Geology

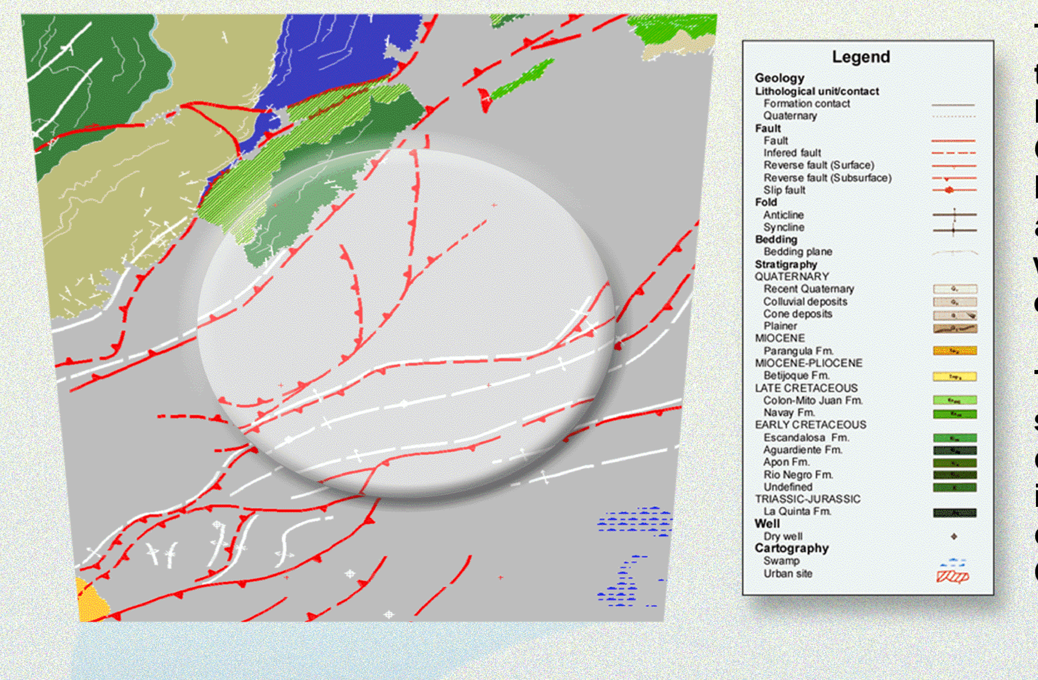
Purpose

To improve the understanding of petroleum systems in fold belts of western Venezuela, using axial surface map analysis and geochemistry surface anomaly maps. This integration is also supported by basin modeling using geochemical & stratigraphic source rock data and structural analysis derived from seismic information.

Experimental

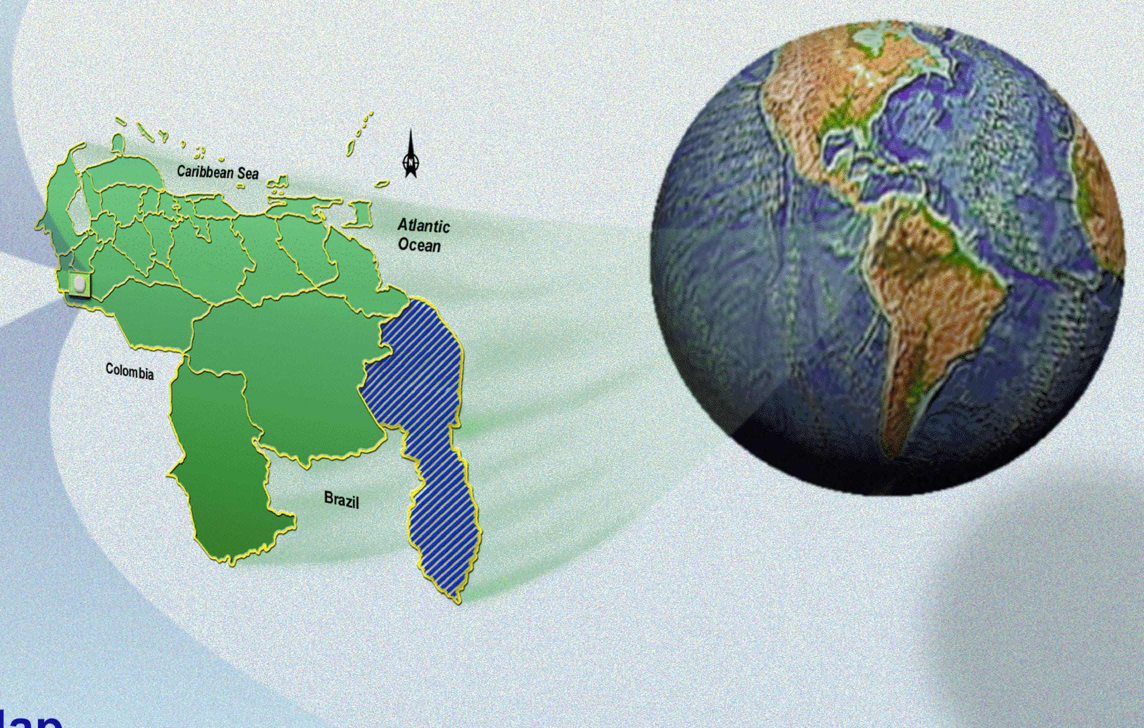
- Interpreted surface geology from Landsat™ and Radarsat™ images.
- Axial surface mapping using vertical projection to preserve the horizontal position of the structures (Shaw *et al*., 1994).
- Gravimetric modeling using bouguer anomalies to support structural interpretation.
- Structural map in depth of the top of reservoir rock (Escandalosa) interpreted by Seiswork/2D.
- 330 samples of free gases in soils for surface geochemistry data (Exploration Technologies Inc., 1997).
- Statistical analysis of surface geochemistry data to differentiate background and 1º, 2º and 3º orders anomalies.
- Combined use of microstation, Geo-frame CPS-3® and Arc-view® to generate bubble and contour maps of surface geochemistry data integrated with the surface geology.
- Quantity and maturity assessment of outcrop samples (TOC and vitrinite reflectance).
- Biomarker analysis and C15+ trace of crudes and organic extracts by gas chromatography - mass spectrometry.
- Geochemical modelling using basin Mod 1D®.
- Integration of the axial surface and geochemistry surface anomaly maps.
- Surface geochemical profiles along seismic lines and balanced cross-sections.
- Integration of the structural map of the top of reservoir rock and surface anomaly maps.

Surface Geology

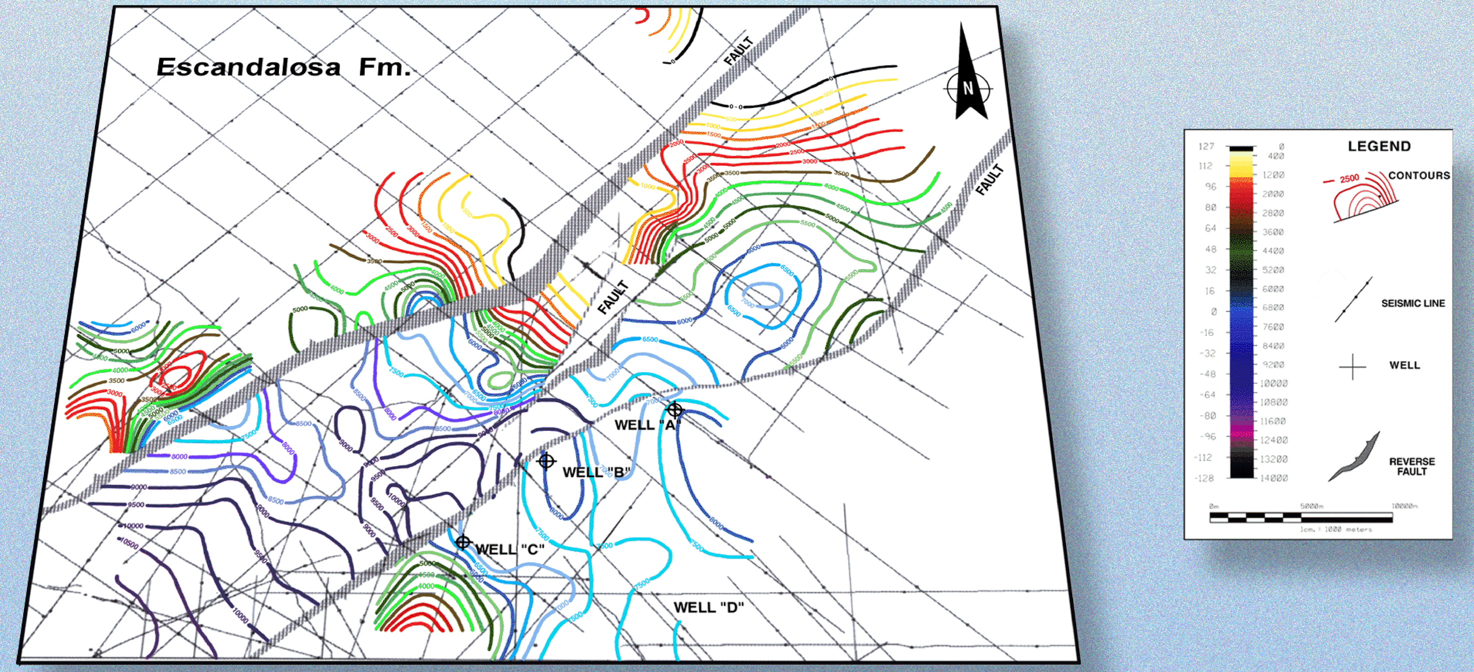


The area is a confluence point of two structural trends, characterized by extensive thrusting and folding. One trend is associated with the Andes Mountains, with NE-SW orientation, and the other trend is associated with the West Colombian Mountains of N-S orientation.

The surface geology, interpreted by satellite images, shows that the faults do not appear to extend to the surface in the study area, which is mainly covered by Quaternary units and by Cretaceous strata in the northwest.

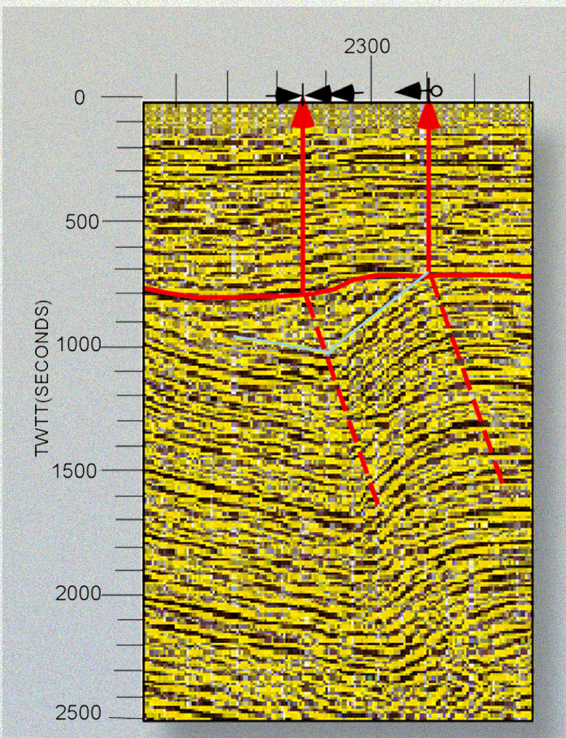


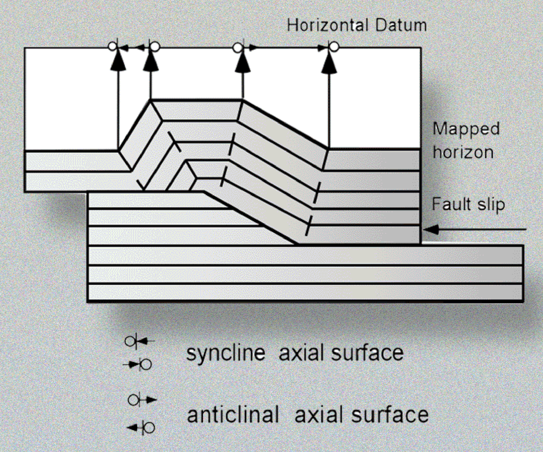
Structural Map of the Reservoir Rock (top)

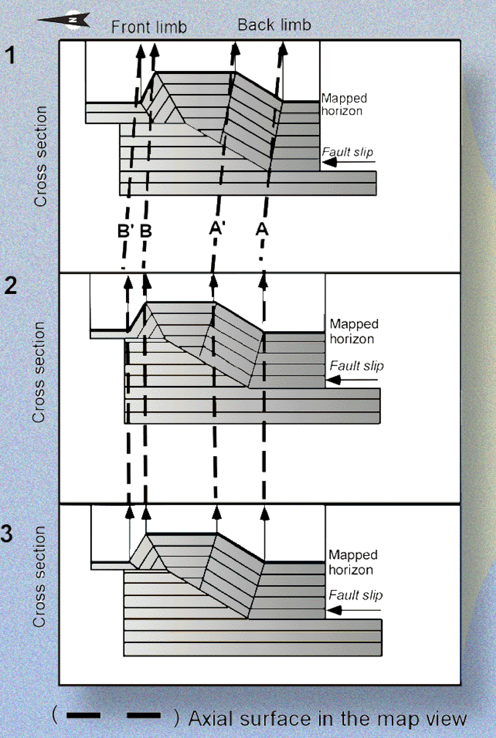


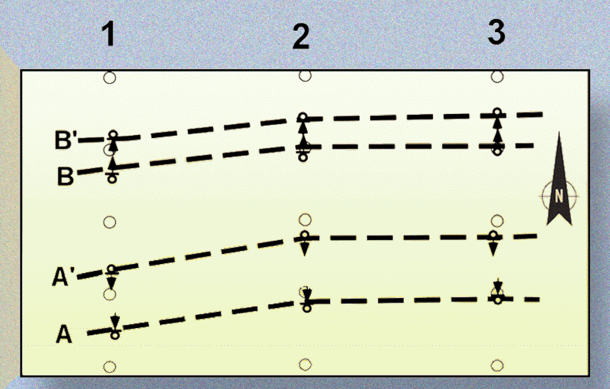
This map shows the structural truncation in the northwestern part of the study area.

Vertical Projection Method (VPM)

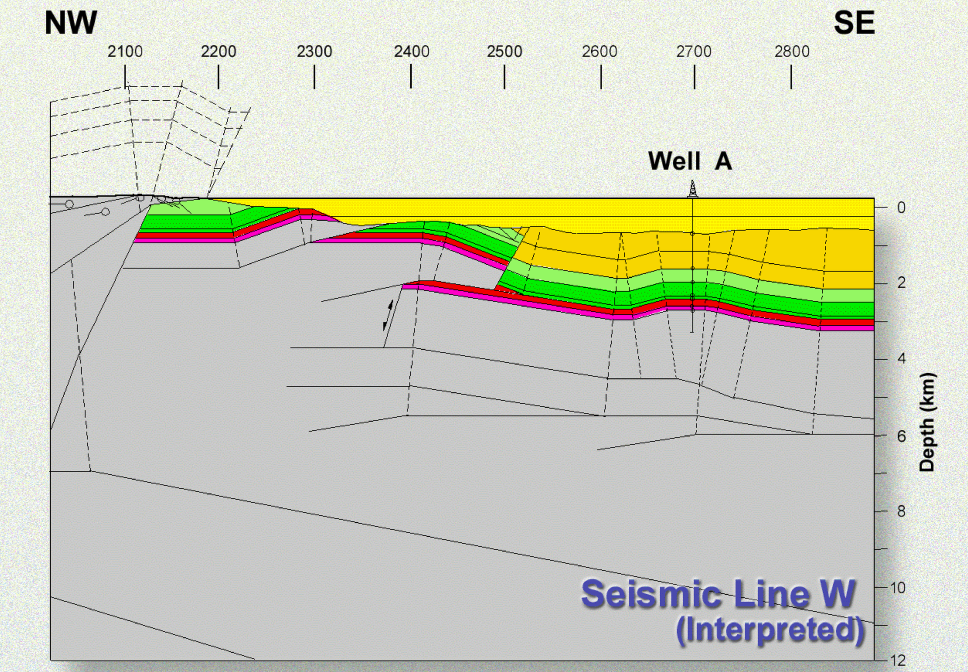


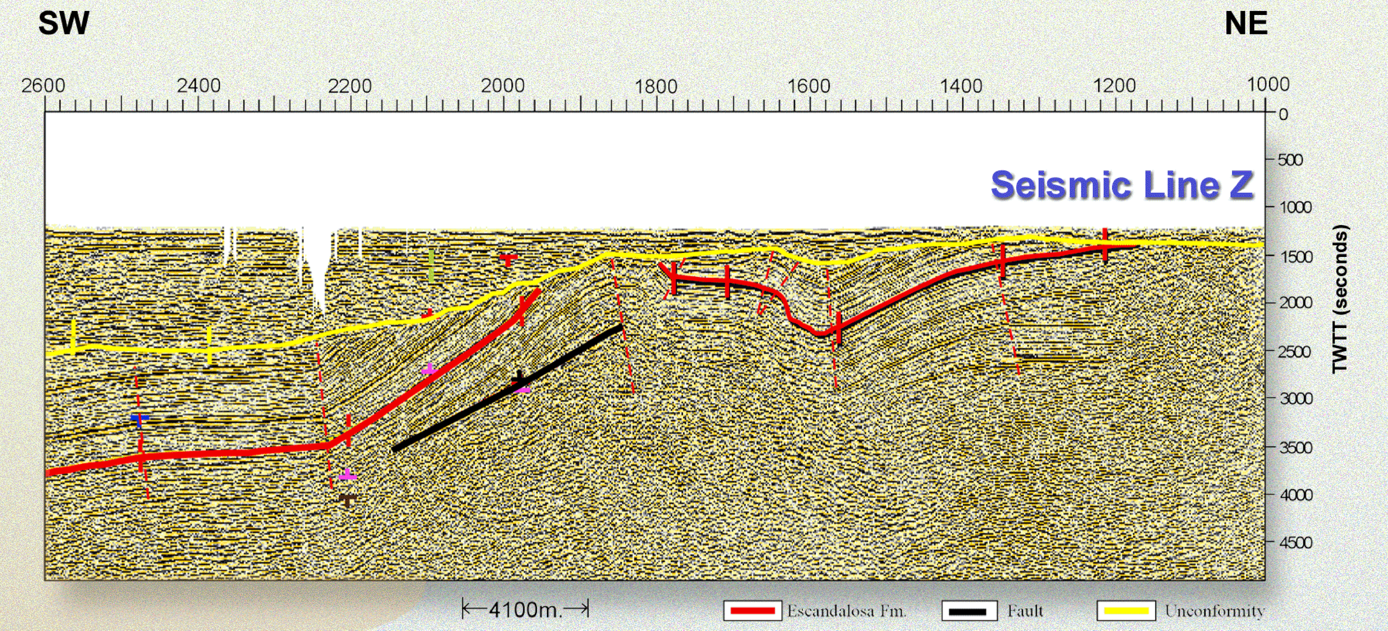




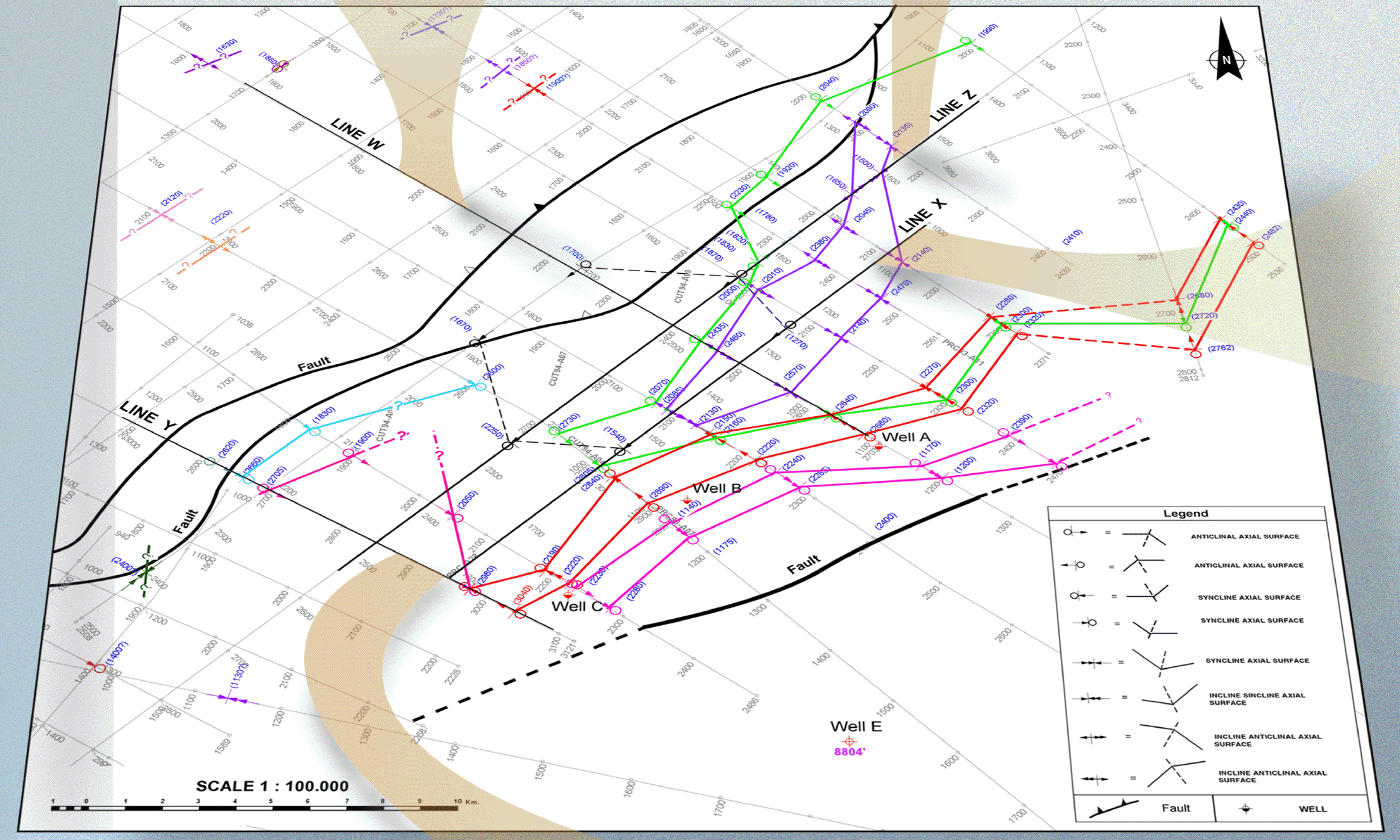


VPM contains straight, parallel axial surfaces and constant though narrower limb widths. In VPM, the structure in the mapped horizon is preserved; however, the kink-band width in map view does not equal the fault slip. (Shaw et al., 1994.)

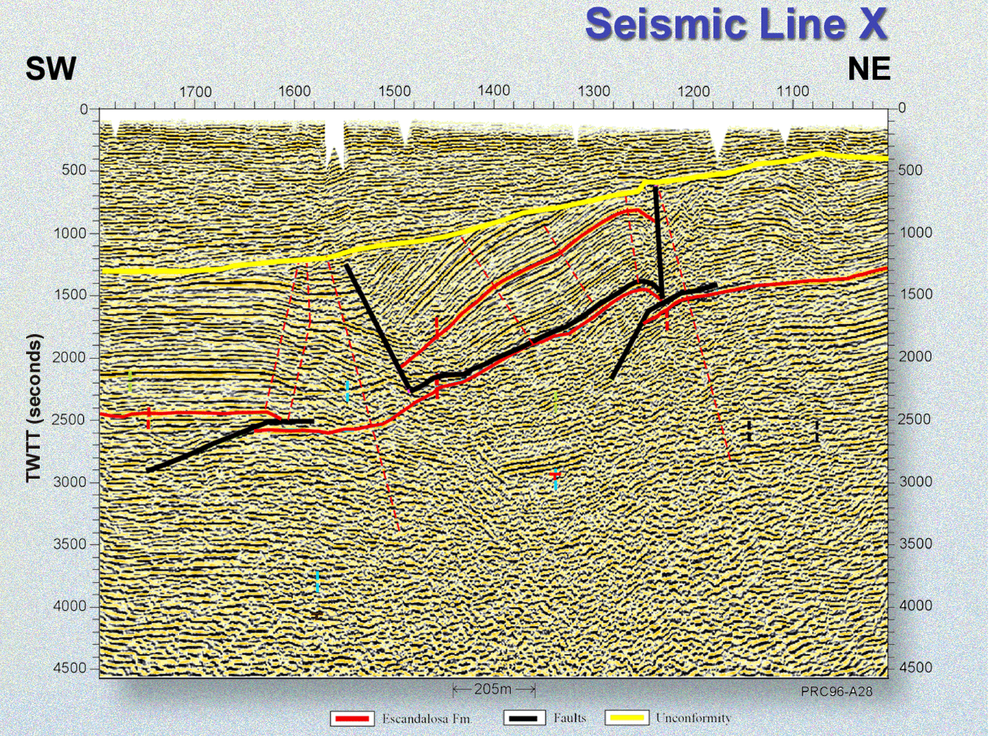


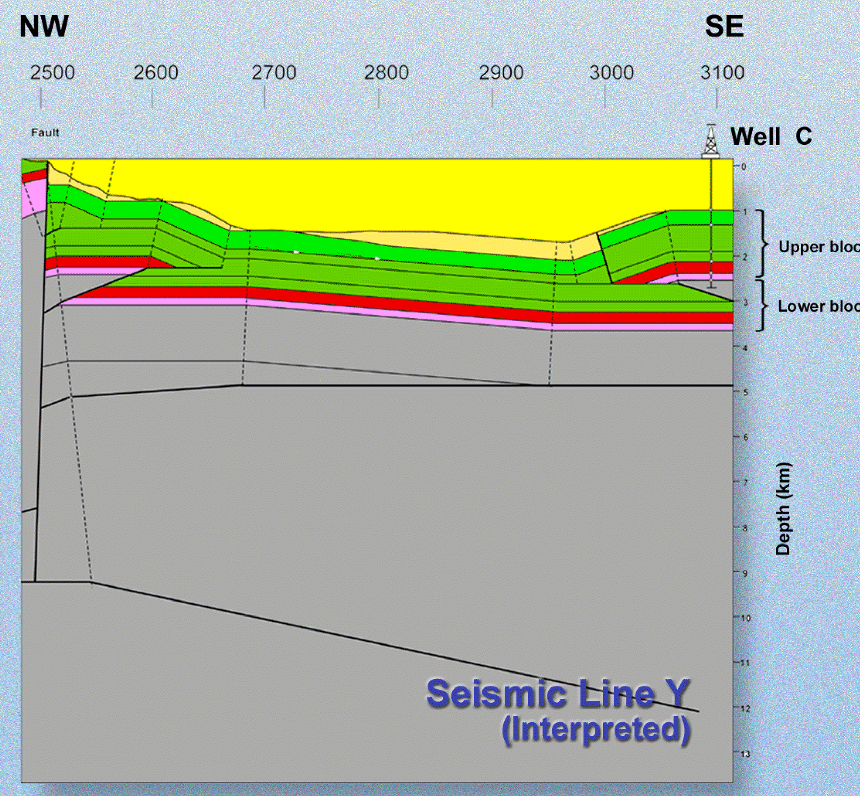


Axial Surface Map



This map defines fold trends, constrains underlying fault geometry and slip, and highlights and connects regions that can be interpreted by a series of balanced cross-sections. Most structural trends in the study area have a NE-SW orientation.



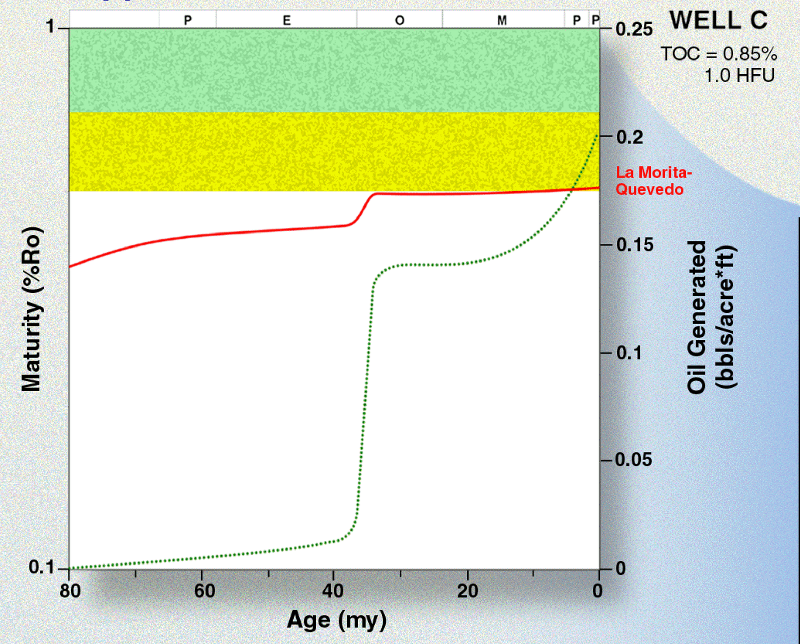


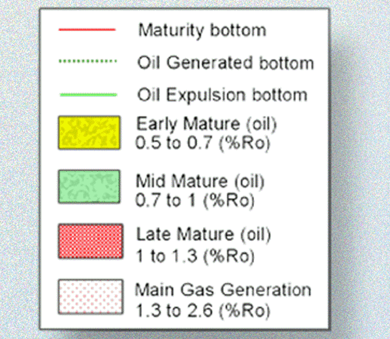
Geochemistry

Subsurface

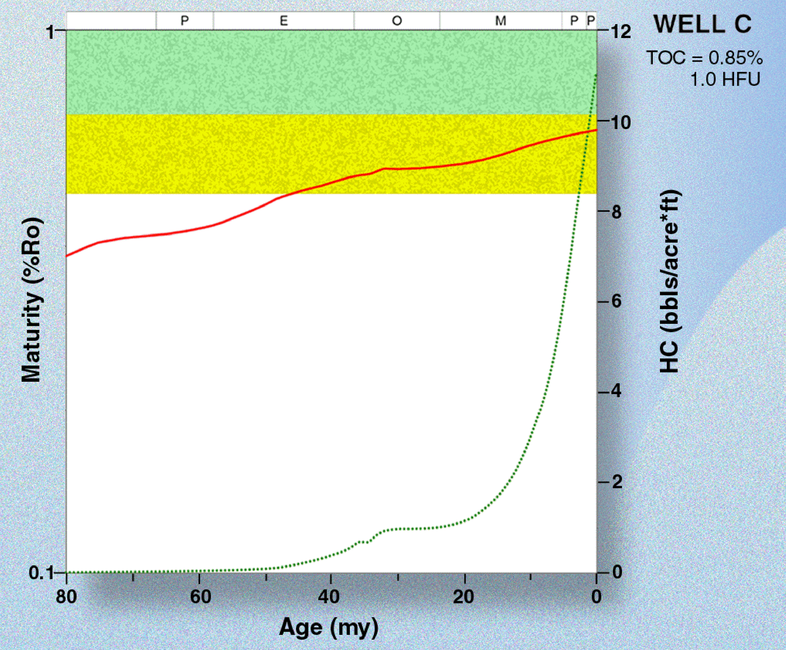
Geochemical Modeling

Upper Block



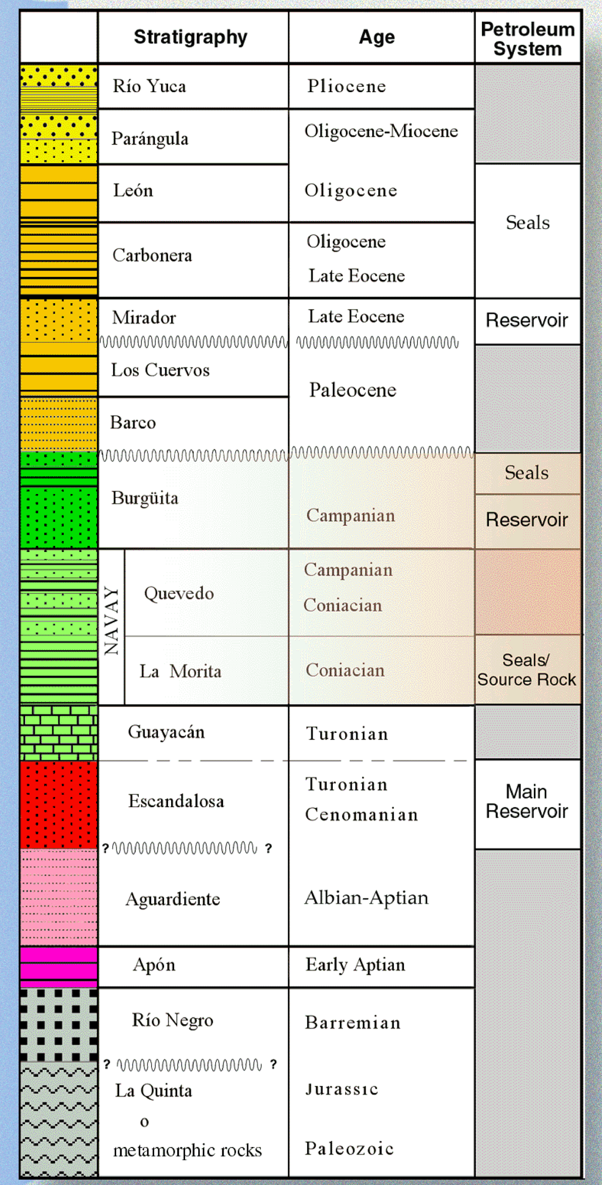


Lower Block

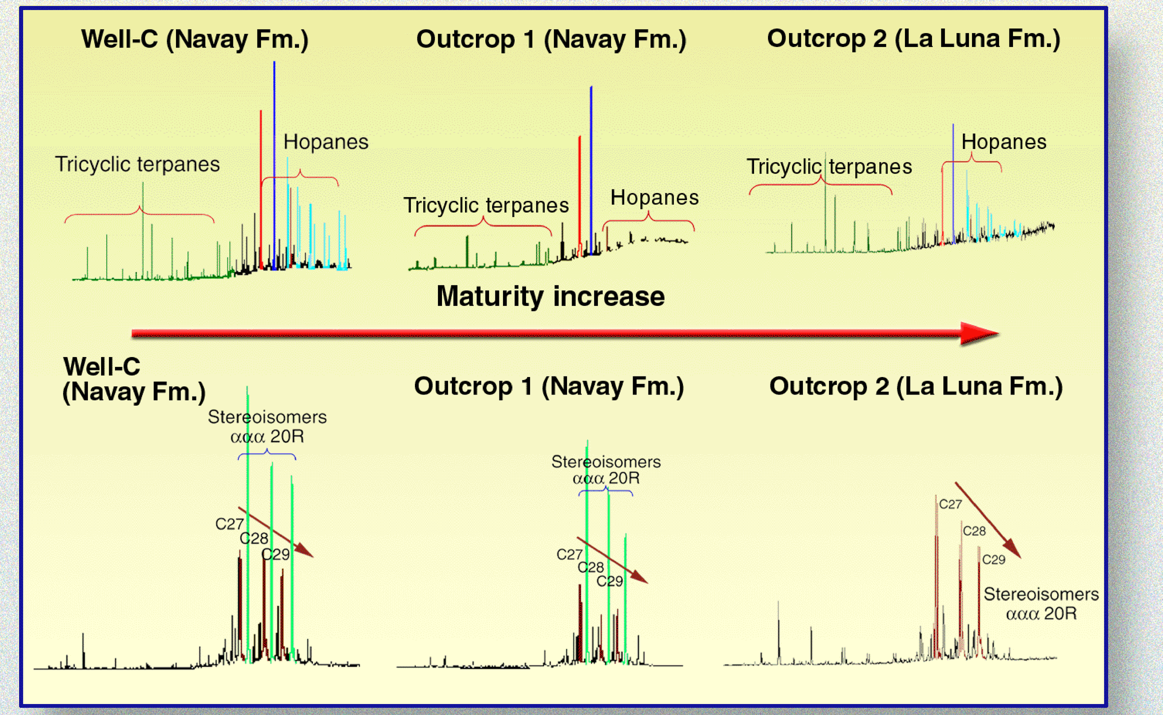


Geochemical modeling indicates that La Morita source rock only reaches the bottom of the oil window with very early oil generation even in the lower structural block. This block was produced by over-thrusting during the Tertiary.

Stratigrafic Column

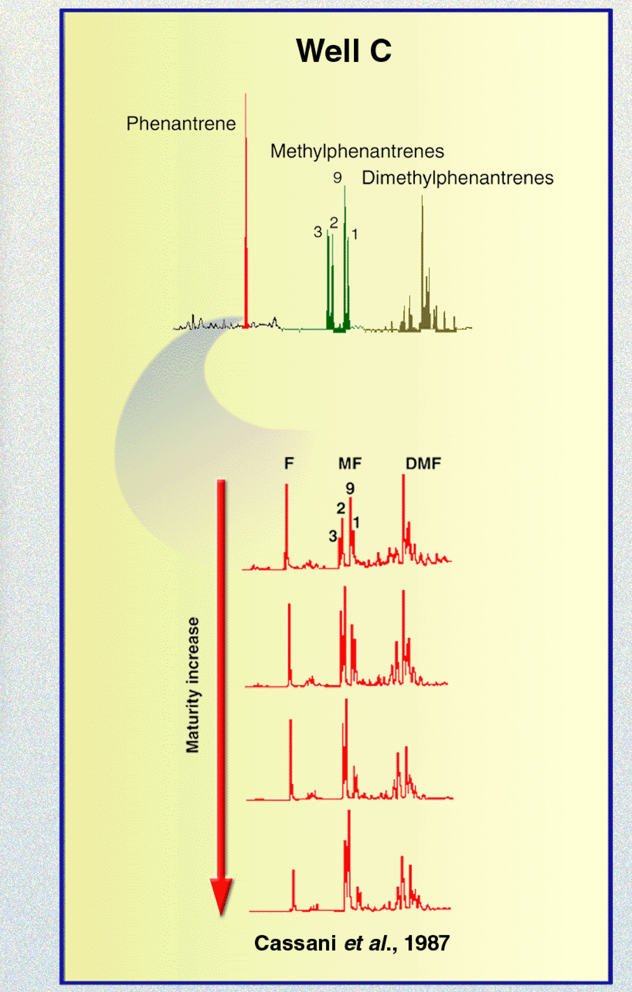


Saturated Biomarkers



Biomarker traces of terpanes, steranes and aromatic steroids allow to assess the maturity level of the source rocks. La Morita, a member of Navay Formation shows low maturity in both outcrop and Well C, as indicated by hopane isomerization, presence of ααα(20R) regular steranes isomers and the high abundance of phenantrane relative to the abundance of methyl and dimethyl phenantranes.

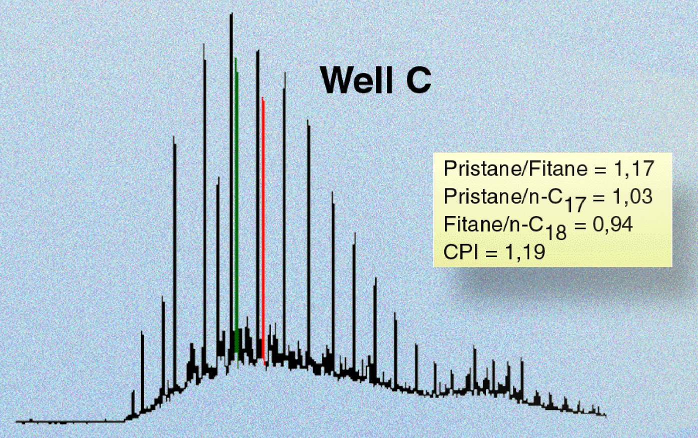
Aromatic Biomarkers



Oil Show (Well C)

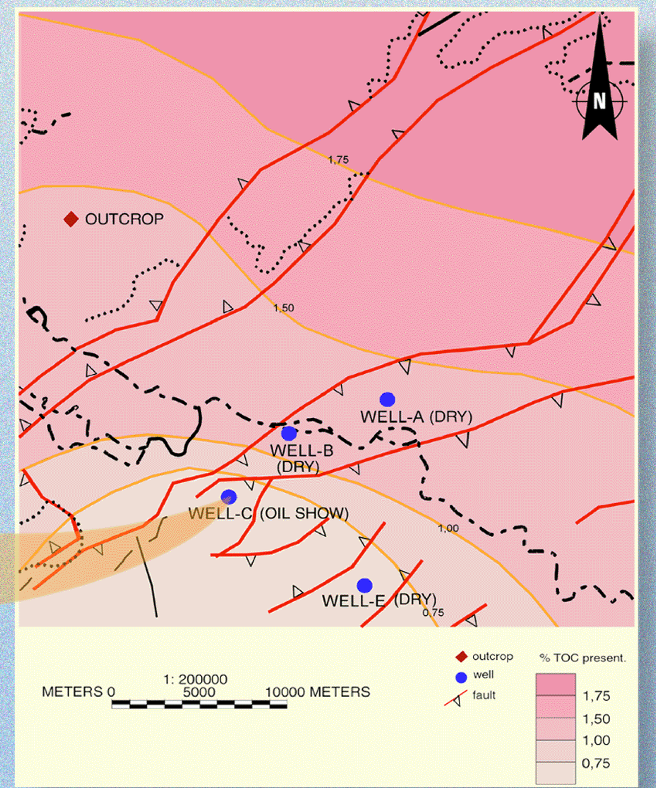
API = 26.7 S(%) = 1.1

C15 + Fingerprint Trace



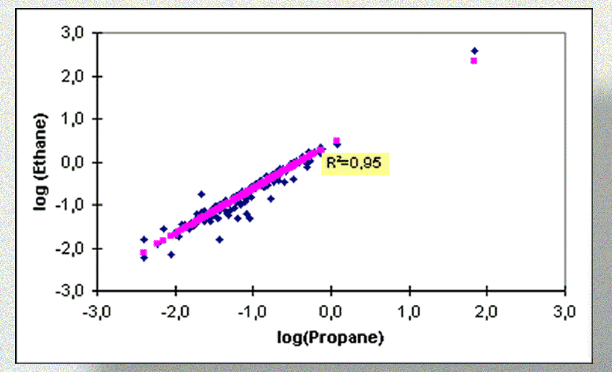
The geochemical parameters calculated from the C15+ chromatographic trace of the oil found in Well C show marine origin with little terrestrial contribution.

TOC Map

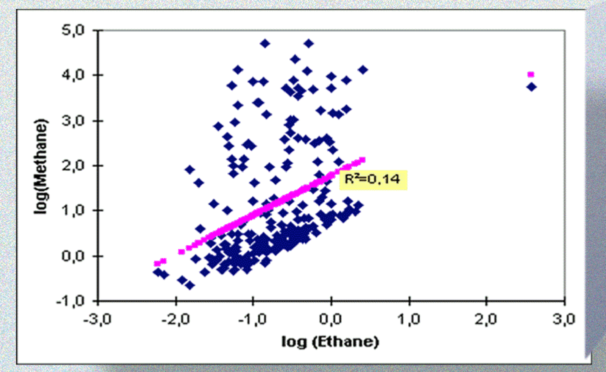


Surface

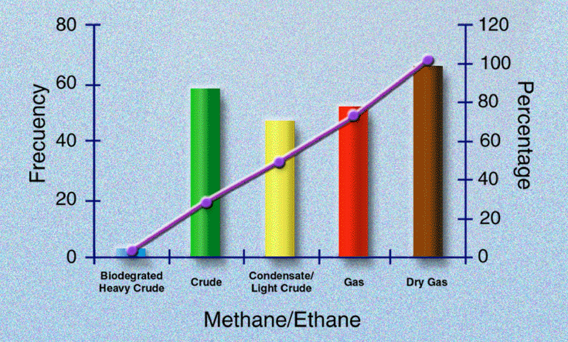
Termogenic Feature



Biogenic Contribution



Empirical Composition Classification

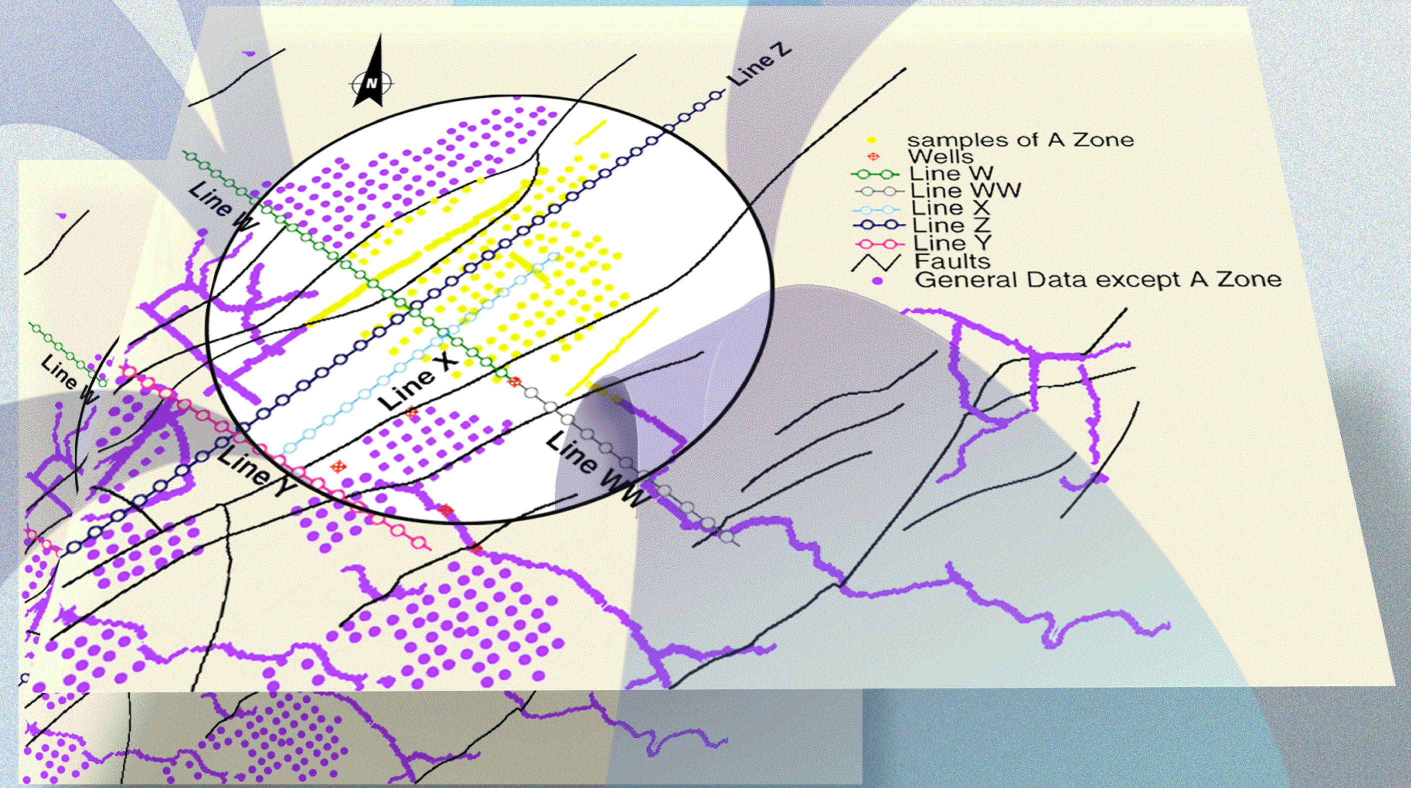


This petroleum composition classification derived from previous surveys over producing fields (Jones & Drozd, 1983) shows a variable composition from gas to oil in the study area.

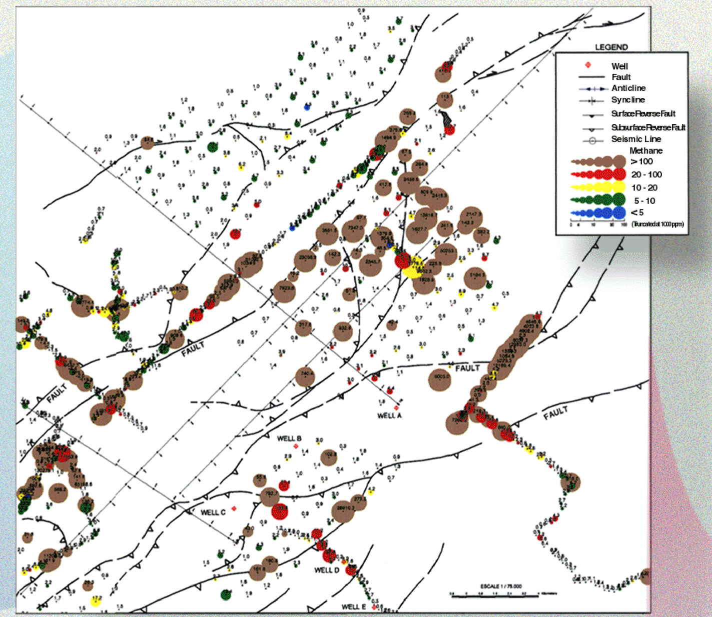
Statistical Values of Surface Gases

Parameters	Me (ppm)	Et (ppb)	Pr (ppb)
Mean/Average	1218	963	454
Median	4	187	83
Mode	1	52	28
Standard Deviation	5348	24390	4676
Variance	28600082	594887	21869
Kurtosis	65	225861	225383
Range	51092	366946	70394
Minimum	0	6	4
Maximun	51093	366952	70398
Confidence Limits (95%)	701	3917	613
Background Mean (········)	3	90	55
1order Anomaly (–·–·–)	6	152	93
2order Anomaly (–··–··–)	8	211	131
3order Anomaly (– – – –)	11	269	168

Geographic Location of Surface Data

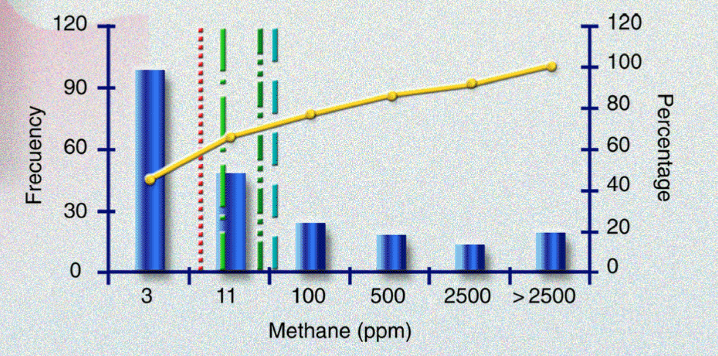


Bubble Map of Methane (ppm)

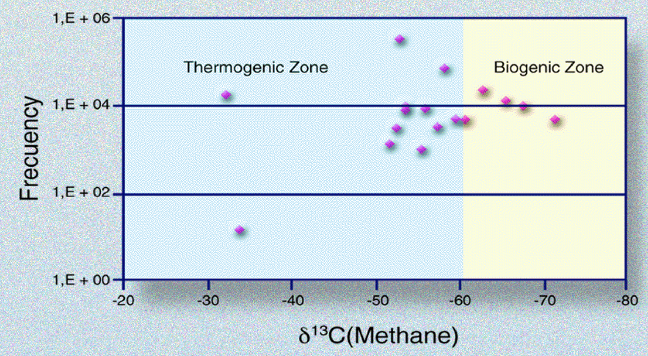


The large methane anomalies on surface with methane/ethane ratio greater than 100 (brown dots), show a strong biogenic contribution, with some thermogenic characteristics confirmed through carbon isotope values.

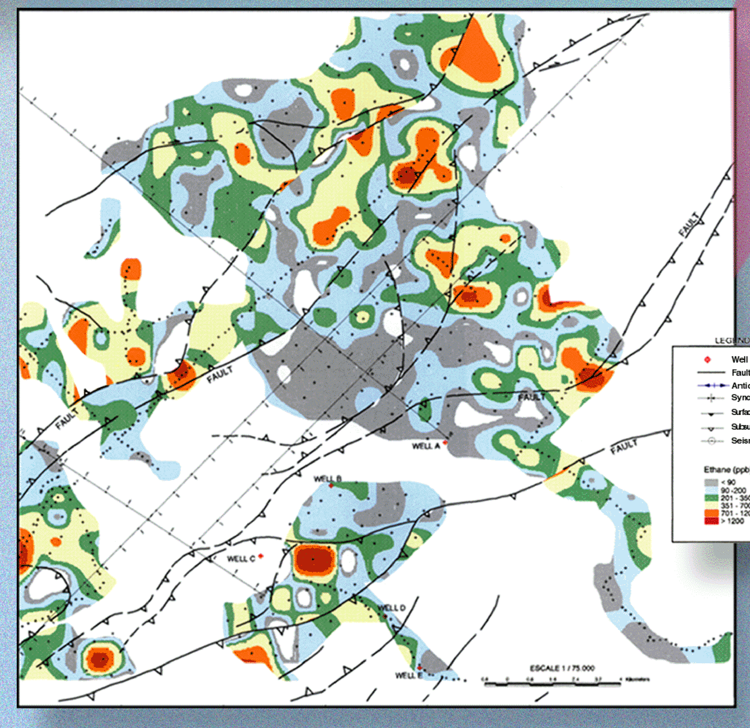
Methane Distribution



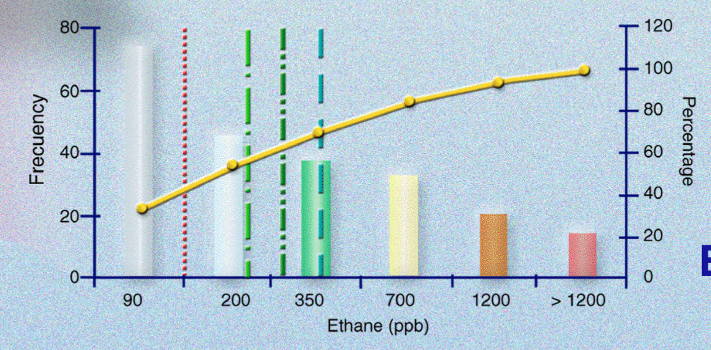
Carbon Isotope of Surface Gases



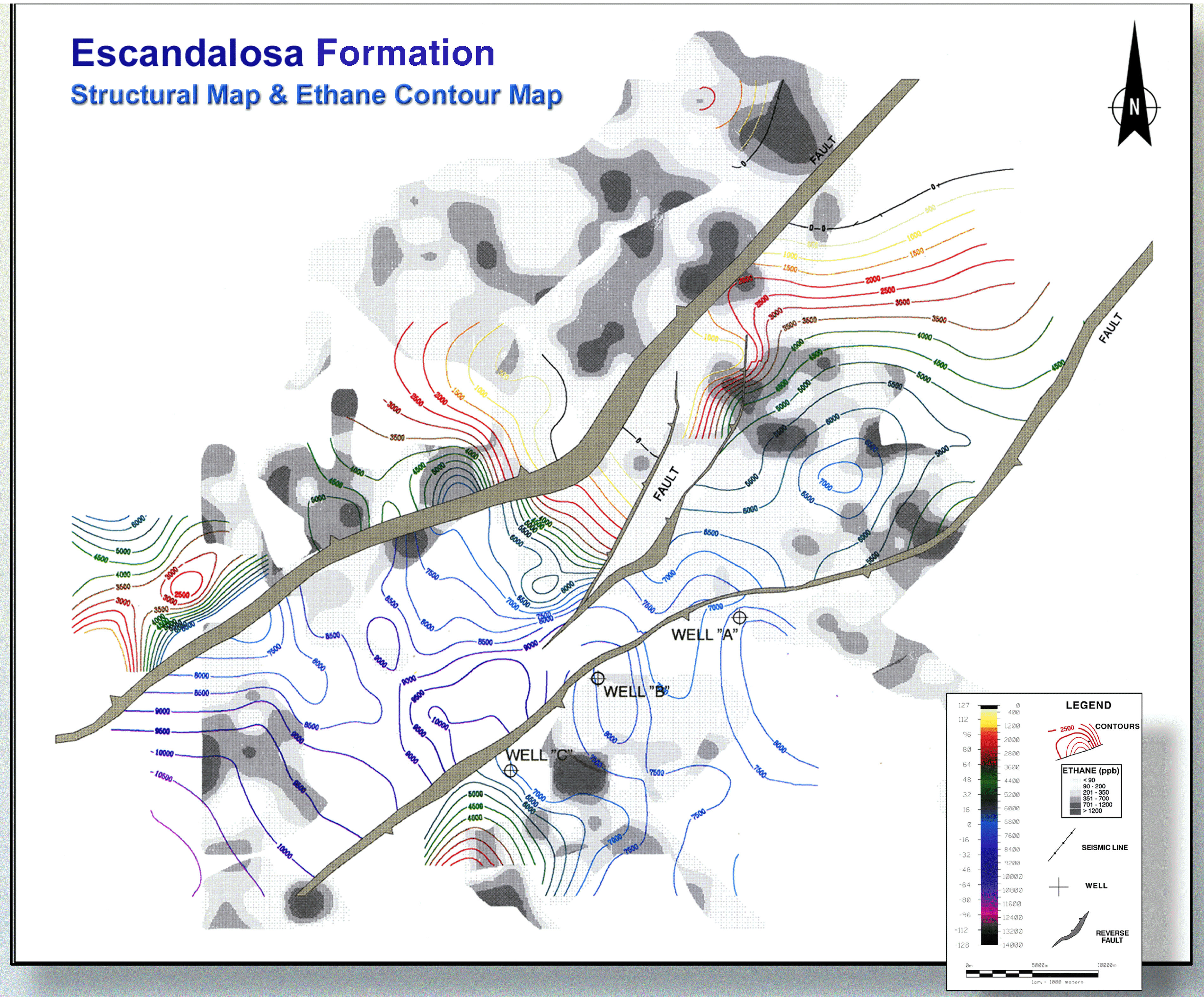
Contour Map of Ethane (ppb)



Ethane Distribution

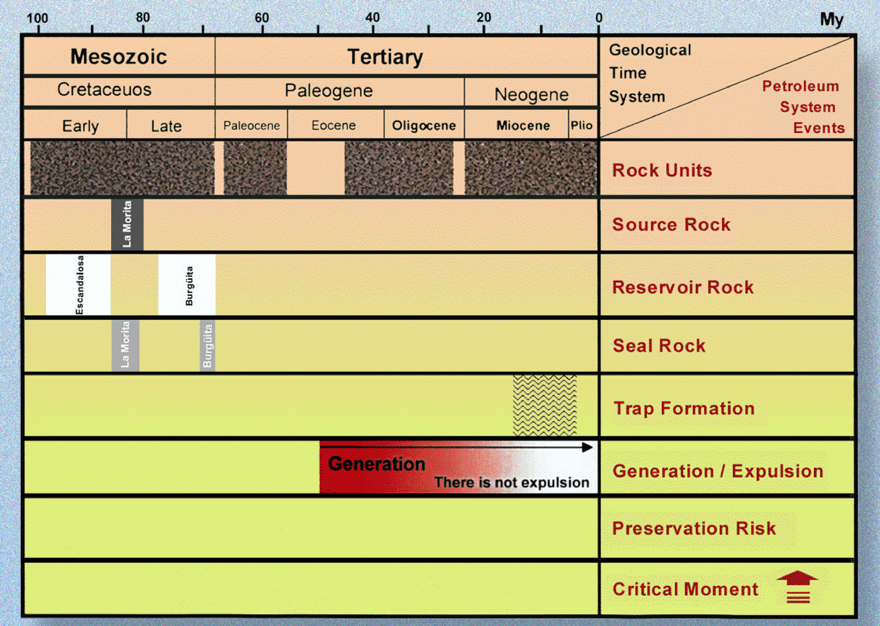


The contour ethane map shows a stronger pattern in the northwestern part of the study area. Some of these anomalies can be associated with the truncation of an anomaly the reservoir rock and fault migration. In addition, anomaly located in the south is confirmed by the presence of oil and gas shows from exploration Well C.



Integration of the structural map of the top of reservoir rock and ethane anomaly maps show that the strongest anomalies are mainly located in northwest where the Escandalosa Formation is truncated.

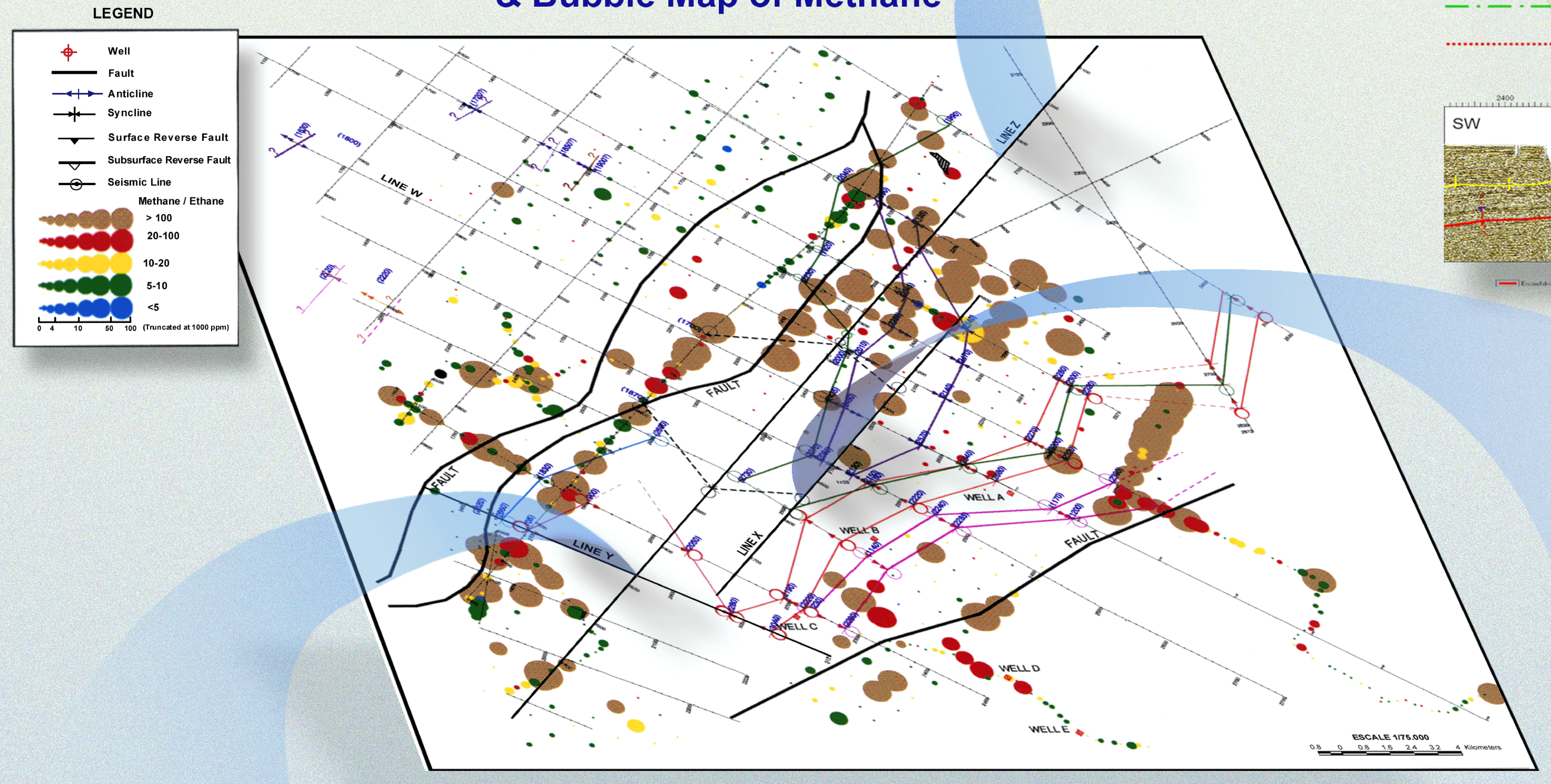
Petroleum System



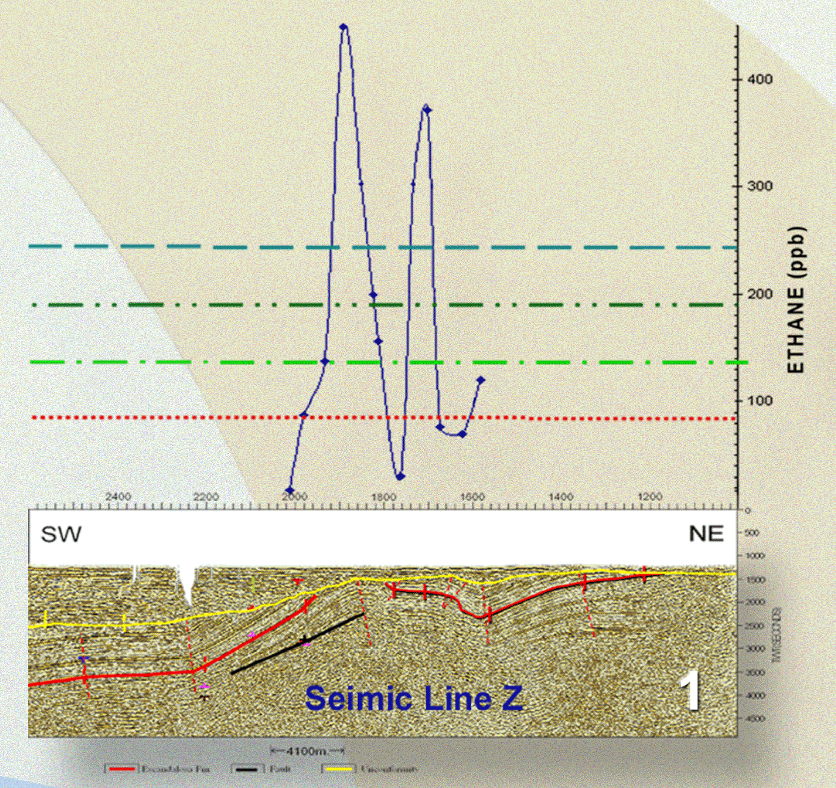
The petroleum system was affected by three erosion events, the most important being the Eocene event. The hydrocarbon generation started at this time but probably did not reach enough maturity for significant oil expulsion. Nevertheless, the small quantities of oil in the exploratory Well C are probably driven by the powerful hydrogeological system of the area.

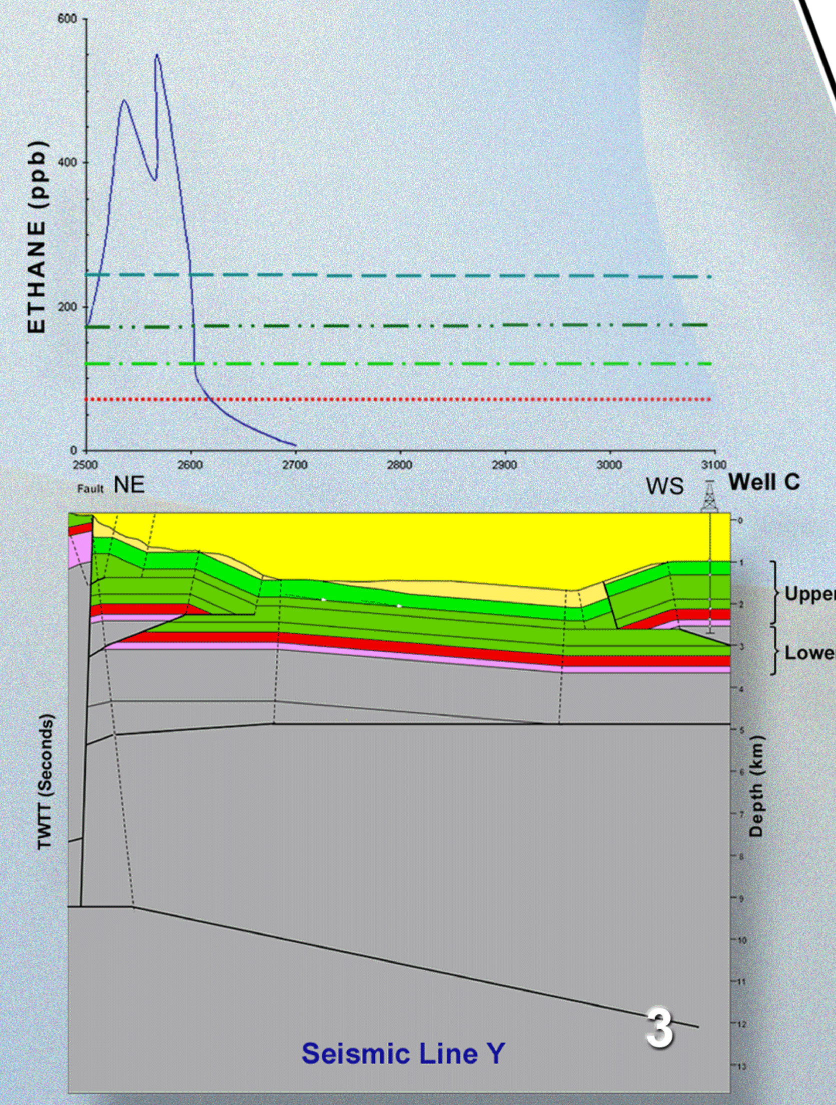
Integration

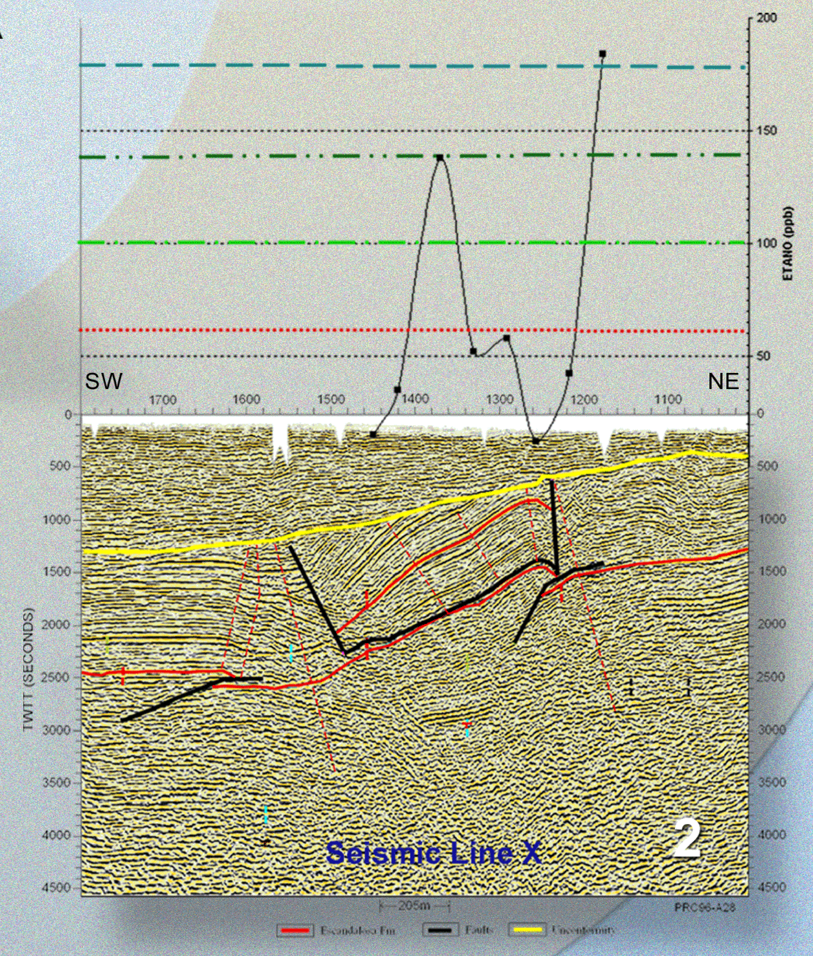
Axial Surface Map & Bubble Map of Methane



Integration of the axial surface and methane anomaly maps shows the agreement between some methane anomalies (with intermediate composition) and the violet and magenta structural trends. Nevertheless, the violet trend does not have structural closure. The magenta trend has not been completely interpreted to the northeastern part of the area due to the lack of seismic information.







The ethane profiles 1 and 3, along the seismic lines Z and Y, show a good correlation between the surface anomalies with truncation of the reservoir rocks and fault, respectively. The ethane profile 2 along the seismic line X shows similar correlation but in this case the reservoir rocks are preserved.

Conclusions

- Biomarker analysis suggests that the small volume of oil found in the area was produced by early generation of hydrocarbons at the beginning of the oil window.
- The seepage magnitudes show an important biogenic contribution.
- The strongest thermogenic surface anomalies are mainly located in northwestern part of the study area, where the reservoir rock is truncated.
- The agreement between some methane anomalies (with intermediate composition) and structural trends interpreted from axial surface analysis, suggests that there is some contribution of thermogenic processes probably from early generation of a Cretaceous source rock.
- Structural truncation of the main explorative objective and low maturity of organic-rich intervals indicate high exploration risk in the study area.
- Combining axial surface map analysis and surface geochemistry helped to prioritize prospective areas for petroleum exploration.

References

Shaw, J., Hook, S.C., and Suppe, J., 1994, Structural trend analysis by axial surface mapping: AAPG Bulletin, v. 78, p. 700-721.

Jones, V., and Drozd, R., 1983, Predictions of oil and gas potential by near-surface geochemistry: AAPG Bulletin, v. 67, p. 932-952.

Cassani, F., Gallango, O., Talukdar, S., Valiegos, C., and Ehrmann, Ursula, 1987/1988, Methylphenanthrane maturity index of marine source rock extracts and crude oils from Maracaibo Basin; Organic Geochemistry, v. 13, p. 73-80.