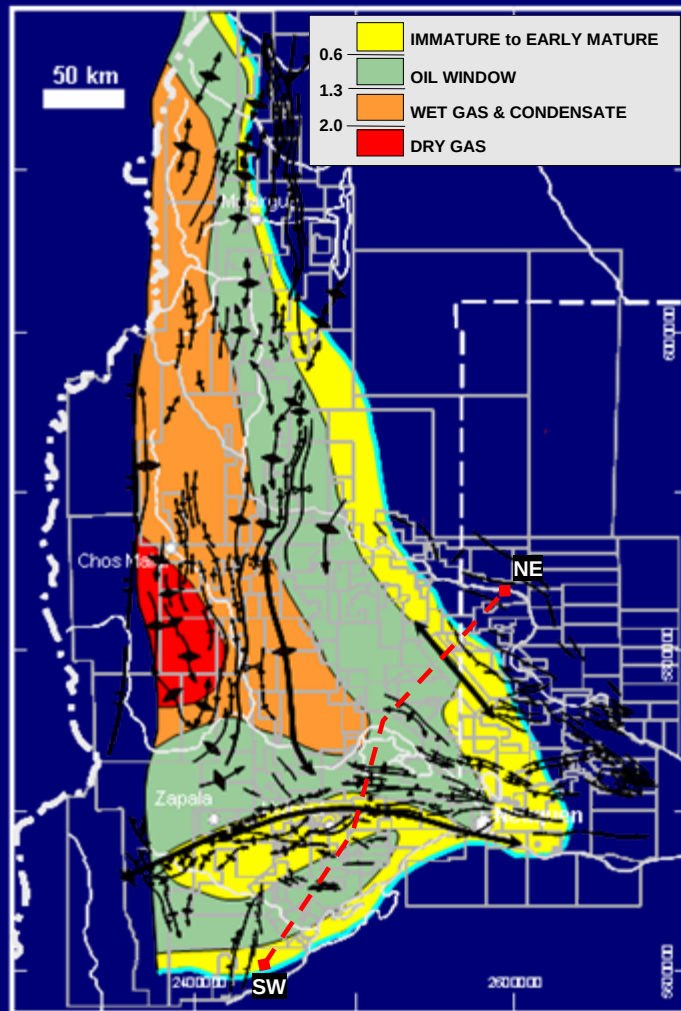
TOC: 1-5%

Kerogen Type: II-III

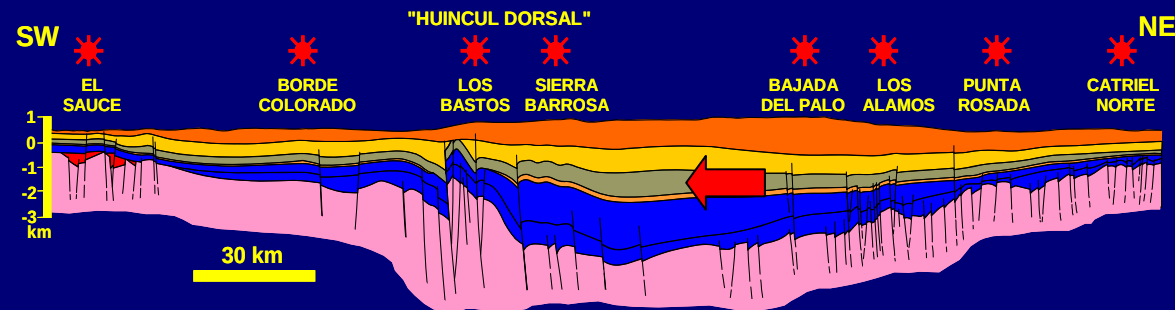
VKA: variations from algal-amorphous to terrigenous

Source Quality/Maturity: mixed for oil and gas. Highly expanded gas kitchen

Thickness: 100 to 800 m. In coincidence with the axis of some Pre-Cuyo half-grabens, Los Molles thickness and TOC content could be controlled by localized ponds



Organic-rich facies developed in a backarc marine embayment, under anoxic conditions, in tune with the Jurassic-Cretaceous ups and downs of eustasy



TOC: 3-8%

Kerogen Type: I/II; locally restricted **type II-S** facies in marginal areas

VKA: high-quality **amorphous**

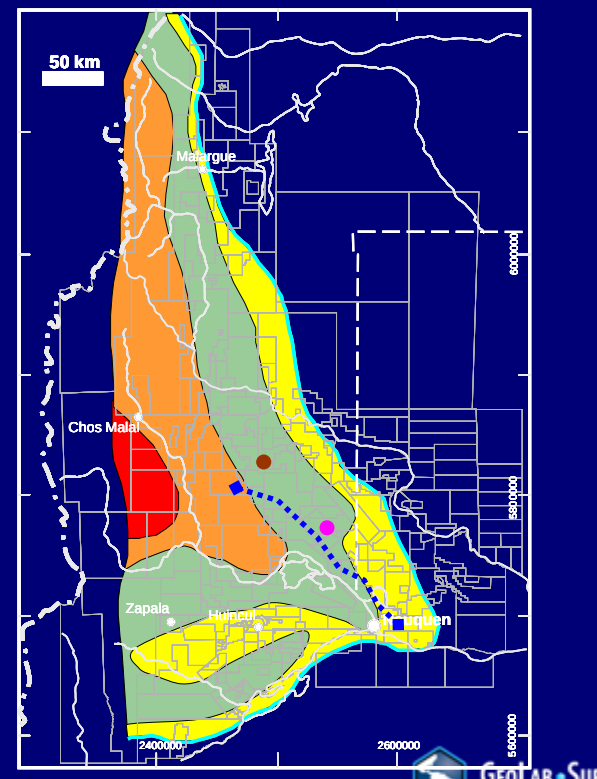
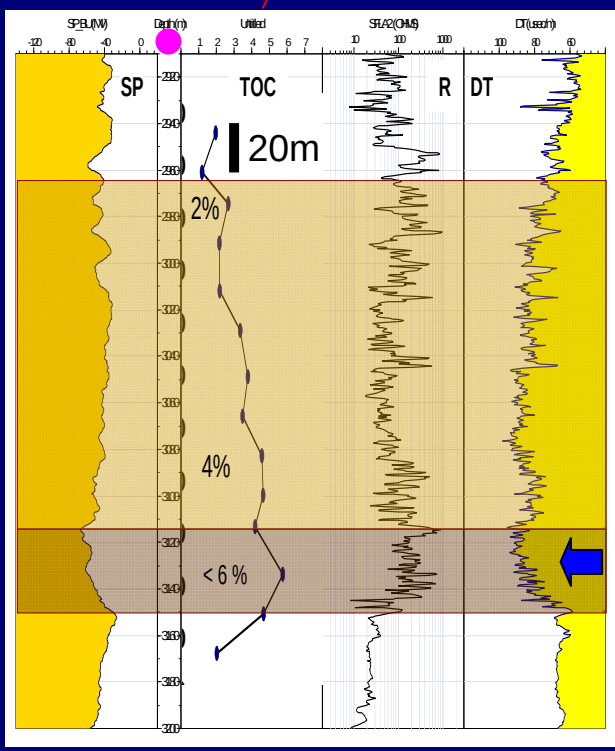
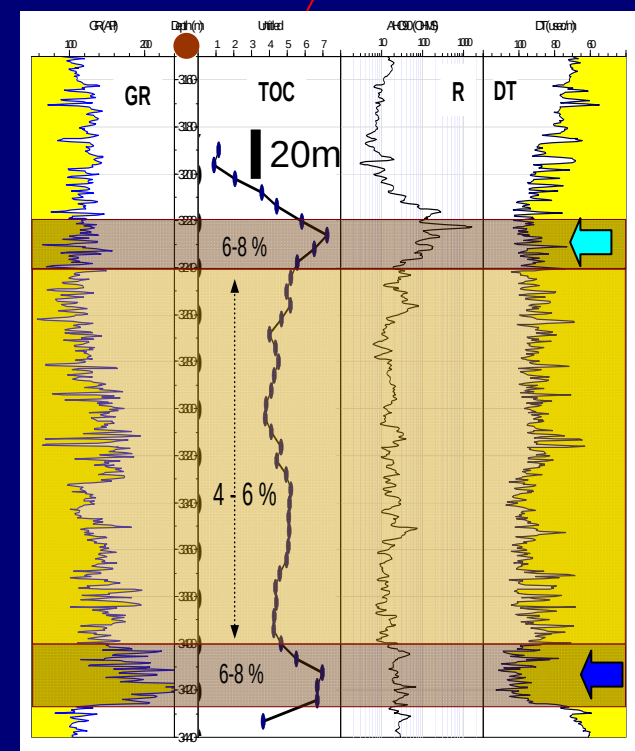
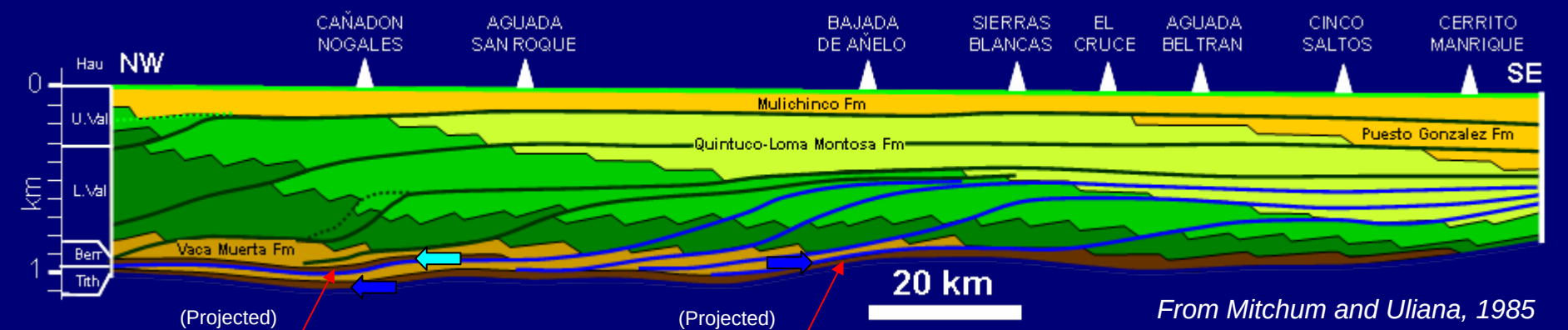
Source Quality/Maturity: extremely prolific, world-class source rock for liquid hydrocarbons; gas and condensate accumulations related to a well developed hydrocarbon kitchen

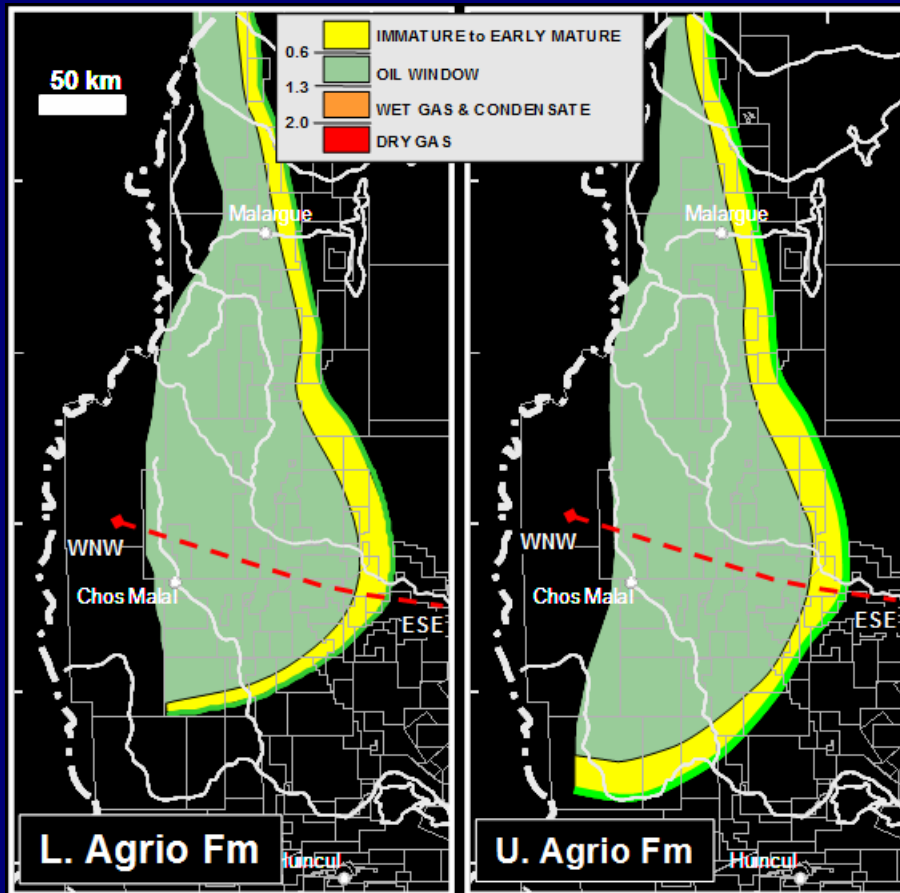
Thickness: 25 to 450 m

Neuquén Basin

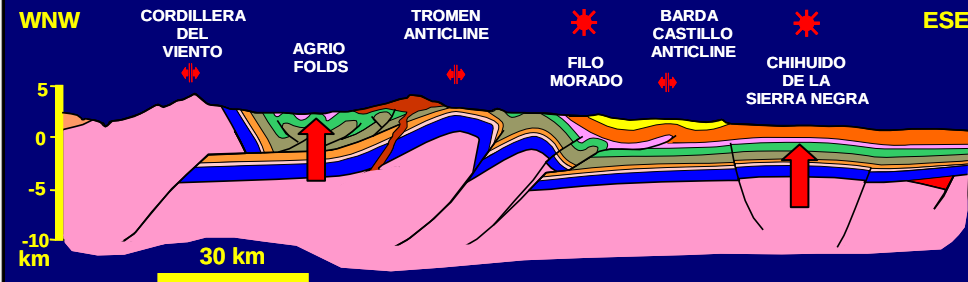
Vaca Muerta Source Rock: Lateral and Vertical Variations

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Organic-rich shales accumulated under anoxic conditions, during two Hauterivian marine flooding events



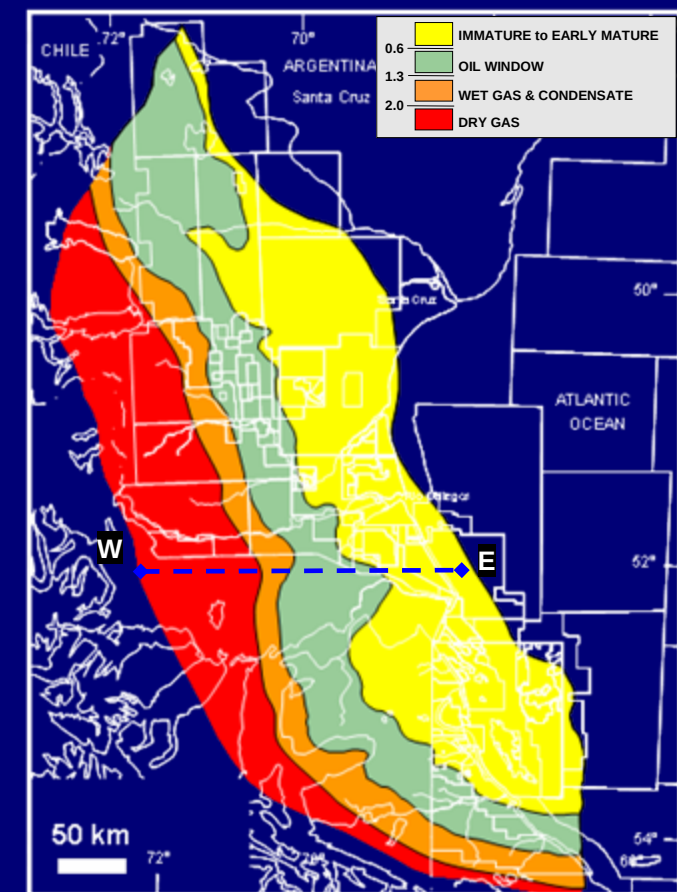
TOC: 2-5%

Kerogen Type: II to II-III

VKA: amorphous, with minor to occasionally significant terrestrial influence

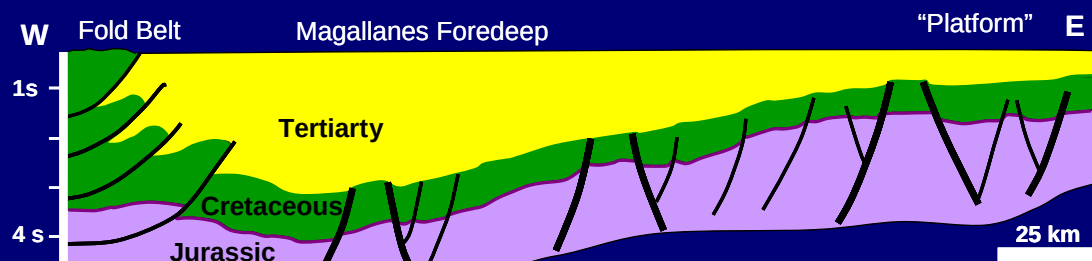
Source Quality/Maturity: dominantly oil-prone; no defined core within the gas generation phase

Thickness: 50 to 400 m



Accumulation of the organic-rich shales is related to the anoxic impingement on the sagging fringe of the South America slab during the Neocomian marine flooding

Also, Jurassic source rock accumulated under restricted lacustrine conditions within small-size half-grabens



TOC: 0.5-2%

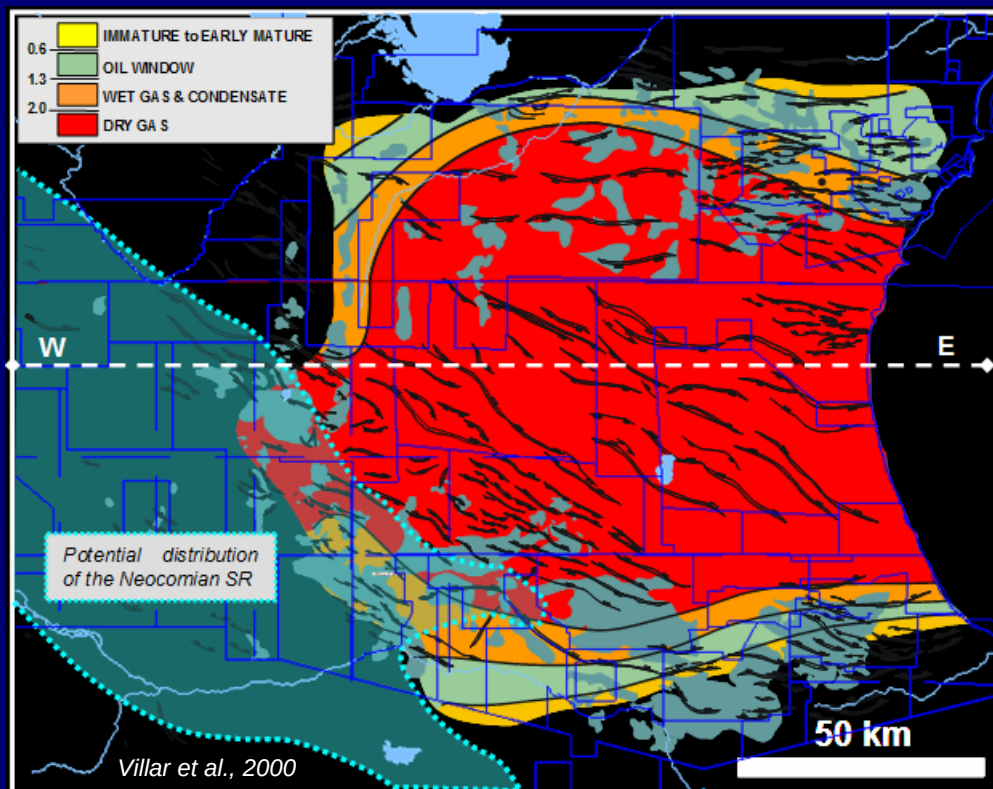
Kerogen Type: II-III

VKA: poorly preserved **amorphous**

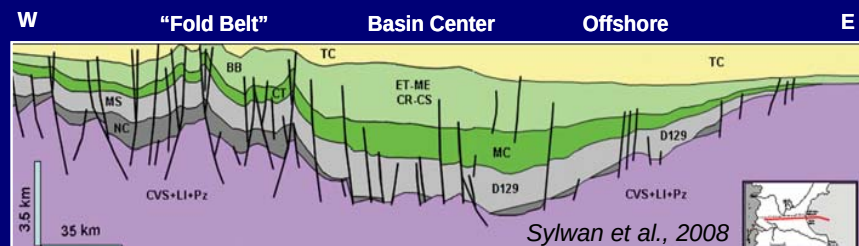
Source Quality/Maturity: Fair generation for liquids and gas. High GOR ratios related to the delayed expulsion of generated hydrocarbons

Thickness: 50 to 400 m

Tobifera: very scattered rock information; lacustrine **type I to III** kerogen, **mixed aquatic-terrestrial**
TOC: **1-3%**; isolated layers over 10% (carbonaceous shales); variable maturity



Accumulated within a series of stacked lacustrine systems located in asymmetric depocenters, partially associated with the Jurassic-Cretaceous midplate volcanism



D-129

TOC: 1-3%

Kerogen Type: I/II (III)

VKA: amorphous algal, minor terrestrial contribution

Source Quality/Maturity: oil-prone; unknown basinward deep facies likely with a higher oil-proneness. “Ring” maturity pattern: from severe overmaturation in the basin center to moderate maturation in the flanks

Thickness: 100 to 2000? m, estimated in the basin center

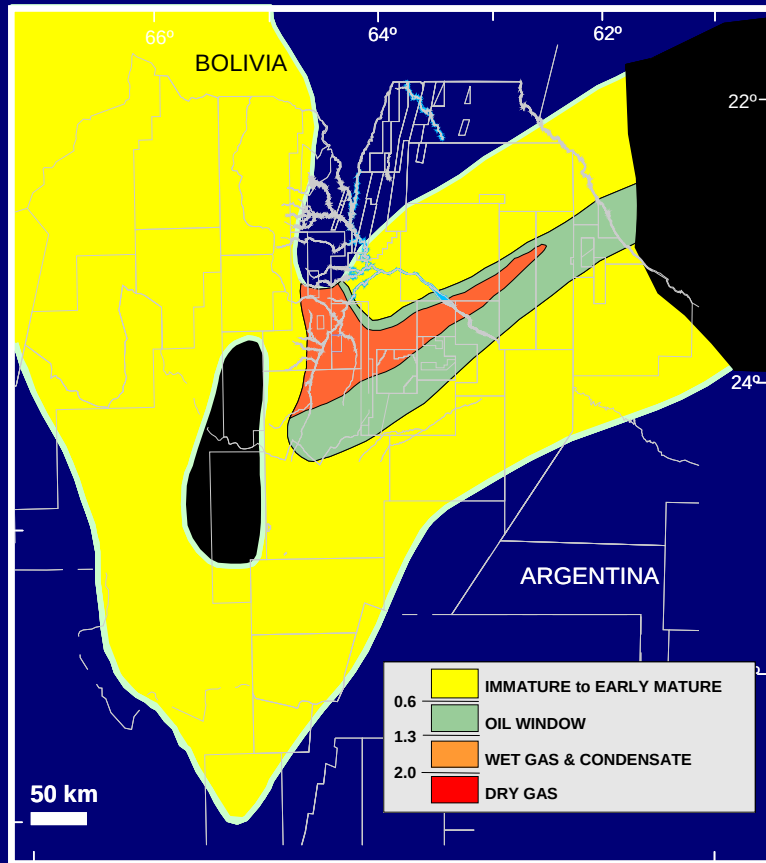
“Neocomiano”: TOC 0.5-3%, kerogen type II/III. Mixed algal-amorphous/structured terrestrial, affected by variable maturation levels

Thickness: 500 to 1800? m

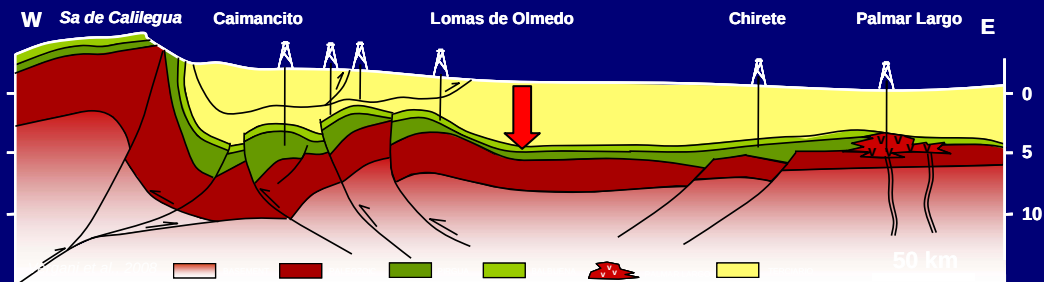
Cretaceous Basin

Yacoraite Fm (Late Cretaceous)

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Source rock consists of thin beds of organic-rich black shales interbedded with limestones deposited in a Late Cretaceous-Paleocene extended shallow lake



TOC: 0.5-6%

Kerogen Type: II (III)

VKA: amorphous

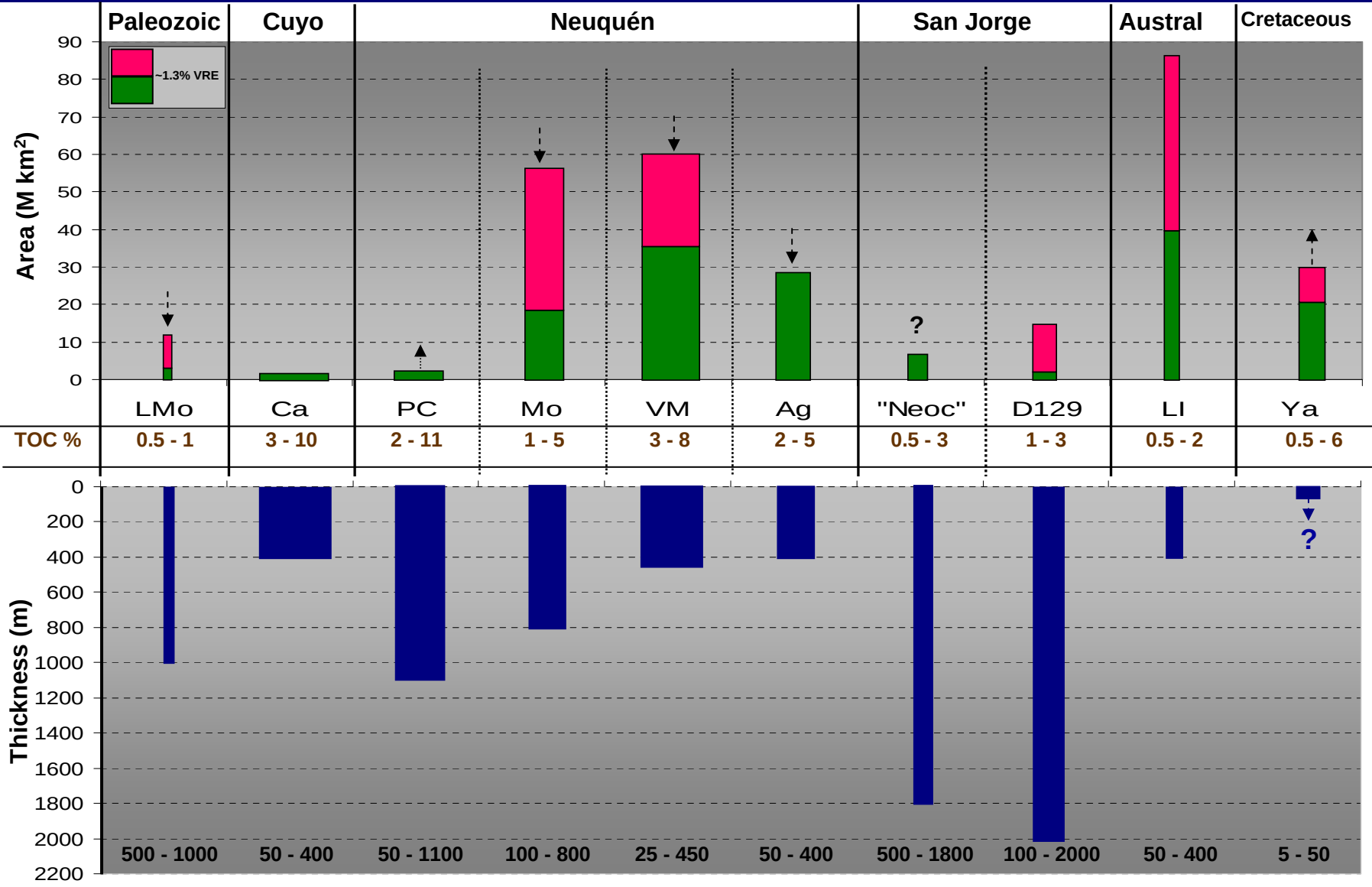
Source Quality/Maturity: moderate to good-quality oil-prone kerogen in thin organic-rich layers

Thickness: total value of 5 to 50 m obtained from thick packages consisting of thin beds of organic-rich shales alternating with limestones

Basins and Source Rocks Comparison

Source Rocks

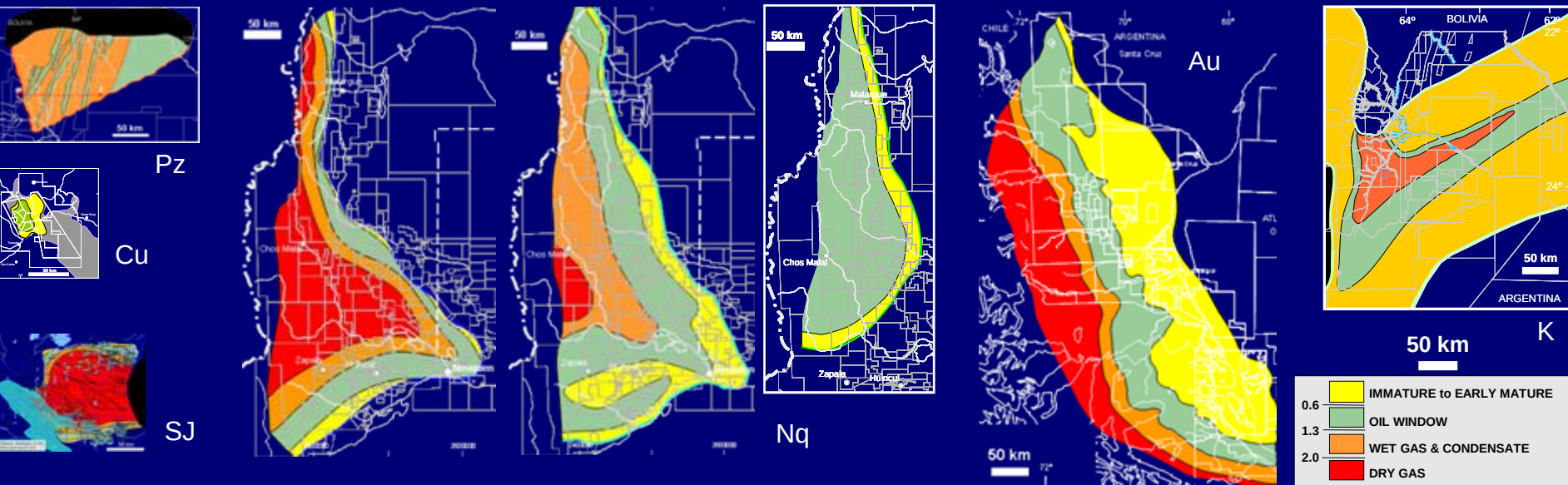
TOC, Thermally Mature Area and Thickness



In all plots bar width is proportional to TOC content

Source Rocks

Organic Richness and Oil & Gas EUR



EUR:

MMbls

TCF

395

12.2

1,240

0.3

3,300

15.9

3,460

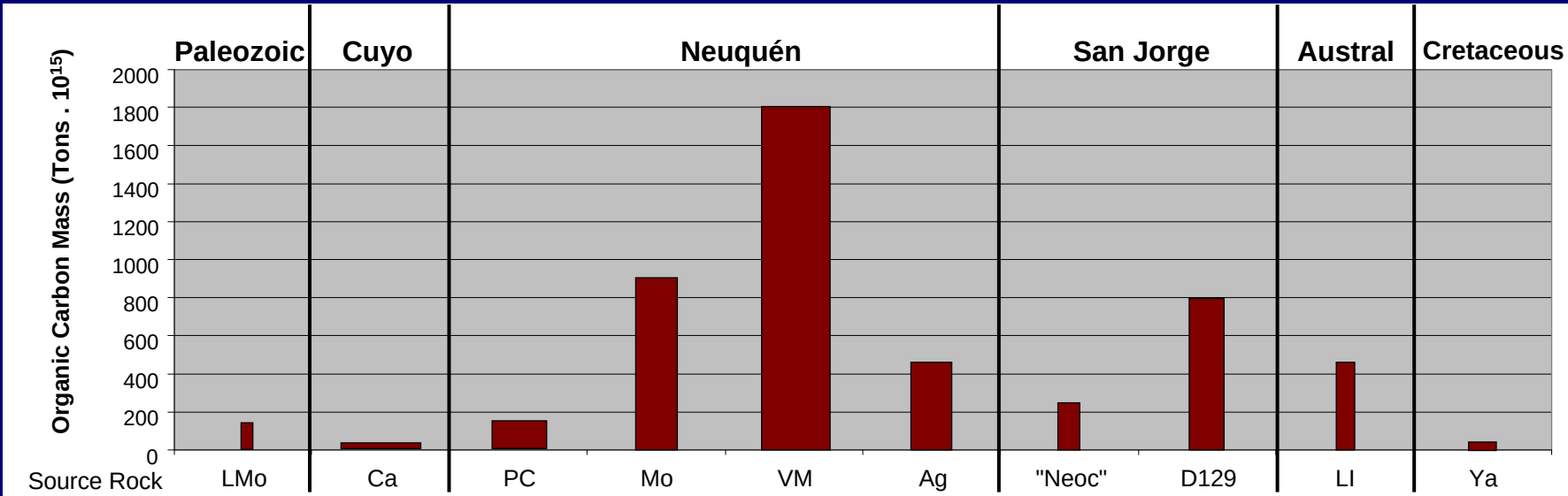
2.2

570

10.2

120

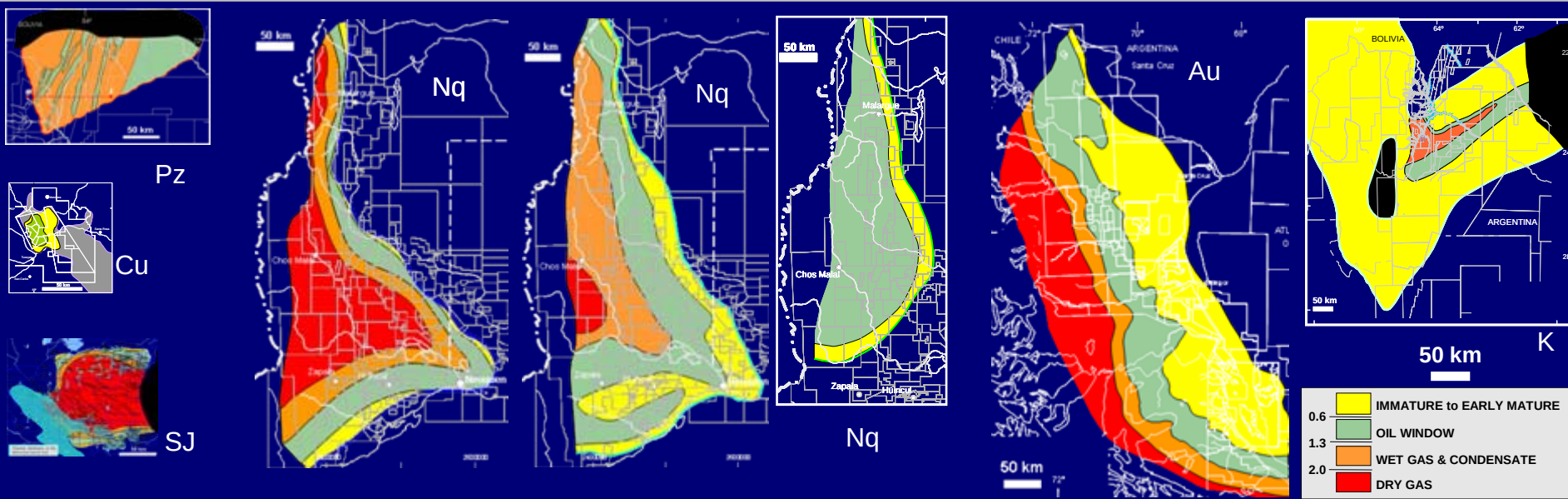
0.2



Petroliferous Basins of Argentina

Depth to Main Potential Shale Resources

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Depth (m)	Paleozoic	Cuyo	Neuquén				San Jorge		Austral	Cretaceous
	LMO	Ca	PC	Mo	VM	Ag	Neo	D129	LI	Ya
0										
1000										
2000										
3000										
4000										
5000										
6000										
7000										
8000										
TOC %	0.5 - 1	3 - 10	2 - 11	1 - 5	3 - 8	2 - 5	0.5 - 3	1 - 3	0.5 - 2	0.5 - 6
Thickness (m)	500 - 1000	50 - 400	50 - 1100	100 - 800	25 - 450	50 - 400	500 - 1800	100 - 2000	50 - 400	5 - 50

Review of the source rocks (1990-2010 published data) is based on the organic type and content, thermal maturity, thickness, area of distribution and present-day depth

Three source rocks seem to have a high potential for unconventional oil and gas resources (*Los Molles*, *Vaca Muerta* and *Agrio*, Neuquén)

The *D-129* (San Jorge) source bears a huge thickness within the gas window but localized at a significant depth

Other sources show either significant thickness (*Los Monos* – Paleozoic) or widespread distribution (*Lower Inoceramus* - Austral) but limited TOC content

Cacheuta (Cuyo), *Pre-Cuyo* (Neuquén), *Tobifera* (Austral) and “*Neocomiano*” (San Jorge) are mostly oil-prone and display reduce areal distribution

Yacoraite (Cretaceous) contains a reduced thickness of thin source beds alternating with limestones, circumscribed to an internal and deep position in the basin

Finally, in basins such as Cañadón Asfalto, Ñirihuau, Chaco-Paranense, Claromecó, Precordillera (San Juan), Triassic Troughs (San Juan-La Rioja), Curamallin (Neuquén) further studies need to be done