

**Transferencia Tecnológica
para la Sustentabilidad energética en México**

Geología de Vaca Muerta:

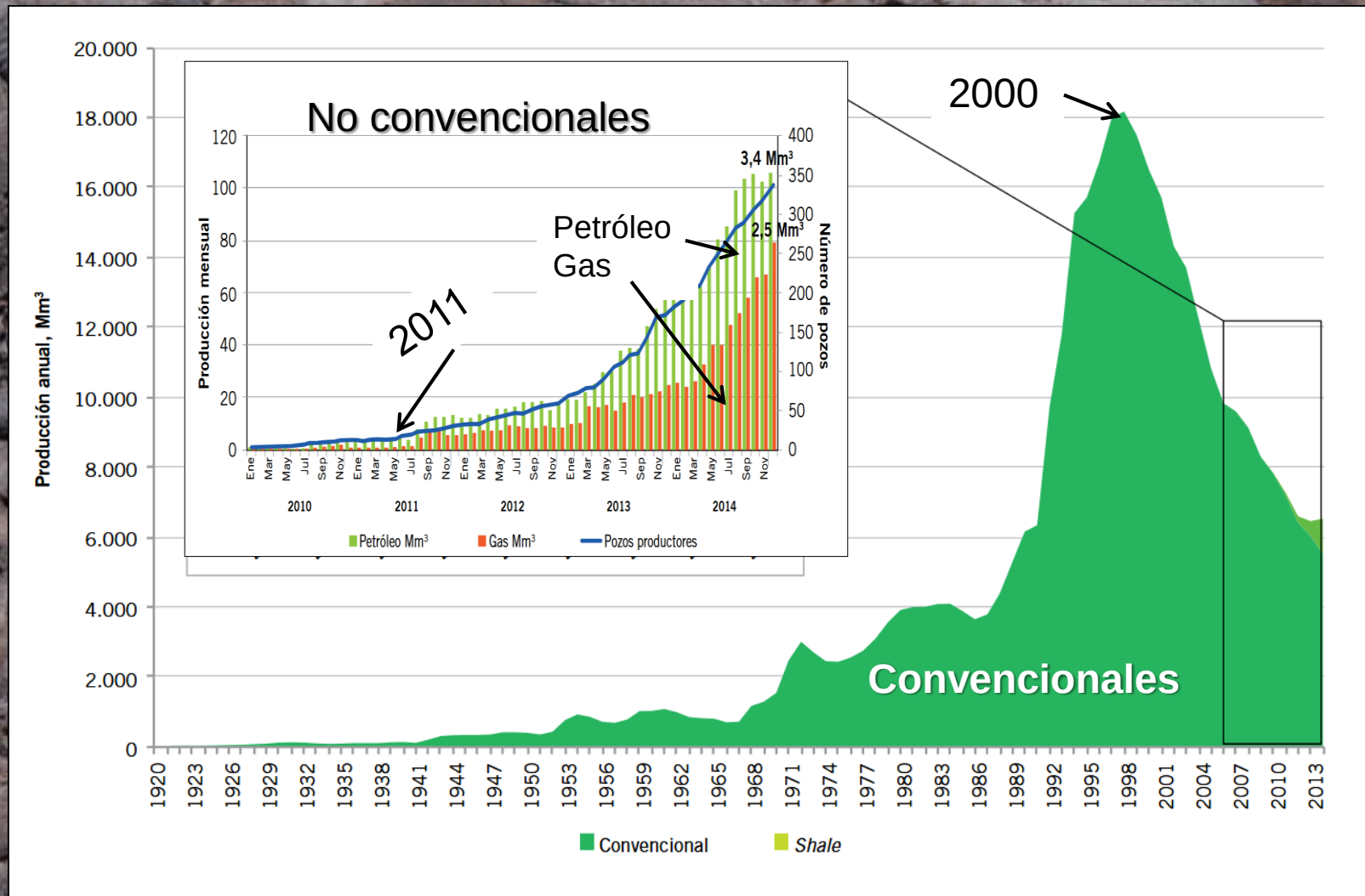
Un cambio de paradigma en los recursos
energéticos de Argentina

Victor A. Ramos
Universidad de Buenos Aires

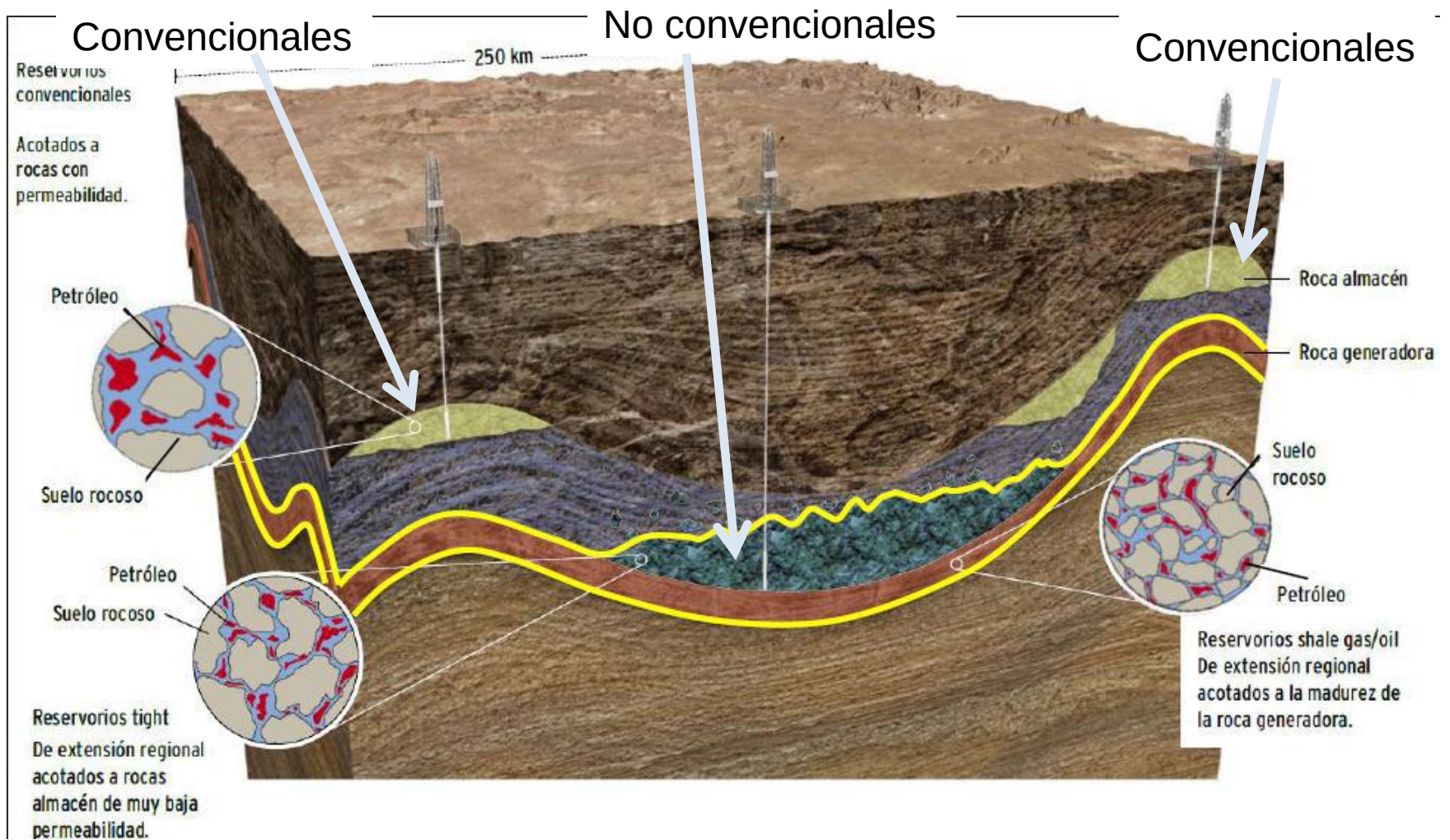
¿Qué pasó en Argentina?

- Cambio de paradigma
- Producción de hidrocarburos declinante
- Cuencas productivas maduras
- Pérdida de autoabastecimiento
- La revolución de Vaca Muerta!

Diez años de declinación constante



Hidrocarburos convencionales y no convencionales



Vaca Muerta

- Roca madre jurásica-cretácica
- Recurso no convencional
- 2º Reserva de gas mundial no convencional
China-> Argentina-> Argelia-> Estados Unidos
- 4º Reserva de petróleo no convencional
Rusia->Estados Unidos->China-> Argentina

Comparación con otras (oil and gas) shales

Shale Play	Barnett	Marcellus	Fayetteville	Haynesville	Woodford	Lewis	Eagle Ford	Vaca Muerta
Edad (Ma)	320	410	330	150	370	85	95	140
Extensión Areal (km ²)	13.000	250.000	23.000	23.000	28.900	26.000	5.000	30.000
Profundidad (km)	2,0 - 2,6	1,2 - 2,6	0,3 - 2,1	3,2 - 4,2	1,8 - 3,4	0,9 - 1,8	1,2 - 4,2	2,0 - 3,5
Gradiente de Presión (psi/ft)	0,43 - 0,44	0,15 - 0,40		> 0,9		0,2 - 0,25	0,6	0,6 - 1,1
Porosidad (%)	4,0 - 5,0	10,0 - 11,0	2,0 - 8,0	8,0 - 9,0	3,0 - 9,0	3,0 - 6,0	4,0 - 15	4,0 - 12,0
Espesor (metros)	60 - 90	30 - 120	30 - 210	60 - 90	90 - 300	150 - 580	20 - 150	30 - 550
Espesor Útil (metros)	15 - 60	15 - 60	15 - 60	61	35 - 67	61 - 92	25 - 100	50 - 350
Tipo Kerogeno	II	II - III	II - III	III	II	II - III	II	II
Madurez Térmica (% Ro)	0,5 - 1,5	0,5 - 2,0	1,0 - 3,0	0,94 - 2,62	0,5 - 3,0	1,7 - 1,9	0,5 - 2,5	0,5 - 2,6
COT (%)	3,0 - 6,0	3,0 - 12	4,0 - 9,8	4,0 - 10	0,6 - 1,0	0,45 - 2,5	4,5 - 5,5	2,0 - 12,0

Impacto internacional de Vaca Muerta



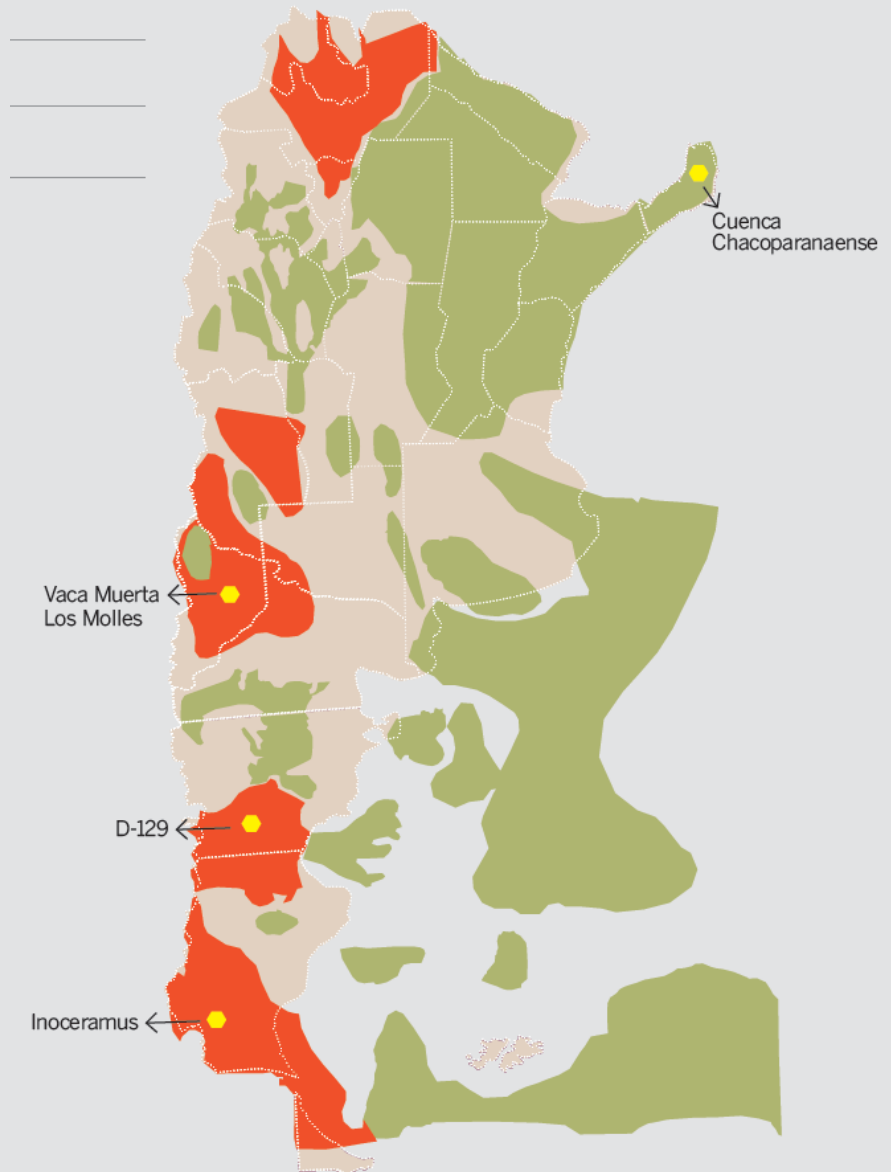
Gas: 308 TCF

Oil: 16.2 Billion bbls

Vaca Muerta (Cuenca Neuquina)



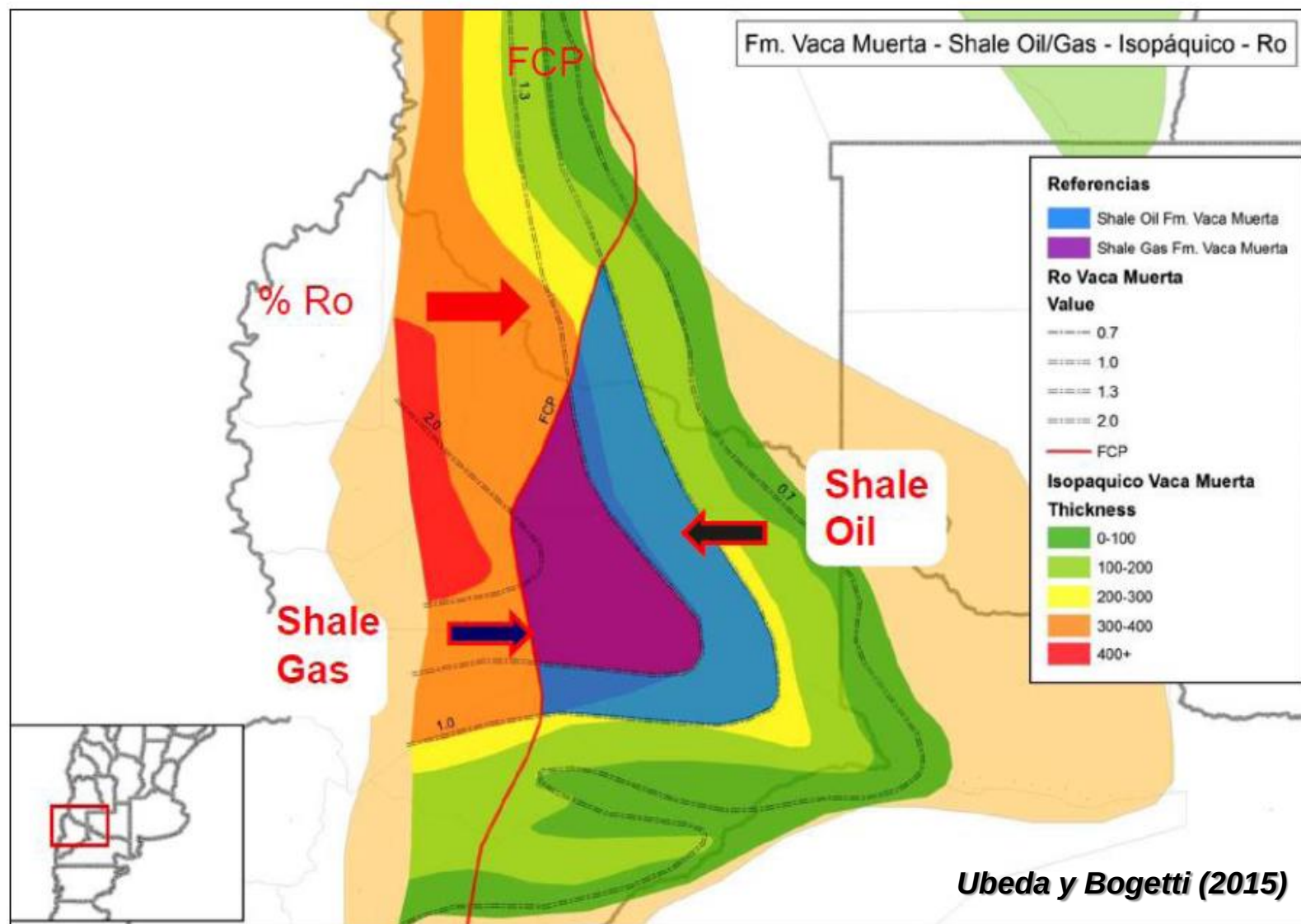
-  Cuenas actualmente sin producción
-  Cuenas productoras
-  Formaciones Shale





**Formación Vaca Muerta
(Cuenca Neuquina)**

Mapa isopáquico de Formación Vaca Muerta



¿Cómo se logró este cambio?

- Investigación básica
- Mapeos geológicos sistemáticos
- Años de exploración convencional
- Aplicación de nuevas tecnologías

Cuenca Neuquina

- Etapa de Rift

(Triásico)

- Etapa de Retroarco

Subducción con extensión

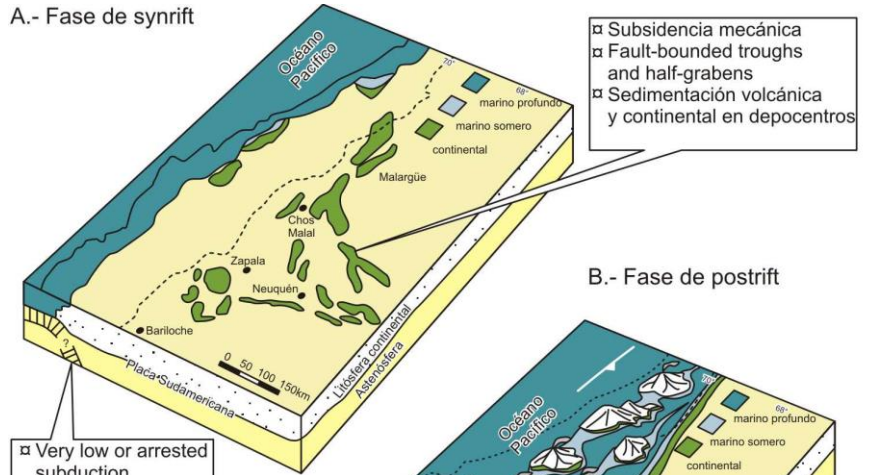
(Jurásico Inferior-
Cretácico Inferior)

- Etapa de Antepaís

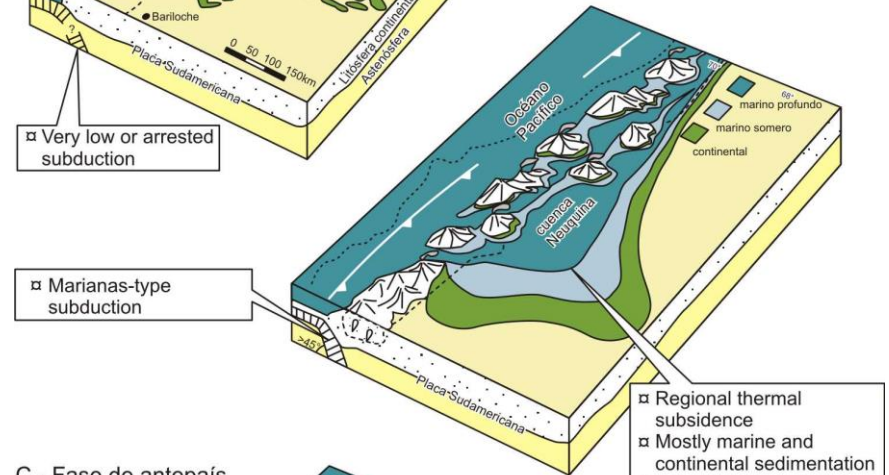
Subducción con contracción

(Cretácico - Terciario)

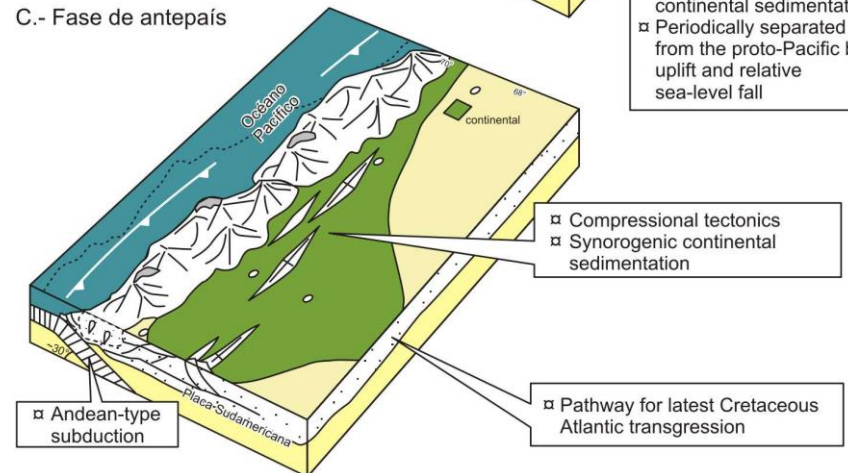
A.- Fase de synrift



B.- Fase de postrift



C.- Fase de antepaís



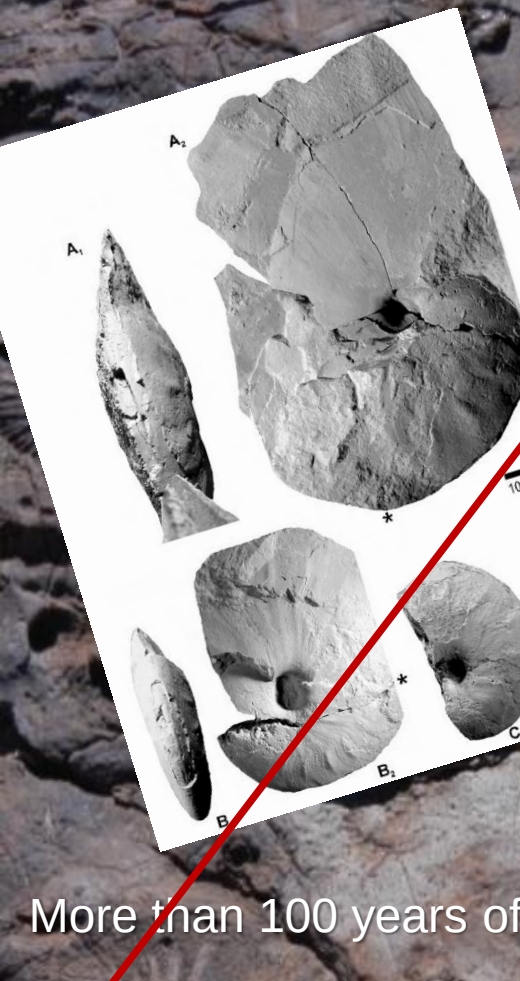


Armando Leanza

Pablo Groeber

Alberto Riccardi

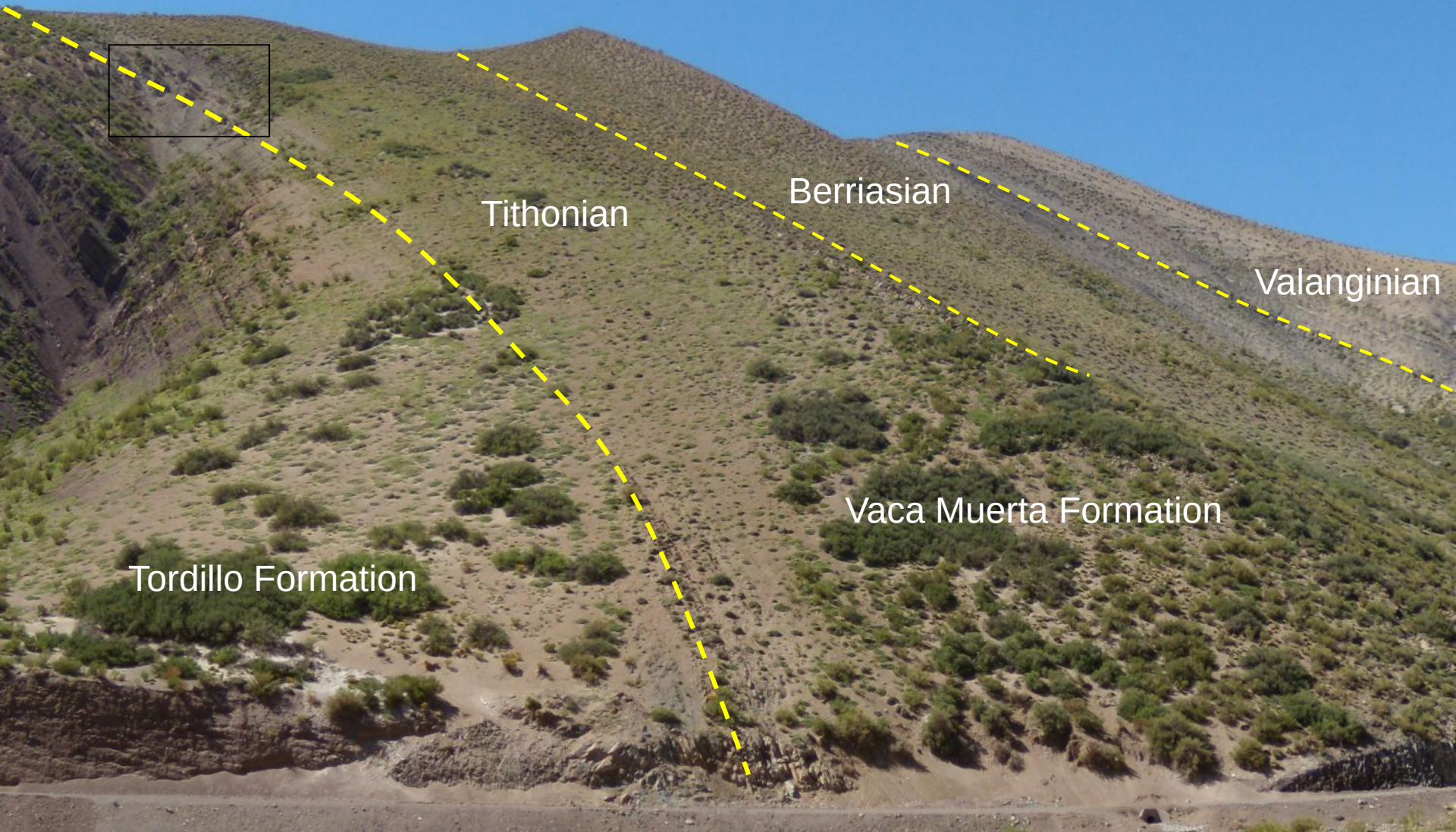
Héctor Leanza



GERTH (1921)		GERTH (1925)		BURKHARDT (1930)		WINDHAUSEN (1931)	
Piso	Biozona de	Piso	Biozona de	Piso	Biozona de	Piso	Biozona de
Valanginiense	<i>Spiliceras dameri</i>	superior	<i>Neocomites (L.) transgrediens</i>	Barriastano	<i>Spiliceras dameri</i>	Valanginiense	<i>Neocomites transgrediens</i>
			<i>Spiliceras dameri</i>				<i>Asteria latcostata</i>
	<i>Stenoceras koenigi</i>	inferior - superior	<i>Thaumaceras fronsdani</i>		<i>Hoplites fronsdani</i>		<i>Berrisella (L.) fronsdani</i>
			<i>Stenoceras permulticostatum</i>		<i>Stenoceras permulticostatum</i>		<i>Stenoceras permulticostatum</i>
Barriastano	<i>Berrisella mendocana</i>	superior	<i>Spiliceras acutum</i>	superior	<i>Spiliceras acutum</i>	Barriastano	<i>Spiliceras acutum</i>
			<i>Stenoceras koenigi</i>		<i>Stenoceras koenigi</i>		<i>Stenoceras koenigi</i>
	<i>Neomayria zitteli</i>	medio	<i>Kilianella burckhardtii</i>		<i>Lytrochilites burckhardtii</i>		<i>Kilianella burckhardtii</i>
			<i>Berrisella mendocana</i>		<i>Kossmatia pseudo-dorsalis optycha</i>		<i>Berrisella mendocana</i>
Tithoniense	<i>Virgatites mendocanus</i>	inferior	<i>Neomayria zitteli</i>	inferior	<i>Paradoloceras zitteli</i>	Tithoniense	<i>Paradoloceras zitteli</i>
			<i>Virgatites mendocanus</i>		<i>Virgatites mendocanus</i>		<i>Virgatites mendocanus</i>
	<i>Virgatites mendocanus</i>	superior	<i>Virgatites mendocanus</i>		<i>Virgatites mendocanus</i>		<i>Virgatites mendocanus</i>
			<i>Virgatites mendocanus</i>		<i>Virgatites mendocanus</i>		<i>Virgatites mendocanus</i>

Investigación básica desde la época de Darwin (1835)

Las Loicas Section



Tithonian

Berriasian

Valanginian

Tordillo Formation

Vaca Muerta Formation

Tordillo Formation

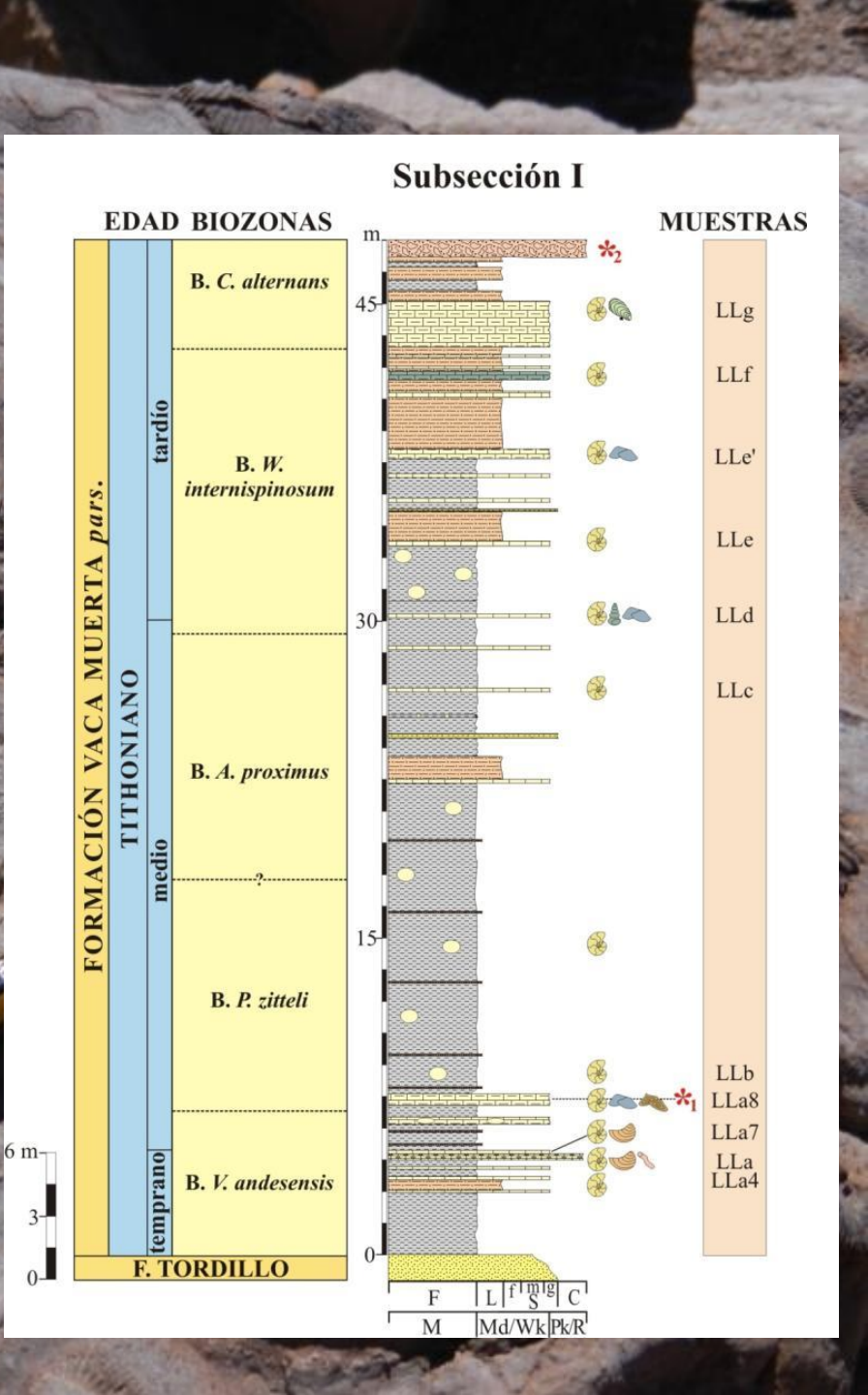


Vaca Muerta Formation



Bioestratigrafía

Formación Vaca Muerta



Bioestratigrafía
Formación Vaca Muerta

Subsección I

EDAD BIOZONAS

FORMACIÓN VACA MUERTA pars.

TITHONIANO

temprano

medio

tardío

B. V. andensis

B. P. zitteli

B. A. proximus

B. W. internispinosum

B. C. alternans

F. TORDILLO

MUESTRAS

LLg

LLf

LLe'

LLe

LLd

LLc

LLb

LLa8

LLa7

LLa

LLa4

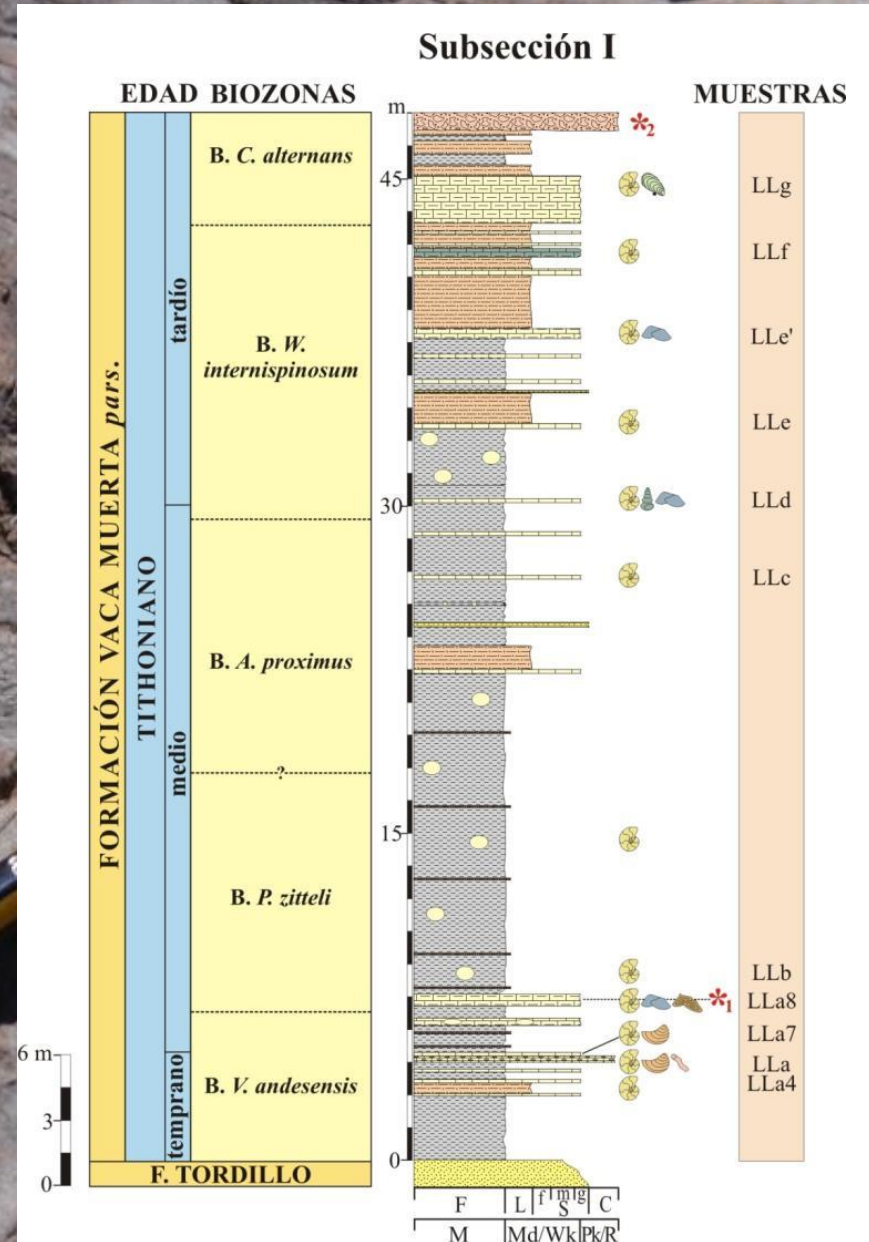
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3

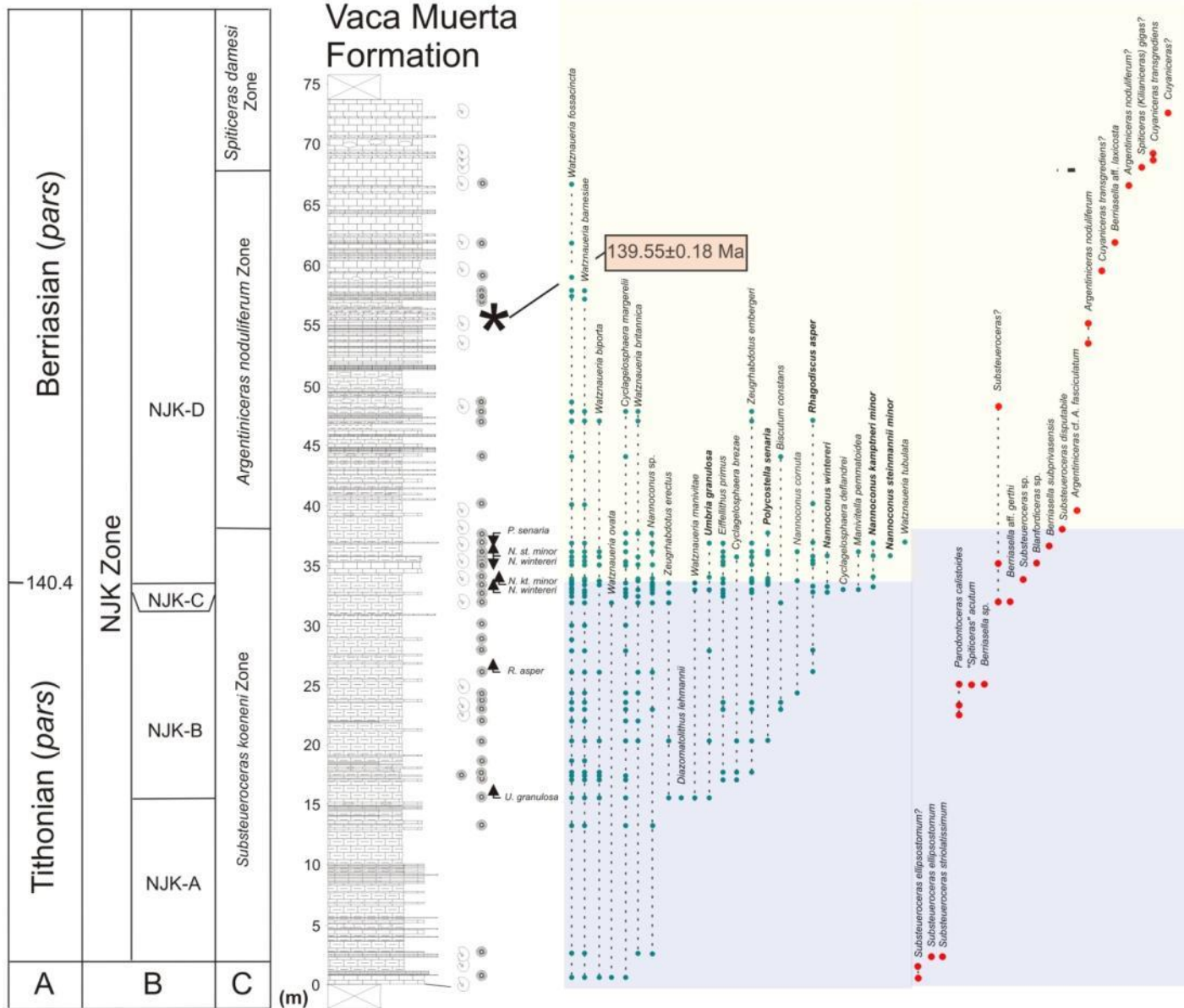
0

F L Lf Lg C

M Md/Wk Pk/R



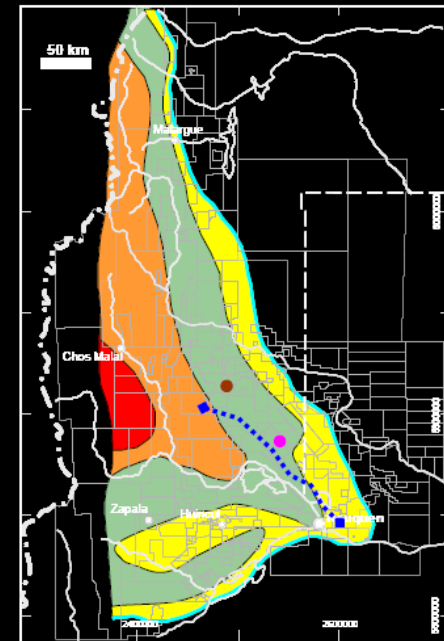
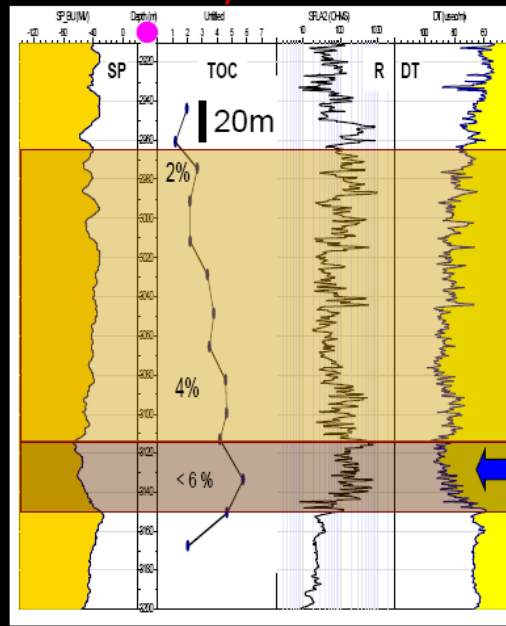
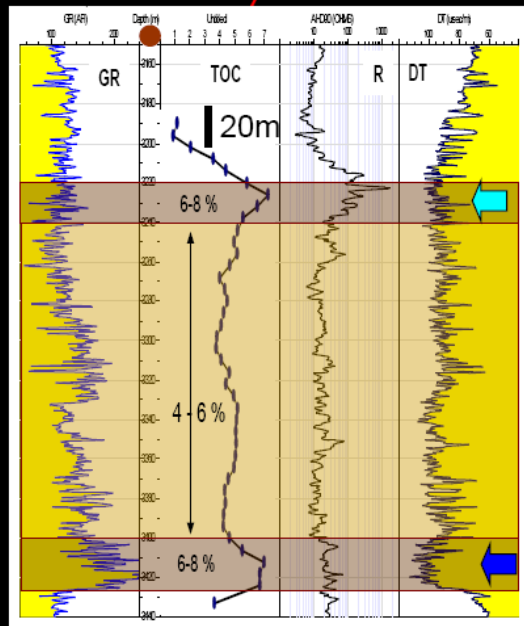
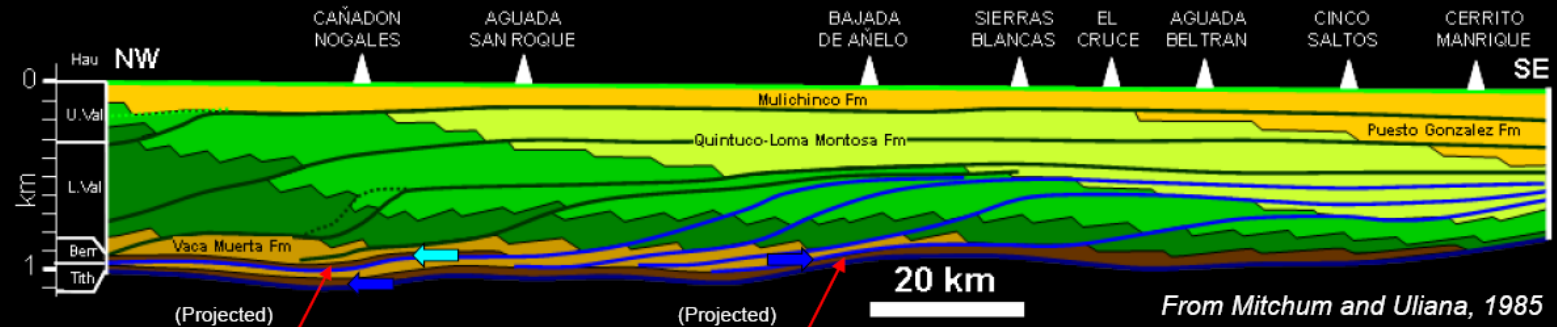
Bioestratigrafía Formación Vaca Muerta



Características de Vaca Muerta: TOC

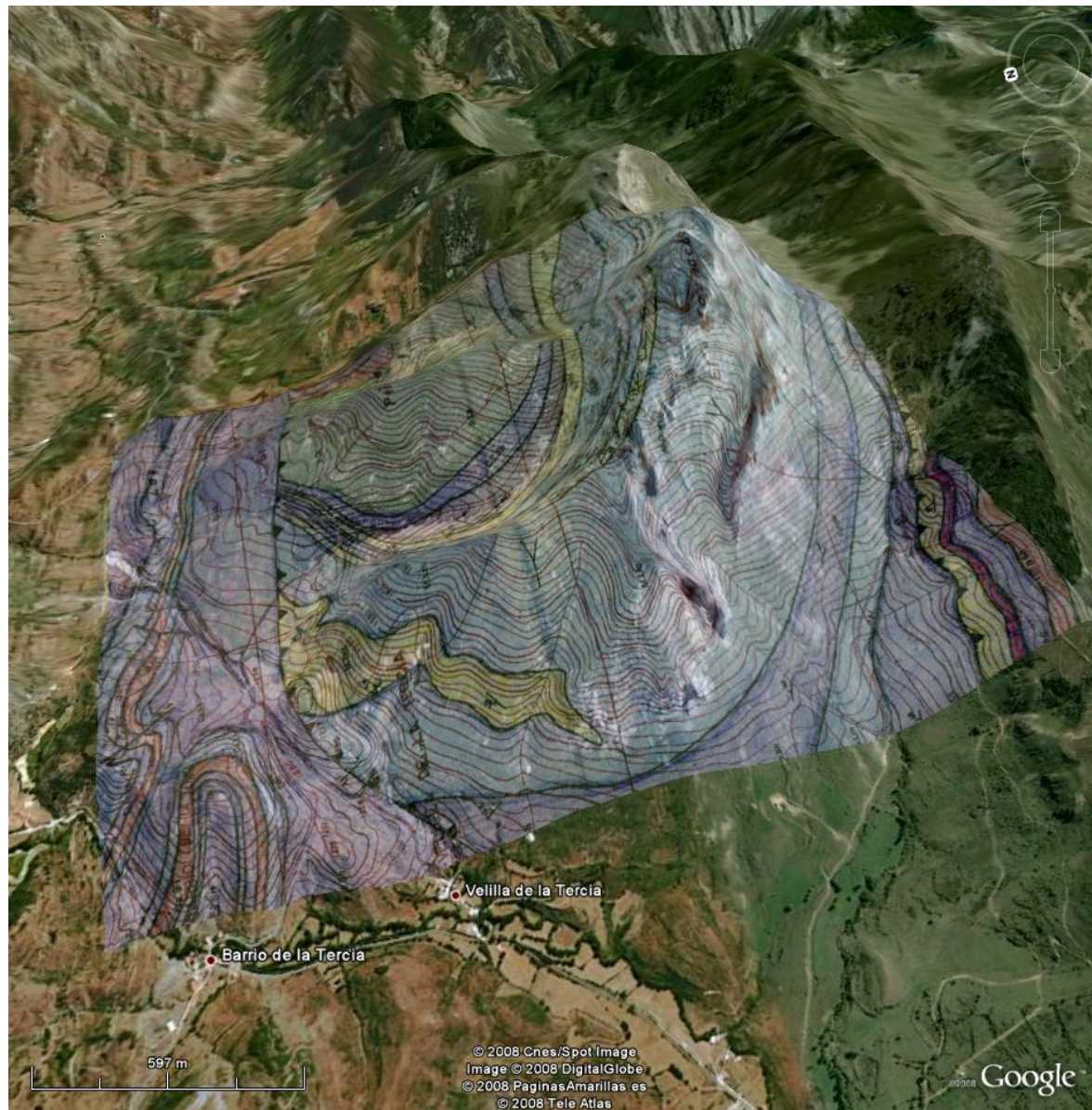
Neuquén Basin

Vaca Muerta Source Rock: Lateral and Vertical Variations

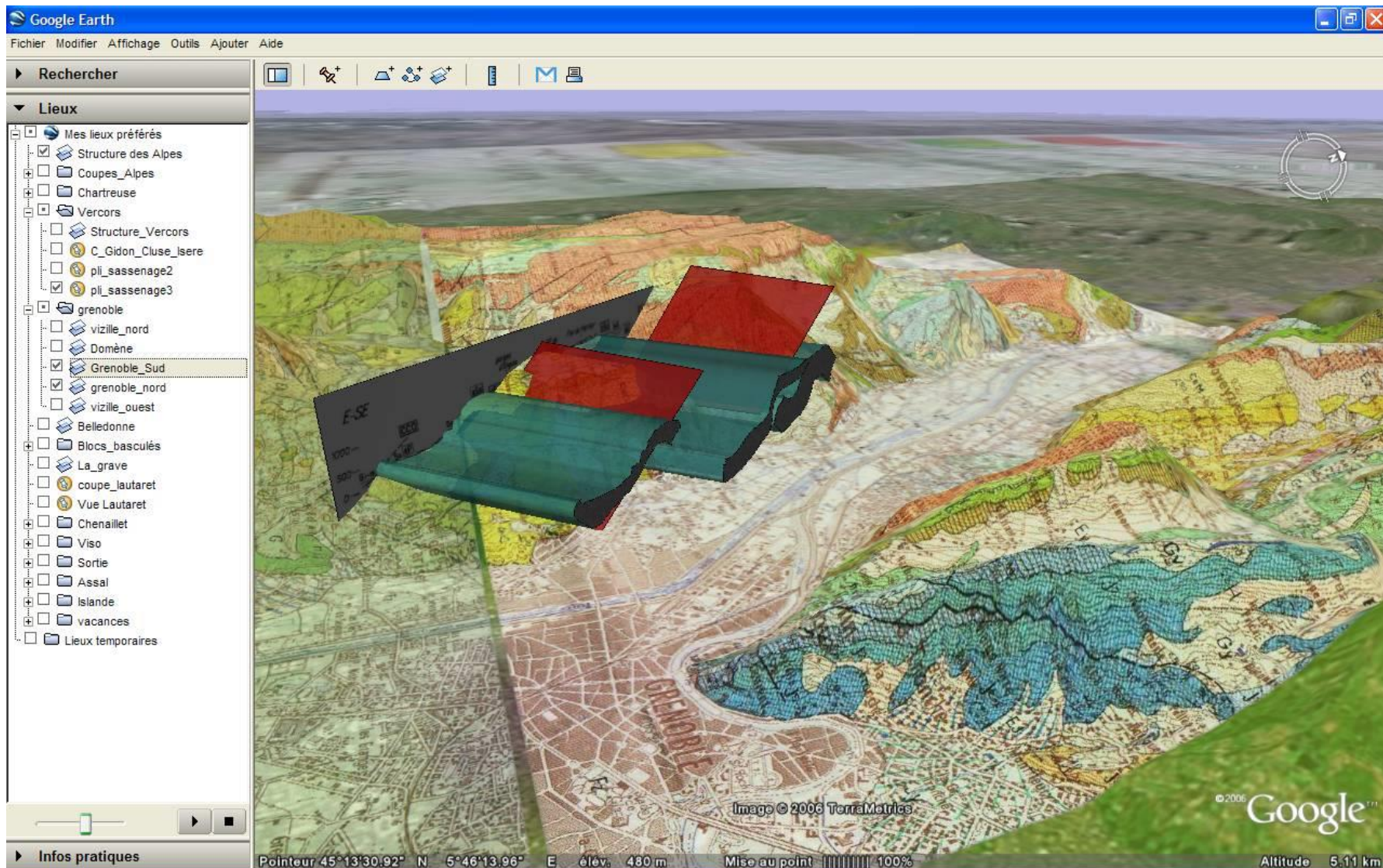


**Se necesita un mapa geológico
con las características estructurales y
extensión de los afloramientos
de la Formación Vaca Muerta
en la Cuenca Neuquina**





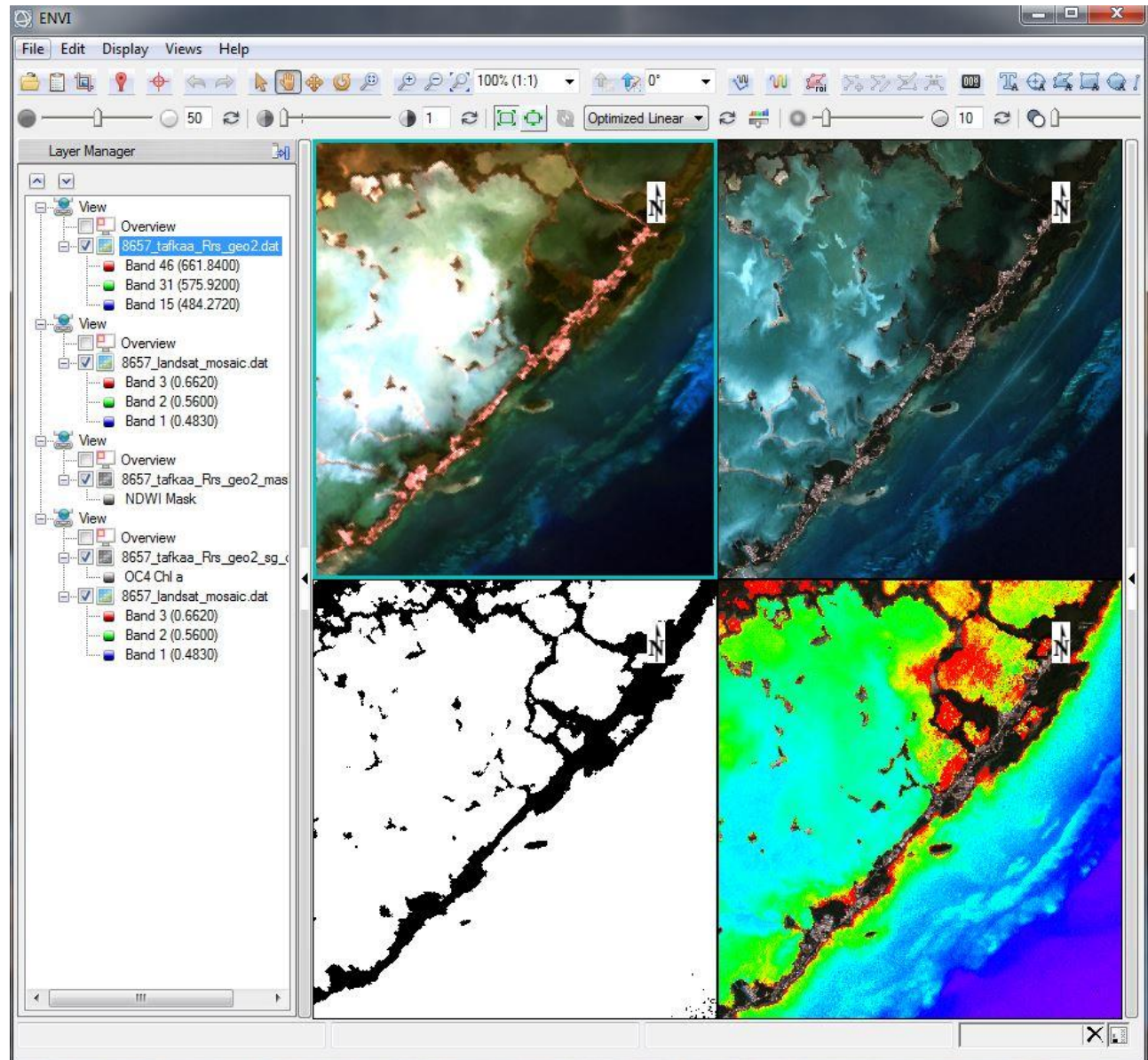


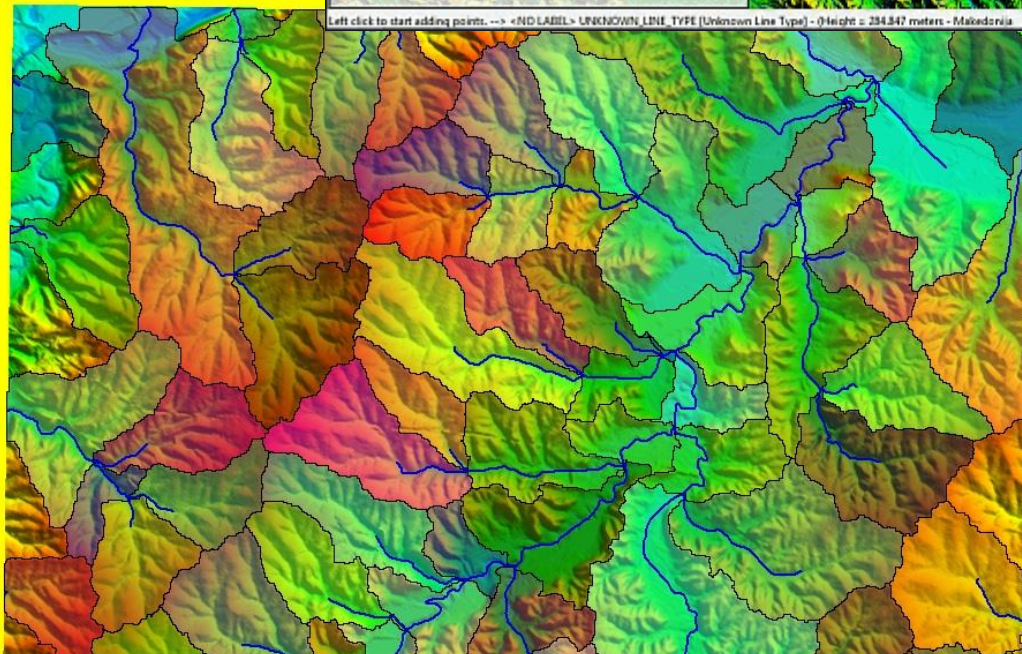
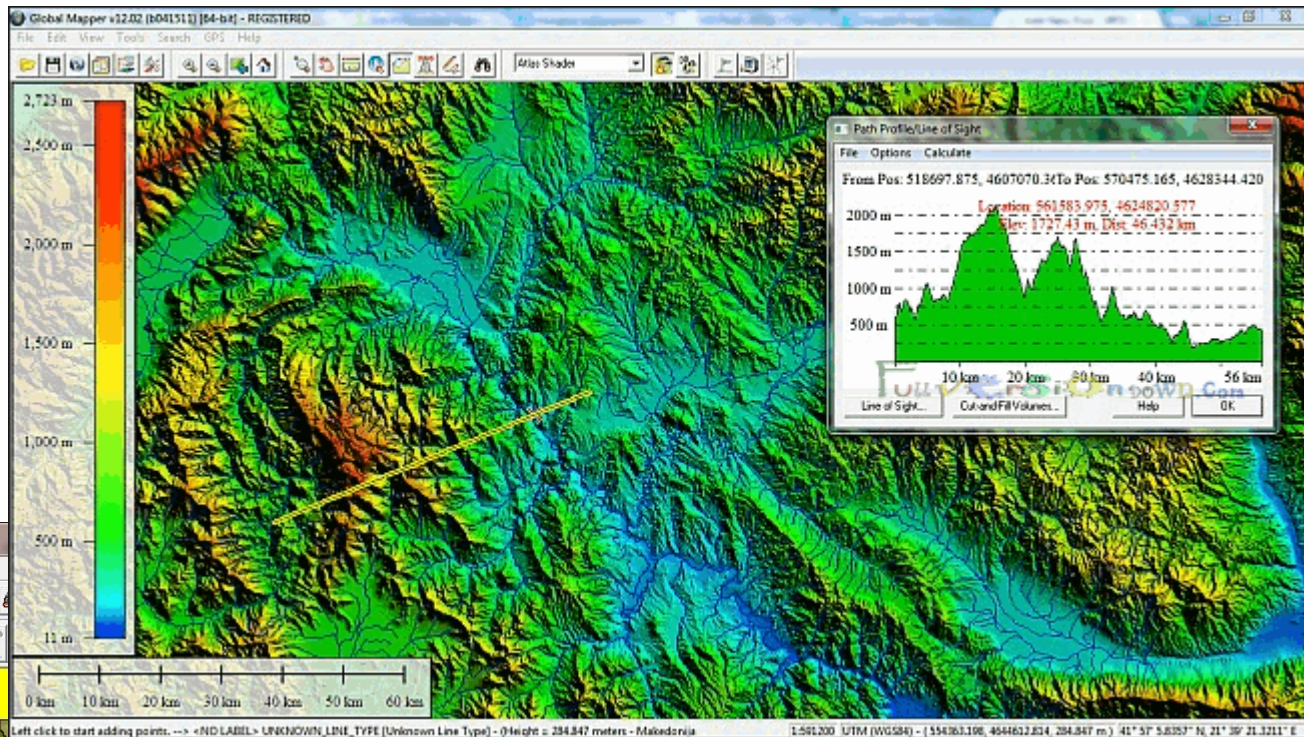




ENVI

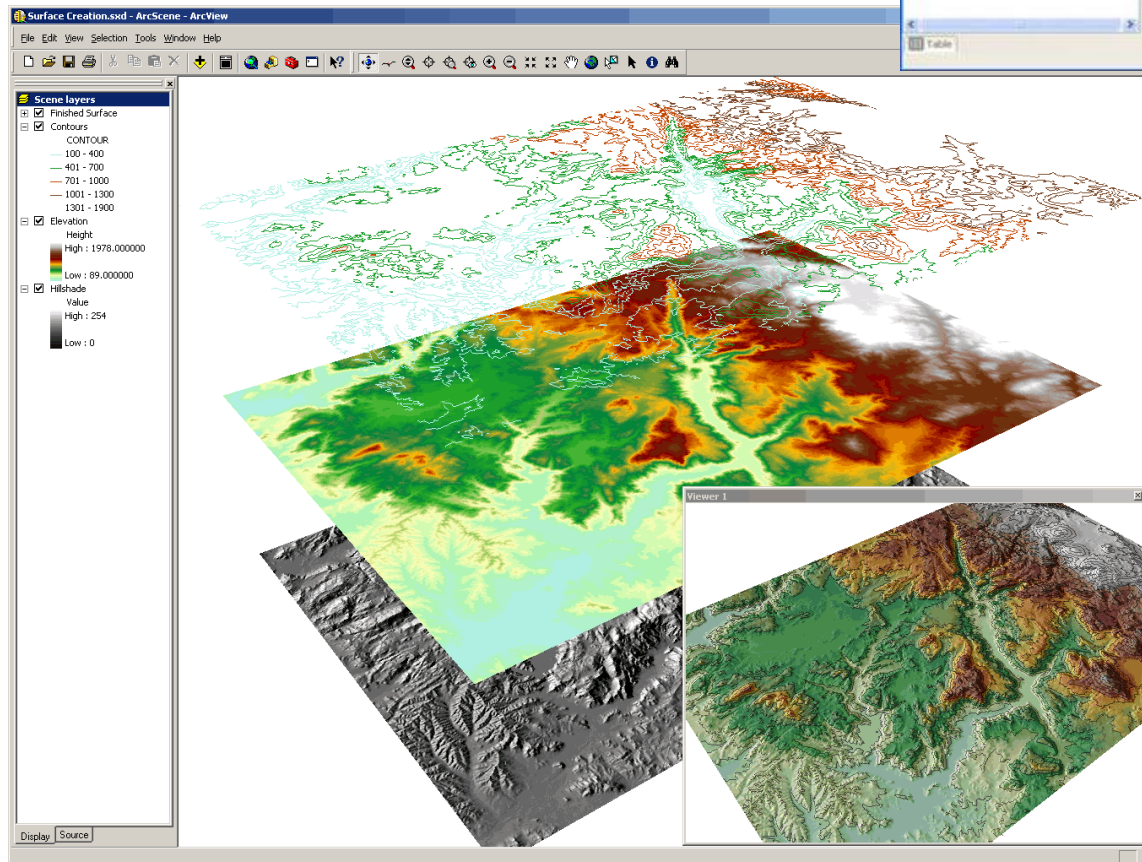
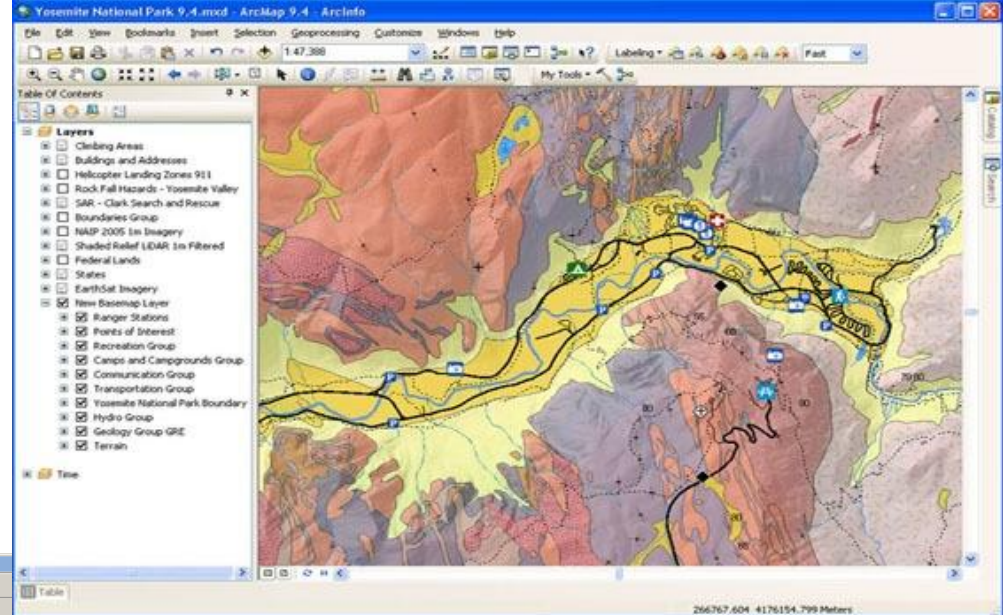
Análisis espectral
de las diferentes
bandas de una
imagen





<NO LABEL> Stream - (Height = 261.585 meters - <blue_springs_4_quads.dem> BLUE SPRINGS, MO)

1:92090 UTM (NAD27) - (381092.752, 4323809.221) 39° 03' 25.7429" N, 94° 22' 27.2539" W



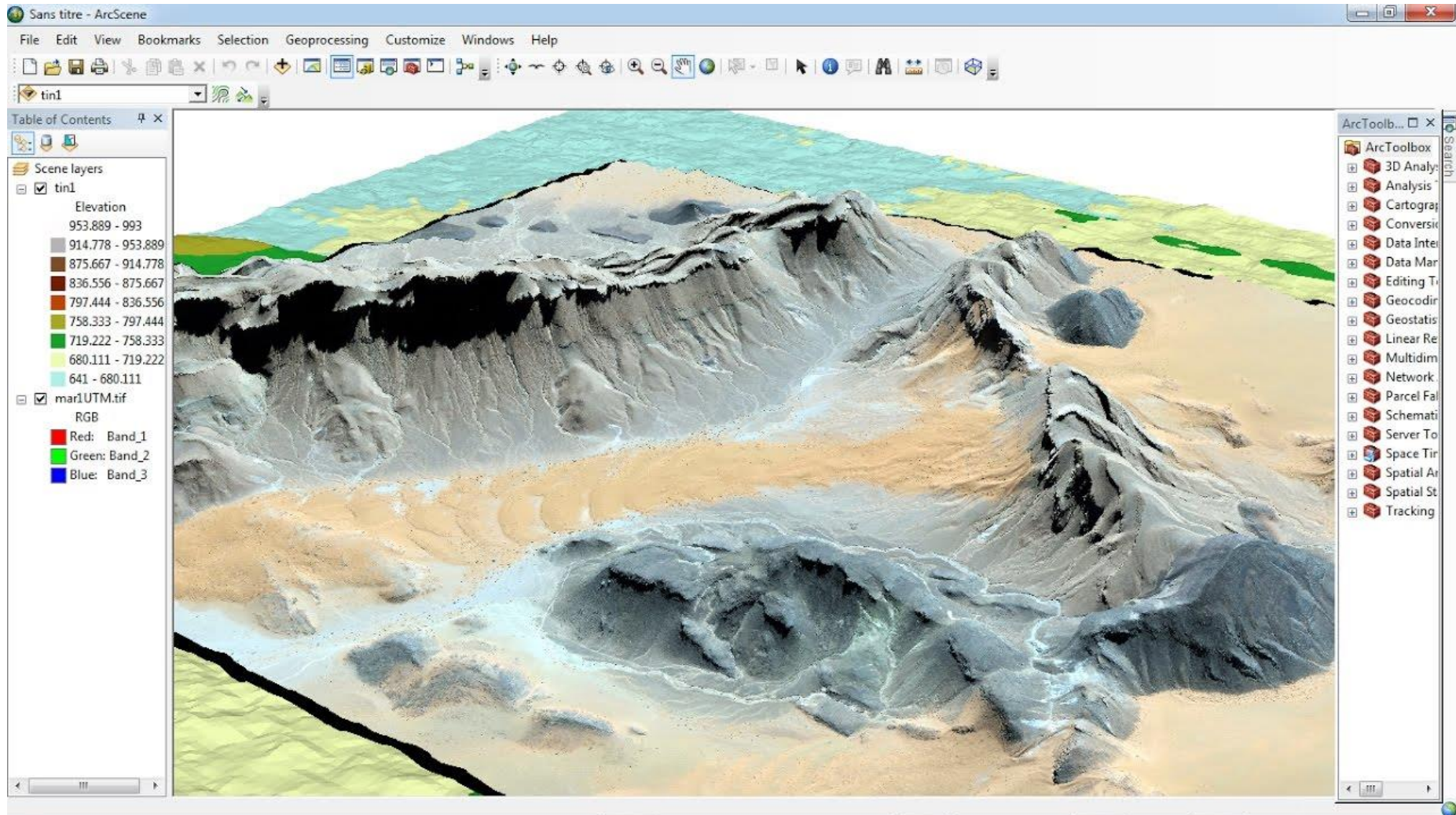


ArcGIS®

+



Google Earth



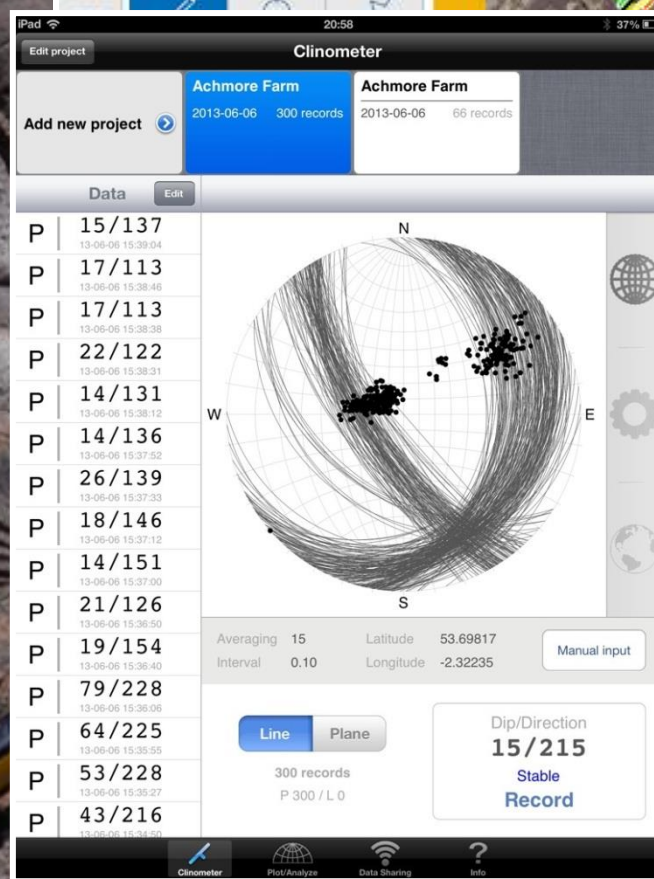
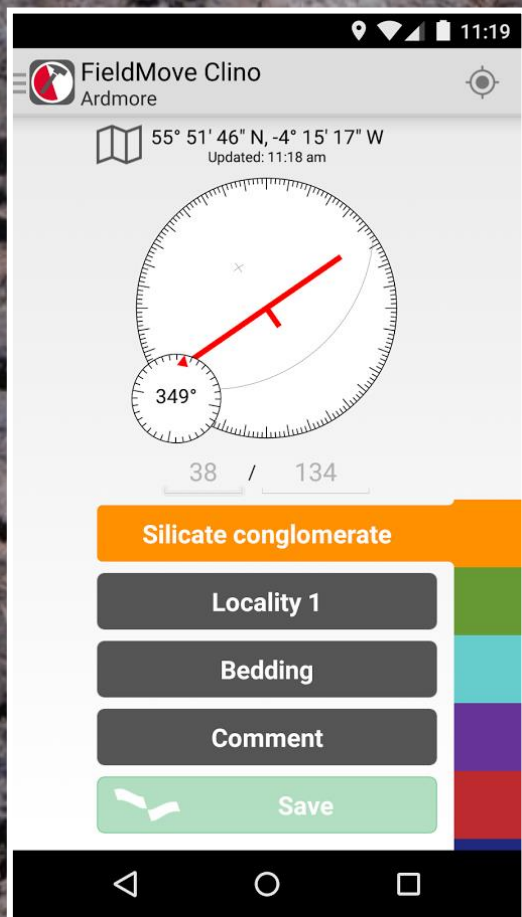
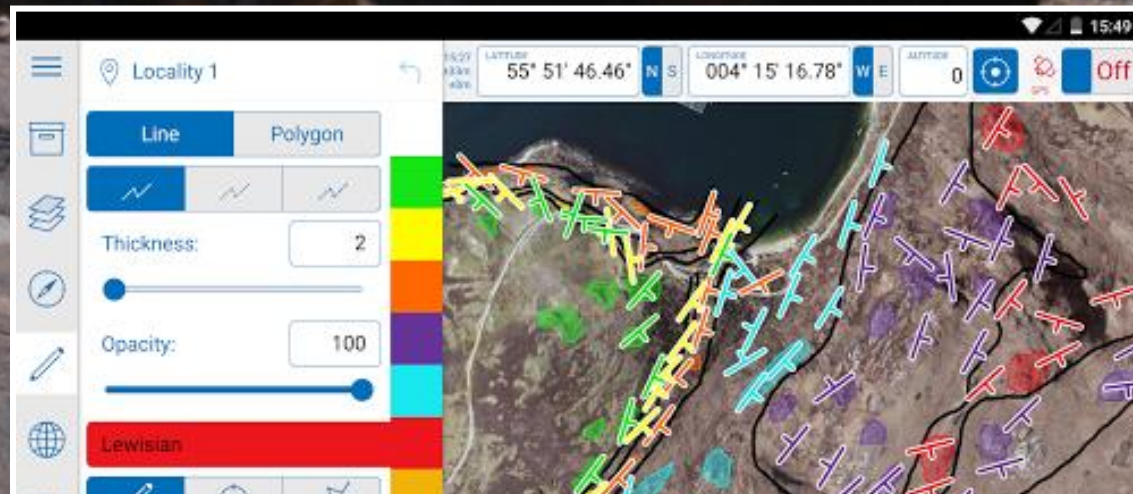


Fieldmove Clino





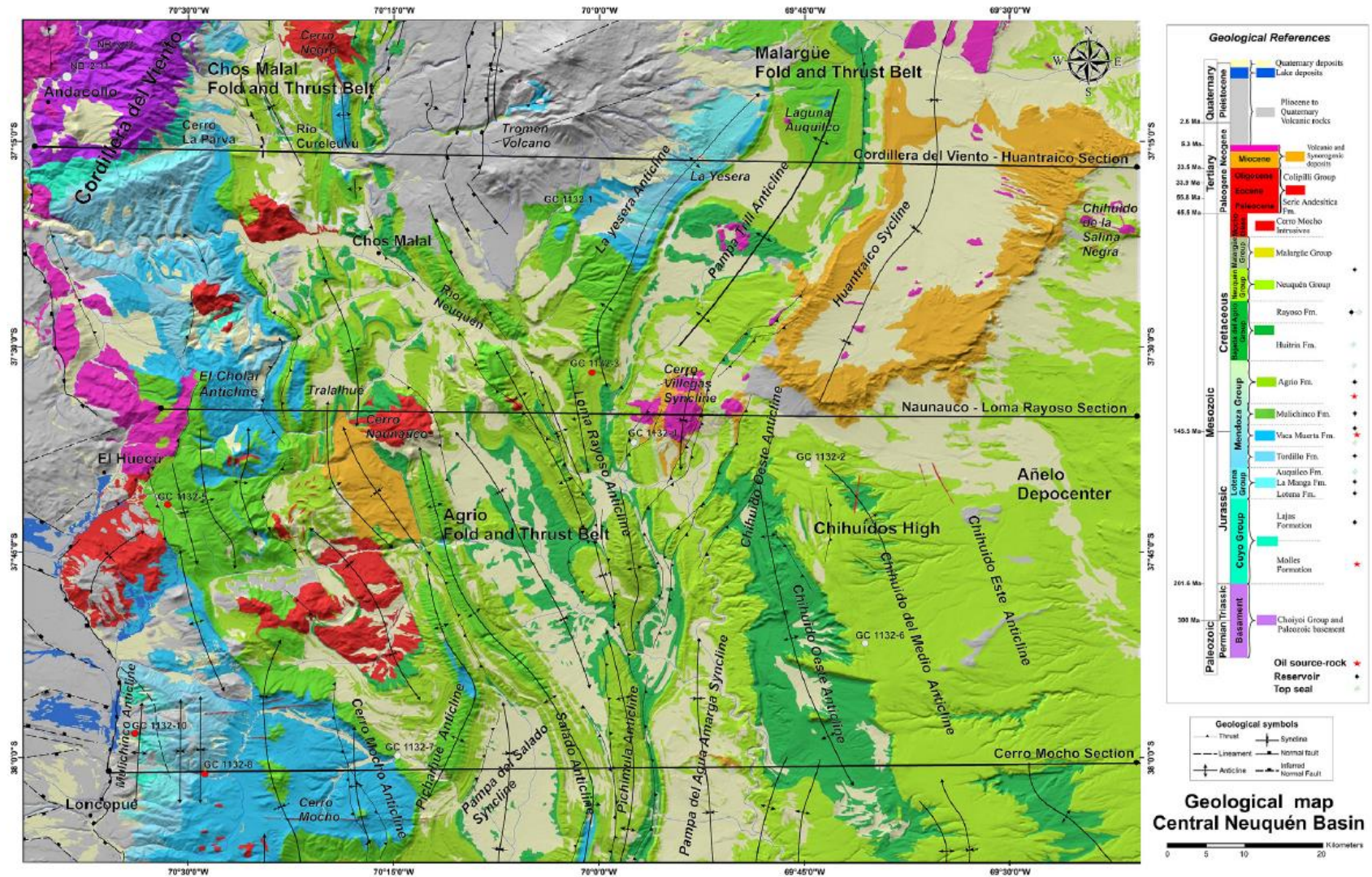
Fieldmove Clino







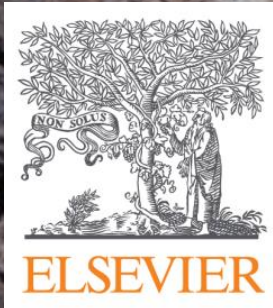
Mapeo Geológico y levantamiento de secciones



Transferencia Tecnológica para la Sustentabilidad energética en México

. Una nueva herramienta para el estudio geológico:

El uso de GeoFacets



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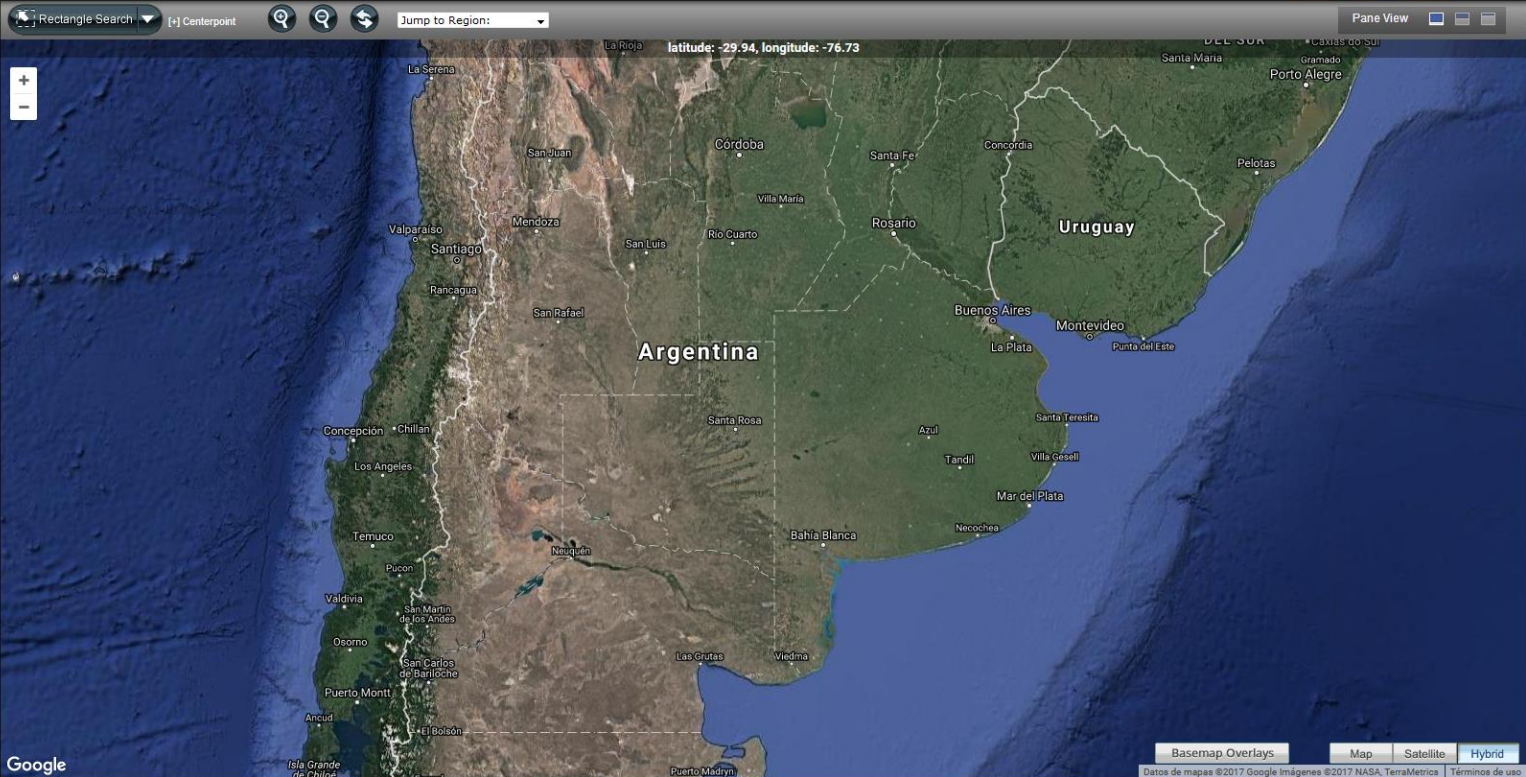
¿Qué se sabe de la Formación Vaca Muerta?

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e.g. Cretaceous AND "rift basin"

[Search](#)

☒ Suggest as you type



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Hay 46 trabajos que se refieren en la Cuenca Neuquina a Vaca Muerta!



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Rápida identificación por orden de relevancia (u autores, o año de producción, u otros)

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- ☐ Location (15)
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- ☐ Temuco Basin (13)

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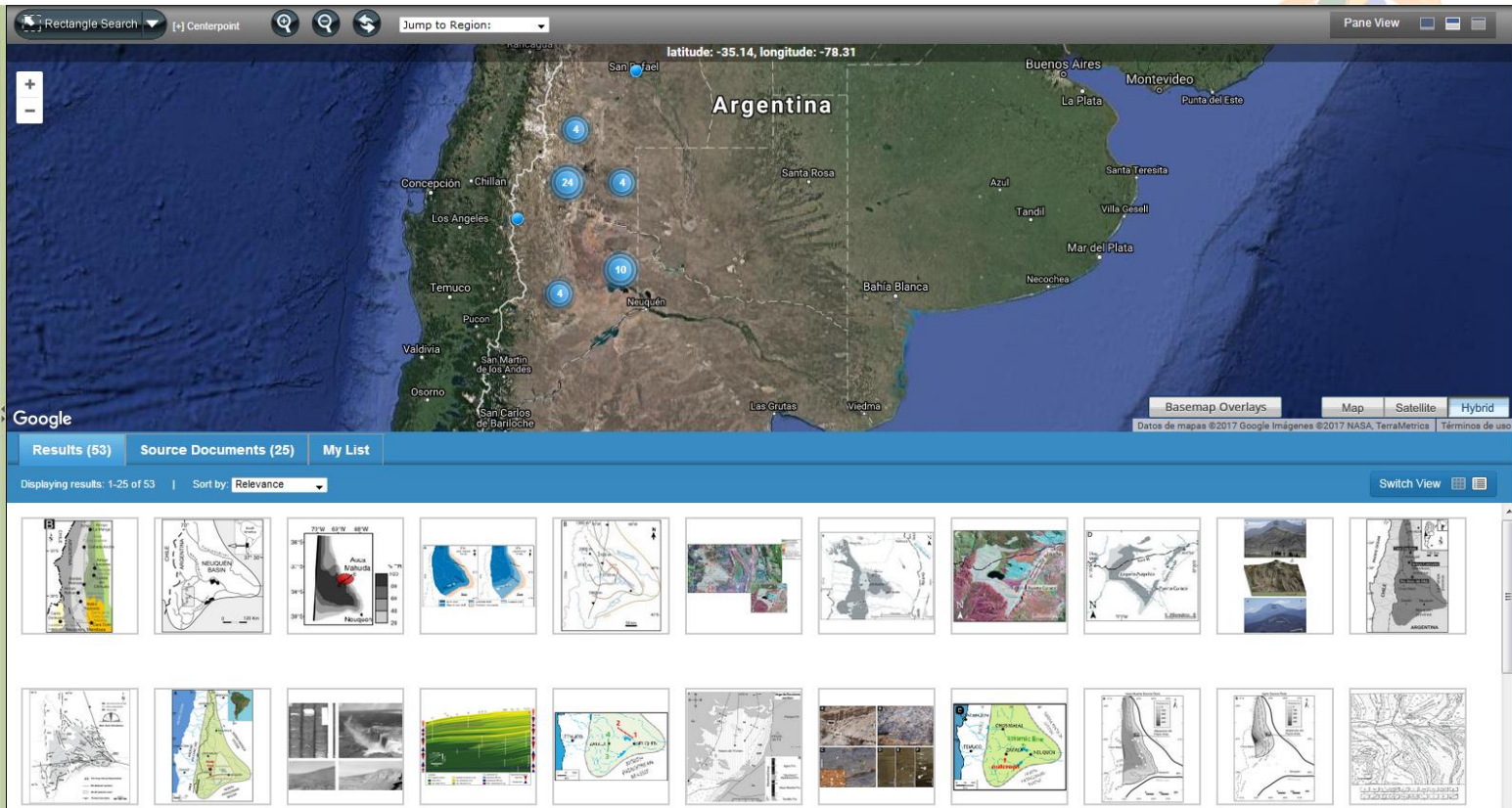
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[Author Keywords](#)

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Búsqueda específica por área de interés y por relevancia.
Uso de keywords, autor, año de publicación, source, etc.

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☒ + Content Type: Map, Sections/Profiles

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☒ Basin

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- ☐ Los Angeles Basin (3)
- ☐ Temuco Basin (2)

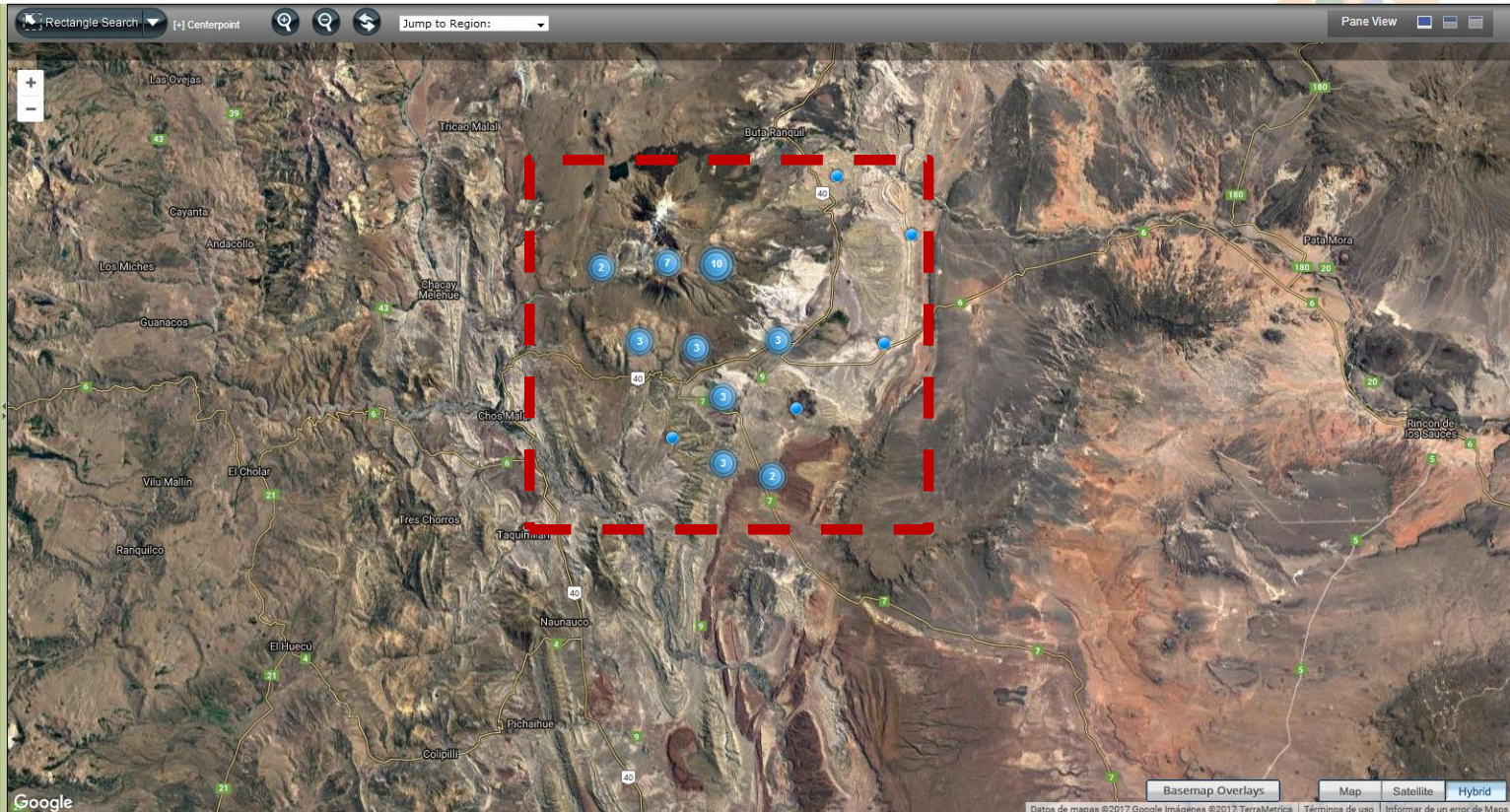
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Diferentes tipos de estudios y mapas sobre la Formación Vaca Muerta

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Switch View

The grid displays 50 thumbnails of geological data. The first row contains 10 thumbnails, including a map of Argentina, a cross-section, and a map of the Vaca Muerta formation. The second row contains 10 thumbnails, including a map of Argentina, a cross-section, and a map of the Vaca Muerta formation. The third row contains 10 thumbnails, including a map of Argentina, a cross-section, and a map of the Vaca Muerta formation. The fourth row contains 10 thumbnails, including a map of Argentina, a cross-section, and a map of the Vaca Muerta formation. The fifth row contains 10 thumbnails, including a map of Argentina, a cross-section, and a map of the Vaca Muerta formation.

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Sequence architecture and heterogeneities of a field - Scale **Vaca Muerta** analog (Neuquén Basin, Argentina) - From outcrop to synthetic seismic

Marine and Petroleum Geology, Volume 66, September 2015, pages 829-847

Zeller, Michael; Reid, Samuel B.; Eberli, Gregor P.; Weger, Ralf J.; Massaferro, Jose Luis



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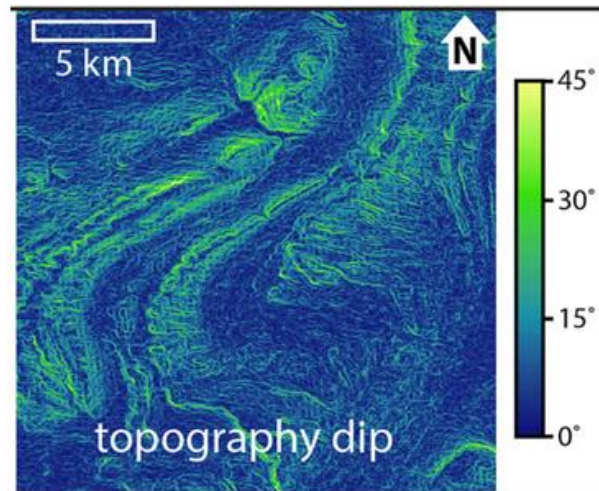
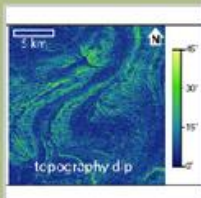
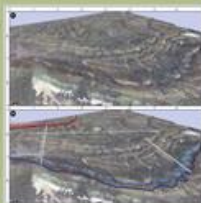


Fig. 3. Workflow of fieldwork and satellite imagery integration: A) Logged sedimentological **sections** and laterally logged beds. B) Geometry interpretation from high-resolution satellite imagery corrected for true vertical thickness. C) Correlation is based on the fieldwork data, **mapped** geometries and identified lithofacies from satellite imagery color changes, fracture patterns and slope angles. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

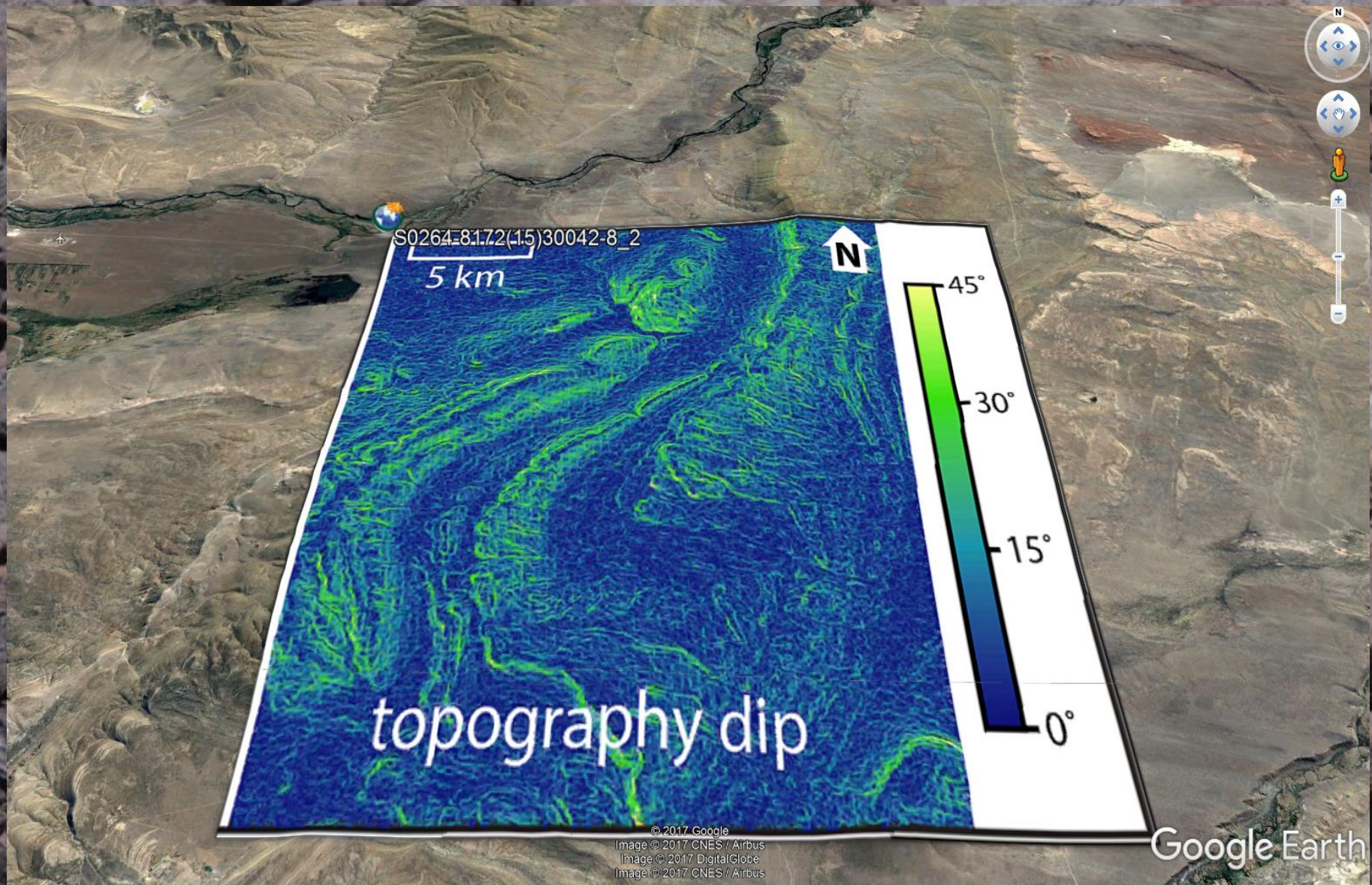
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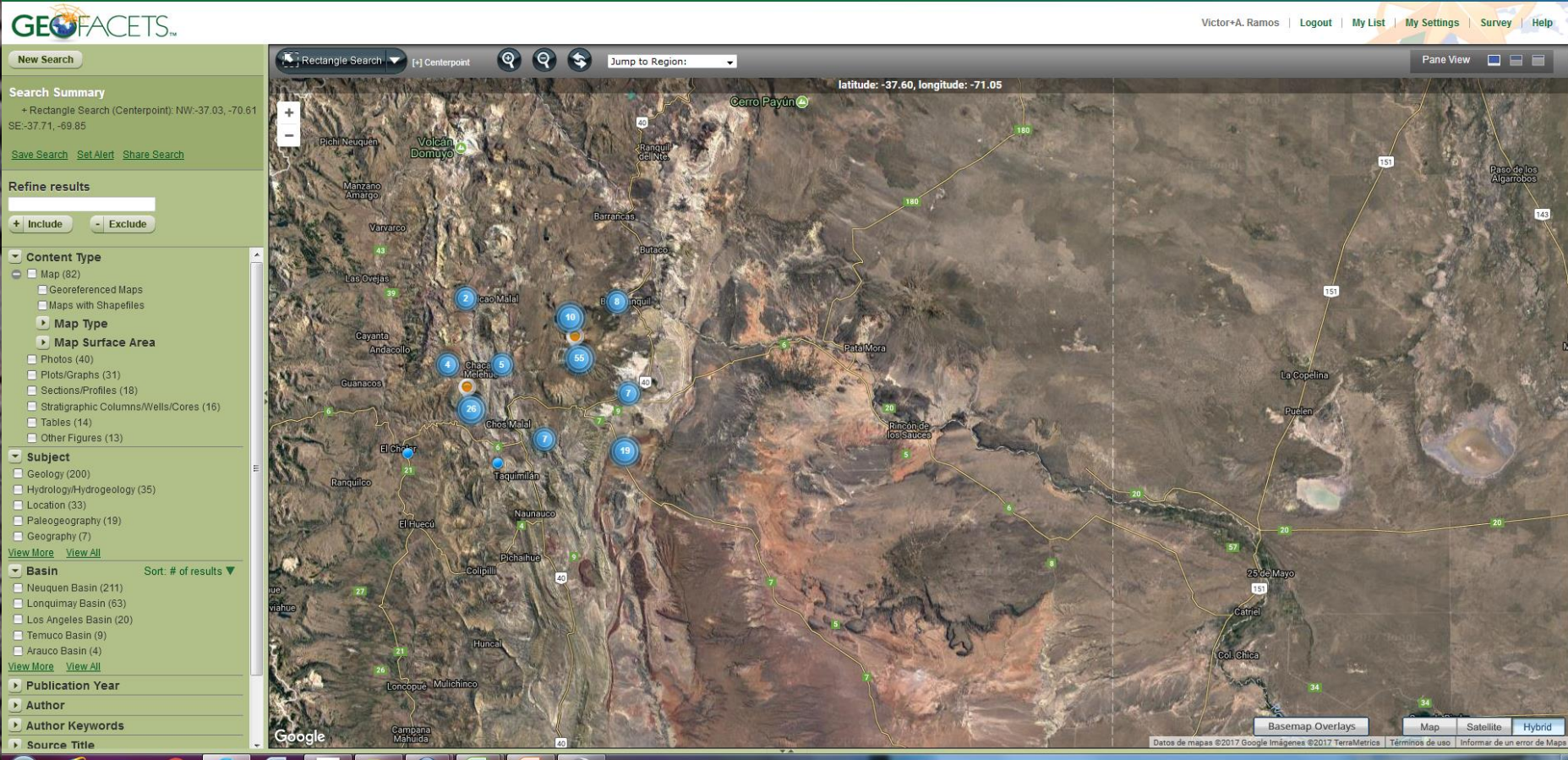
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Búsquedas específicas: ¿Modelos deposicionales de la Formación Vaca Muerta?



Formación Vaca Muerta

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Sequence architecture and heterogeneities of a field - Scale **Vaca Muerta** analog (Neuquén Basin, Argentina) - From outcrop to synthetic seismic

Marine and Petroleum Geology, Volume 66, September 2015, pages 829-847

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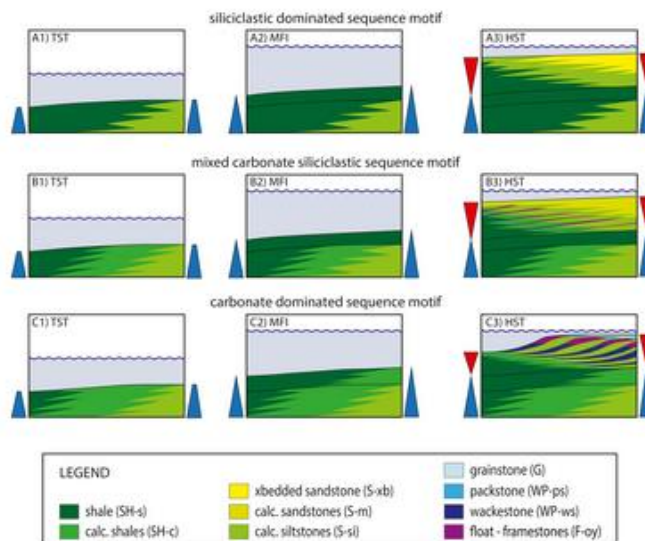
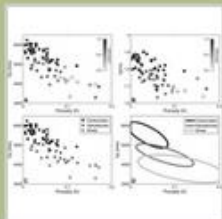
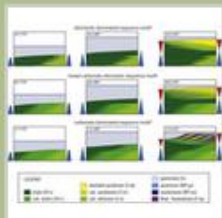


Fig. 9 Depositional Models: A1-3) Siliciclastic dominated sequence, B1-3) mixed sequence, C1-3) carbonate dominated sequence; TST: transgressive systems tract, MFI: maximum flooding interval, HST, highstand systems tract.

Modelos deposicionales

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Sources: Elsevier, The Geological Society of London, Geological Society of America, Society for Sedimentary Geology, Society of Economic Geologists, AGU- American Geophysical Union, Wiley, Society of Exploration Geophysicists, Bureau of Economic Geology, and many others...

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SE:-37.71, -69.85

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 - ☒ Map Surface Area
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 - ☐ Sections/Profiles (18)
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 - ☐ Tables (14)
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- ☐ Location (33)
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- ☐ Geography (7)

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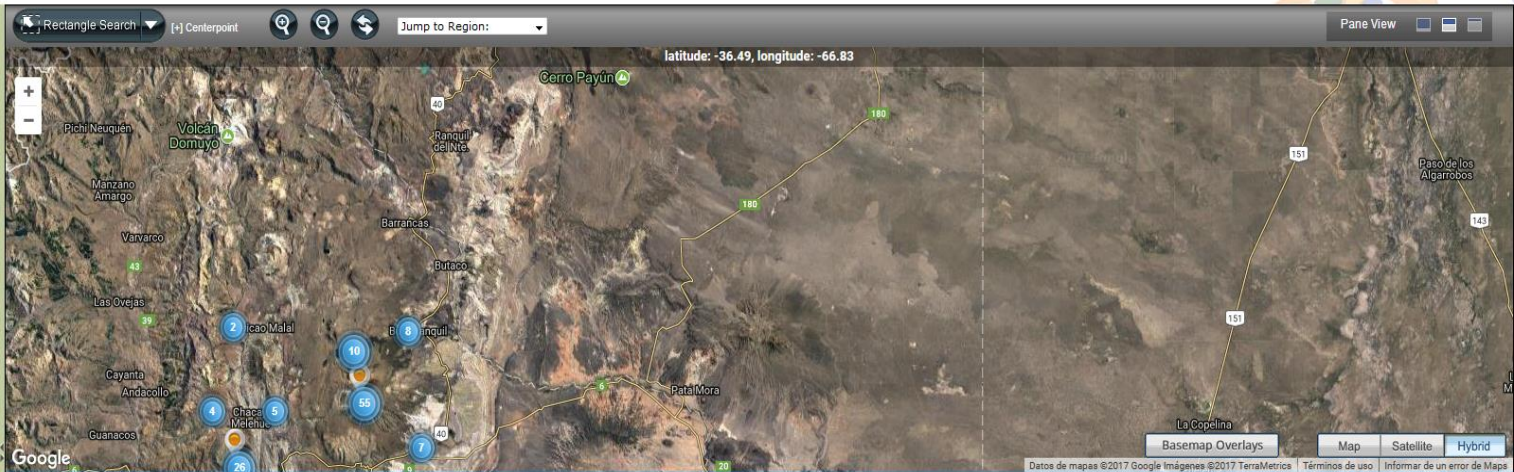
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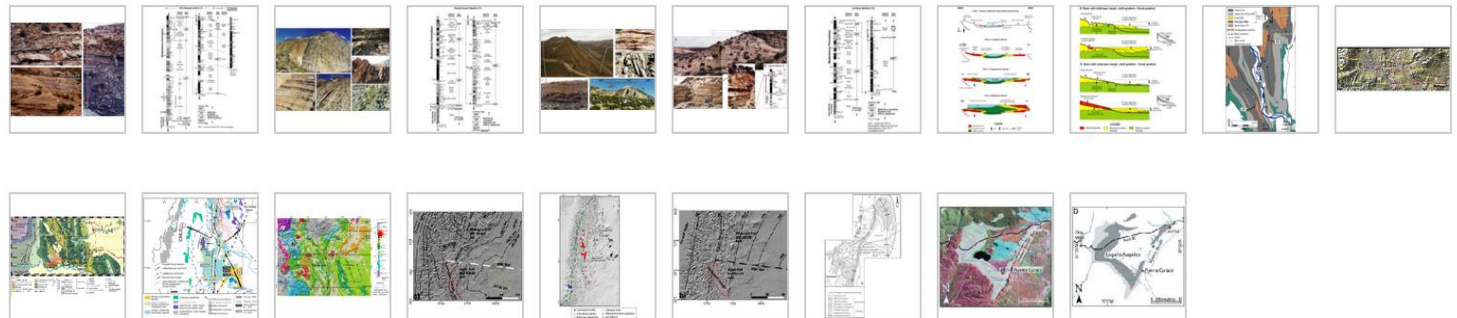
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Selección del mejor mapa geológico estructural disponible de la Formación Vaca Muerta, junto al informe del estudio y los análisis específicos.

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Evolution of the Chos Malal and Agrio fold and thrust belts, Andes of Neuquén: Insights from structural analysis and apatite fission track dating

Journal of South American Earth Sciences, Volume 64, December 2015, pages 418-433

Rojas Vera, E.A.; Mescua, J.; Folguera, A.; Becker, T.P.; Sagripanti, L.; Fennell, L.; Orts, D.; Ramos, V.A.



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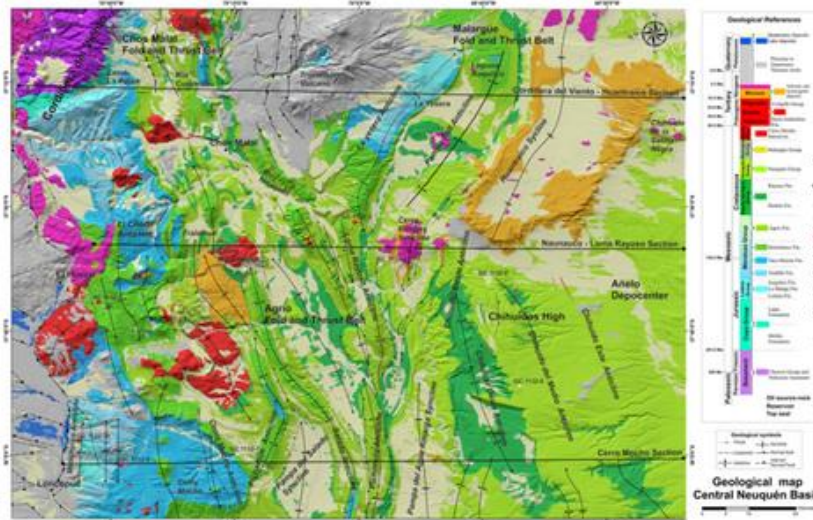
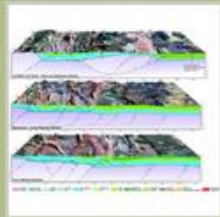
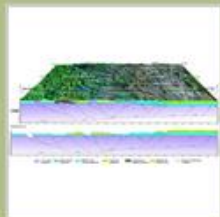
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Mapa geológico
estructural y sección
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Fig. 2. **Geological map** of the study area. Structural cross sections are indicated with black lines, and the location of the samples used for fission track analyses with points. Red points indicate samples used for the thermal history model. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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Structural style of the Chos Malal fold and thrust belt, Neuquén basin, Argentina: Relationship between thick- and thin-skinned tectonics

Journal of South American Earth Sciences, Volume 64, December 2015, pages 399-417

Sánchez, Natalia; Turienzo, Martín; Lebinson, Fernando; Araujo, Vanesa; Coutand, Isabelle; Dimieri, Luis



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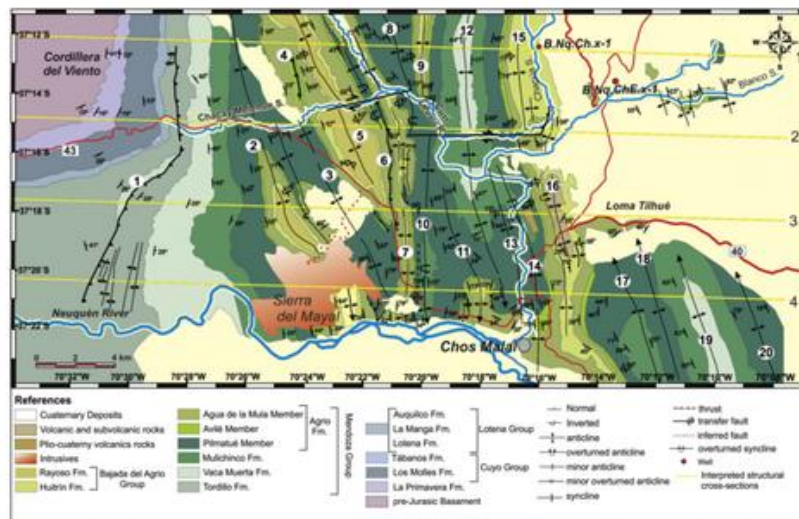


Fig. 3. Regional geological map of the Chos Malal FTB based on own field data (simplified from Sánchez, 2015). Paleozoic to Triassic basement rocks are exposed in the Cordillera del Viento anticlinorium, northwest of the study area. To the east of this basement-involved structure, N-S to NNW trending folds and thrusts of different scale and vergence characterize the Chos Malal FTB. Numbers in white circles identify the main thin-skinned structures mapped in the area: 1: El Alamito backthrust; 2-3: Mayal syncline-anticline; 4-5: Cañada Seca anticline-syncline; 6: Chacay Melehue backthrust; 7: Chacay Melehue syncline; 8-9: Cerro Negro anticline-syncline; 10-11: Chos Malal anticline-syncline; 12: Las Máquinas anticline; 13-14: Curi Leuvú syncline-anticline; 15-16: Chapúa anticline-syncline; 17-18: Tilhué Oeste anticline-syncline; 19-20: Tilhué anticline-syncline.

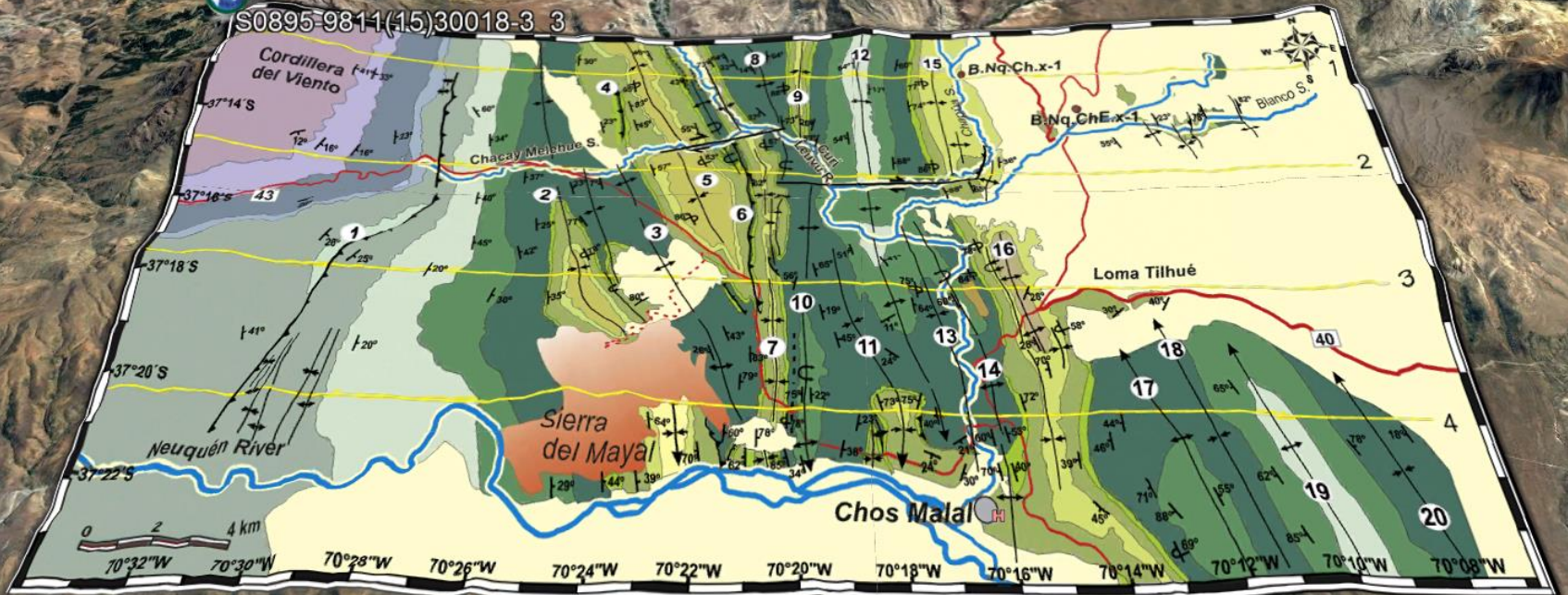
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< Previous

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Next >



Evolution of the Chos Malal and Agrio fold and thrust belts, Andes of Neuquén: Insights from structural analysis and apatite fission track dating

Journal of South American Earth Sciences, Volume 64, December 2015, pages 418–433

Rojas Vera, E.A.; Mescua, J.; Folguera, A.; Becker, T.P.; Sagripanti, L.; Fennell, L.; Orts, D.; Ramos, V.A.



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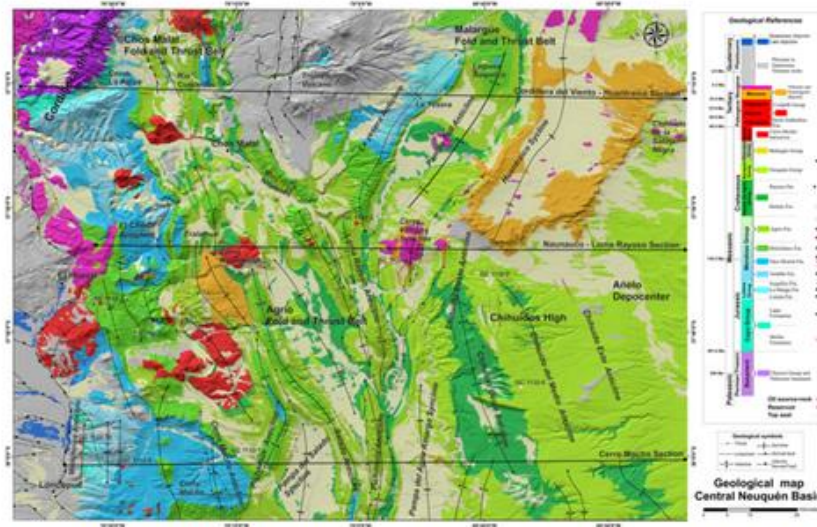
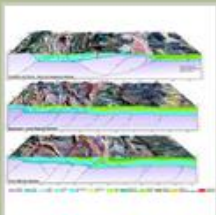
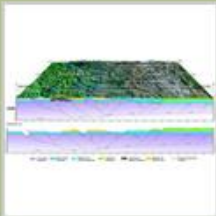
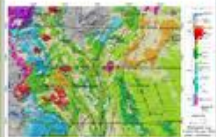


Fig. 2. Geological map of the study area. Structural cross sections are indicated with black lines, and the location of the samples used for fission track analyses with points. Red points indicate samples used for the thermal history model. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

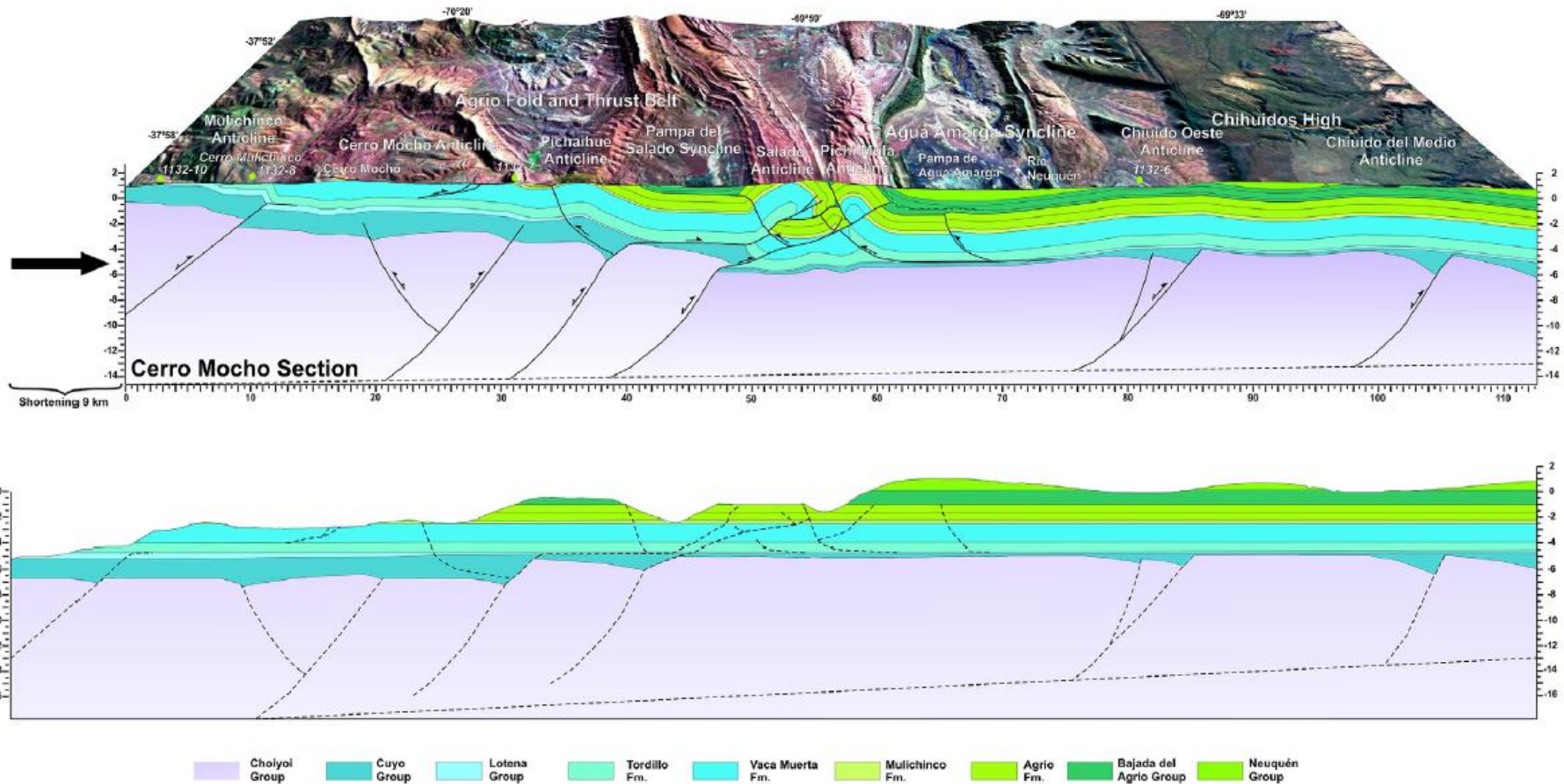
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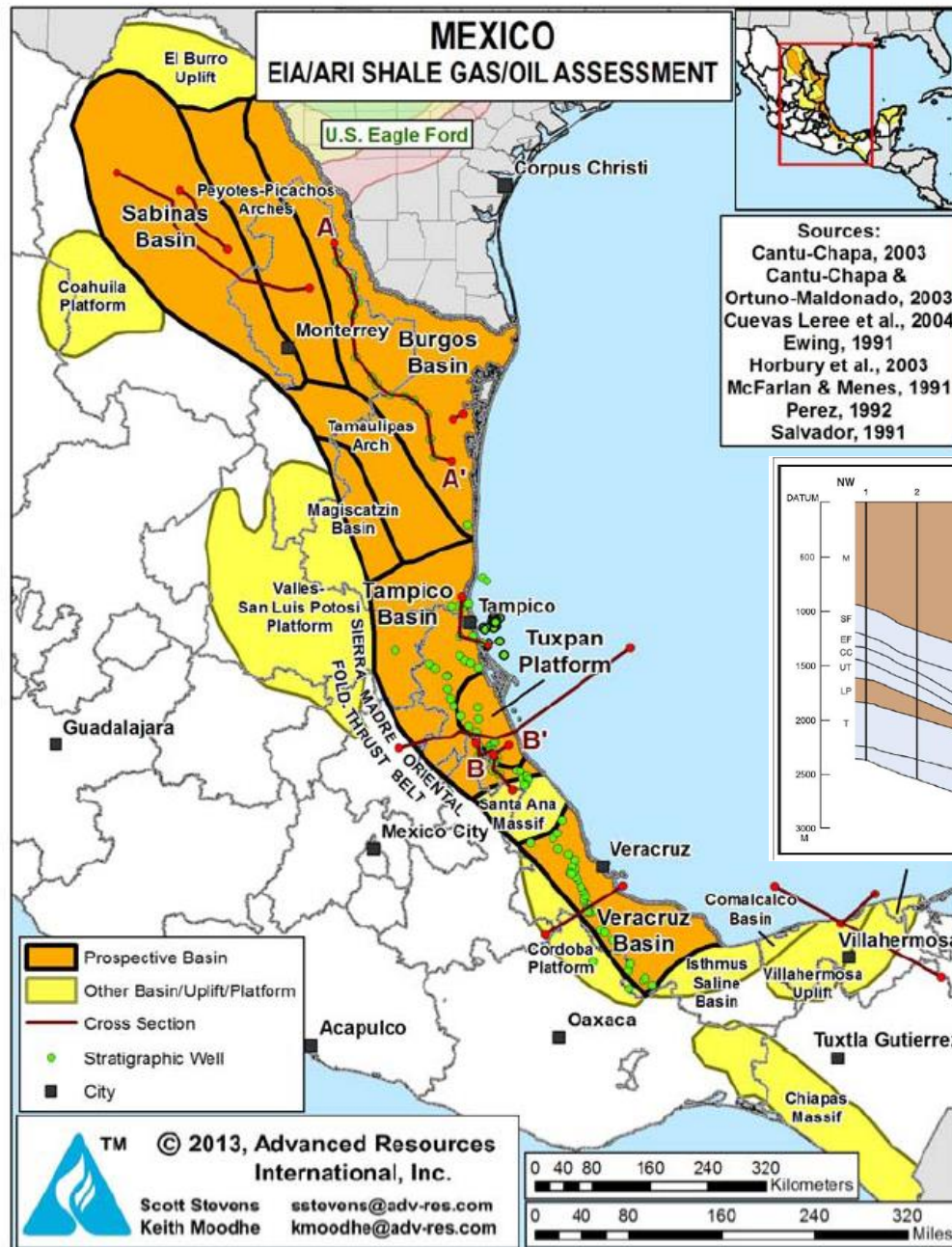
Búsqueda de una sección estructural balanceada del área



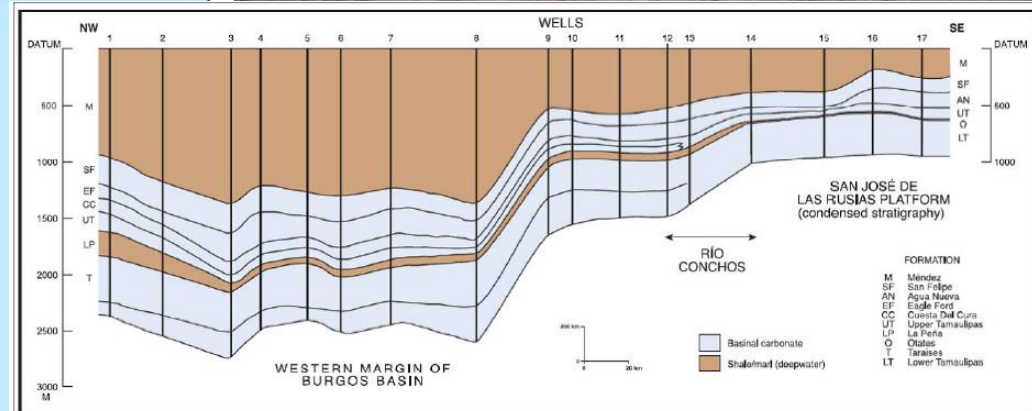
Resultados obtenidos con



- Una rápida evaluación de la información existente en un área específica.
- Acceso directo a mapas georeferenciados de diferentes tipos junto con los estudios específicos.
- Capacidad de integrarse con diferentes plataformas para rápida visualización de la estructura de las potenciales áreas de interés.



Áreas de similares características geológicas en México para un promisorio futuro de exploración



Eagle Shale:
300 a 100 m

Conclusiones

- Se necesita una sólida investigación básica a través de las universidades y el Servicio Geológico Nacional.
- Una excelente preparación profesional de nuestros exploracionistas.
- Un acceso a las modernas tecnologías para hacer una adecuada evaluación de nuestros recursos.

Muchas gracias