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Exploration Studies using Surface Geochemical Data: Case Studies in the Eastern and Western Venezuelan Basins

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The detection of soil-gas anomalies is a useful tool for hydrocarbon exploration studies. The key to reliable soil-gas data interpretation is the way in which this technique is applied and understood, since there is a large number of geological factors that can affect the expression of gas anomalies on the surface, such as: depth, reservoir quality, seal integrity, and presence of fractures/faults. In addition, other minor effects like soil-type and meteorological changes have been reported (Jones et al., 2000).

Since 1993, several surface geochemical surveys were conducted in Venezuela for exploration studies, covering 7.500 Km^2 with free soil gas data, 6.000 Km^2 with sorbed soil gas data, and around 700 Km^2 with microbial techniques. Also, there are some offshore areas with sniffer data. (See Figure 1).

The signal intensity that has been registered in onshore exploration areas with free soil gas data varies significantly, with an ethane-median from 30 ppb in producing areas to more than 900 ppb in some non-producing areas. Nevertheless, the laboratory calibration might affect these magnitudes.

Recent efforts to optimize geological-geochemical models of exploration studies have required a review of numerous surface geochemical data, specially using free soil gas data, which have matched well with the geological and structural data.

Calibration

Data of 152 well-head gases of more than 24 production fields located in Western and Eastern Venezuela have been used to calibrate the free soil gas data, using Pixler gas ratios. The results show 4 zones in which the composition of the surface-gas can be correlated with the underlying reservoirs of: heavy/segregates crudes (*Zone 1*), medium&light crudes (*Zone 2*), free gas (*Zone 3*) and dry gas/biodegraded crudes (*Zone 4*). (See Figure 2).

Table 1 shows the calibration ranges that have resulted from this work to infer the probable subsurface hydrocarbons accumulations using free soil gas data. The ranges for medium and light crude oils could not be well differentiated. The depletion degree of the fields and its gas/oil ratios could alter the real location of the curves in the pixler graph. Probably isotopic analysis may contribute to have a better definition of these pixler traces, with the real association of the gases with their own fluids through the isotopic fingerprints.

The results of this work are quite similar to those for the ranges of medium & light crudes and gas reported by Jones & Drozd (1983). However, major differences occur for the ranges of some heavy and extra-heavy crudes. The high values of methane obtained in gas samples were related with probable contributions from biodegradation processes. These processes are also common in some Canadian shallow reservoirs (Rich et al., 1994).

These calibration ranges were tested in three producing fields using Pixler graphs, to compare anomalous soil gas samples with well-head gases. The results show good agreement of the surface oil predictions with the production data, specially with the C2/C3 gas ratio less affected by biodegradation processes. The displacement observed in Oil Field 2 might be associated to different origins of the sources. (See Figure 3).

CASE 1:

350 free soil gas samples were taken by PDVSA in a 70-Km^2 region located in the Eastern Venezuela Basin. In this area a wild cat was drilled recently. The ethane data in this area showed a normal asintotic distribution (from 0 to 3,000 ppb), that has been separated with the ethane-median to differentiate the non anomalous samples from the anomalous ones. Distribution resulted in about 50% of the samples in each group. This statistic has been quite consistent in all the studied areas.

The bubble map of ethane displayed over the shallow structural features of the area showed excellent alignments of the higher surface gas anomalies with the flanks and tops of two shallow structural highs. On the other hand, lower gas anomalies were located along the syncline that separate these two highs. This effect can be understood by the preferential migration of the gases to the flanks and tops of the highs, that decreases the signals in the deeper parts. Close to the exploratory location some lower gas anomalies were also detected. (See Figure 4).

On the other hand, the structural section North-South with stratigraphic data presents the location of oil shows at 1 sec depth (5000 feet). The surface ethane bubbles along this section are found aligned with the shallow structural high illustrated in the previous ethane bubble map, and also close to the south part of the exploratory location. (See figure 5).

The area where oil shows were detected was analyzed by a special epi-fluorescence technique developed at PDVSA-Intevep. Cutting samples at a depth from 3,900' to 7.500' were taken to be submitted on color and intensity fluorescence variation associated with the oil composition and maturity (Ruggiero et al., 2001).

The fluorescent results showed an estimated API distribution between 15° to 30° API gravity, discarding the mud interference. This API range matches the prediction of the surface gas data, proposing that the source of the surface gas anomalies might be the oil shows. In addition, the shallow structural highs in this area might focus on the gas migration to the surface from it.

Actually, other deeper sources are being studied until completion of the wild cat evaluation. In thrusted areas like case study 1, different migration pathways of the hydrocarbons to surface may difficult the integration between surface and subsurface data.

CASE 2:

The second example is in a 375-Km^2-exploration area located in Western Venezuela. In this case, 725 "free soil gas" data (ETI Job 97-516) showed an ethane distribution with similar pattern to that in Case Study 1, with 50% of non-anomalous samples. However, the signal intensity of ethane (from 0 to 66,000 ppb) and heavier hydrocarbons were higher by more than one order of magnitude.

Outcrop samples of La Luna Formation (source rock in this area) showed reflectance values in the Oil Window, and original Total Organic Carbon (TOC) between 1 and 5 %. In addition, the generation potential was estimated between 500 to 600 mg HC/g TOC. All this data suggest excellent conditions to have an active "Kitchen Area", where important surface gas anomalies are also found. These results have been confirmed with geochemical modeling, which indicate that the hydrocarbon expulsion is still ongoing and is feeding the oil seeps located in the study area (Gallango et al., 2001). (See figure 6).

The surface observation of the “Generation Area” was also studied by remote sensing data, in which spectral anomalies related to stressed vegetation were detected (Arrieche et al., 2001). Other magnetic susceptibility measurements were conducted to confirm the location of anomalous zones in this area related with hydrocarbons gas leakage (Aldana, et al., 2001).

On the other hand, the structural section West–East aligned with the surface ethane bubbles, shows the “Generation Area”, which is active only in the Eastern part. The main Cretaceous reservoir rock is located above La Luna source rock, with oil migration pathways indicated by blue arrows.

In this section, larger gas anomalies were found aligned with the flanks and top of one of the most important exploratory location of this area, showing a “Halo Effect”. Also, there are important anomalies in which an oil seep was located, and other gas anomalies were found aligned with a fault merging to the surface. (See figure 7).

Nowadays, PDVSA is studying the economics of the exploratory locations of this area.

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Figure 1: Areas with surface geochemical data

Figure 2: Pixler Graph with Venezuelan Well-Head Gases

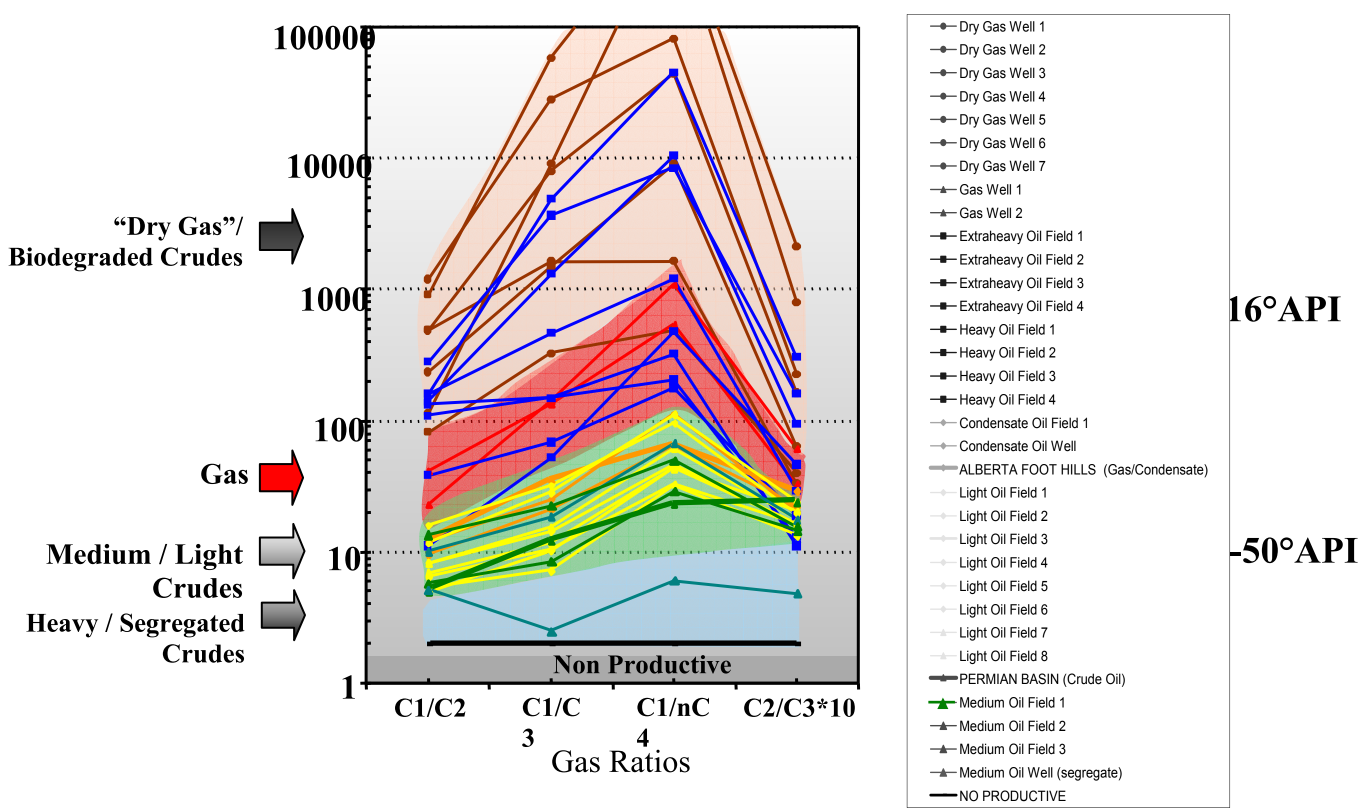
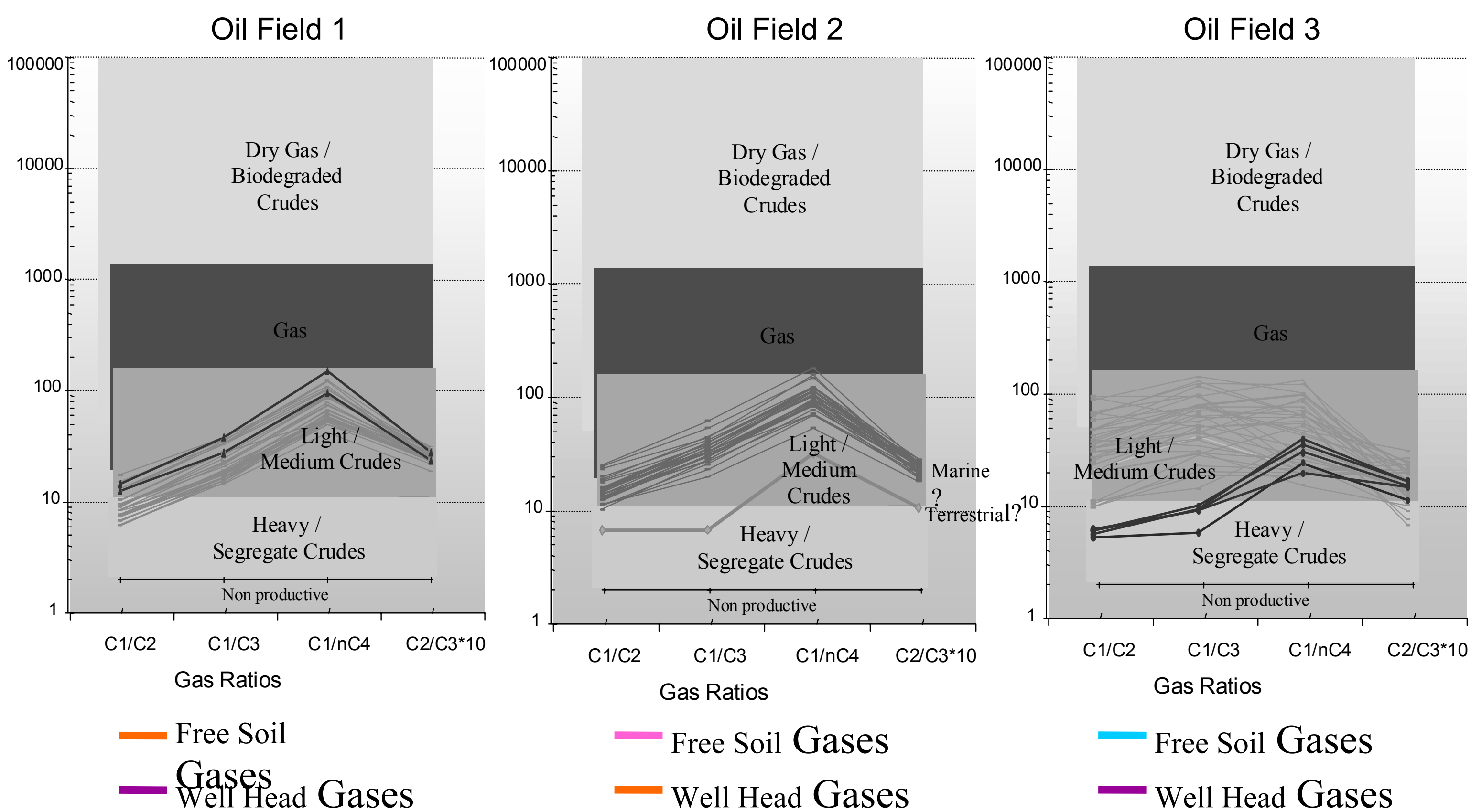


Table 1: Pixler correlations with well-head-gas data of Venezuelan oil fields

		Pixler Gas Ratios C1/C2	C1/C3	C2/C3
ZONE 4	Dry Gas/Biodegraded Crudes	>100	>160	>45
ZONE 3	Gas	20,1 - 100	40,1 - 160	30,1 - 45
ZONE 2	Light/	10,1 - 20	20,1 - 40	20,1 - 30
ZONE 2	Medium Crudes	4,0 - 10	5,0 - 20	15,0 - 20
ZONE 1	Heavy/Spilled/Segregated Crudes	<4	<5	<15

Figure 3: Validation of the calibration ranges with surface anomalous samples in three Venezuelan production fields.



CASE 1

Figure 4: Bubble map of ethane (ppb) overlapped to the shallow structural features of the area.

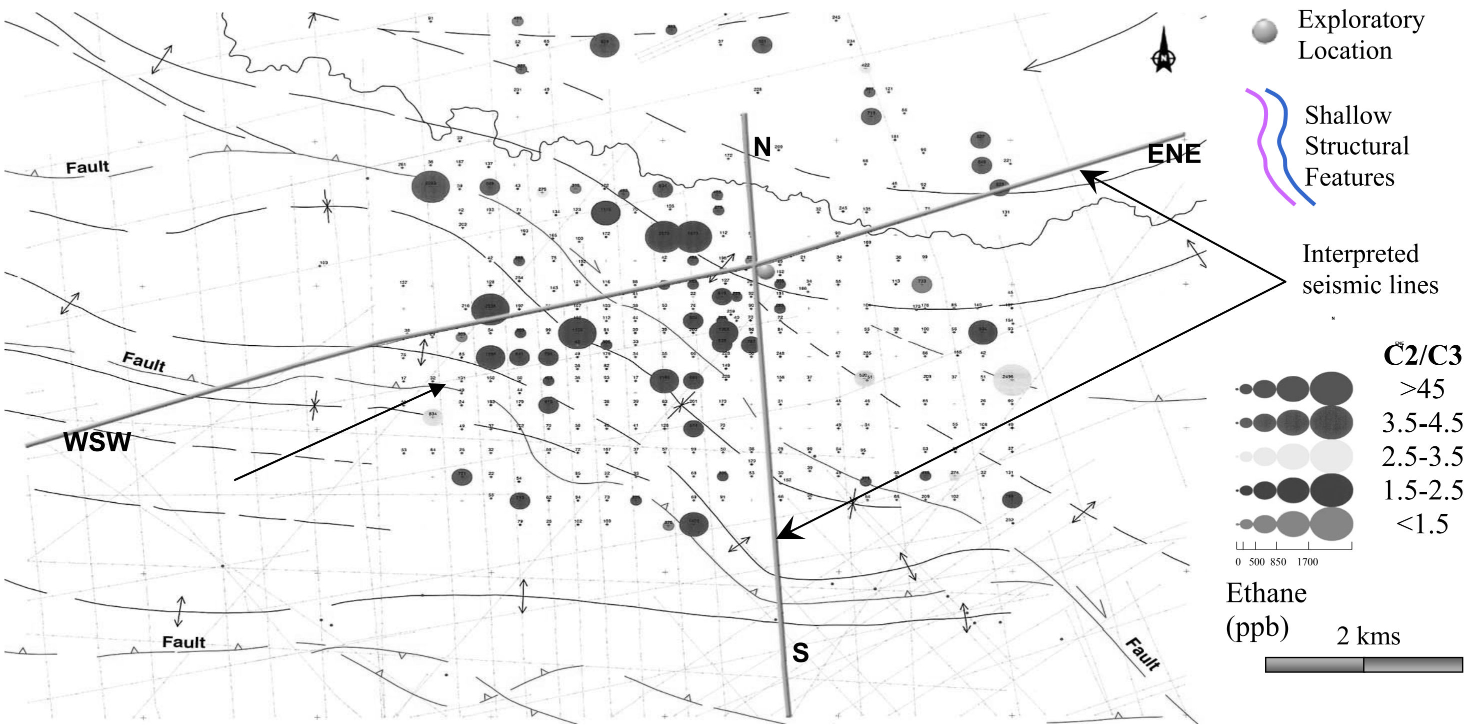
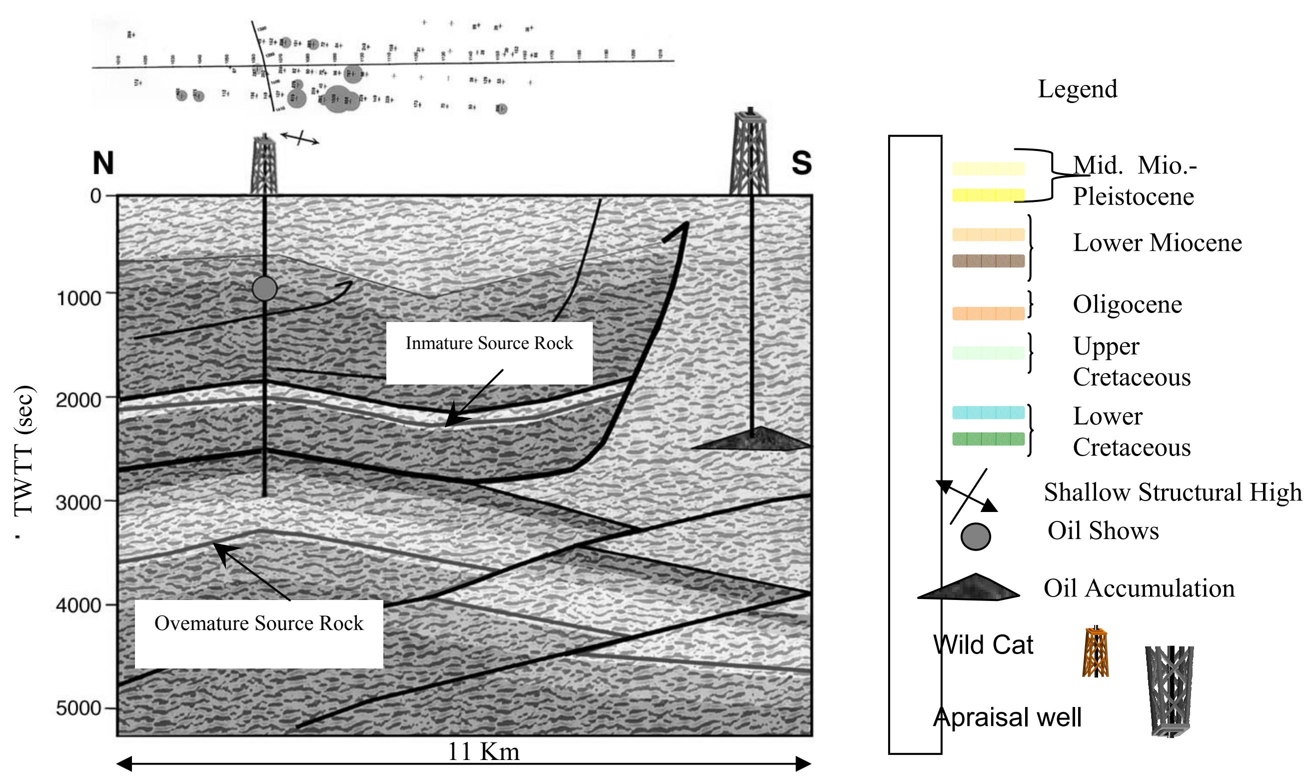
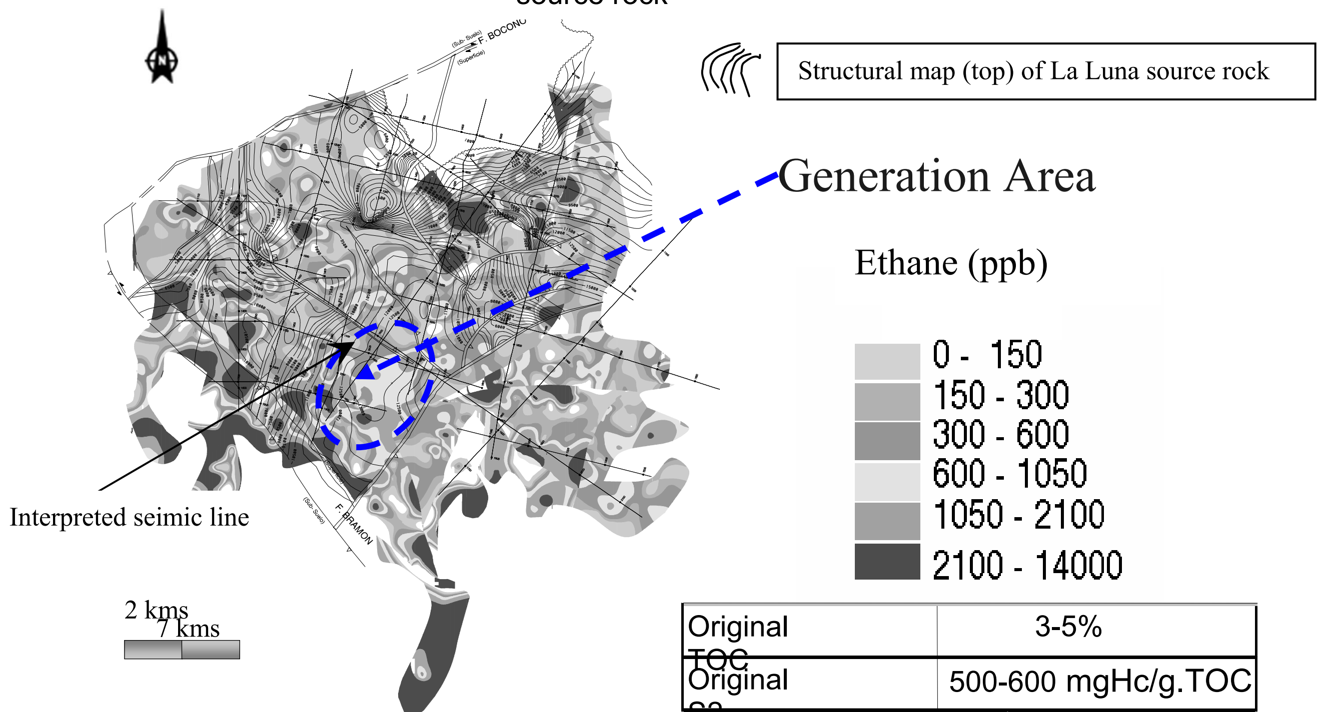


Figure 5: Structural section N-S with surface ethane bubbles along it.



CASE 2

Figure 6: Contour map of ethane overlapped to the structural map (top) of La Luna source rock



Original TOC	3-5%
Original S2	500-600 mgHc/g.TOC

Gallango et al., 2001

Figure 7: Structural section W-E with surface ethane bubbles along it.