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Source Rocks and Hydrocarbons South of The Santa Cruz Elbow, Bolivia and Northwestern Argentina.

The development of a new stratigraphic framework (Fig. 1) in the Tarija Basin allowed the review of the hydrocarbon source potential within the typically recognized Devonian sequence sets. Nearly 1000 rock samples data (TOC, Rock-Eval pyrolysis and kerogen microscopy) were evaluated for source rock typing and maturity assessment. The samples were collected from several wells and outcrops from a broad area comprising the thrust belt, Chaco Plains and Izozog High (Fig. 2), between the Santa Cruz Elbow (Latitude 17°15' S) and the Ramos gas field in Northwestern Argentina (Latitude 22°45' S).

Poor to moderate, and occasionally good source rock qualities have been recorded in most of the evaluated samples, consistent with the findings of Moretti et al. (1995). Typical TOC contents are around 1% or lower, although peak values attain 2%. Variations from thermal immaturity to overmaturity are dependent on stratigraphic position and geologic setting. Kerogen, although predominantly unstructured, shows as type II/III to type III by pyrolysis Rock-Eval, with primary capacity for mixed (gas/oil) generation. Due to the limited organic contents and partly refractory character of the kerogen, effective expulsion of hydrocarbons is believed to begin at relatively high levels of thermal stress ($VRE > 0.9-1.0\%$), with prevalence of gassy hydrocarbons. The fair/moderate-TOC-bearing Givetian and Eifelian sections (*Iquiri* and *Los Monos*) contain the richest hydrocarbon-prone organic facies (Figs. 3-4) in most of the evaluated areas. However, the Givetian beds are disfavored as effective generating sources due to the overall low thermal maturity. The Emsian section (*Los Monos-Huamampampa*) has poor organic content in Bolivia but is an essentially gas source in Northwestern Argentina (Disalvo and Villar, 1999). The Lochkovian section (*Icla-Santa Rosa*) recorded the highest organic contents in the Santa Cruz influence area and Izozog High and is probably an active source rock in that zone. Scattered information on the Silurian in the thrust belt indicates low residual organic richness with an advanced overmaturity, but it could have had higher TOC values previously.

Modeling of hydrocarbon generation of the Devonian source rocks (see also Dunn et al., 1995; Moretti et al., 1996) demonstrates that the main episodes of expulsion and charge occurred coupled to the Andean tectonics. A generally low thermal heat flow linked to the Tertiary foreland deposits constrained the maturation process. In the Santa Cruz influence area (Fig. 5a) the Tertiary thickness (less than 2500 m) is not enough to induce maturation of the Eifelian (*Los Monos*) section, but the Lochkovian interval reaches the maturity required for effective hydrocarbon expulsion (0.9-1.1% Ro). Southwards, in the Río Pilcomayo-Villamontes influence area, an increase of the thermal heat flow is recorded and consequently the Eifelian section becomes an effective source rock. Towards northern Argentina, the Tertiary column is thicker and the thermal heat flow is probably higher. In the thrust belt, the mild thermal regime is counterbalanced by thick orogenic columns up to 6000 m (Fig. 5b). The Eifelian beds are proven source rocks for oil and gas, while the Givetian (*Iquiri*) section could be an active source if adequately buried. Overburden during Carboniferous times is viewed to be significant in terms of source rock maturation for the Silurian deposits.

Hydrocarbon occurrences (Illich et al., 1981) are restricted to light oil, condensate and gas. Gas chromatography and biomarker data of 8 oil/condensate samples along with isotope data of 17 gas samples from different reservoirs and fields were evaluated. The predominance of condensate accumulations precluded assessing definite oil-source correlation patterns. Nevertheless, genetic relations were proved for Givetian and, particularly, the Eifelian sources which have generated oils carrying a typical mixed marine-terrestrial signature. In detail, the Givetian section sourced an early oil seeping at the Taputá Creek, in the emergent thrust front at the Charagua Hill. Molecular data (Fig. 6) supports the genetic link of the Monteagudo oil with Eifelian source rocks in the thrust belt. In the Santa Cruz area, an oil of Rio Grande Field has been generated close to the peak oil phase, at a maturity level comparable to that of the Lochkovian section. Gas accumulations are attributed to multiple sources. Isotope data, arranged by reservoir (Fig. 7) and geographic location, point to

significant variations in thermal maturity, allowing for distinct kitchens of a same source rock and/or co-sourcing.

Three petroleum provinces are recognized in the Tarija Basin (Fig. 8): a) the Santa Cruz Province where the Lochkovian section is probably the main source rock in a context of low thermal heat flow; b) the Pilcomayo Province, extending up to northern Argentina, where the Eifelian section is a proven source rock; c) the South Subandean thrust belt, where there is a considerable Tertiary overburden and the Eifelian section is the source for oil and gas. Additionally two intervals are considered: the Silurian as a potential contributor to the oldest reservoirs, and the Givetian as a source related to deep (kitchen) positions.

References

- Disalvo A. and H.J. Villar, 1999.** Los Sistemas Petrolíferos del Area Oriental de la Cuenca Paleozoica Noroeste, Argentina. *IV Congreso Exploración y Desarrollo de Hidrocarburos, Actas I*, pp. 83-100.
- Dunn J., K. Hartshorn and P. Hartshorn, 1995.** Structural Styles and Hydrocarbon Potential of the Sub-Andean Thrust Belt of Southern Bolivia, in A.J. Tankard, R. Suarez S. and H.J. Welsink, *Petroleum Basins of South America: AAPG Memoir 62*, pp. 523-543.
- Illich H. A., F. R. Haney and M. Mendoza, 1981.** Geochemistry of Oil from Santa Cruz Basin, Bolivia: Case Study of Migration-Fractionation. *AAPG Bull.* **65**, 2388-2402.
- Moretti I., E. Díaz Martínez, G. Montemurro and M. Pérez, 1995.** The Bolivian Source Rocks. Subandean Zone, Madre de Dios, Chaco. *Revue de l'Institut Français du Pétrole* **50**, 753-777.
- Moretti I., P. Baby, E. Méndez and D. Zubieta, 1996.** Hydrocarbon generation in relation to thrusting in the Sub Andean Zone from 18 to 22°S, Bolivia. *Petroleum Geoscience*, **Vol. 2**, pp.17-28.

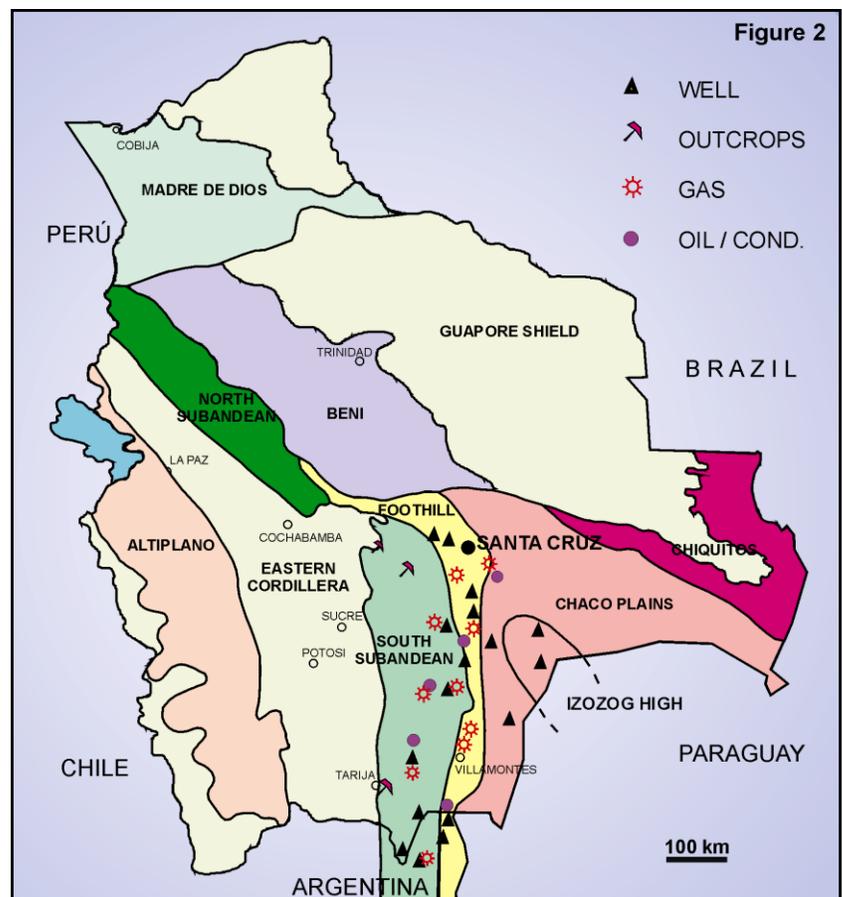
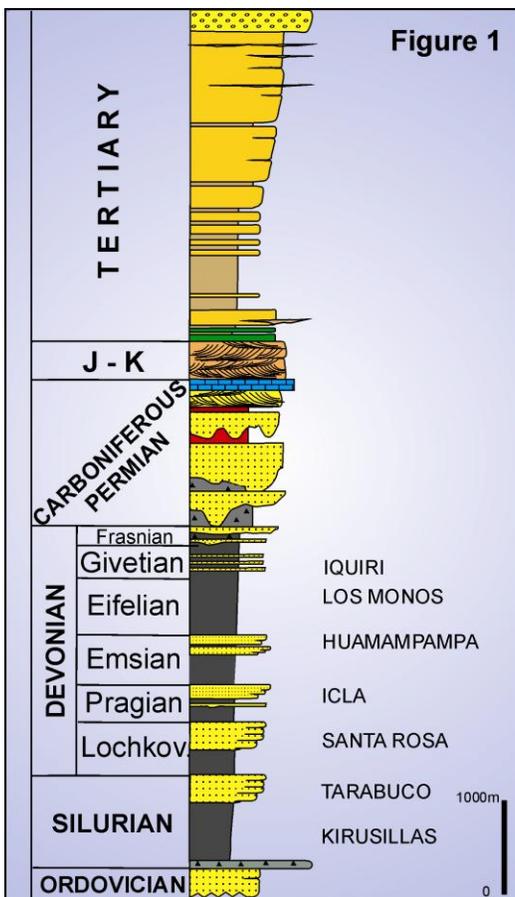


Figure 3 - ORGANIC CONTENT DISTRIBUTION

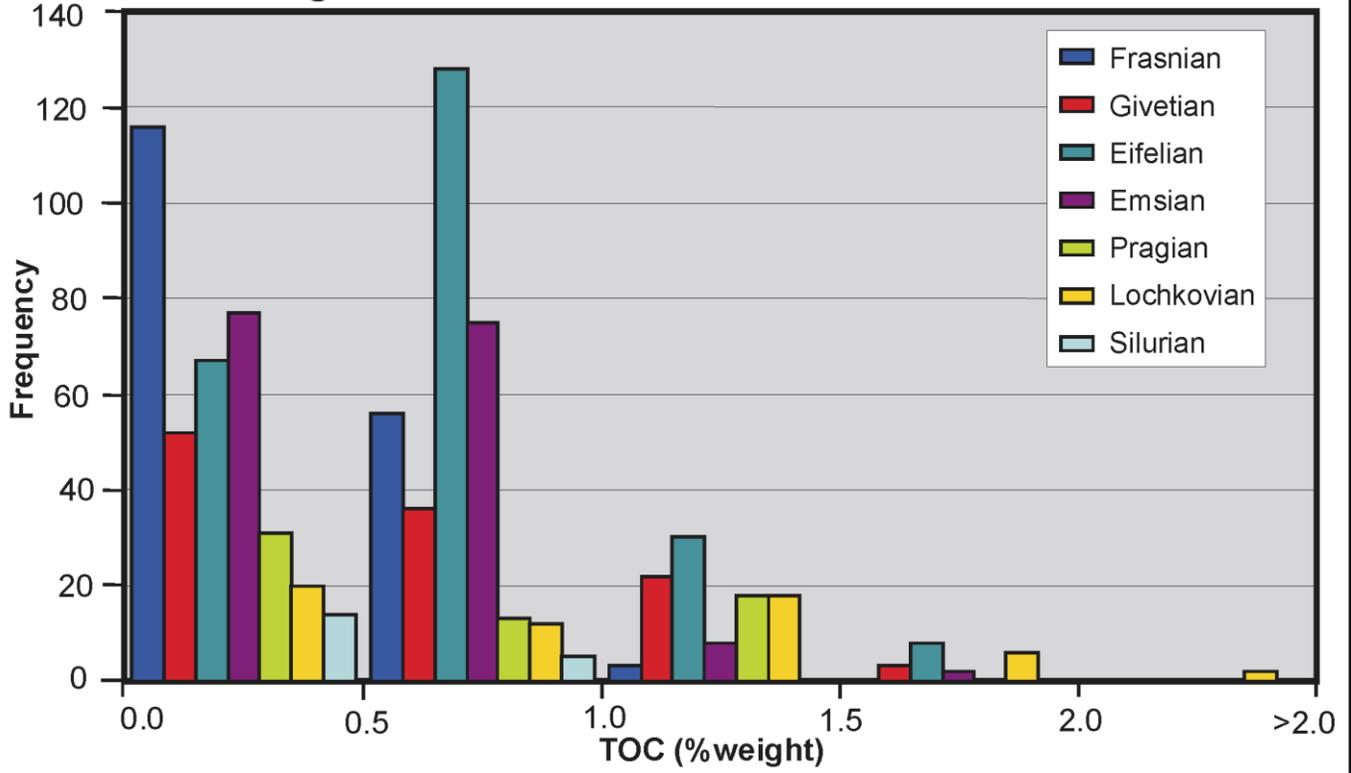


Figure 4 - HI / OI DIAGRAM

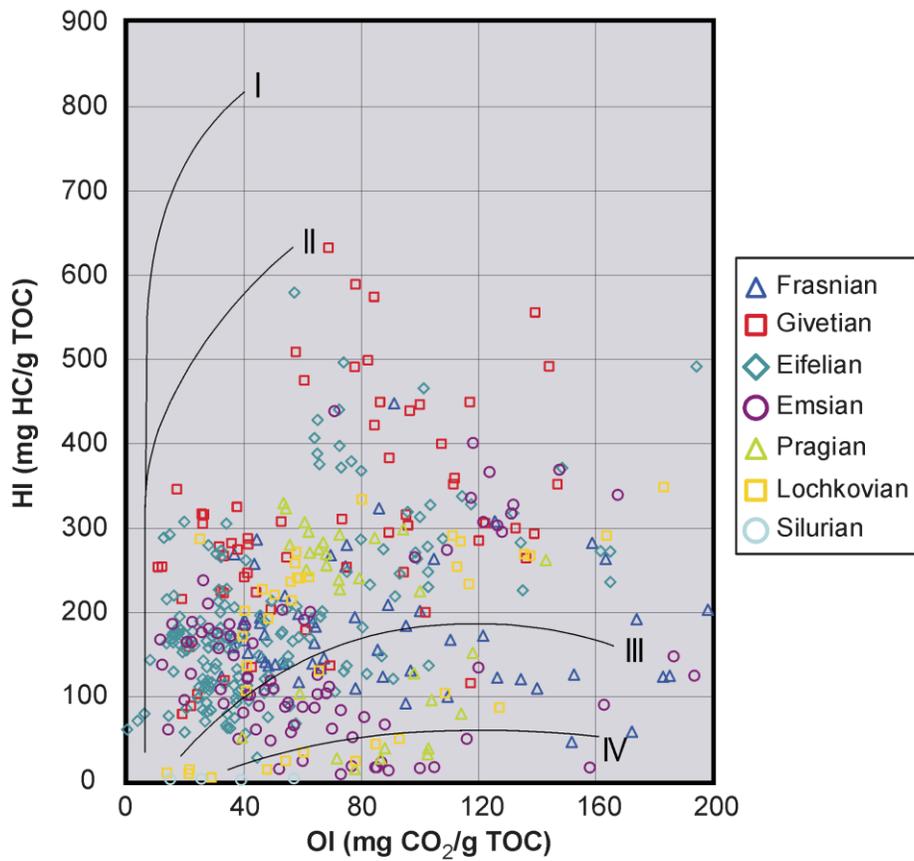


Figure 5 - MATURITY WINDOWS GEOHISTORY

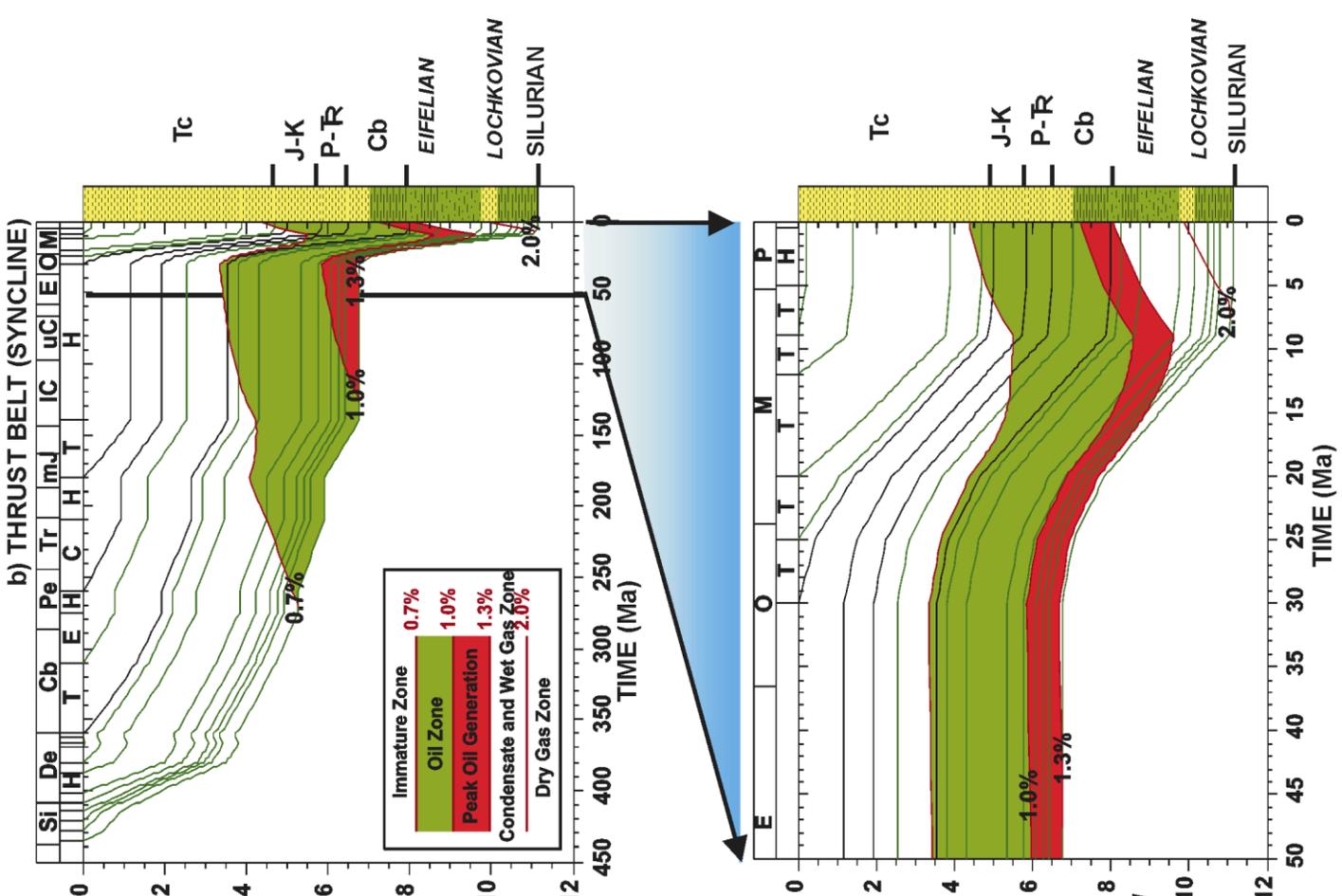
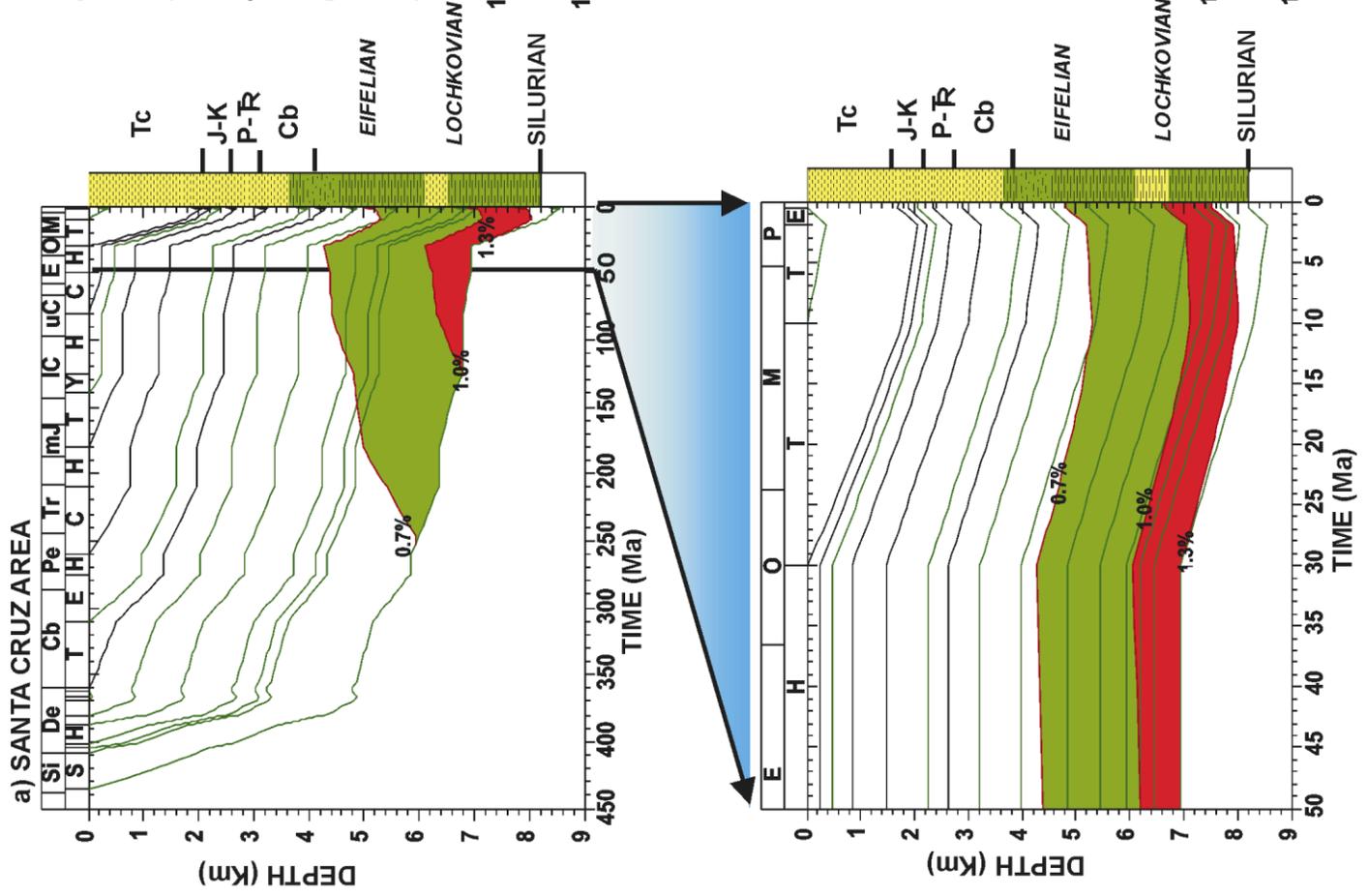


Figure 6 - OIL - SOURCE ROCK CORRELATION

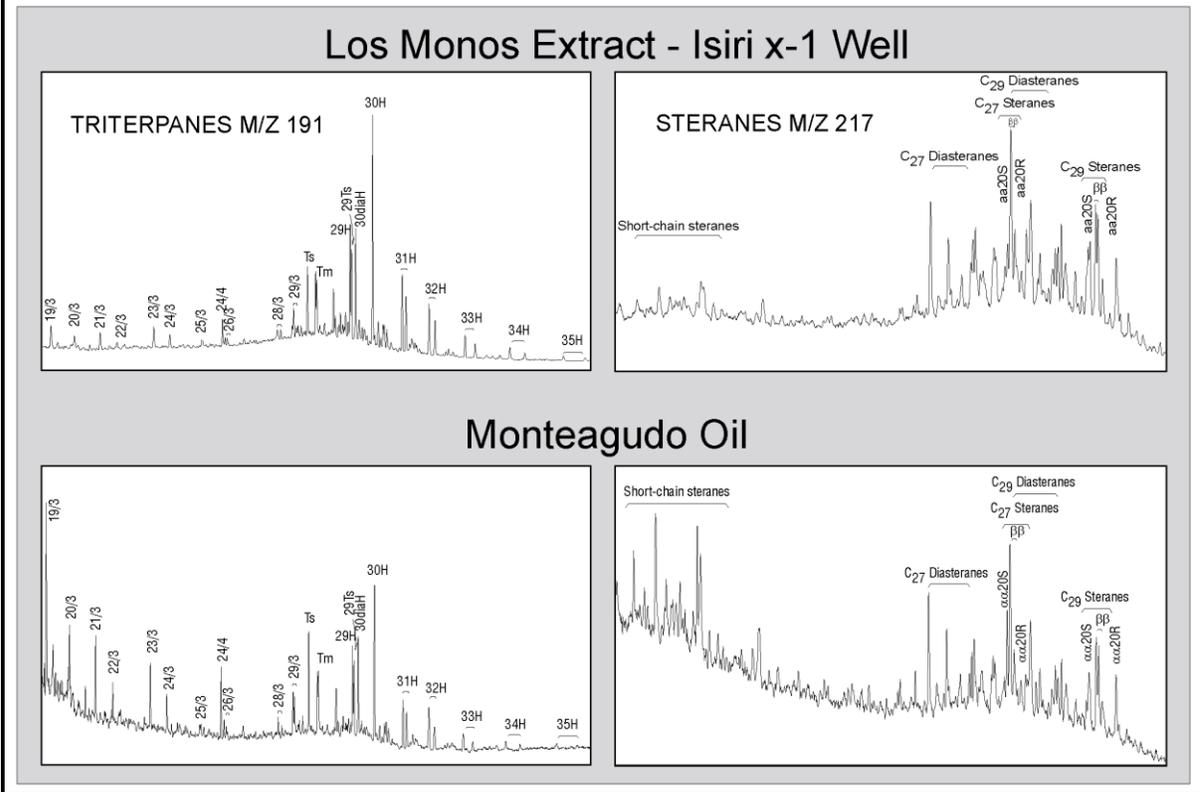


Figure 7 - GAS CHARACTERIZATION

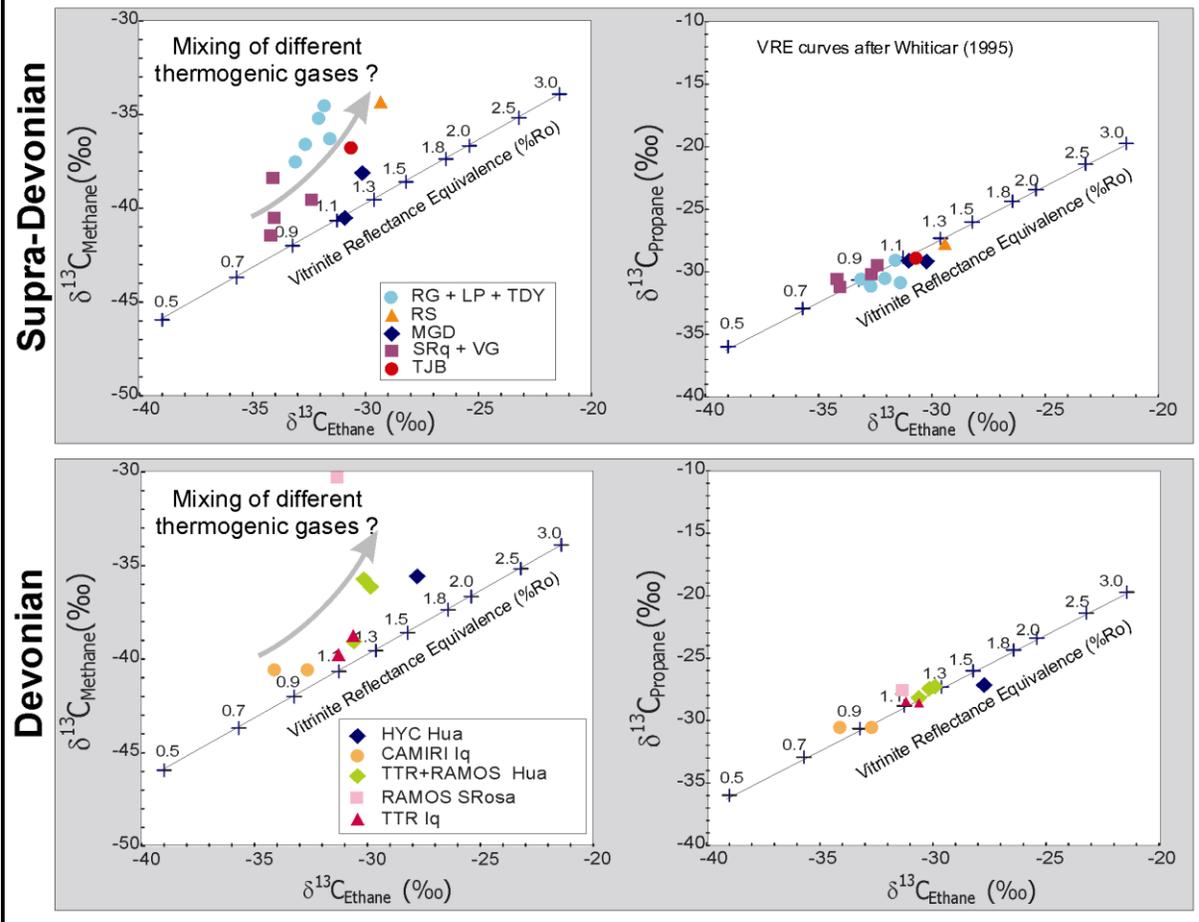


Figure 8 - PETROLEUM PROVINCES

