

Dealing with Poor Quality Data and Uncertainty in Petroleum System Modeling: An Example from the Fold and Thrust Belt of Bolivian Sub-Andean Ranges*

Ignacio Cambon¹, Martin Pereira¹, Juan Manuel Reynaldi¹, and Ramsis Guerrero¹

Search and Discovery Article #42495 (2020)**

Posted January 27, 2020

*Adapted from oral presentation given at 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:10.1306/42495Cambon2020

¹Pluspetrol S.A., Buenos Aires, South America (icambon@pluspetrol.net)

Abstract

The petroleum systems of the Bolivian sub-Andean ranges were investigated utilizing data from both, wells and outcrops, to better understand the timing of hydrocarbon generation, expulsion and migration. Fields of Bolivian sub-Andean ranges currently produce around 2 BCF/d of natural gas with 2P reserves of 12.5 TCF. Kirusillas, Icla and Los Monos Middle Paleozoic age source rocks are responsible for the generation of hydrocarbons during periods of subsidence within the Cordilleran (Middle Paleozoic), Subandic (Upper Paleozoic) and Andic II (Paleogene to present) tectonic cycles. These source rocks typically have moderate to poor quality, characterized by low generation and expulsion efficiency. Due to the sparse and relatively poor-quality data available with respect to initial total organic carbon, source rock kinetics, ancient heat flow and actual maturity, the petroleum system modeling output generates a wide range of uncertainty. To mitigate this uncertainty, two different aspects were evaluated. First, critical factors that control the source rock such as hydrocarbon generation and expulsion were analyzed and integrated into a basin scale. Secondly, a probabilistic analysis of generation and expulsion timing, transformation ratio and critical moment was done, using different calibrated 1-D petroleum system models run by location, combining maximum and minimum values for the three key input parameters (source rock kinetics, heat flow and lithology). Models were calibrated with cores, logs, well tests, pressure data, Rock-Eval pyrolysis, vitrinite reflectance, thermal alteration index, and regional stratigraphic and structural cross sections. Additionally, a sensitivity analysis on the critical parameters was used to evaluate different outputs. Model results demonstrate that most of hydrocarbon generation is mainly before the Andean deformation during the Paleozoic and into the Mesozoic. Therefore, we should expect that some generated hydrocarbons would be expelled during both the Upper Paleozoic and Mesozoic times. Remaining volumes within these rocks would be expelled and migrate during Andean deformation through the main thrusts. These results are very encouraging for exploration of stratigraphic traps developed during the Upper Paleozoic and Mesozoic times

References Cited

Baur, F., Di Benedetto, M., Fuchs, T., Lampe, C., Sciamanna, S., 2009, Integrating structural geology and petroleum systems modeling - A pilot project from Bolivia's fold and thrust belt, *Marine and Petroleum Geology*, v. 26, no. 4, p. 573–579.

Chávez, M.A., Meunier J.P., Nicoletis S., Sabat, J.P., 2016, Perforar La Formación Los Monos Subandino Sur Bolivia, Lecciones Aprendidas, XXII Congreso Boliviano de Geología, no. 71.

Gohrbandt, K., 1993, Paleozoic paleogeographic and depositional developments on the central proto-Pacific margin of Gondwana: Their importance to hydrocarbon accumulation, *Journal of South American Earth Sciences*, v. 6, no. 4, p. 267-287.

Hernández, N., M. Iribarne, D. Apreda, G. Laffitte, and G. Vergani, G., 2011, Nuevos conceptos estructurales a partir de la perforación del pozo profundo Ramos xp-1012 en el Yacimiento Ramos, Sierra de San Antonio, Provincia de Salta: VIII Congreso de Exploración y Desarrollo de Hidrocarburos, Instituto Argentino del Petróleo y del Gas, Mar del Plata, Argentina, p. 599–617.

Kusiak, M.E., 2008, El Mesozoico del Sistema Subandino de Bolivia: evolución sedimentaria y síntesis de la cuenca. Ph.D. Thesis, Faculty of Natural Sciences, University of Buenos Aires, Buenos Aires, Argentina, 173 p.

Pereira, M., Vergani, G., Cambon, I., Reynaldi, J.M., Iturrealde, J., Guerrero, R., González, G., 2018, Andean deformation and its control on hydrocarbon generation, migration, and charge in the wedge-top of southern Bolivia, in G. Zamora, K. R. McClay, and V. A. Ramos, eds., Petroleum basins and hydrocarbon potential of the Andes of Peru and Bolivia: AAPG Memoir 117, p. 531–554.

Schneider, F., Constantini, L., Mayta, R., Rousse, S., Esquivel, J., 2018, Contribución a la Evaluación del Potencial Petrolífero del Subandino Sur de Bolivia, X Congreso de Exploración y Desarrollo de Hidrocarburos, Instituto Argentino del Petróleo y el Gas, p. 187–208.

Starck, D., 1995, Silurian - Jurassic stratigraphy and basin evolution of northwestern Argentina, in A. J. Tankard, R. Suárez S., and H. J. Welsink, Petroleum basins of South America: American Association of Petroleum Geologists Memoir 62, p. 251-267.

Starck, D., 1999, Los sistemas petroleros de la Cuenca de Tarija: IV Congreso de Exploración y Desarrollo de Hidrocarburos, Instituto Argentino del Petróleo y el Gas, p. 63–82.

Starck, D., 2011, Cuenca Cretácica-Paleógena Del Noroeste Argentino, VIII Congreso de Exploración y Desarrollo de Hidrocarburos, Instituto Argentino del Petróleo y el Gas, p. 407–453.

Starck, D., and del Papa, C, 2006, The northwestern Argentina Tarija Basin: Stratigraphy, depositional systems, and controlling factors in a glaciated basin, *Journal of South American Earth Sciences*, v. 22, no. 3-4, p. 169–184.

Veizaga-Saavedra, J.G., Poiré, D.G., Vergani, G.D., Salfity, J.A., 2018, Mineralogía y Madurez Termal de la Formación Los Monos (Devónico), Cuenca De Tarija, X Congreso de Exploración y Desarrollo de Hidrocarburos, Instituto Argentino del Petróleo y el Gas, p. 389–411.



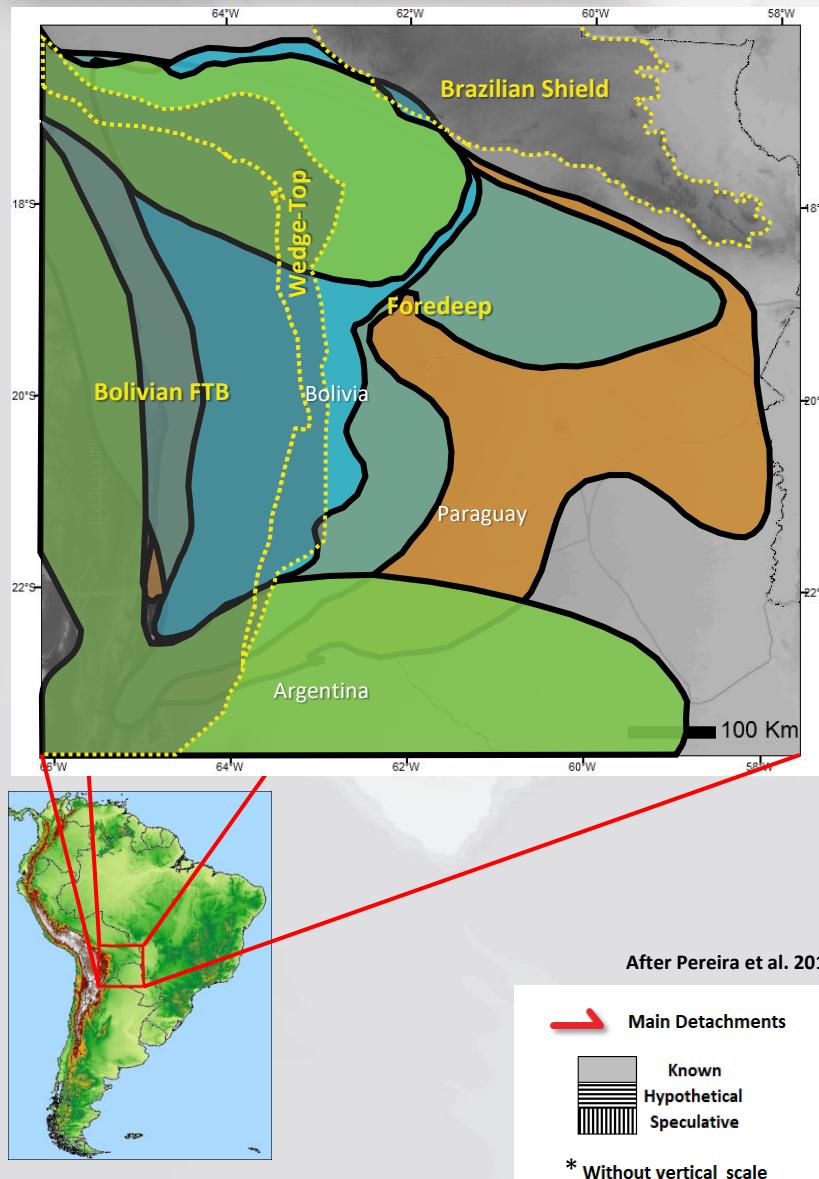
Dealing with poor quality data and uncertainty in Petroleum System Modeling: An Example from the Fold and Thrust Belt of Bolivian sub-Andean Ranges

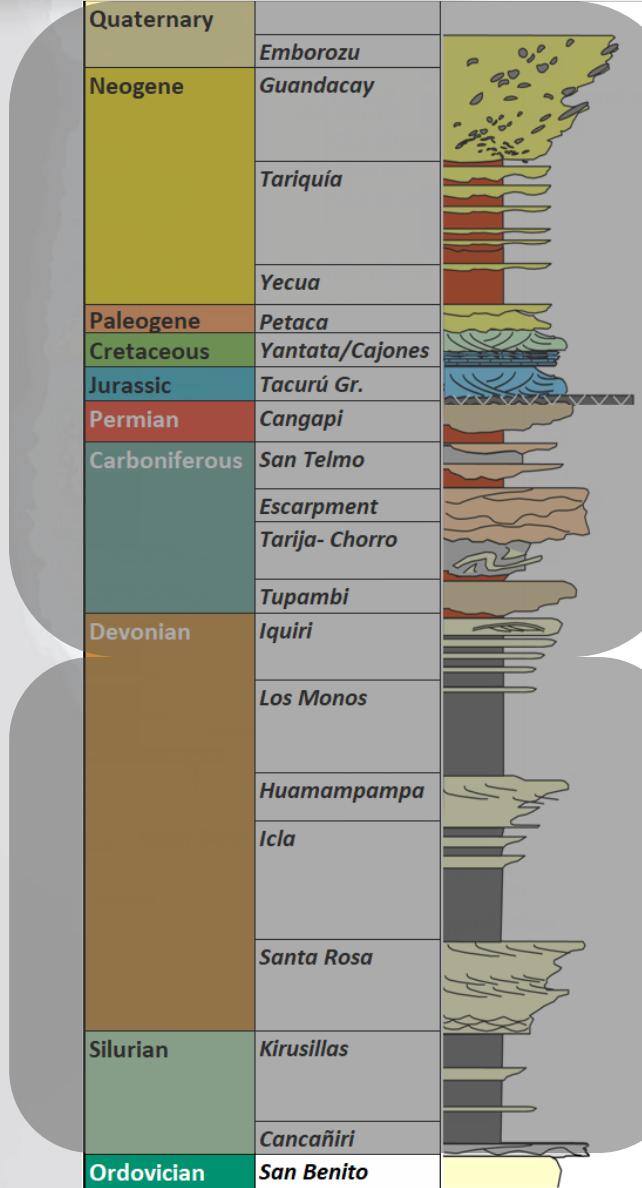
CAMBON Ignacio, PEREIRA Martin, REYNALDI Juan Manuel, GUERRERO Ramsis

Pluspetrol S.A.



Sub-Andean Ranges & Chaco Plain General Stratigraphic Column





1D Petroleum System Modelling Uncertainties

Sub-Andean Ranges & Chaco Plain

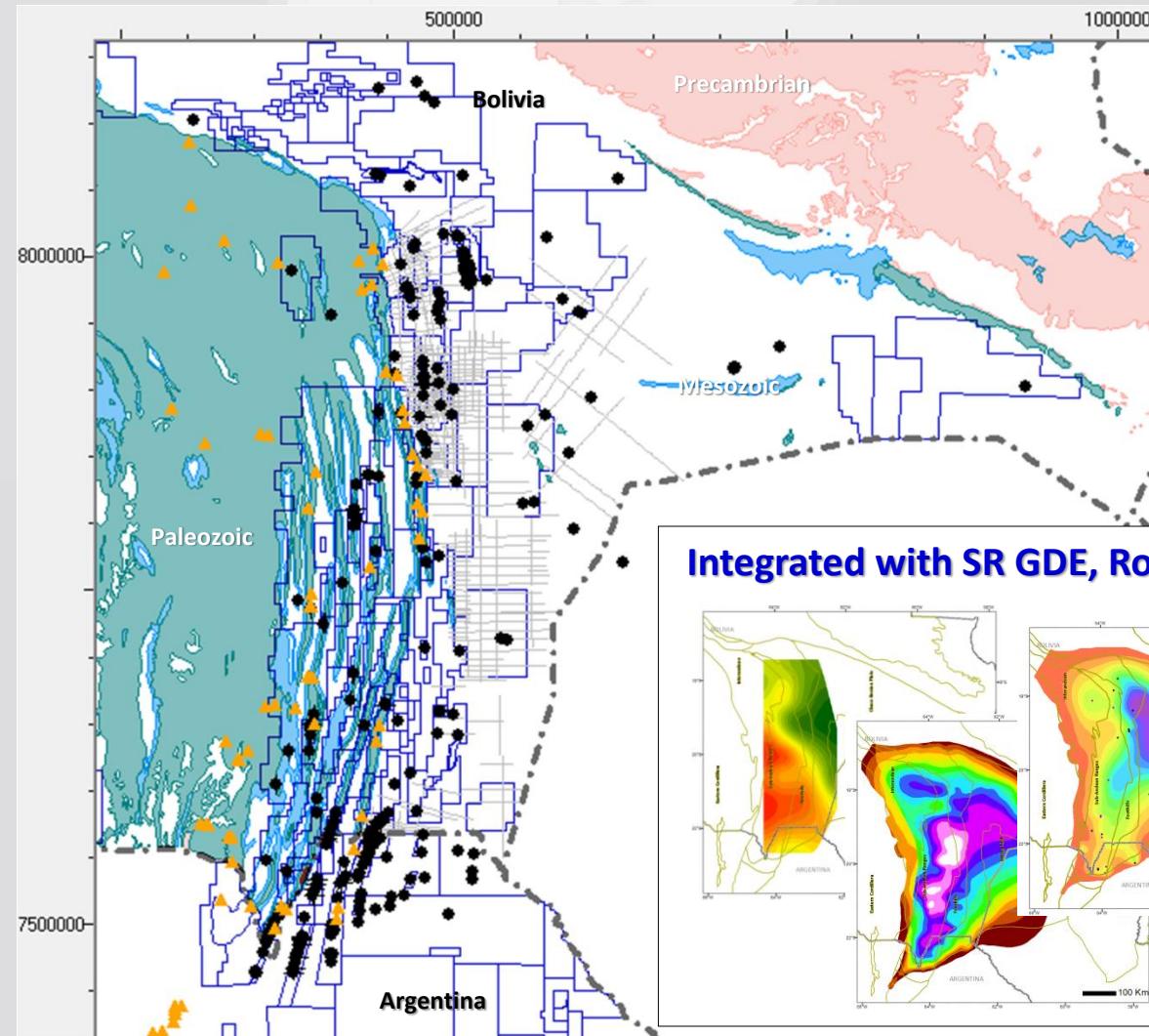
Overburden

- ≋ Thickness & Age
- ≋ Eroded Thickness
- ✓ Thermal Conductivity (Lithology & Porosity)
- Heat Flow: ✓ Current & ✗ PaleoHF

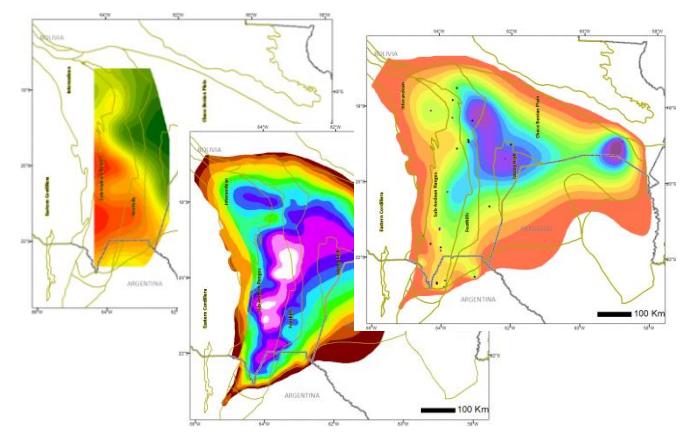
Source Rocks

- ≋ Thickness & Age
- ≋ Lithology
- ✓ TOC & ≋ oTOC (oHI)
- ≋ Kinetic
- ✓ Maturity
- ✓ Pressure
- ≋ Expulsion Method / Saturation Threshold / Porosity

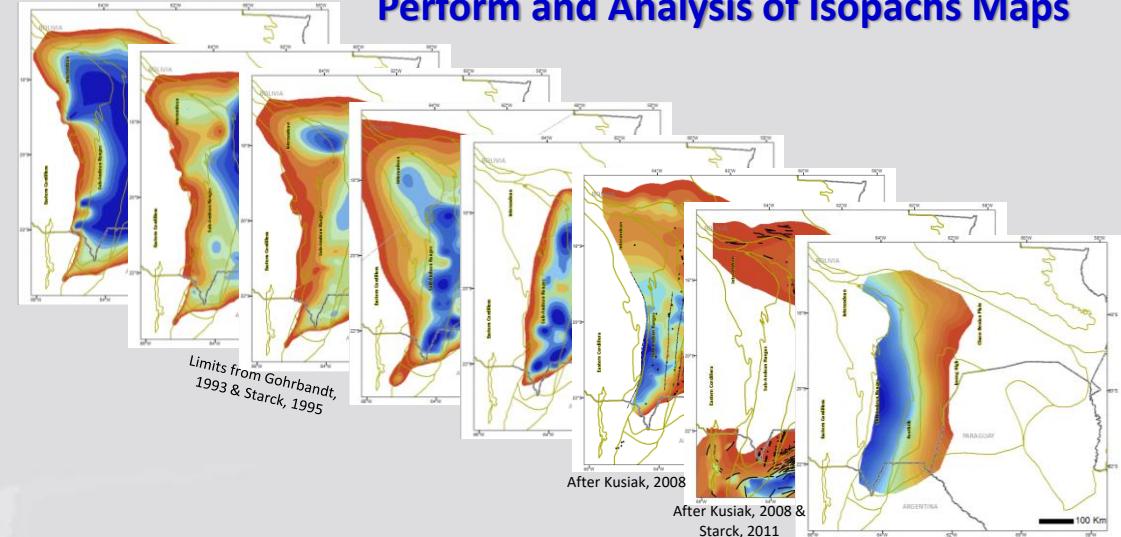
Wells & Field Sections Correlated & Calibrated with 2D seismic & Biostratigraphy



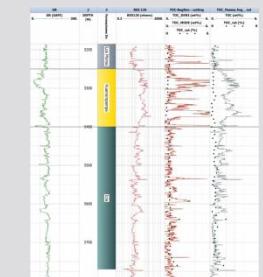
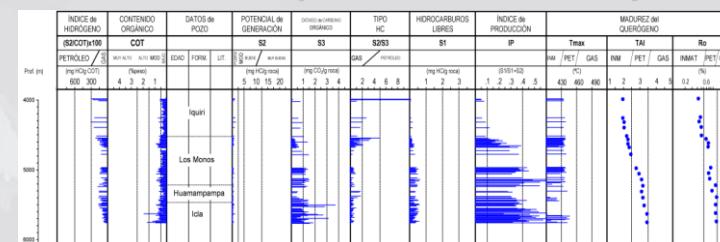
Integrated with SR GDE, Ro, TOC Maps



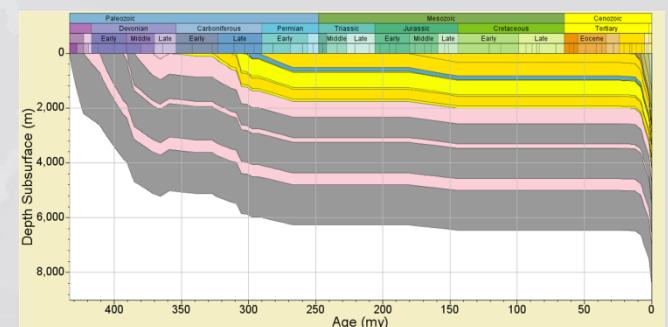
Perform and Analysis of Isopachs Maps



56 Wells & 23 Outcrops SR Geochemistry Analysis

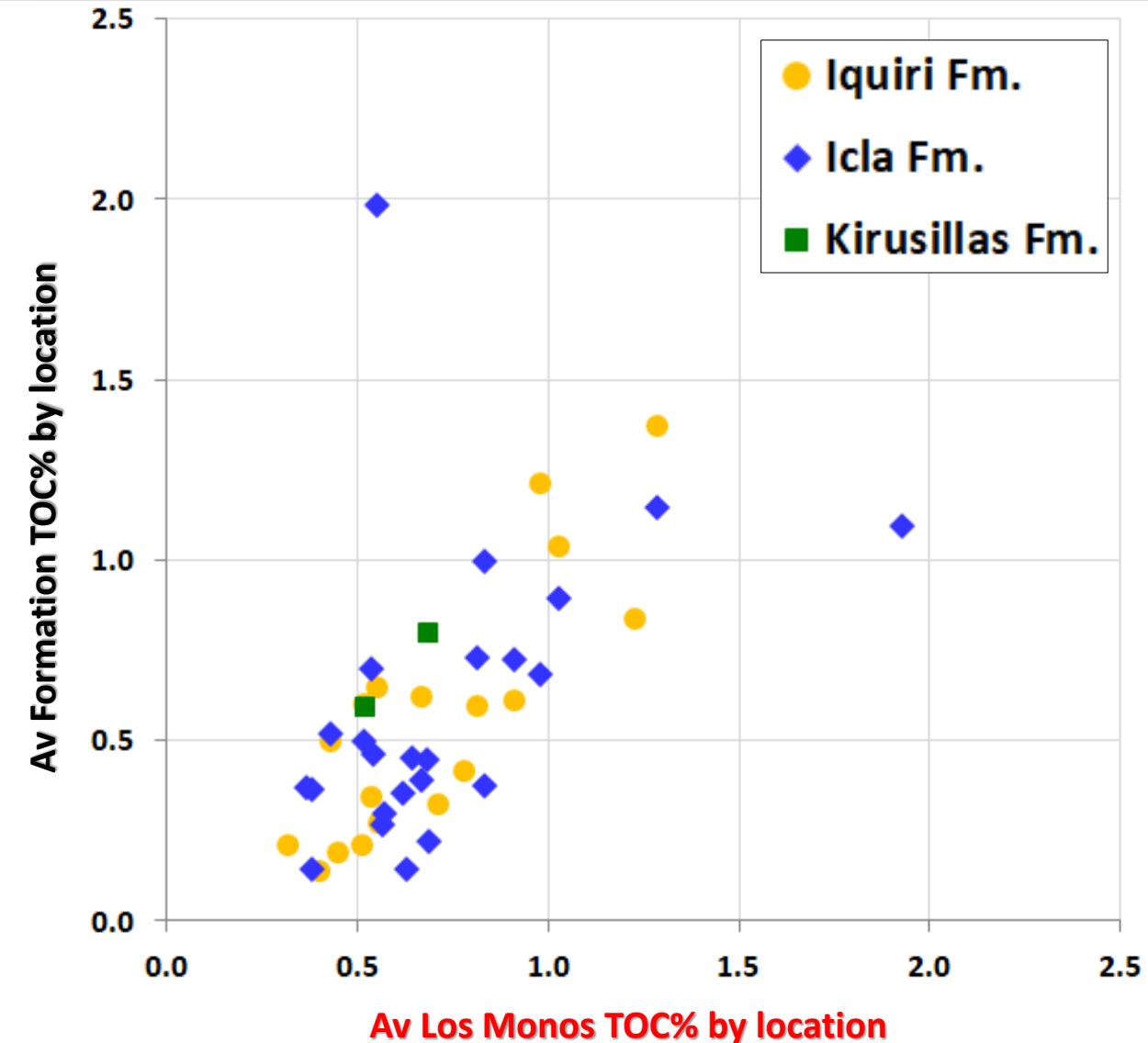
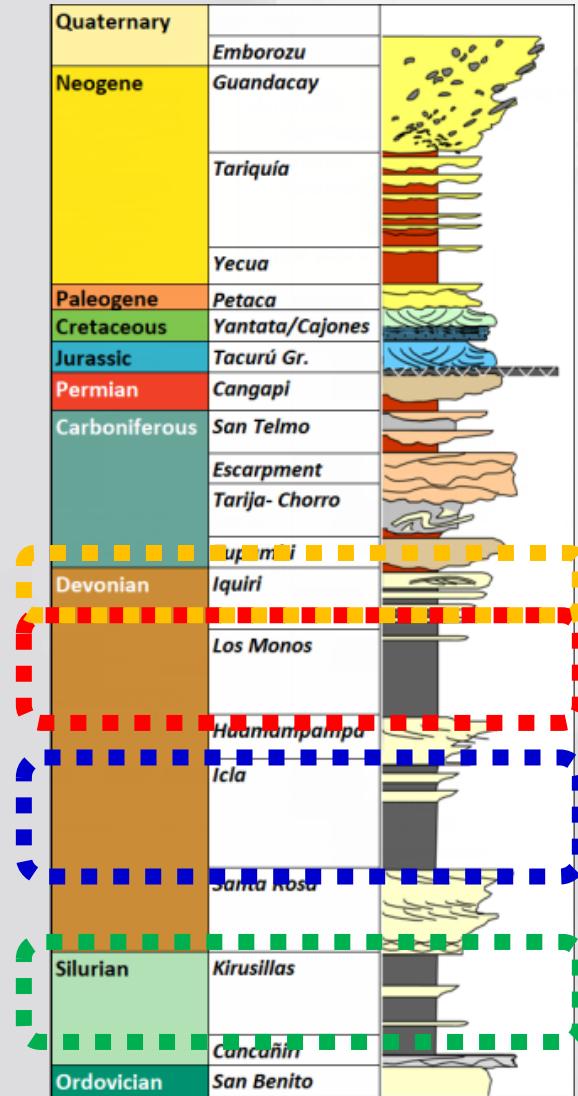


1D PSM



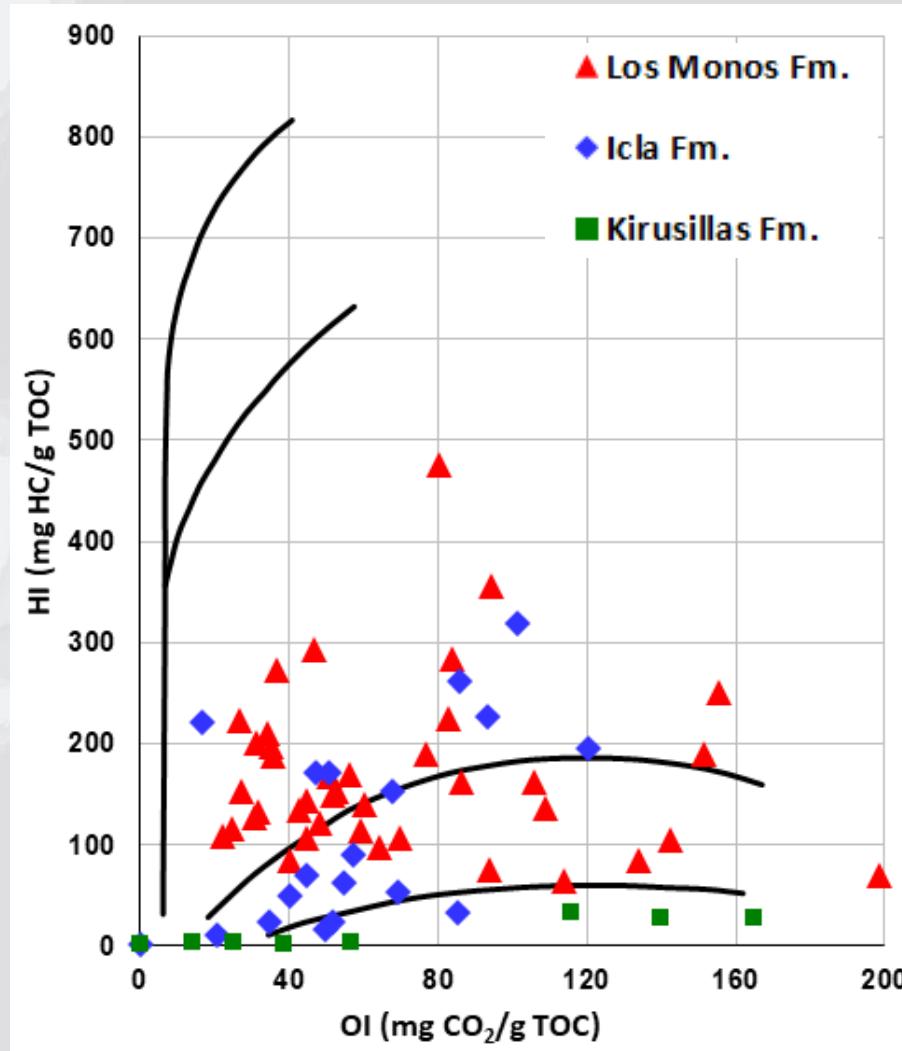


Parameters & Variables Quality Control: TOC





Parameters & Variables Quality Control: Kinetics

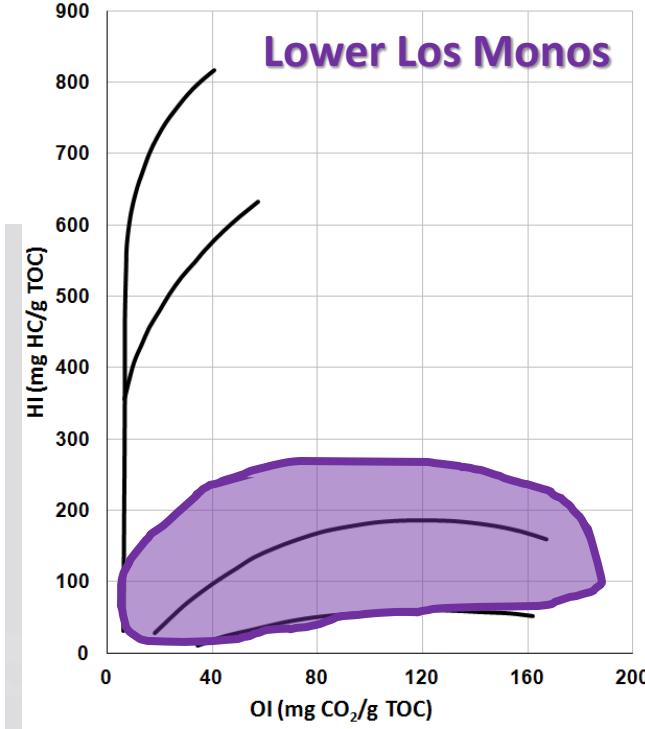
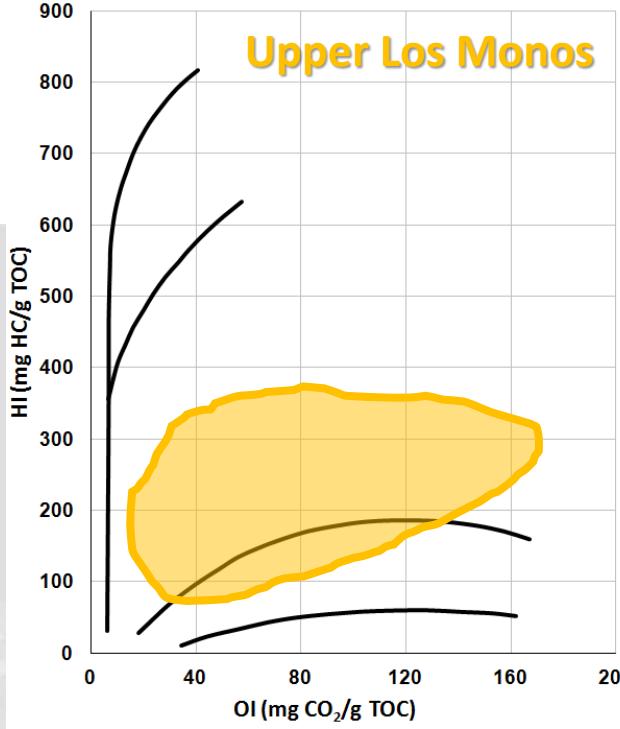
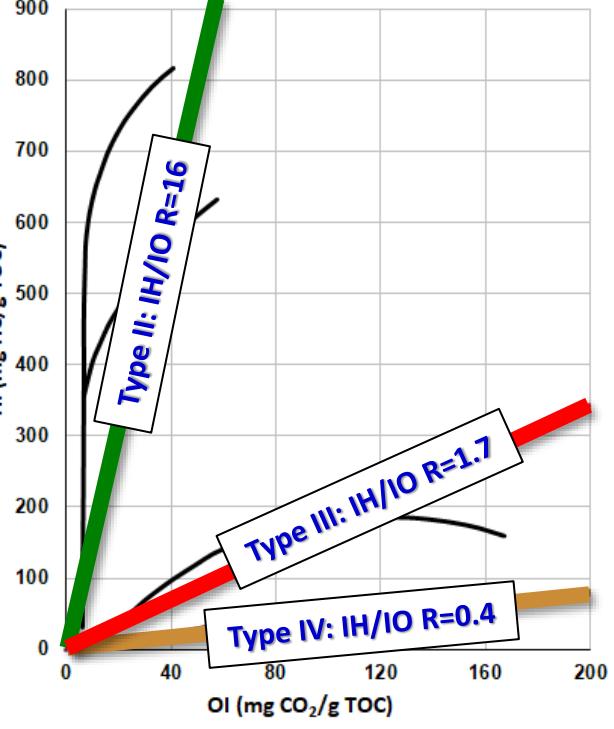
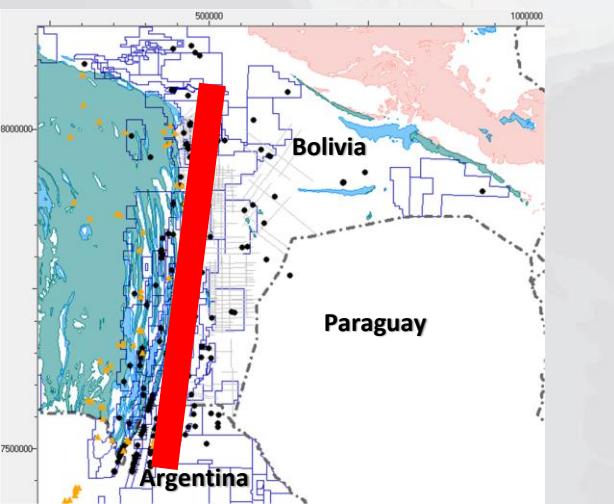
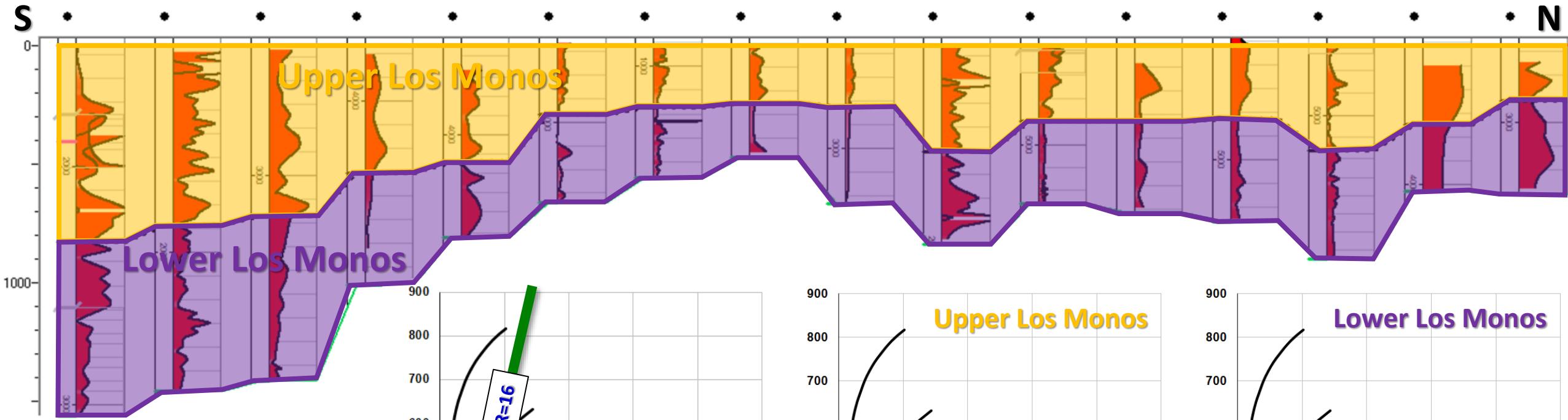


Los Monos: 40 locations, 825 samples

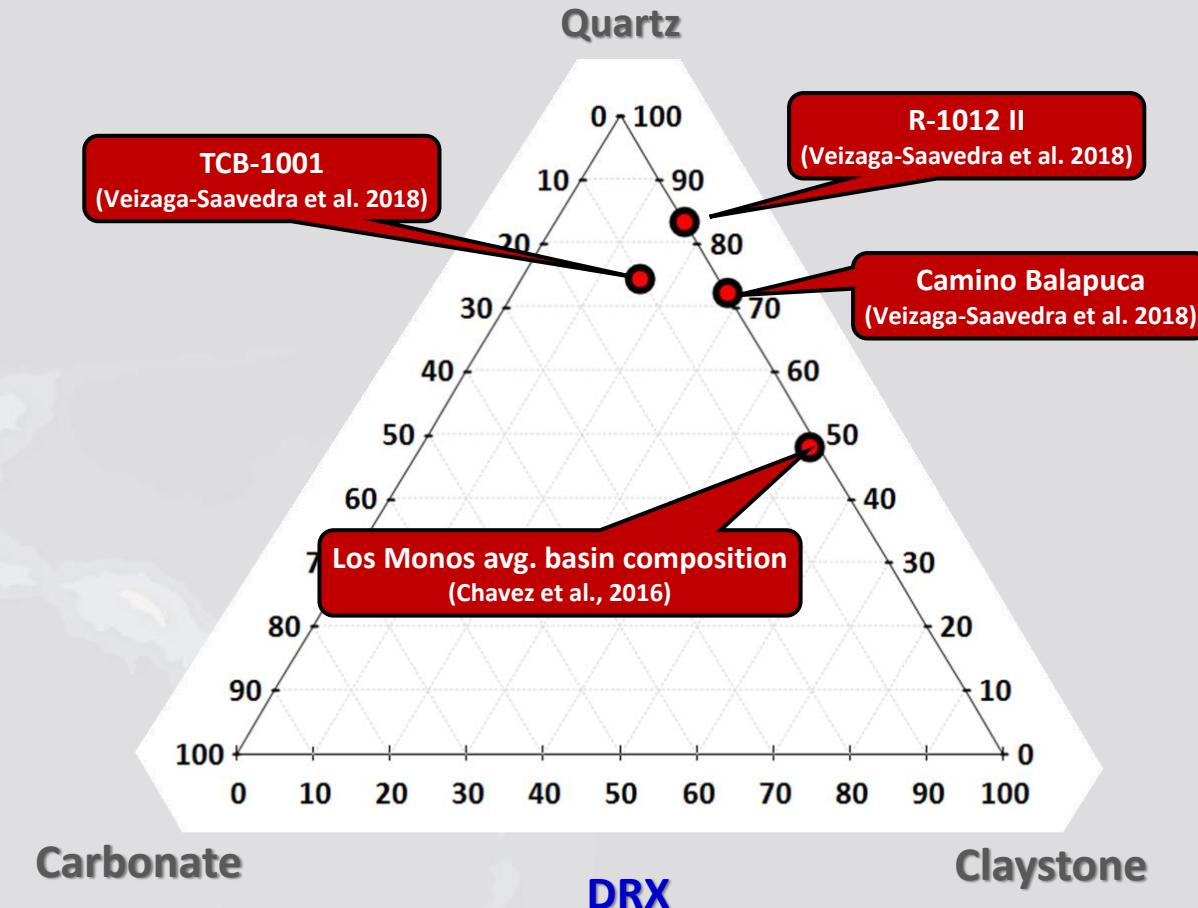
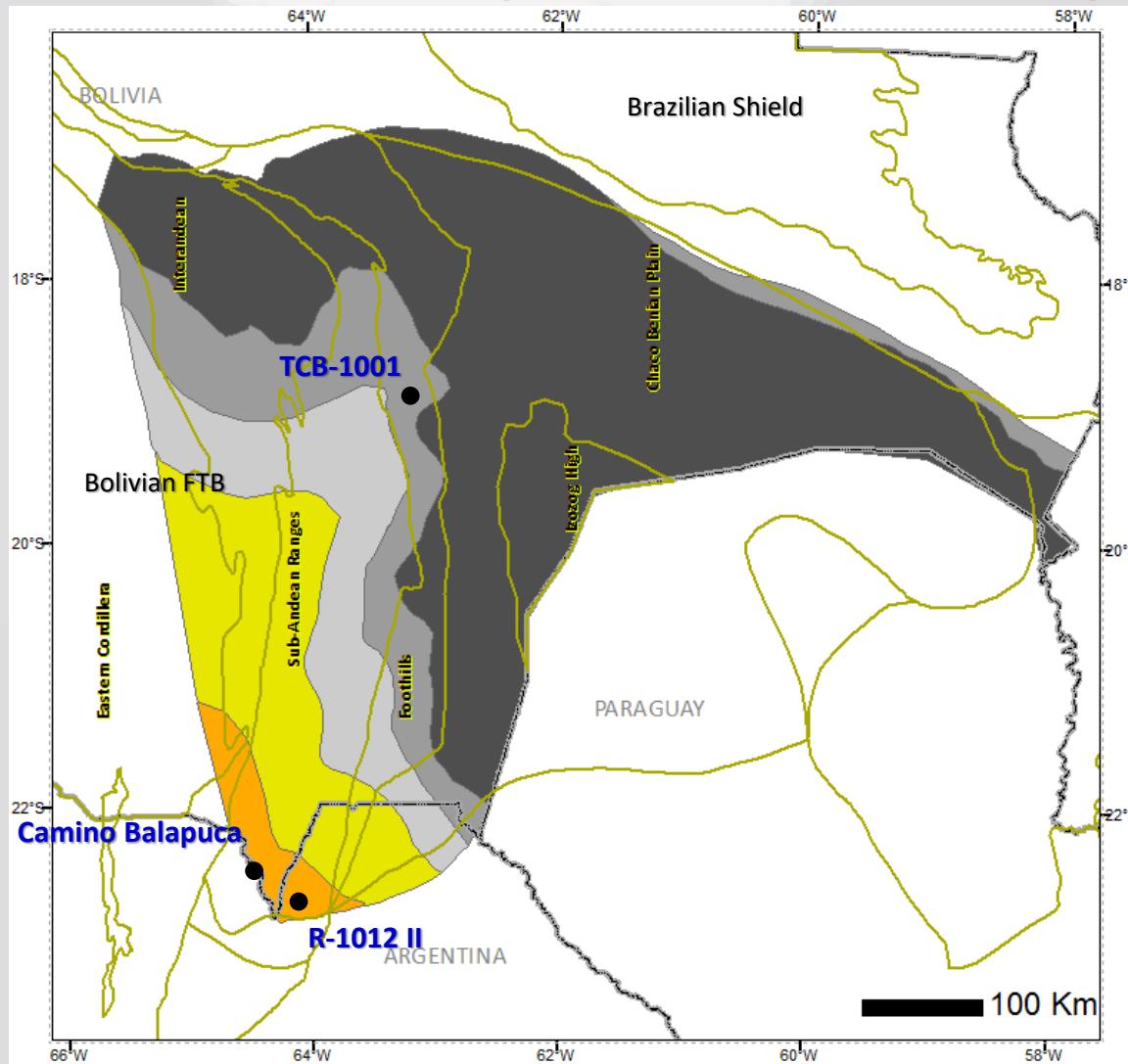
Icla: 22 locations, 266 samples

Kirusillas: 5 locations, 10 samples

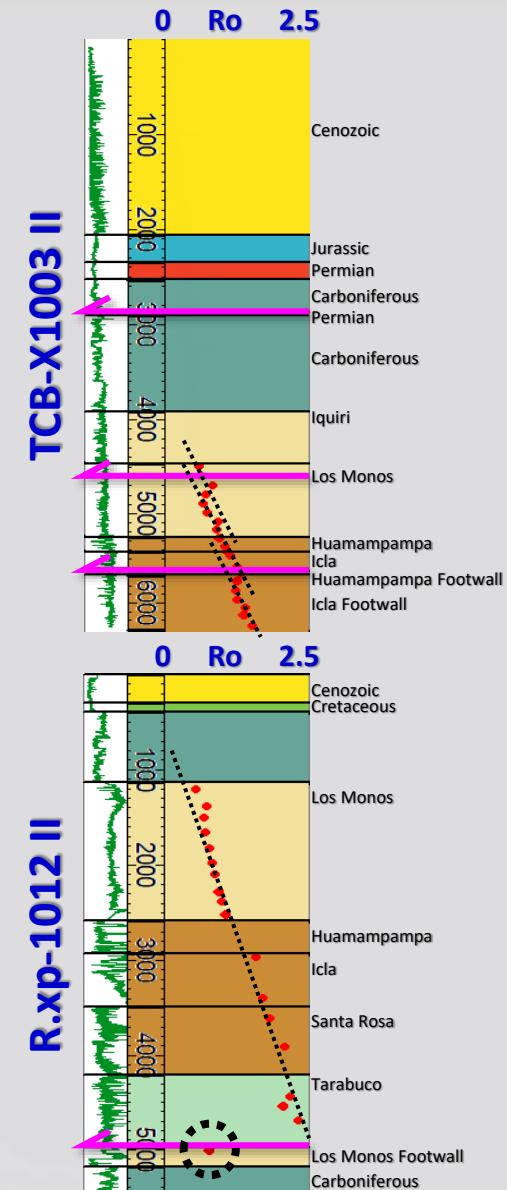
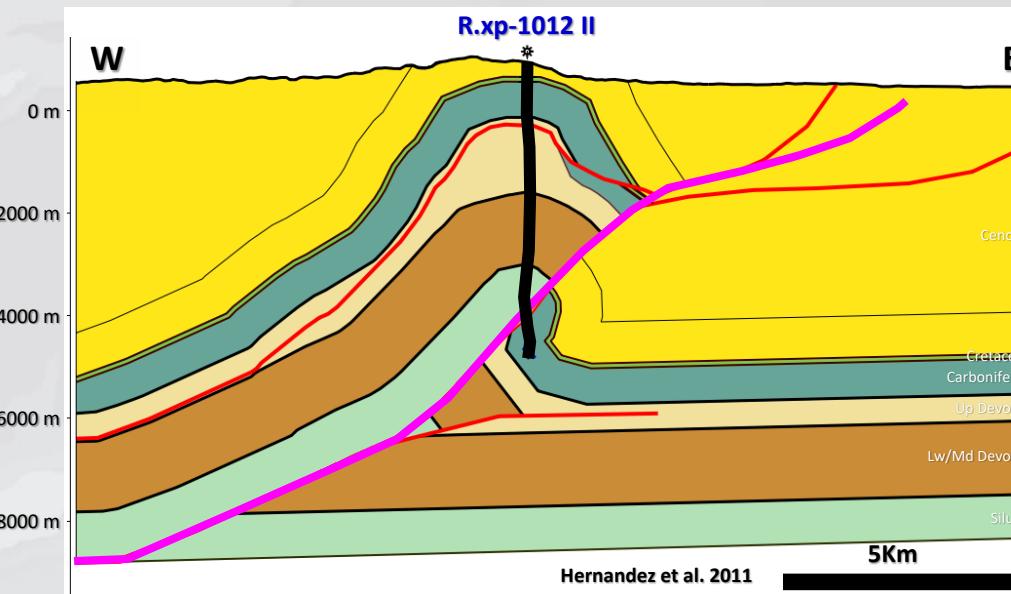
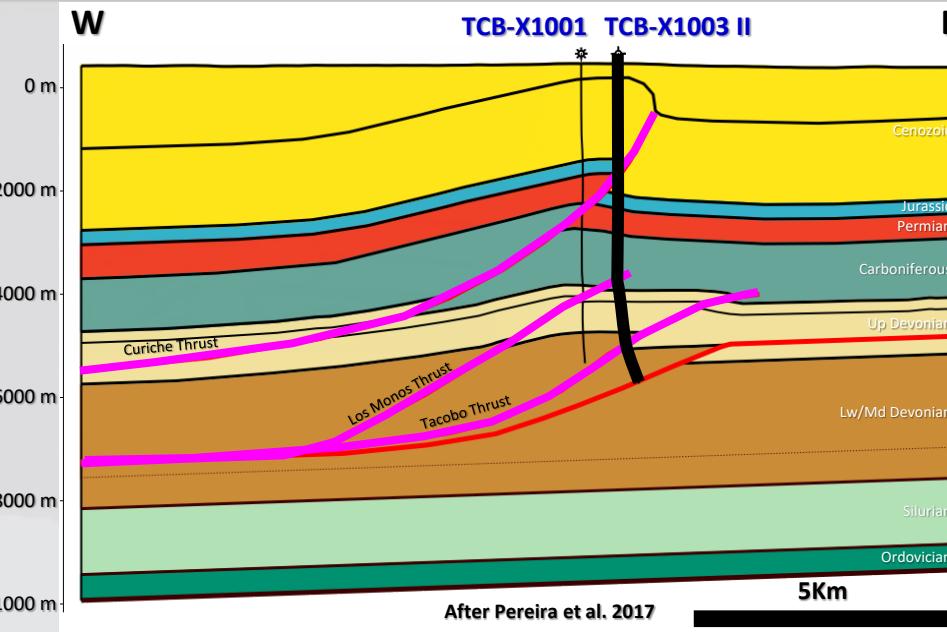
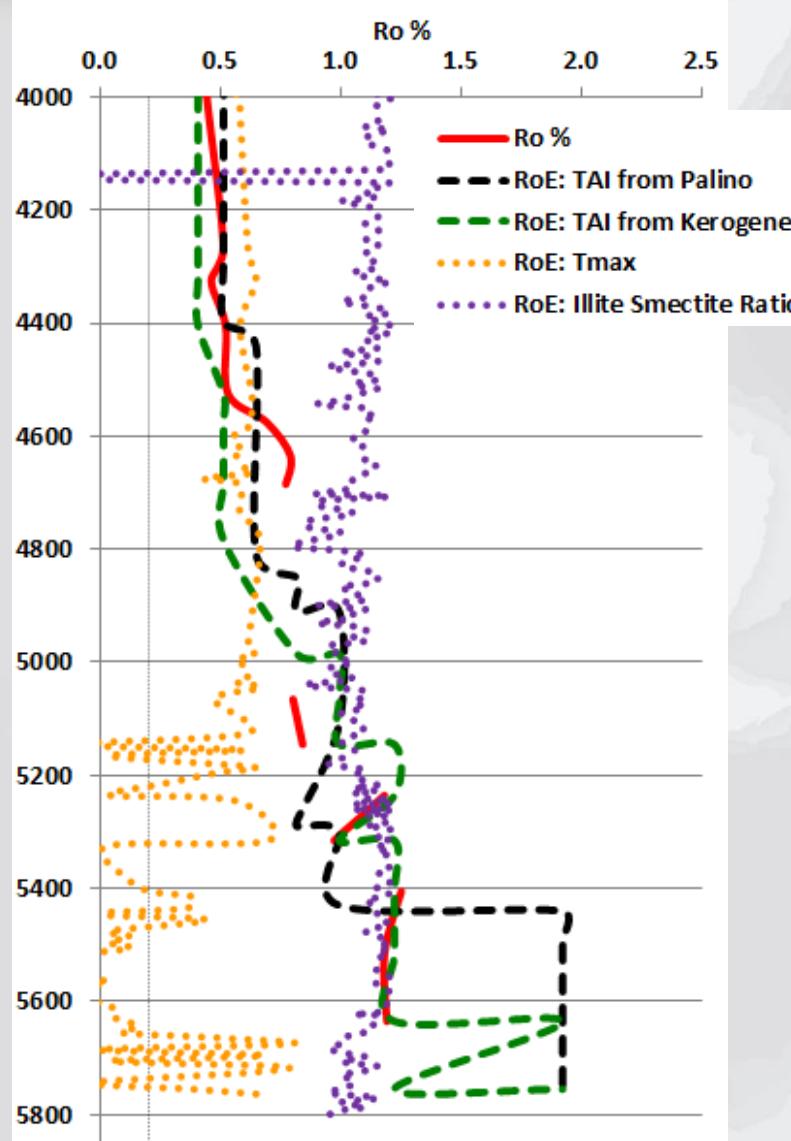
Parameters & Variables Quality Control: Kinetics



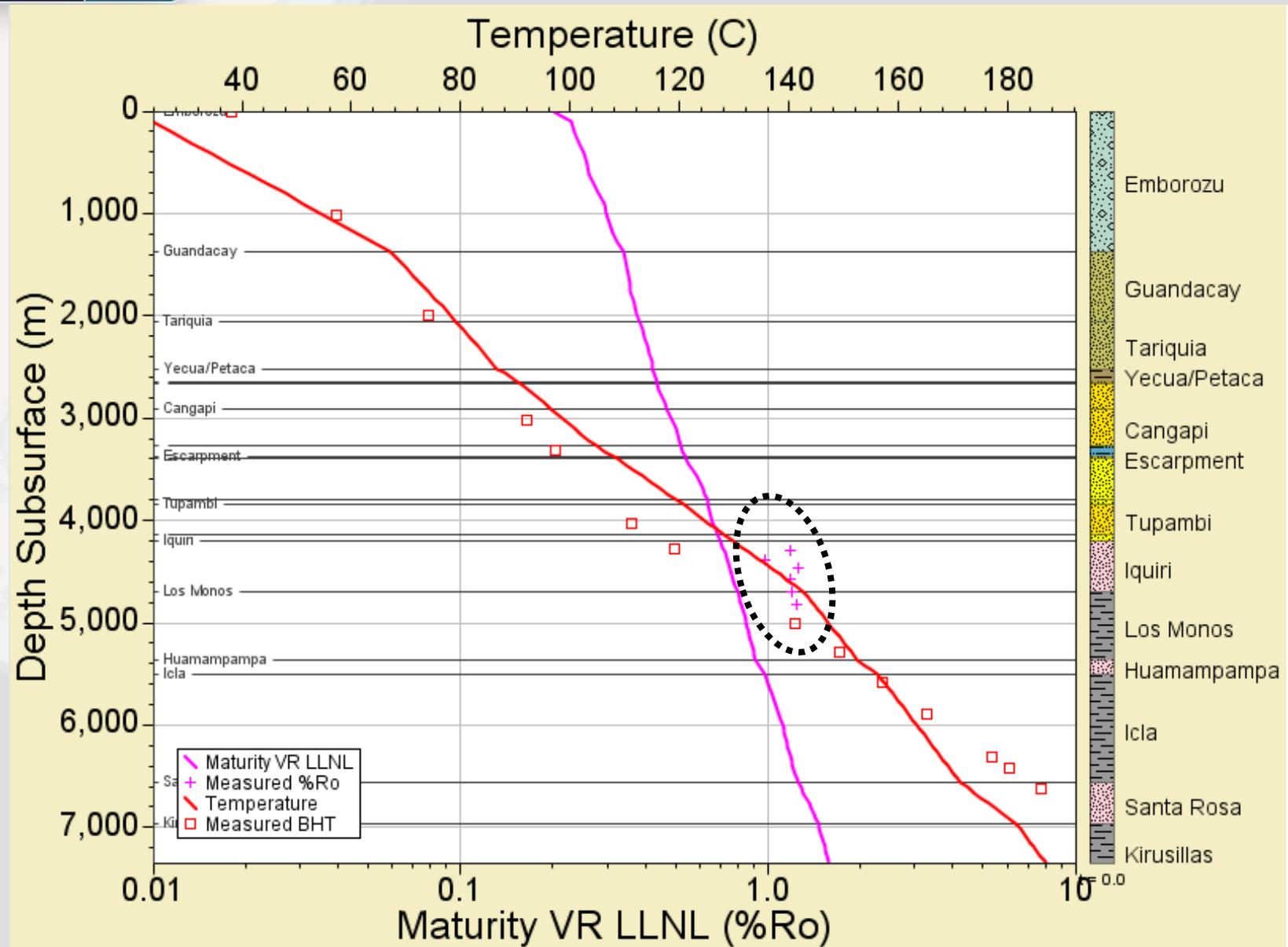
Los Monos Fm. GDE (After Schneider et al. 2018)



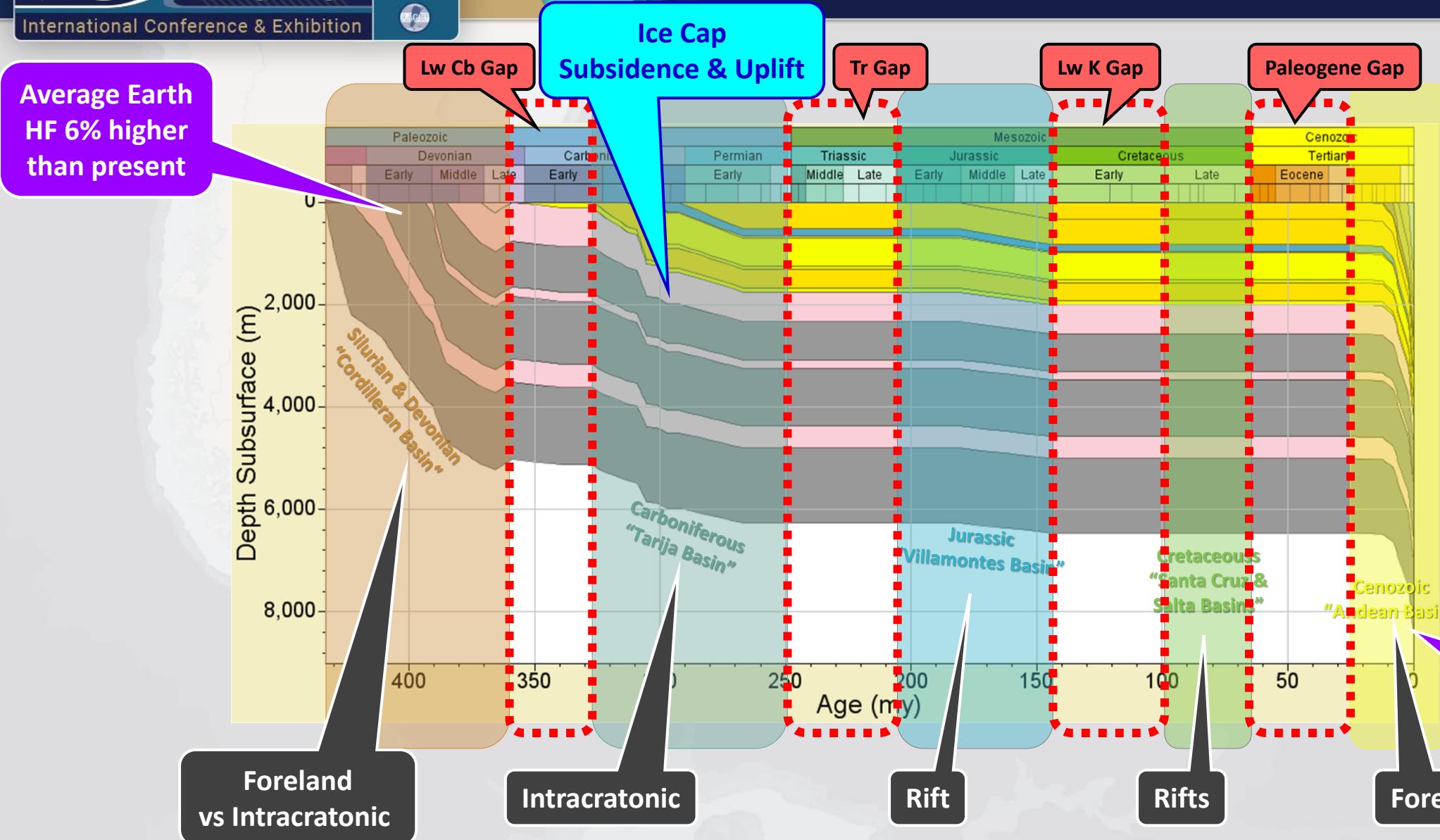
Parameters & Variables Quality Control: Maturity



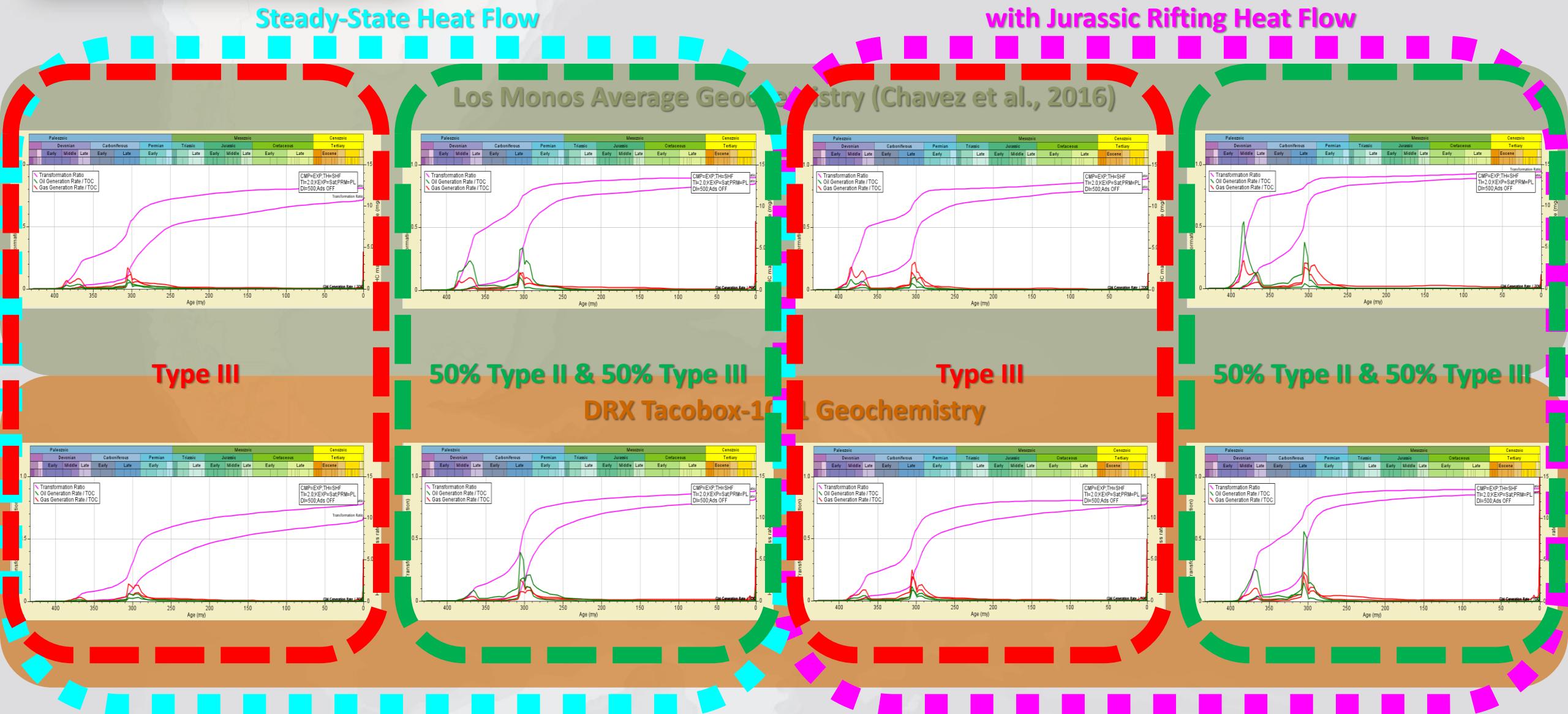
Temperature vs. Maturity Calibration Evidences of a Higher Paleo-Heat-Flow



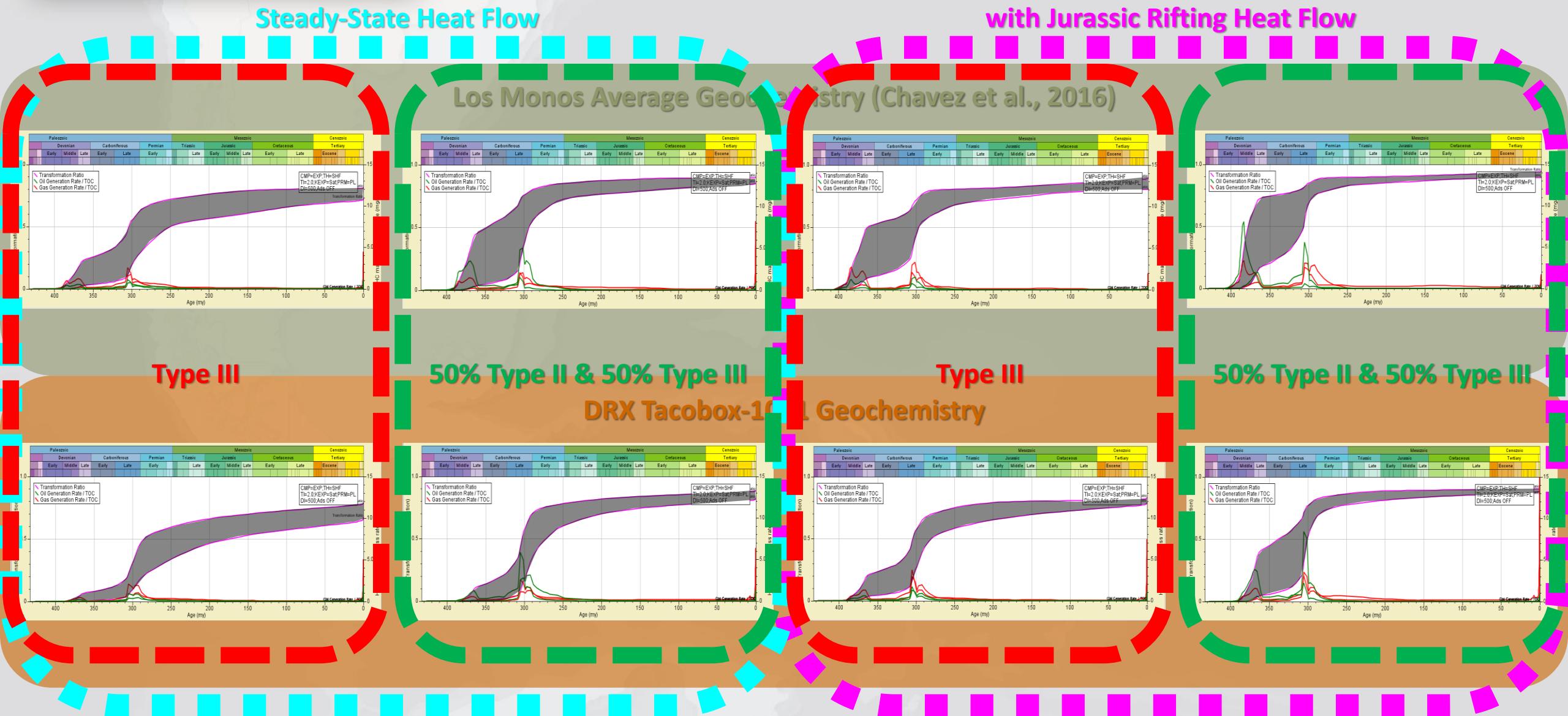
Paleo-Heat-Flow: Basin Dynamics & Thermal Events



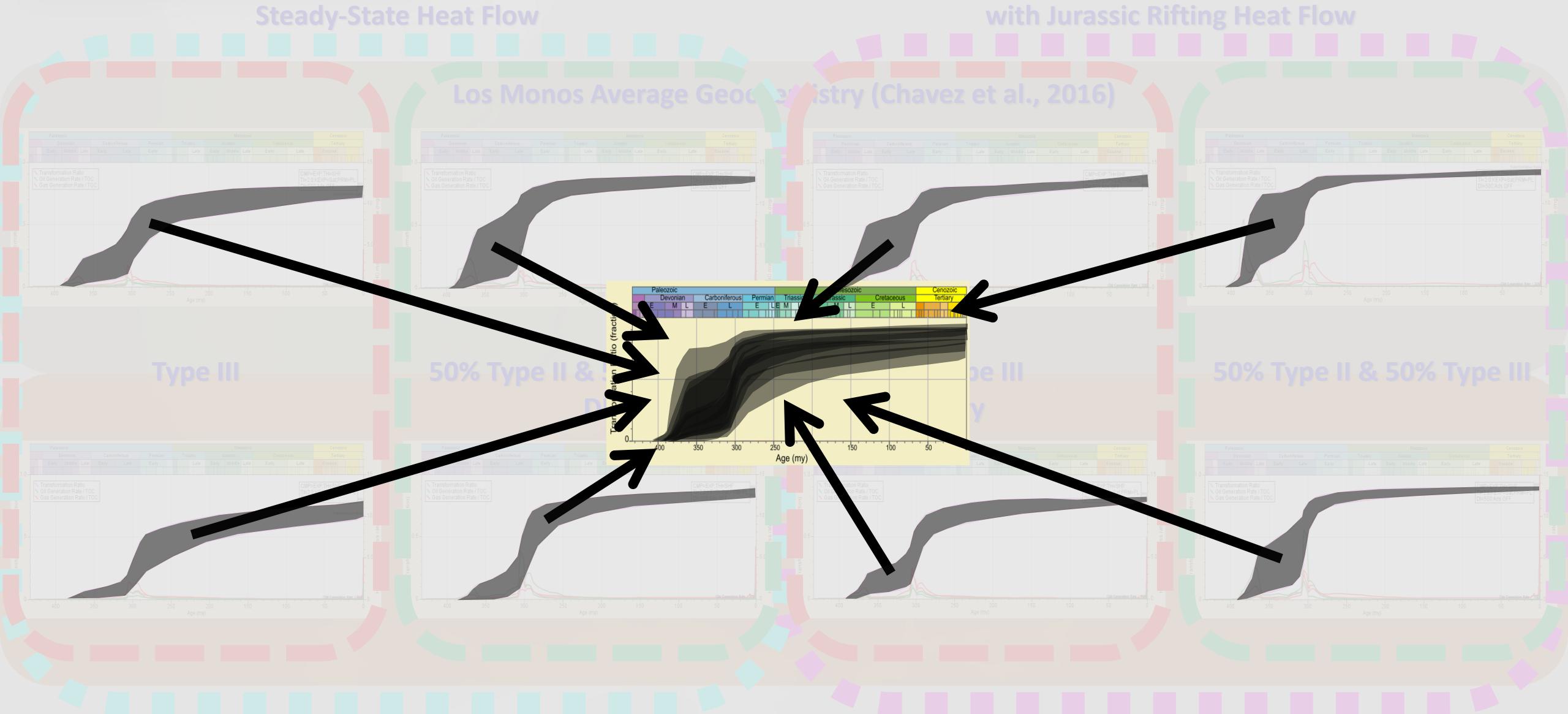
Overlapping Source Rock Transformation Ratio Diagrams



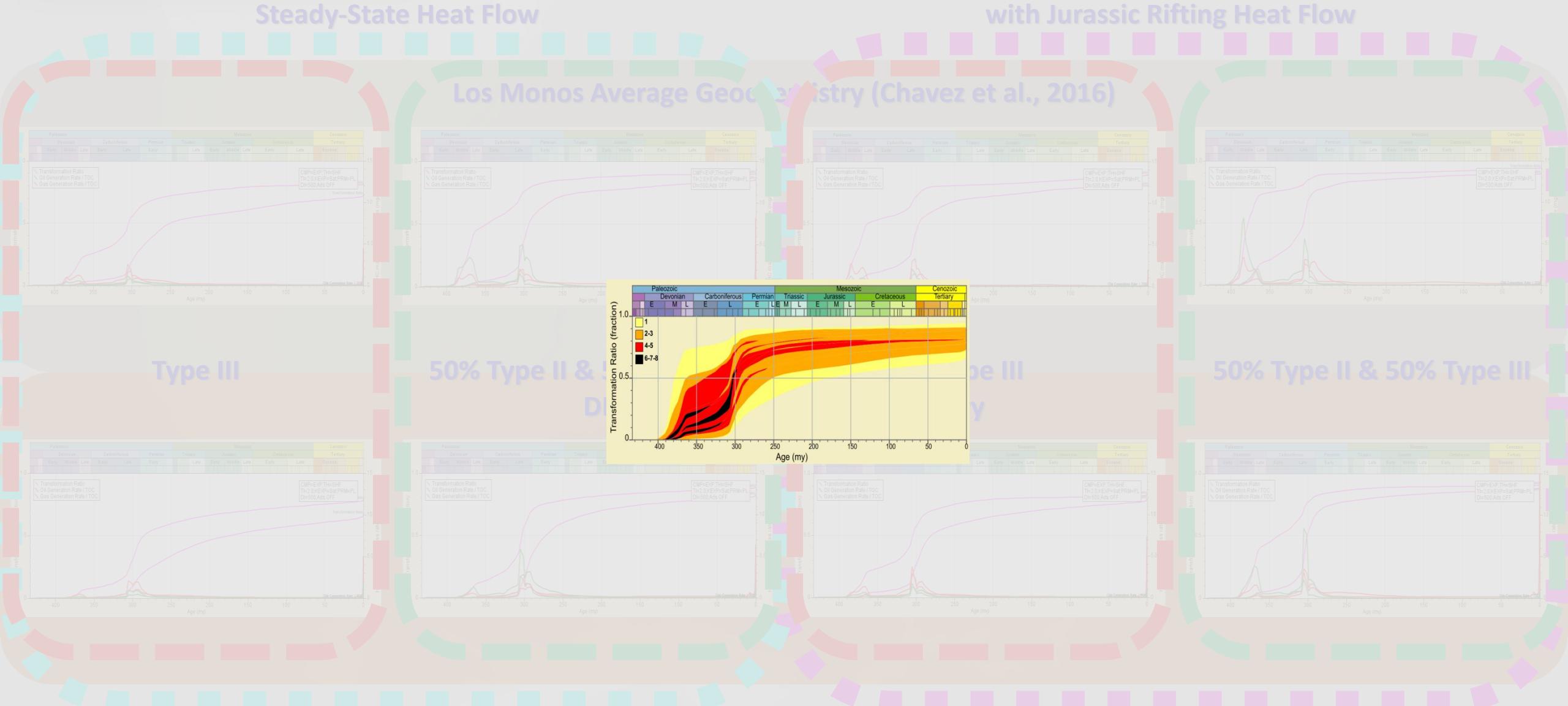
Overlapping Source Rock Transformation Ratio Diagrams



Overlapping Source Rock Transformation Ratio Diagrams



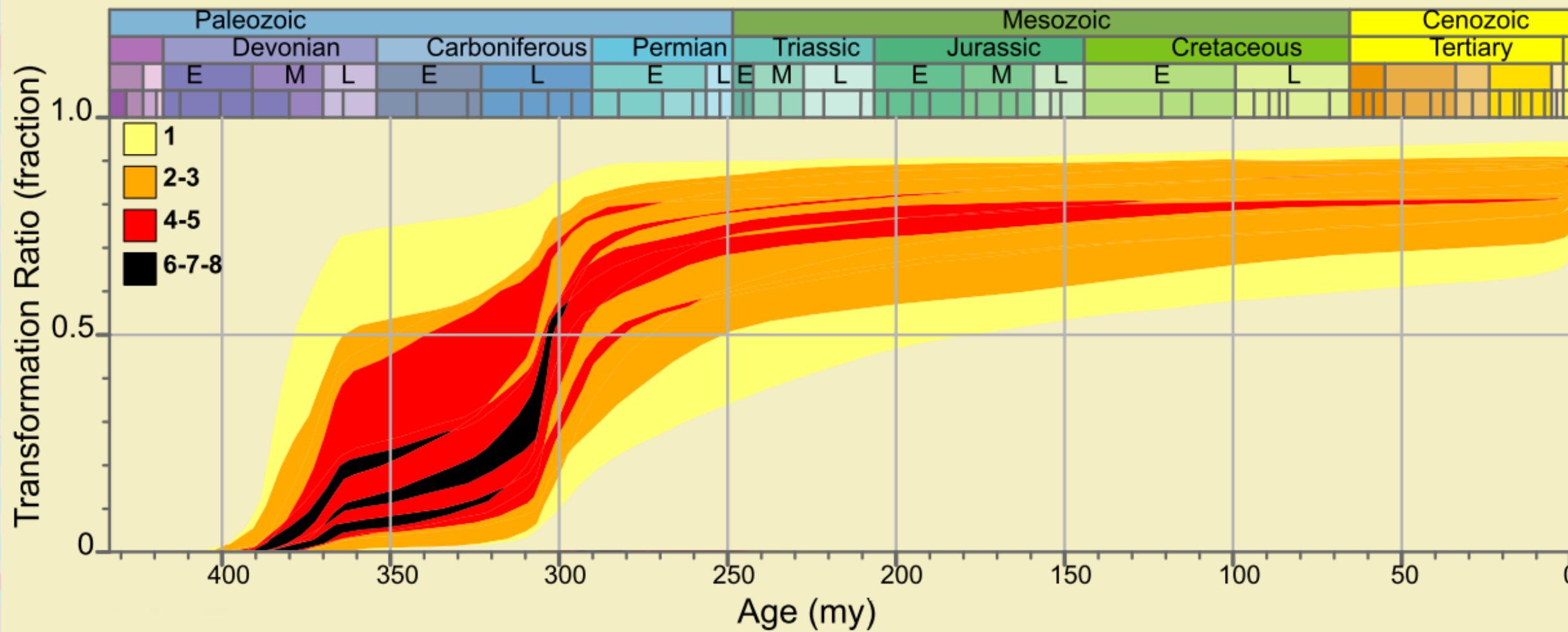
Overlapping Source Rock Transformation Ratio Diagrams



Overlapping Source Rock Transformation Ratio Diagrams

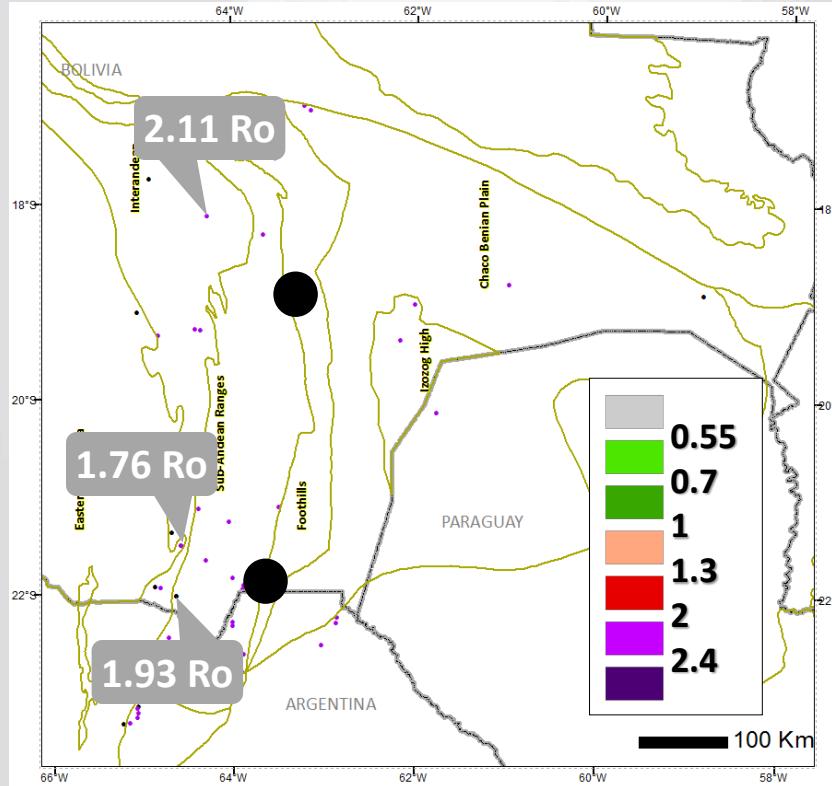
Steady-State Heat Flow

with Jurassic Rifting Heat Flow

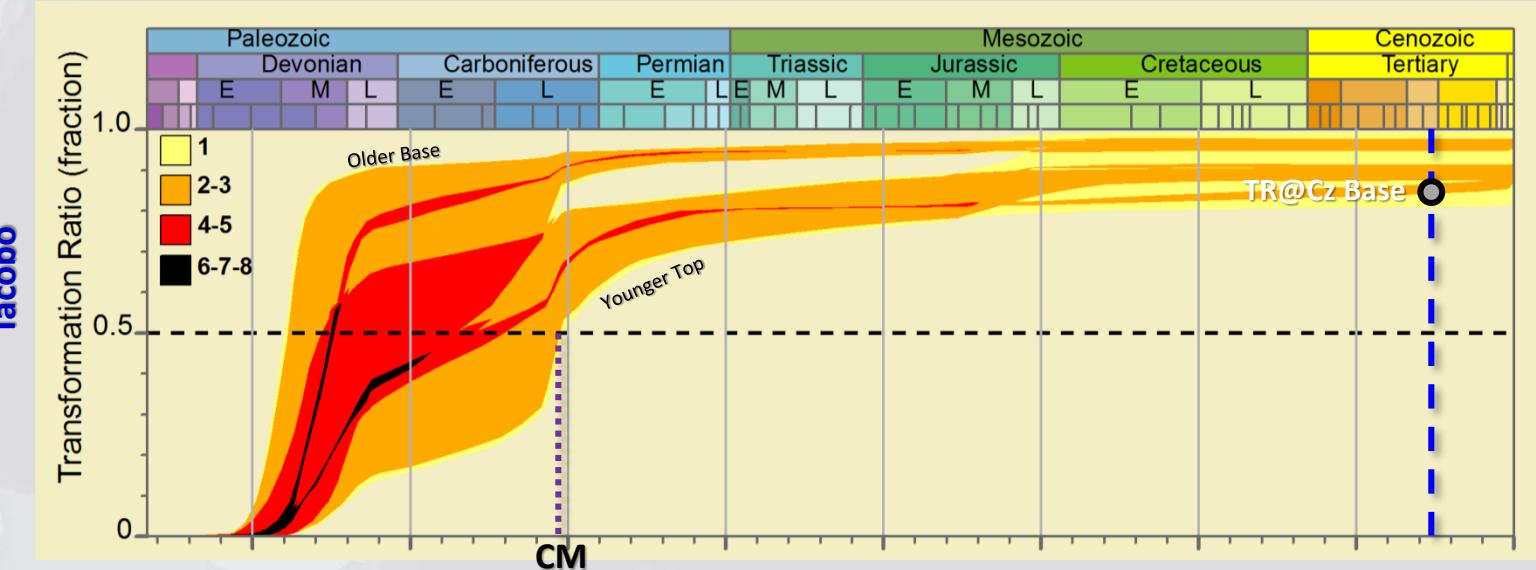


Kirusillas Fm. Source Rock Transformation Ratio Diagram

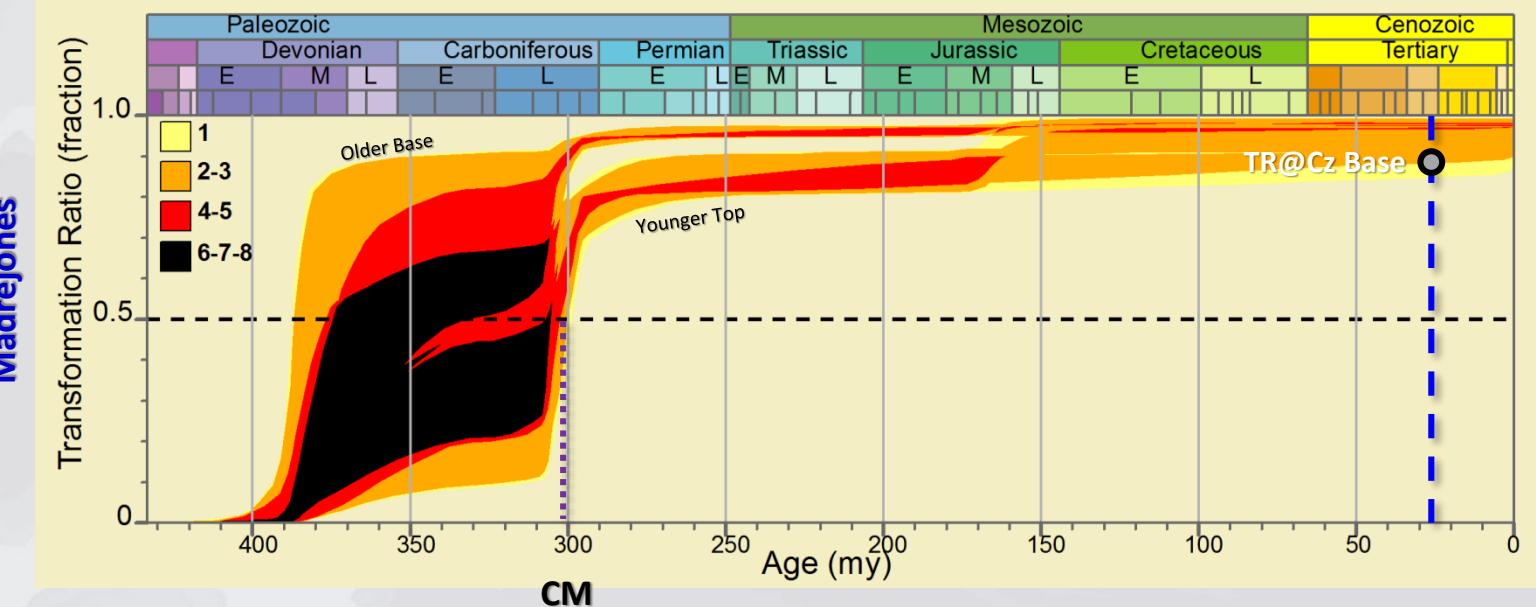
Kirusillas Ro Maturity Map



Tacobo

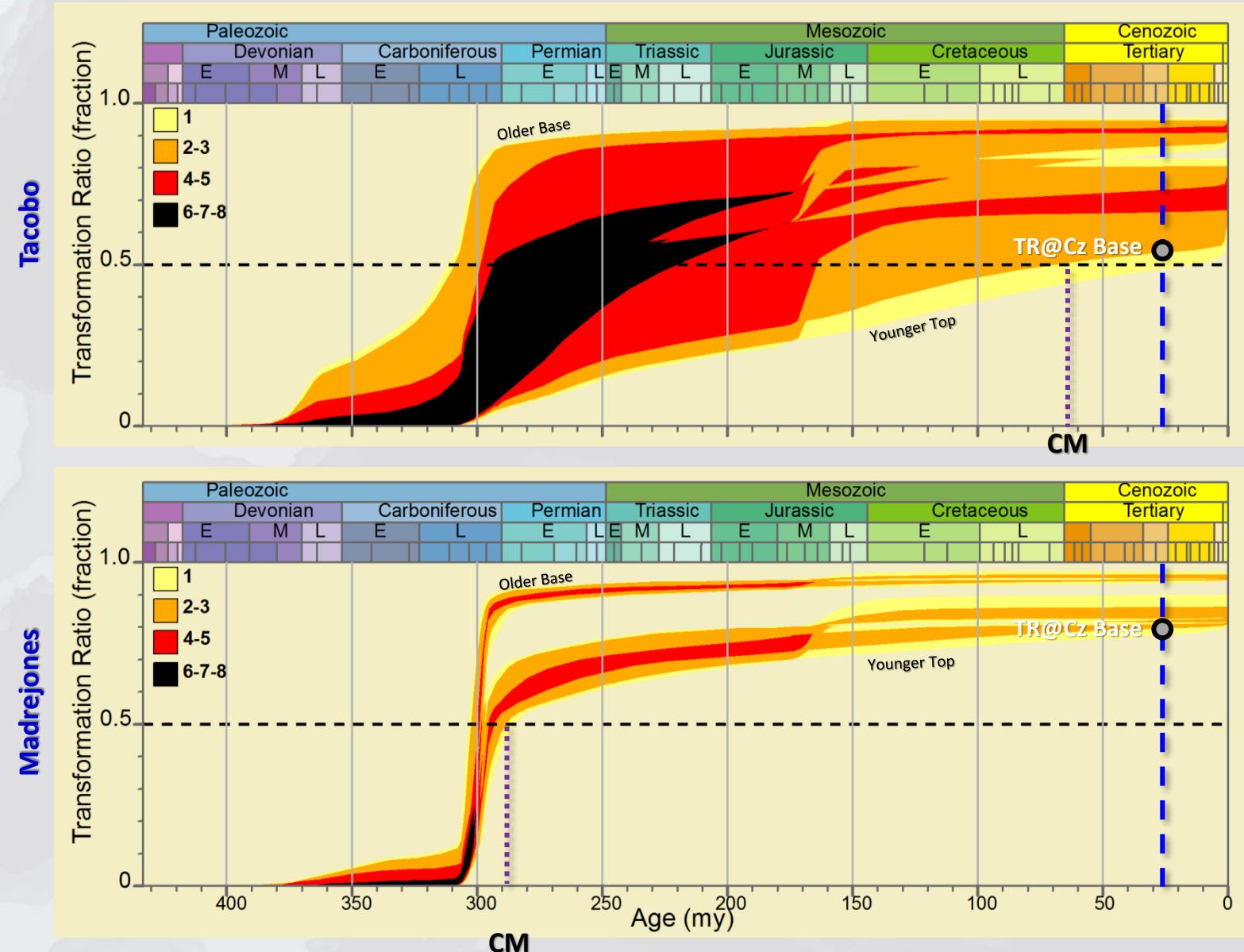
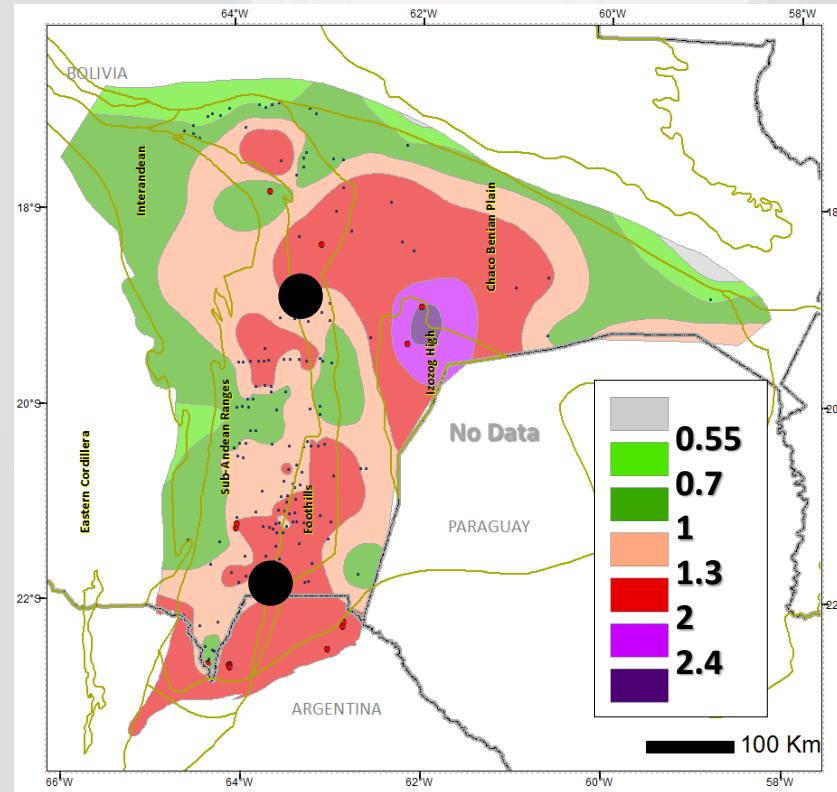


Madrejones



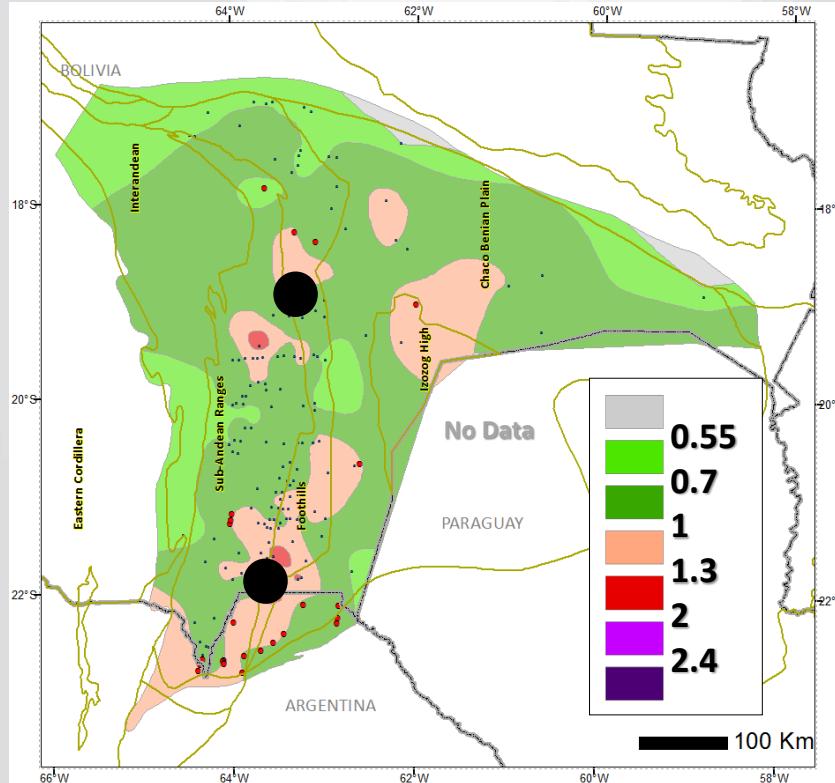
Icla Fm. Source Rock Transformation Ratio Diagram

Icla Ro Maturity Map
(After Schneider et al. 2018)

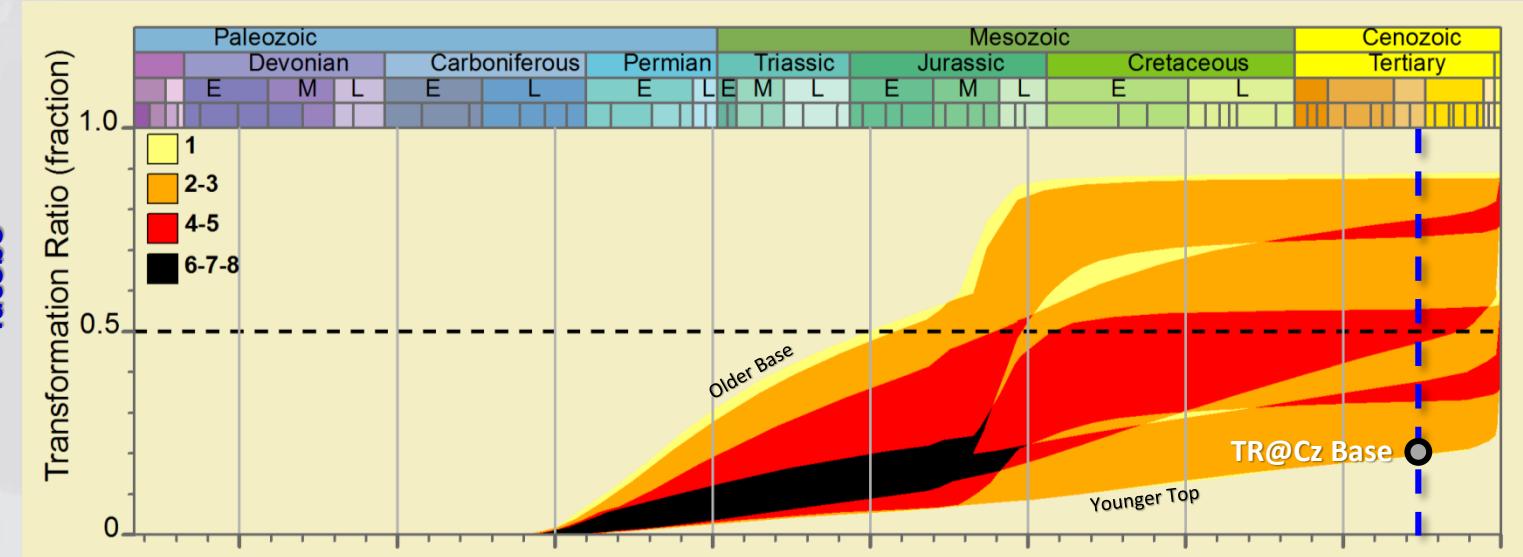


Los Monos Fm. Source Rock Transformation Ratio Diagram

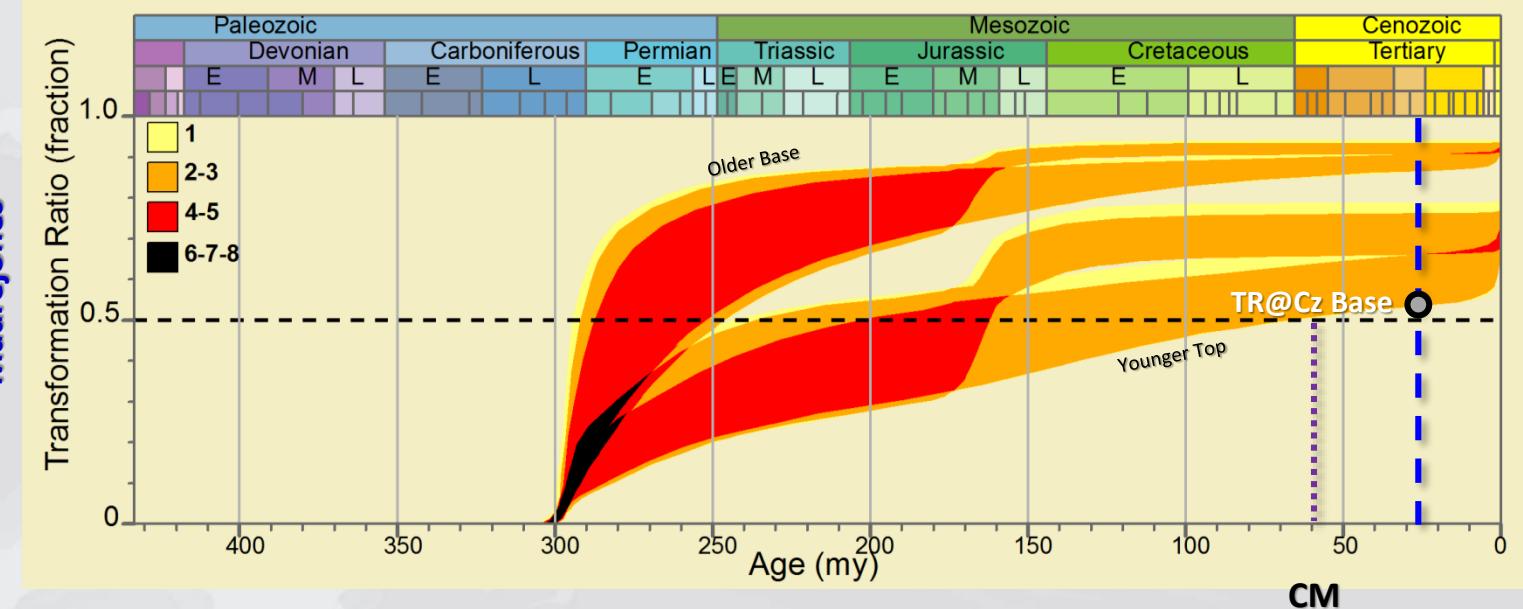
Los Monos Ro Maturity Map
(After Schneider et al. 2018)



Tacobo



Madrejones





- Wide range of uncertainty in the petroleum system modeling due to complex tectonic evolution, and for Icla and Kirusillas Source Rocks sparse and relatively poor quality data available for calibration.
- A probabilistic analysis of generation timing, transformation ratio and critical moment was done, using different calibrated 1-D petroleum system models run by location, combining maximum and minimum values for the three key input parameters.
- Kirusillas Fm. modeling shows that most of hydrocarbon generation is during the Upper Paleozoic.
- Icla Fm. modeling shows that generation started in the Upper Paleozoic, reaching the base of Cenozoic with more than 50% of the Transformation Ratio. Variation between North and South are related to an combination of the thickening of Upper Paleozoic to the South and higher Heat Flow.
- Generation timing for the Los Monos Fm. started during the Permian/Mesozoic and continued up to the present, with high sensibility to adding of a Mesozoic Thermal Event.

A wide-angle photograph of a mountainous landscape at sunset or sunrise. The sky is filled with soft, scattered clouds. In the background, a range of mountains is visible, their peaks bathed in warm sunlight. The middle ground shows rolling hills covered in green vegetation. In the foreground, there's a field with some low-lying plants and a portion of a rustic wooden fence. The overall atmosphere is peaceful and natural.

Thank You



- Baur, F., Di Benedetto, M., Fuchs, T., Lampe, C., Sciamanna, S., 2009, Integrating structural geology and petroleum systems modeling - A pilot project from Bolivia's fold and thrust belt, *Marine and Petroleum Geology*, v. 26, no. 4, p. 573–579.
- Chávez, M.A., Meunier J.P., Nicoletis S., Sabat, J.P., 2016, Perforar La Formación Los Monos Subandino Sur Bolivia, *Lecciones Aprendidas, XXII Congreso Boliviano de Geología*, no. 71.
- Gohrbandt, K., 1993, Paleozoic paleogeographic and depositional developments on the central proto-Pacific margin of Gondwana: Their importance to hydrocarbon accumulation, *Journal of South American Earth Sciences*, v. 6, no. 4, p. 267-287.
- Hernández, N., M. Iribarne, D. Apreda, G. Laffitte, and G. Vergani, G., 2011, Nuevos conceptos estructurales a partir de la perforación del pozo profundo Ramos xp-1012 en el Yacimiento Ramos, Sierra de San Antonio, Provincia de Salta: *VIII Congreso de Exploración y Desarrollo de Hidrocarburos*, Instituto Argentino del Petróleo y del Gas, Mar del Plata, Argentina, p. 599–617.
- Kusiak, M.E., 2008, El Mesozoico del Sistema Subandino de Bolivia: evolución sedimentaria y síntesis de la cuenca. Ph.D. Thesis, Faculty of Natural Sciences, University of Buenos Aires, Buenos Aires, Argentina, 173 p.
- Pereira, M., Vergani, G., Cambon, I., Reynaldi, J.M., Iturrealde, J., Guerrero, R., González, G., 2018, Andean deformation and its control on hydrocarbon generation, migration, and charge in the wedge-top of southern Bolivia, in G. Zamora, K. R. McClay, and V. A. Ramos, eds., *Petroleum basins and hydrocarbon potential of the Andes of Peru and Bolivia: AAPG Memoir 117*, p. 531–554.
- Schneider, F., Constantini, L., Mayta, R., Rousse, S., Esquivel, J., 2018, Contribución a la Evaluación del Potencial Petrolífero del Subandino Sur de Bolivia, *X Congreso de Exploración y Desarrollo de Hidrocarburos*, Instituto Argentino del Petróleo y el Gas, p. 187–208.
- Starck, D., 1995, Silurian - Jurassic stratigraphy and basin evolution of northwestern Argentina, in A. J. Tankard, R. Suárez S., and H. J. Welsink, *Petroleum basins of South America: American Association of Petroleum Geologists Memoir 62*, p. 251-267.
- Starck, D., 1999, Los sistemas petroleros de la Cuenca de Tarija: *IV Congreso de Exploración y Desarrollo de Hidrocarburos*, Instituto Argentino del Petróleo y el Gas, p. 63–82.
- Starck, D., 2011, Cuenca Cretácica-Paleógena Del Noroeste Argentino, *VIII Congreso de Exploración y Desarrollo de Hidrocarburos*, Instituto Argentino del Petróleo y el Gas, p. 407–453.
- Starck, D., and del Papa, C, 2006, The northwestern Argentina Tarija Basin: Stratigraphy, depositional systems, and controlling factors in a glaciated basin, *Journal of South American Earth Sciences*, v. 22, no. 3-4, p. 169–184.
- Veizaga-Saavedra, J.G., Poiré, D.G., Vergani, G.D., Salfity, J.A., 2018, Mineralogía y Madurez Termal de la Formación Los Monos (Devónico), Cuenca De Tarija, *X Congreso de Exploración y Desarrollo de Hidrocarburos*, Instituto Argentino del Petróleo y el Gas, p. 389–411.