Applications of Biodegradation Processes Measurable by Biomarker Parameters for Better Production Strategies of a Reservoir

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- **Panel 1**
- **Panel 2**
- **Panel 3**
- **Panel 4**
- **Panel 5**
- **Panel 6**

Abstract

Integrated reservoir management includes a wide range of disciplines and technologies working in an effort to determine the optimal development strategy, both from the reservoir and economics point of view. This approach was applied to the D6 project of Tía Juana Field, Zulia State, West of Venezuela (Fig. 1). To apply this methodology, all geological and geochemical data available was collected and evaluated to select a pilot area inside the project. From these data, old 2D seismic lines were reinterpreted showing a progradational sedimentation trend that was interpreted as vertical reservoir compartments, laying one on top of the other (Fig. 2), while horizontal structural barriers were not found (Lopez *et al.*, 1998).

As part of this integration, a geochemistry study was conducted in order to evaluate the horizontal continuity of the reservoir. This study has shown one of the most severe cases of aerobic biodegradation and water washing of heavy and extraheavy crude oils at shallow depths in Venezuela. The biodegradation of a crude in the reservoir reduces its quality due to a sequential removal of n-alkanes as conditions for microbial oxidation become increasingly favorable; others branched alkanes, isoprenoids, steranes, hopanes, diasteranes, aromatics steroids and porphyrins have also sequentially altereted. (Reed, 1977; Alexander *et al.*, 1983; Volkman *et al.*, 1983; Connan, 1984; Peters and Moldowan, 1992). Due to this differential resistance to biodegradation, comparisons of relative amounts of biomarker types can be used to rank oils as to the extent of biodegradation, when other technics like $C15^-$ and $C15^+$ can not be used.

In this case ion 177 and 191 give a measure of the amount of alteration of biomarkers product of the biodegration process. In this work, preview HPLC separations of 53 crude samples (9° to 12 °API) were performed in order to obtain the SARA fractions of each crude, for further biomarker analysis of the saturated fractions by MID-GC-MS, using the m/z 177 and m/z 191 ions.

The results have shown that the studied crude oils had been exposed to heavy biodegradation, since the tricyclic terpanes have been also altered (Fig. 3), although these compounds are considered one of the most resistant to biodegradation.

On the other hand, the results have shown a very similar bulk composition of the crudes (Table and Fig. 4) and also a similar distribution of the extended Nor-hopanes C_{30}-C_{34} (Fig. 5), which may indicate that biodegradation process has been similar for the whole area, and there were strong possibilities of hydraulic horizontal communications in the reservoir. Nevertheless, preferentially low molecular-weight of the 17a,21b(H)-25-Norhopanes for conversion of extended hopanes has been used to rank the extent of crude biodegradation (Peters et al., 1996). The correlation between the C_{35} Hopane Index [% C_{35}/(C_{31}-C_{35}), m/z 191] and the 25-Norhopane Ratio {%[(C_{30}-C_{34}), m/z 177 / (C_{30}-C_{34}), m/z 177 + (C31-C_{35}), m/z 191]} has shown differences to classify the crude oils (with the personal criteria of the authors) in three levels of biodegradation of the pentacyclic triterpanes: "Low" with 25-Norhopane ratios below 55%, "Middle" with ratios between 55% and 70%, and "High" with ratios above 70% (Fig. 6). This information has been very useful to locate the zones with the best crude qualities and the biodegradation pathways within the reservoir.

Crude locations with its classification of biodegradation in the map have shown a clear tendency of microbial attack and water washing increasing from east to west of the field (Fig. 7). This tendency can be related to changes of lithologic facies of the reservoir-rock that control the recharge of the meteoric water from north to south and/or from north-west faults of the field. These data have been correlated with the sedimentological and petrophysical data.

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Alexander R., Kagi, R.I., Volkman J.K. and Woodhouse G.W. (1983). The Geochemistry of some biodegraded Australian Oils. APEA J. 23, 53-63.

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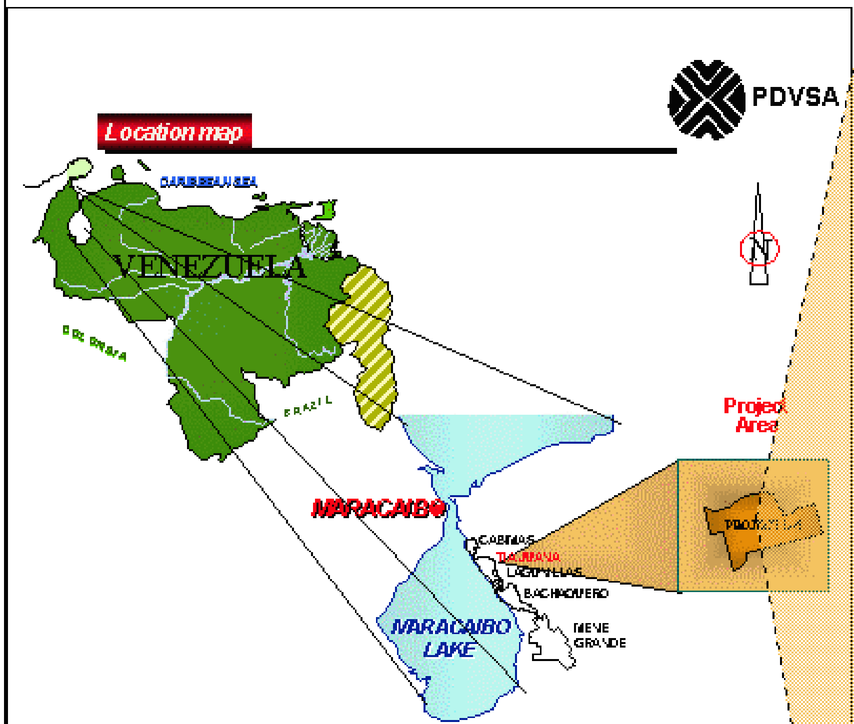
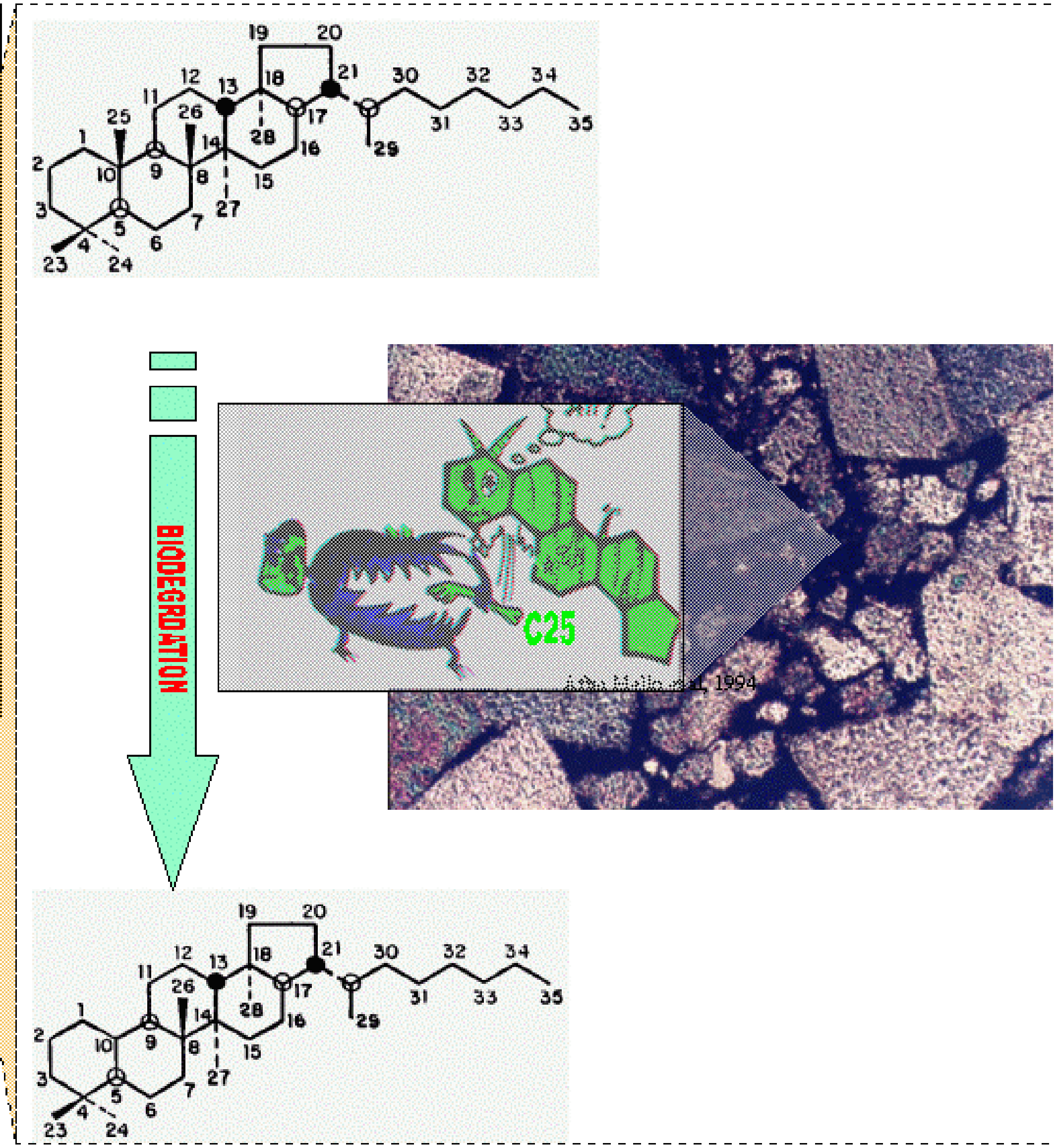
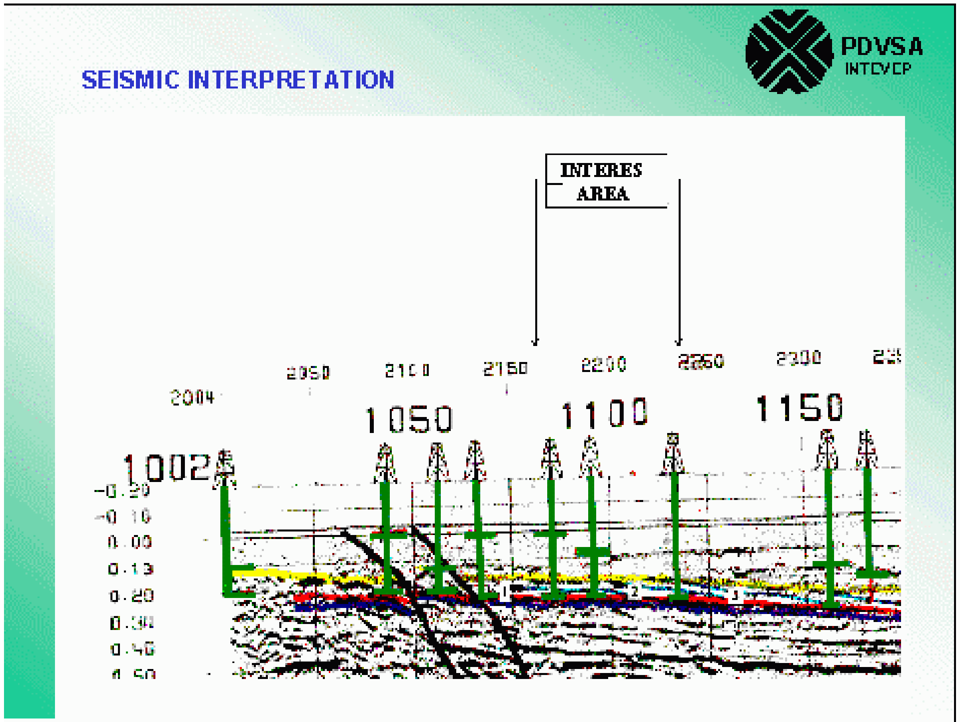
Purpose





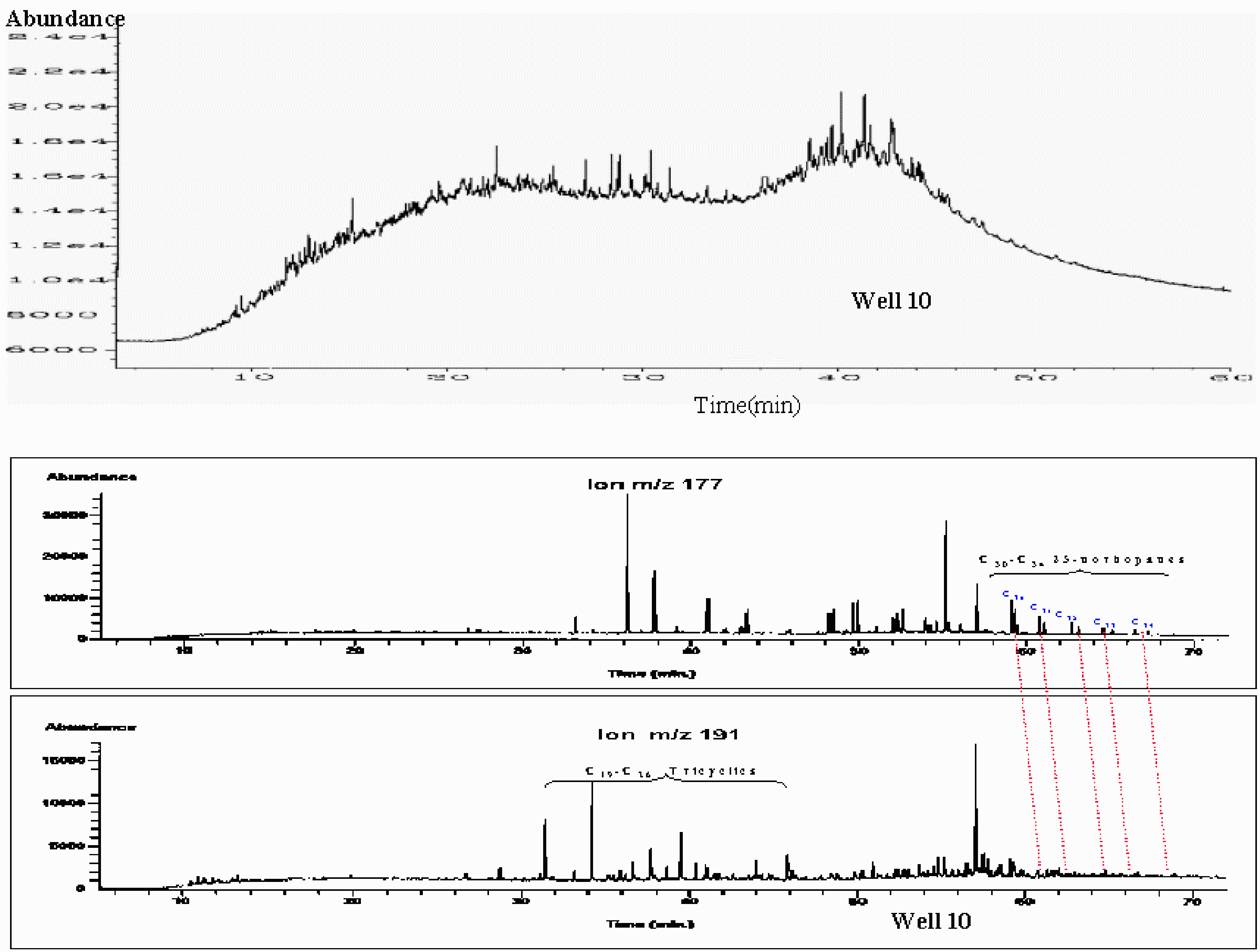
To study the biodegradation and/or water washing of Tia Juana crude oils in Maracaibo basin (west Venezuela) in order to optimize the geological model for better production strategies

Methodology



Old 2D seismic lines were reinterpreted showing a progradational sedimentation trend that was interpreted as vertical reservoir compartments, laying one on top of the other, while horizontal structural barriers were not found (Lopez et al., 1998).

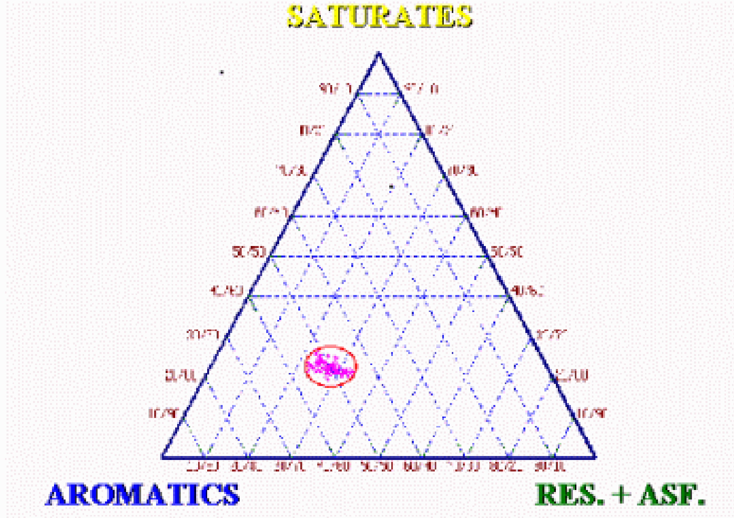
53 crude oils (9° to 12 °API) were well-head sampling and preview HPLC separations were performed in order to obtain the SARA fractions of each crude, for further C15+ and biomarker analysis of the saturated fractions by GC and MID-GC-MS using the m/z 177 and m/z 191 ions.

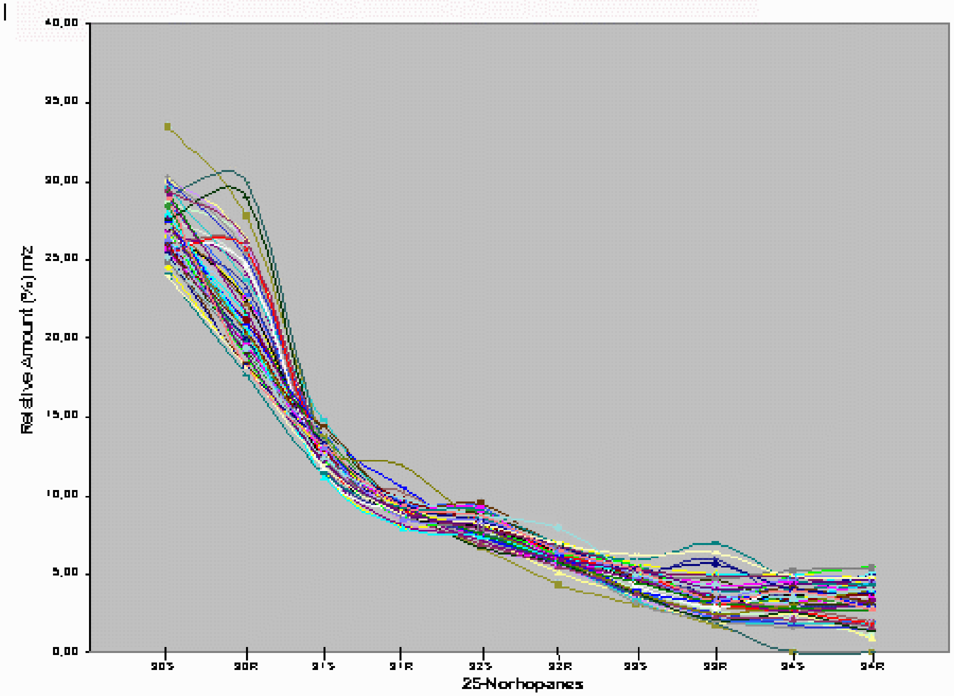


This study has shown one of the most severe cases of aerobic biodegradation and water washing of heavy and extraheavy crude oils at shallow depths in Venezuela. The differential resistance to biodegradation, comparisons of relative amounts of biomarker types have been used to rank oils as to the extent of biodegradation, due to other technics like $C15^{-}$ can not be used. In this case ion 177 and 191 give a measure of the amount of alteration of biomarkers product of the biodegration process.

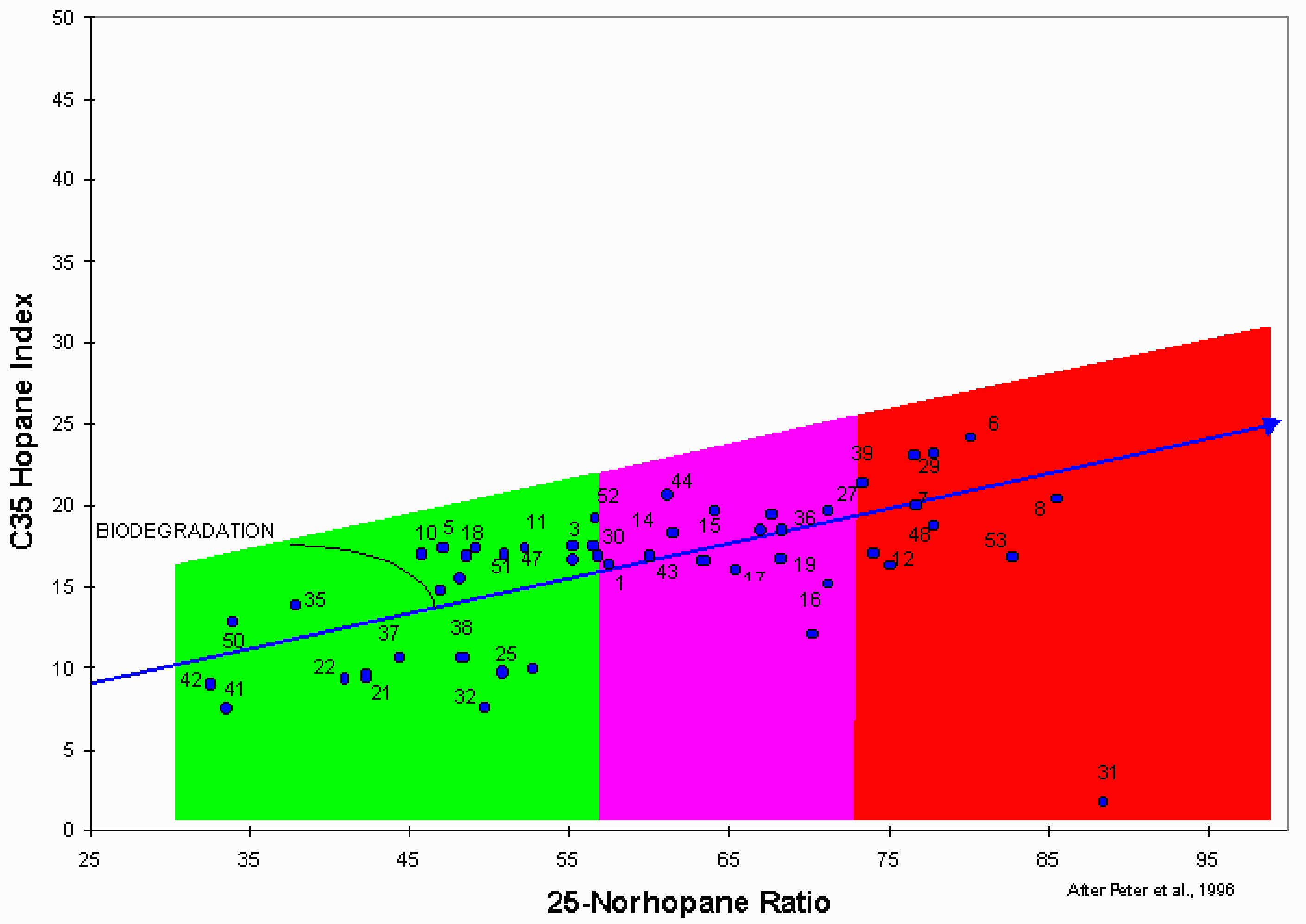
Results

WELL	°API	%Sat	%Arom	%Res	%Asf	% Res+%Asf	S (%)	V (ppm)	Ni (ppm)	V/Ni
1	8,8	19,8	43,8	28,3	8,1	36,4	2,68	329	44	7,48
2	9,1	20,6	45,2	26,8	7,4	34,2	2,36	323	44	7,34
3	9,1	20,1	46,4	27,0	6,5	33,5	2,54	339	46	7,37
4	9,2	20,8	43,9	26,5	8,9	35,3	2,30	315	43	7,33
5	9,2	21,4	45,6	25,8	7,2	33,0	2,44	313	42	7,45
6	9,2	19,8	44,1	28,5	7,7	36,1	2,76	354	45	7,87
7	9,3	19,0	42,6	29,6	8,8	38,4	2,58	372	48	7,75
8	9,3	19,3	42,1	30,9	7,7	38,5	2,52	288	36	8,00
9	9,3	20,0	45,1	28,3	6,5	34,9	2,42	254	33	7,70
10	9,4	20,0	45,1	26,5	8,3	34,8	2,40	325	44	7,39
11	9,4	19,8	45,7	27,0	7,6	34,5	2,52	337	46	7,33
12	9,4	20,8	49,6	21,5	8,2	29,6	2,53	348	45	7,73
13	9,5	19,5	44,5	27,3	8,7	36,0	2,12	287	38	7,55
14	9,6	18,5	47,7	25,9	7,9	33,8	2,70	365	49	7,45
15	9,6	19,6	43,4	29,0	8,0	37,0	2,74	358	45	7,96
16	9,6	19,9	46,4	27,4	6,2	33,7	2,73	254	32	7,94
17	9,6	21,6	48,0	22,4	8,1	30,5	2,34	312	41	7,61
18	9,7	19,5	46,9	26,2	7,4	33,6	2,24	289	39	7,41
19	9,7	19,8	41,8	29,5	8,9	38,4	2,34	360	47	7,66
20	9,8	20,1	48,5	23,8	7,6	31,5	2,09	271	37	7,32
21	9,8	21,5	50,3	20,5	7,8	28,3	2,55	303	40	7,58
22	9,8	20,8	49,0	23,5	6,7	30,2	2,07	255	35	7,29
23	9,8	20,1	49,0	22,8	8,2	30,9	2,24	308	42	7,33
24	9,9	22,0	45,1	26,1	6,8	33,0	2,20	292	40	7,30
25	9,9	20,0	45,8	25,9	8,3	34,2	2,54	360	50	7,20
26	9,9	21,2	49,6	21,5	7,7	29,2	2,67	332	43	7,72
27	9,9	19,4	45,3	26,3	9,0	35,3	2,84	370	48	7,71
28	10,1	21,8	46,9	23,7	7,5	31,3	2,72	363	49	7,41
29	10,1	19,6	45,5	29,4	5,5	34,9	2,74	354	46	7,70
30	10,1	20,4	45,9	25,9	7,7	33,6	2,60	303	40	7,58
31	10,2	20,5	46,0	27,1	6,4	33,5	1,99	207	27	7,67
32	10,2	22,1	47,3	23,4	7,3	30,6	2,61	322	44	7,32
33	10,2	20,2	51,5	20,9	7,4	28,4	2,63	332	43	7,72
34	10,4	19,8	43,1	29,0	8,1	37,1	2,65	294	39	7,54
35	10,5	20,6	46,5	24,9	8,0	32,9	2,67	363	50	7,26
36	10,6	20,8	46,4	25,5	7,3	32,8	2,31	306	42	7,29
37	10,6	19,7	47,0	24,7	8,6	33,3	2,72	359	48	7,48
38	10,6	23,0	43,9	25,5	7,6	33,1	2,57	229	38	6,03
39	10,6	20,0	46,7	25,0	8,3	33,3	2,79	365	47	7,77
40	10,7	24,6	47,8	20,9	6,7	27,6	2,40	262	34	7,71
41	10,7	22,2	48,4	22,4	7,0	29,4	2,07	239	32	7,47
42	10,8	21,5	48,5	22,1	8,0	30,1	2,54	304	41	7,41
43	10,9	19,6	46,5	26,3	7,6	33,9	2,43	370	51	10,90
44	10,9	20,4	46,8	25,0	7,7	32,8	2,51	340	45	10,90
45	10,9	21,4	46,7	25,1	6,8	31,9	1,74	229	31	7,39
46	11,1	21,0	48,0	24,6	6,5	31,1	2,48	288	38	7,58
47	11,1	22,6	48,3	22,2	6,9	29,1	2,50	329	44	7,48
48	11,1	19,4	45,5	26,5	8,7	35,2	2,47	336	43	7,81
49	11,2	23,2	45,1	23,6	8,1	31,7	2,54	310	42	7,38
50	11,2	23,5	47,4	22,4	6,7	29,1	2,43	310	42	7,38
51	11,2	21,1	44,7	25,2	9,0	34,2	2,77	369	50	7,38
52	12,0	19,7	44,0	26,8	9,5	36,4	2,72	357	48	7,44
53	12,0	19,6	46,8	25,6	8,1	33,6	2,76	353	45	7,84
Averag.	10,1	20,6	46,3	25,4	7,7	33,1	2,5	317,1	42,3	7,6





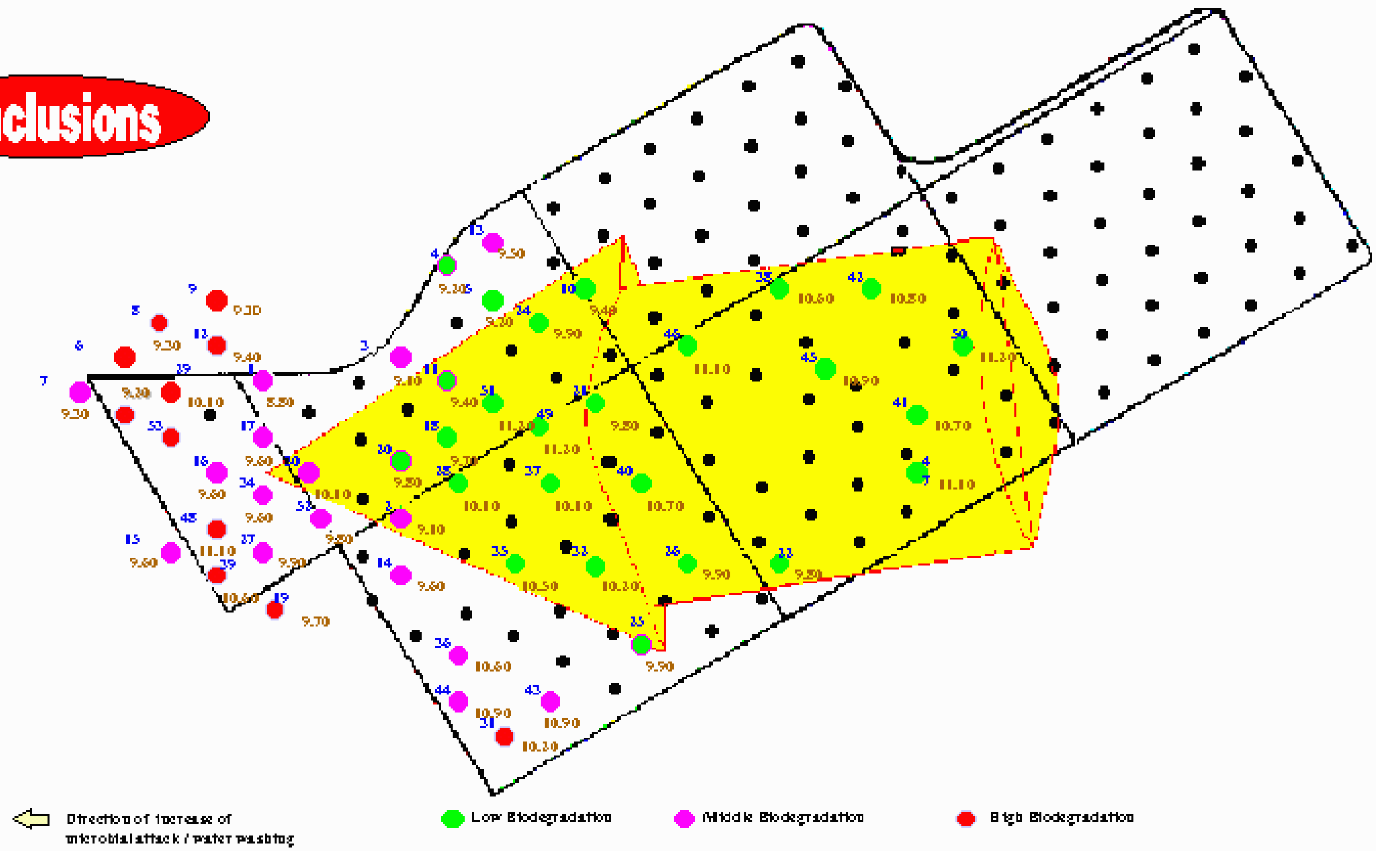
- The results have shown that the studied crude oils had been exposed to heavy biodegradation, since the tricyclic terpanes have been also altered, although these compounds are considered one of the most resistant to biodegradation.
- On the other hand, the results have shown a very similar bulk composition of the crudes and also a similar distribution of the extended Nor-hopanes C_{30}-C_{34}, which may indicate that biodegradation process has been similar for the whole area, and there were strong possibilities of hydraulic horizontal communication in the reservoir.



The correlation between the C_{35} Hopane Index [% C_{35}/(C_{31}-C_{35}), m/z 191] and the 25-Norhopane Ratio {%[(C_{30}-C_{34}), m/z 177 / (C_{30}-C_{34}), m/z 177 + (C_{31}-C_{35}), m/z 191]} has shown differences to classify the crude oils (with the personal criteria of the authors) in three levels of biodegradation of the pentacyclic triterpanes: “Low” with 25-Norhopane ratios below 55%, “Middle” with ratios between 55% and 70%, and “High” with ratios above 70%.

This information has been very useful to locate the zones with the best crude qualities and the biodegradation pathways within the reservoir.

Conclusions



- The Tia Juana crude oils have similar composition, with higher content of aromatics (46.6%), 21% of saturates, and 33% of polar compounds, 2.5 % S and 7.6 V/Ni. Nevertheless, its asphaltene content is lower (8%), compared with other extraheavy crude oils
- The crude oils show a severe biodegradation and water washing, with removal of n-alkanes, isoprenoids, part of steranes and hopanes (including some tricyclics) and some aromatics, which have reduced its quality drastically
- Same distribution of the extended hopanes C_{30}-C_{34} might indicate that biodegradation process has been similar for whole area and strong possibilities of horizontal hydraulic comunication of the reservoir.
- Nevertheless, preferentially low molecular-weight of the 17α,21β(H)-25-Norhopanes for conversion of extended hopanes has been used to rank the extent of crude biodegradation.
- The correlation between the C_{31} Hopane Index and the 25-Norhopane Ratio has shown differences to classify the crude oils (with the personal criteria of the authors) in three levels of biodegradation of the pentacyclic triterpanes: "Low" with 25-Norhopane ratios below 55%, "Middle" with ratios between 55% and 70%, and "High" with ratios above 70%.
- This information has been very useful to locate the zones with the best crude qualities and the biodegradation pathways within the reservoir.
- Crude locations with its classification of biodegradation in the map have shown a clear tendency of microbial attack and water washing increasing from east to west of the field. This tendency can be related to changes of lithologic facies of the reservoir-rock that control the recharge of the meteoric water from north to south and/or from north-west faults of the field. These data have been correlated with the sedimentological and petrophysical data.