Worldwide Near Surface Geochemical Exploration Services

Present day exploration for oil and gas requires a coordinated effort based on the successful integration of geophysics, geology, and geochemistry. Surface geochemical prospecting provides the explorationist a cost effective tool to reduce exploration risk. Specifically, the analysis of light hydrocarbons in soil vapor, seismic shothole, and marine piston core samples are used to:

* quickly evaluate the productive potential of unexplored regions
* differentiate oil from gas prone areas
* optimize the location of geophysical data acquisition
* high-grade or rank existing prospects
* extend existing productive trends

Exploration Technologies, Inc.

Representative Experience

Exploration Technologies, Inc. (ETI) has collected and analyzed over 65,000 soil gas samples for petroleum exploration projects since 1984, including sampling programs in over 10 countries. ETI's South and Central America experience includes studies in Venezuela, Argentina, Colombia, Panama, Peru and Honduras. These previous studies are very important for establishing the usefulness and limitations of surface geochemical data (Jones and Drozd, 1983).

It is very important to note that there are no halos that magically appear at the surface only over economic deposits. All reservoirs and source rocks have leakage anomalies that follow the most permeable pathways to the surface. The surface geochemical anomalies are direct, although not necessarily vertical. In addition, there is no relationship between the magnitudes of surface geochemical anomalies and the economics of the subsurface deposits that provide the subsurface sources for these surface geochemical anomalies. Mass balance for the source rock/reservoir systems suggest that less than 20% of the hydrocarbons generated are trapped within commercial fields. The remaining 80% greatly influences the near surface seepage. Regional seepage is obviously not confined only to commercial fields, but occurs over the entire basin. The regional trends and fairways are often well defined by near surface seepage and the compositional types, (oil versus gas) are easily defined.

Surface geochemical prospecting was demonstrated by early work conducted by Gulf Oil Company scientists. In these studies the value and usefulness of surface geochemical data was shown by mapping compositional changes (gas versus oil) that could be directly related to the compositional changes in subsurface reservoirs (Teplitz and Rodgers, 1935; Jones, 1979; Janezic, 1979; Mousseau and Williams, 1979; Weismann, 1980; Drozd, et al., 1981; Jones and Drozd, 1983; Richers, 1984; Price and Heatherington, 1984; Matthews, et al., 1984; Jones, et al., 1984; and Williams, et al., 1981). These geochemical relationships have been extended to numerous underground gas generation and storage reservoirs (Pirkle and Drozd, 1984; Jones and Thune, 1982; Jones, 1983; and Jones and Burtell, 1996).

Zones of Seismic Disturbance (ZOD's)

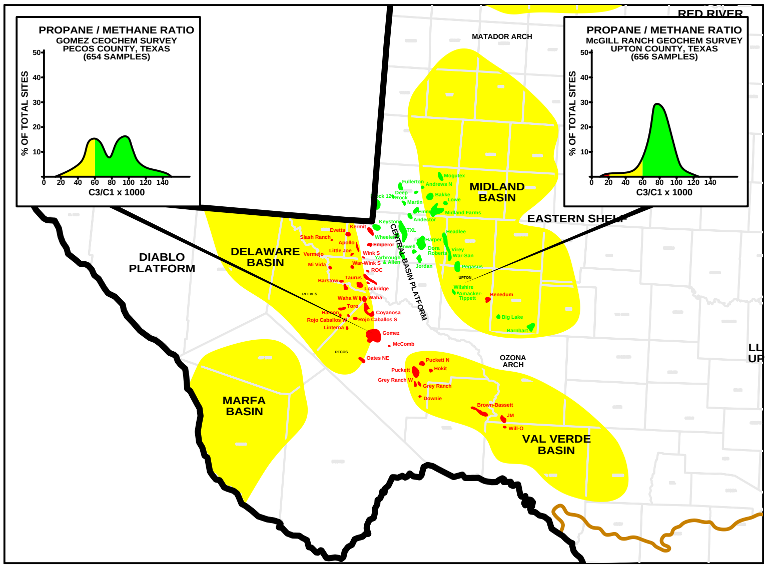


Figure 1. Gomez Deep Gas Field and Spraberry Oil Field, West Texas

In the late 1970's and early 1980's, Gulf Oil Company scientists noted that both magnitude and compositional changes in the near-surface hydrocarbon seepage appeared to be related to subsurface areas where high frequency attentuation was occurring in the seismic data. It was postulated that the seismic attentuations (termed ZOD's, that is zones of seismic disturbance) could be caused by gas in fractures, either within the reservoir zone or within some overlying fractured rock where the seismic reflections appeared to "wipe out" and disappear. Such features were first observed by Gulf Oil Company explorationists in offshore California, the North Sea and Indonesia. For example, the giant Hondo field in offshore California was noted to have no coherent seismic reflectors at all. The lack of reflectors suggested the possibility that vertical gas migration might be responsible. There were very large gas seeps observed within the California offshore in areas where seismic ZOD's were also known to occur (Mousseau and Williams, 1979). To test this concept, Gulf Oil Company conducted several very detailed seismic/geochemical studies to determine whether surface geochemistry could be used to confirm that some seismic wipeout zones (ZOD's) might be related to the presence of gas in fractures, either in the reservoir or from gas leakage into the overlying formations.

Limited information from three test areas are presented below. Two studies were conducted in West Texas over the Gomez deep gas field and the giant Spraberry Oil field. These two field areas show an excellent contrast. As shown by Figure 1, Spraberry lies within an area dominated by oil fields, while Gomez lies in an arcuate belt of producing fields that are dominated by gas; Gomez does have the complication of having both shallow oil and deep gas. In addition, Spraberry produces mainly oil from a fractured reservoir zone, which is over 5000 feet thick. Gomez, on the other hand, produces very large volumes of gas (500 to 700 MMcf) and condensate from a depth of 14,000 to 20,000 feet. Of particular importance for Gomez is the presence of a blanket oil sand at 3000 feet, which produces from the Yates (Queen City) Formation. This shallow Fort Stockton oil field (approximately 3000 feet) produces everywhere within the area tested by the seismic/geochemical survey. This combination of shallow oil and deep gas makes for a very interesting contrast, and tests the compositional soil gas concept previously published by Jones and Drozd (1983).

The third seismic/geochemical test area was the giant Whitney Canyon and Ryckman Creek oil and gas condensate fields, which lie within the Western Overthrust Belt in the Utah-Wyoming area of the United States. This area is dominated by gas and gas condensate fields. Figure 2 illustrates the fairly gassy C3/C1 ratios observed within this survey area, which lies along the strike of several major gas fields, such as Whitney Canyon and Ryckman Creek. A compositional contour map of these C3/C1 ratios are shown in Figure 2.

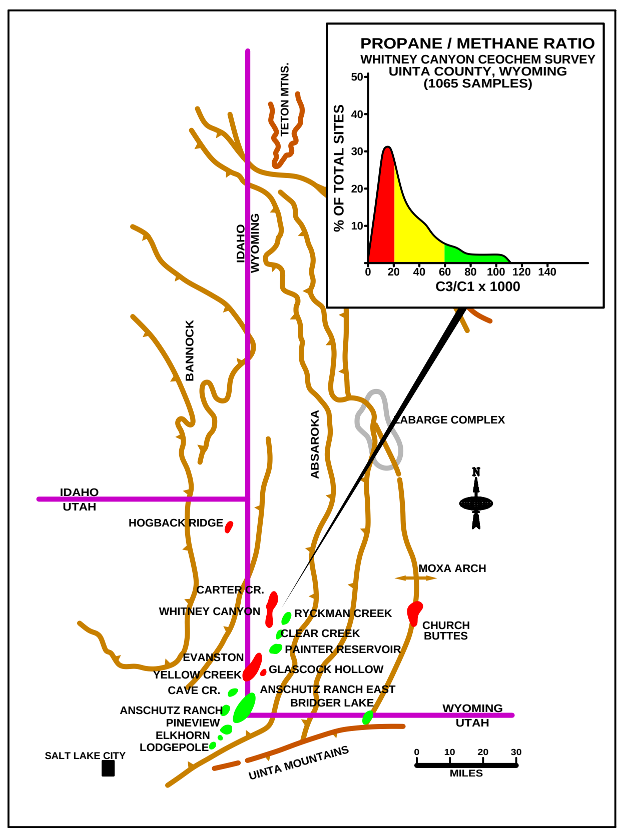
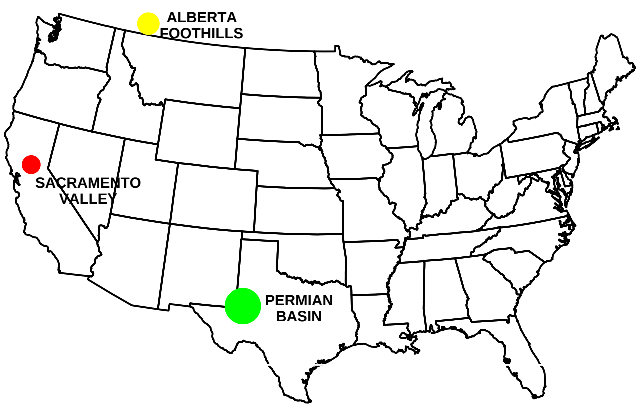


Figure 2. Whitney Canyon and Ryckman Creek, Wyoming

LOCATION OF GAS, OIL AND CONDENSATE SURVEYS



COMPOSITIONS OF TYPICAL C1 TO C4 RESERVOIR HYDROCARBONS

RESERVOIR HYDROCARBON	DRY GAS	HIGH-PRESSURE GAS	HIGH-PRESSURE OIL	LOW PRESSURE OIL
Methane	*0.91*	*0.81*	*0.77*	*0.37*
Ethane	*0.05*	*0.07*	*0.08*	*0.21*
Propane	*0.03*	*0.07*	*0.08*	*0.21*
Butanes	*0.01*	*0.05*	*0.07*	*0.21*

****In mole fractions. After Katz and Williams (1952)***

TYPICAL HISTOGRAMS OF DRY GAS AND OIL SURVEY DATA

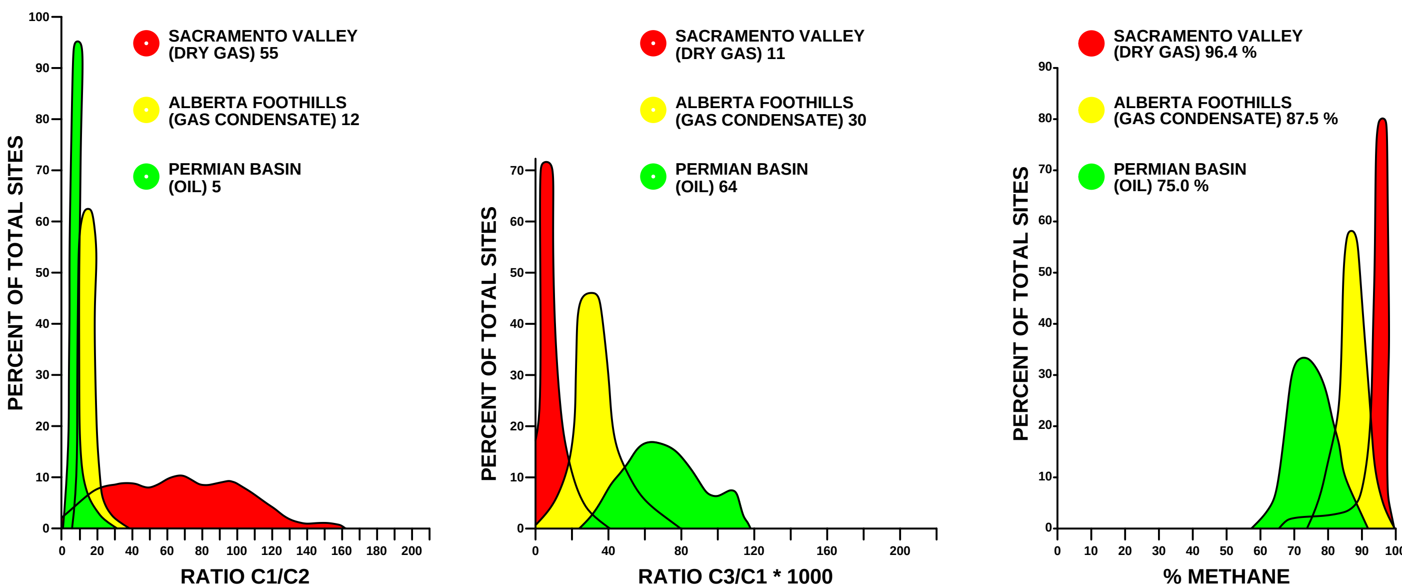


Figure 3a. Predictions of Oil or Gas Potential by Near Surface Geochemistry

Previous experience gathered by Jones and Drozd (1983) established several compositional ratios that selectively discriminated between different oil versus gas reservoirs. One of the ratios, the C3/C1 times 1000 (see Figures 3a and 3b), which was found to be particularly useful for distinguishing between oil and gas source areas, will be employed for evaluating these three seismic-geochemical test areas. The previous soil gas sampling conducted by Jones and Drozd (1983) consisted of low density regional grids (1/4 to 1/2 mile centers) over existing fields and petroleum source areas of a common oil or gas composition.

These three seismic/geochemical survey areas also allowed for a much more expansive test of the compositional coherence of the geochemical soil gas data. In all three test cases, the geochemical data for these seismic/geochemical surveys were collected on 110 foot centers (30.5 meters) along several close spaced seismic lines located directly over known producing fields. This consisted of a very high density soil gas grid, with as many as 650 to 1000 samples collected within an area of only about 6 to 10 square miles. In all three seismic/geochemical test cases, all samples were collected within the field boundaries, so that the focus was on seeing the internal reservoirs within the fields rather than detecting the field area relative to background (areas outside the fields).

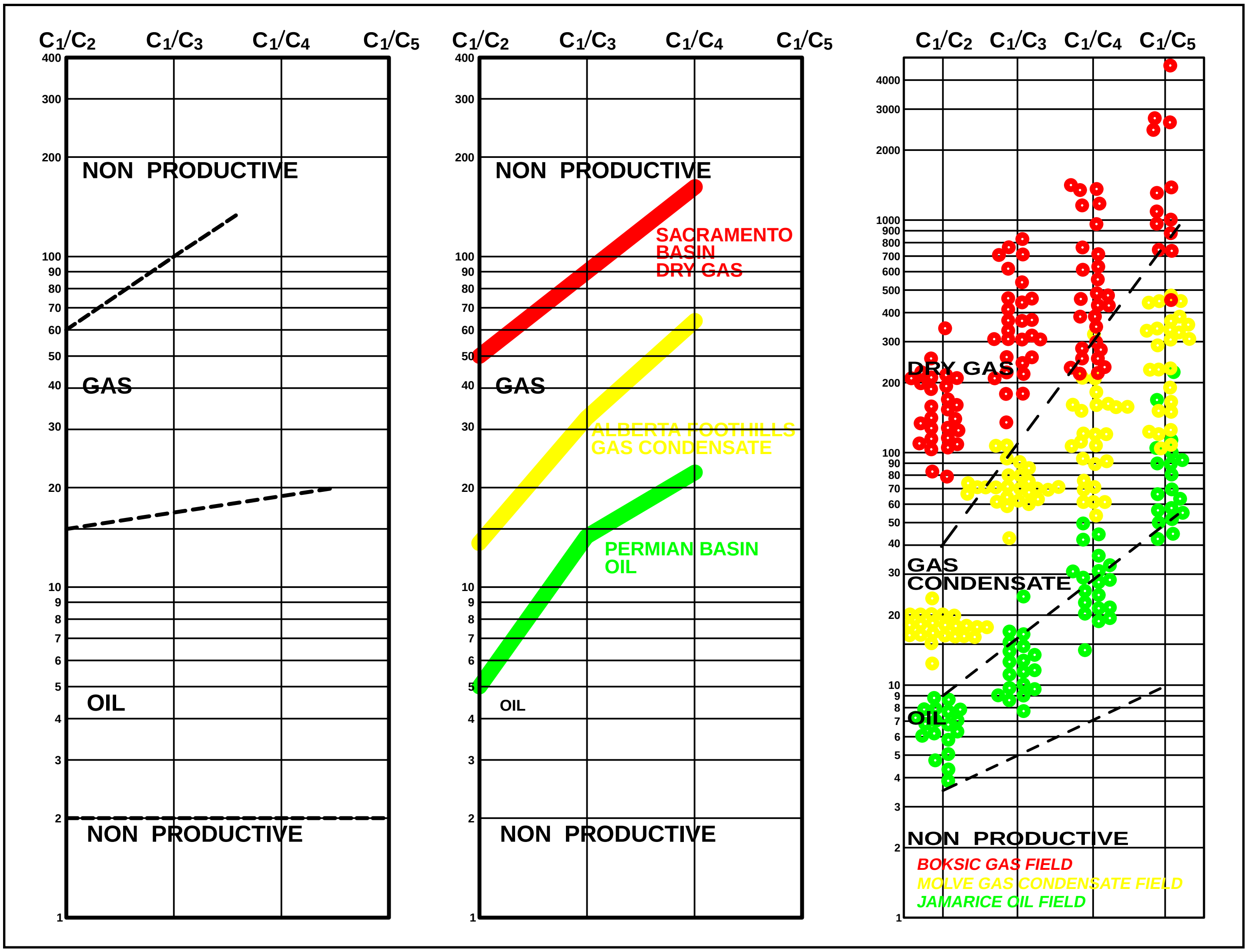


Figure 3b. Pixler Ratio Plots

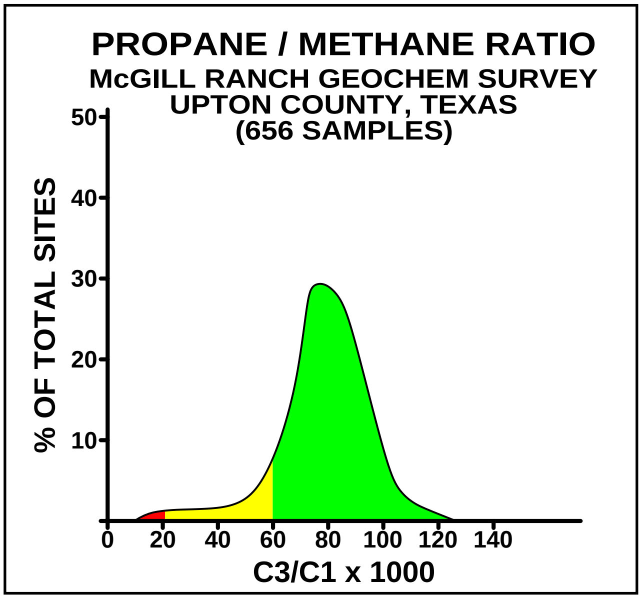


Figure 4. C3/C1 Histogram - McGill Ranch

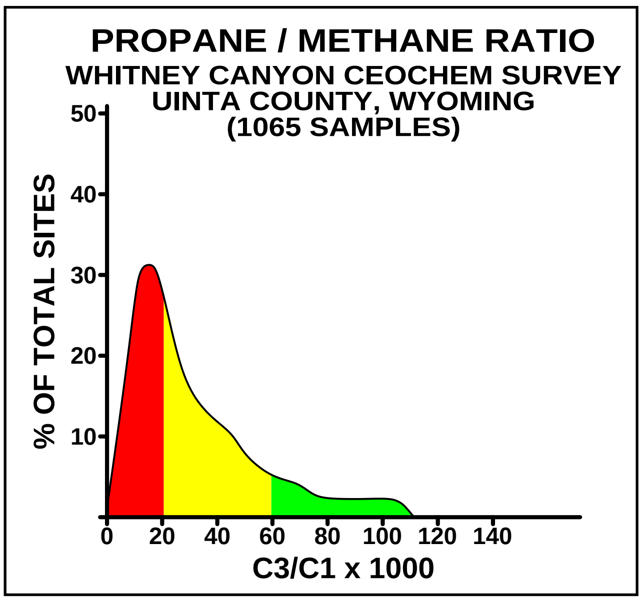


Figure 5. C3/C1 Histogram - Whitney Canyon

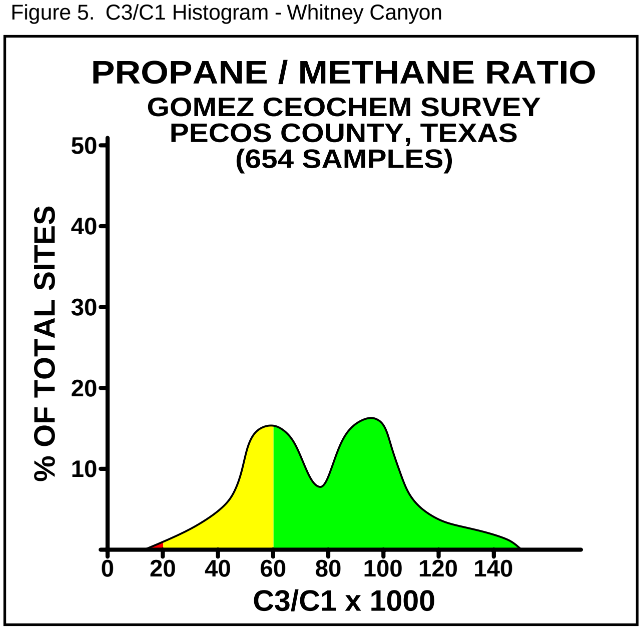


Figure 6. C3/C1 Histogram - Gomez Deep Gas Field

Histograms of the C3/C1 times 1000 ratio for each of these three test areas are shown in Figures 4 through 6. The Spraberry histogram is remarkably uni-modal, as expected, for a close spaced grid within the Permian Basin that is dominated by oil fields and lies directly over the largest oil field in the basin. In contrast, the survey grid within the Western Overthrust Belt is obviously dominated by gas, but does have an "oily tail". As shown by Figure 7, these oilier samples are nearly all located over and up-dip of the giant Ryckman Creek gas condensate field. A secondary group of slightly oilier samples occurs over and up-dip of the giant Whitney Canyon field. Otherwise, the data is very gassy, within this regional gas belt that extends along the strike of the overthrust belt.

The Gomez/Fort Stockton field area, however, provides a very striking example. As expected, this area of mixed production (shallow oil underlain by deep gas) shows an intermediate, mixed signature, which is obviously dominated by the shallow oil field. Typical (C3/C1 x 1000) ratio boundaries previously established by Jones and Drozd (1983) for discriminating between different oil and gas sources on regional survey grids had suggested break points of 10, 20 and 60 for gas, gas and oil, and oil deposits, respectively. These propane to methane ratio break points are shown on Figures 4, 5 and 6 as red, yellow and green areas for comparison between these seismic/geochemical test areas, and with previous regional studies. These considerably more detailed studies, completed over the three test areas provided exactly what was predicted by the previous regional surveys. However, more importantly, these very close-spaced detailed grids showed that in areas of mixed production, the seeps would be mixed, and probably dominated by the shallowest production. The question then, is whether the C3/C1 ratio is also sensing the deep gas reservoir through the shallow blanket oil sand.

In order to answer this question the magnitude and compositional information was calculated, posted and contoured along all seven of the seismic lines for the Gomez data set. Profiles were also constructed to scale along each of the seismic lines, one of which is shown in Figure 8. Contours of the Initial Production (IP's) for the deep gas condensate wells are shown on Figure 9, along with contours for the C3/C1 ratios for the soil gas data collected at 110 foot centers along each seismic line. Although the typical empirical compositional cuts derived from regional geochemical data do not work for this Gomez data set, there is an obvious bi-modal distribution shown by the C3/C1 ratio, and an inflection break in the curve that forms a tail below a ratio of 40. Color contours for this mixed soil gas data were therefore, chosen at 40 for gas and 80 for oil, based on this histogram. Thus, when the gassier, intermediate and oilier areas are colored red, yellow and green on Figure 9 using these altered cuts for the C3/C1 times 1000 ratio, and then compared with the locations of the deep gas wells, there is an obvious correlation. The gassier geochemical data is clearly located directly over the high volume, deep gas production.

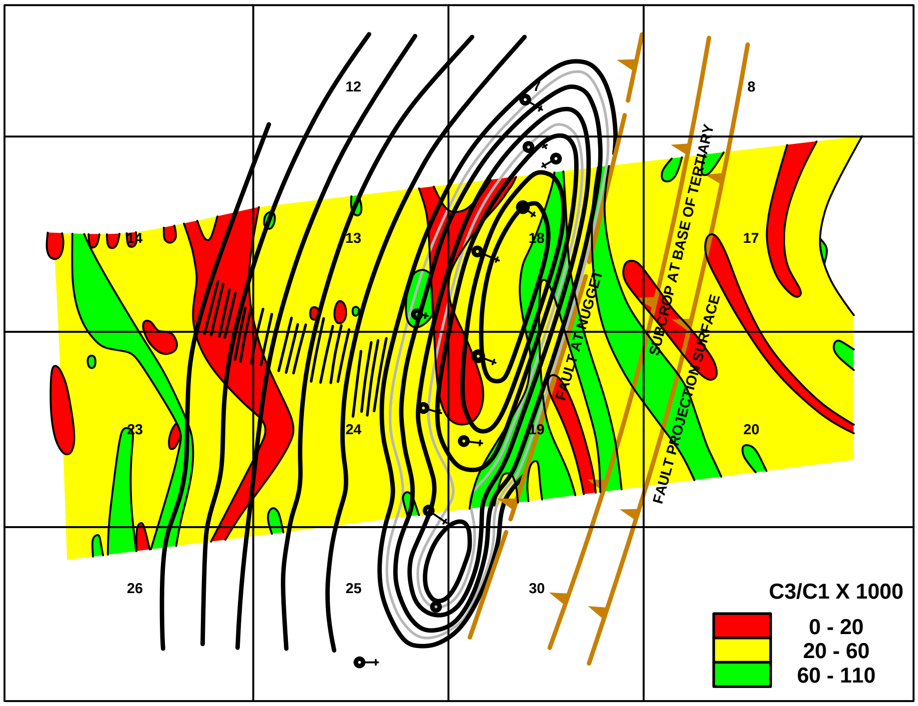


Figure 7. Ryckman Creek Condensate Field

The Wolfcamp field research area was originally selected because of the previous observation of seismic wipeout zones (ZOD's) at a depth of 8000' in the Wolfcamp Formation. When Gulf initially drilled deep gas wells, when they had to flare gas, while drilling through the Wolfcamp, they encountered a very high potential gas well at depth. Therefore, it was expected that the seismic data would exhibit ZOD's in the Wolfcamp (from gas charging of the fractures from depth). This was found to be true for all seismic lines gathered directly over the high volume, deep gas producers. More importantly, the soil gas data was also found to be gassier over these Wolfcamp wipeout zones, correlating directly with the seismic data.

Thus, these two independent tools could be used in concert to locate (correlated) seismic and geochemical anomalies. This is very significant since geochemistry provides a very inexpensive lead generation tool that can be used to reduce the areal extent to be surveyed the much more expensive seismic program. Seismic can then be used to confirm the geochemical anomalies, thus explaining the nature of the geochemical anomalies. The seismic can also be used to image the ZOD's and then provide depth information for drilling.

Although, no difference in composition was noted within the very high density grid conducted over the Spraberry oil field (654 samples collected over only a six square mile area), a different and equally important seismic/geochemical correlation was noted. The Spraberry area was selected because the field is so large that the seismic/geochemistry test area definitely fell within the field. In addition, it was selected because the field produces from fractures that occupy a 5000 foot thick reservoir zone. Four, two mile long seismic lines were laid out over this field in a sub-area called McGill Ranch. Two of the seismic lines were parallel to the fracture directions and two were perpendicular to the fractures. It was assumed that lines parallel to the fractures would exhibit ZOD's because of the presence of hydrocarbons in the fractures, while the perpendicular lines would not show ZOD's. This assumption was correct. The high frequency seismic attentuation from one of the parallel lines is shown in Figure 10, along with the C1-C4 hydrocarbon magnitudes collected along the seismic line. Again, the geochemical data was collected at very close spacing (110 foot centers (30 meters)) along all four of the seismic lines. Soil gas samples have been collected every 110 feet (30.5 meters) for over two miles. There is nearly one mile without either seismic attentuation or geochemical anomalies, and then one mile where both occur in abundance, and in concert. The only conclusion to be reached is that this anomalous portion of this seismic line must lie directly over the fractured reservoir, confirming our proposed model. This conclusion is supported by the fact that the seismic attentuation can be calculated using a floating vertical window that can be adjusted to various depths, either above, below or within the reservoir zone. This calculation for this specific case indicated that the seismic attentuation was occurring within the 5000 foot reservoir zone.

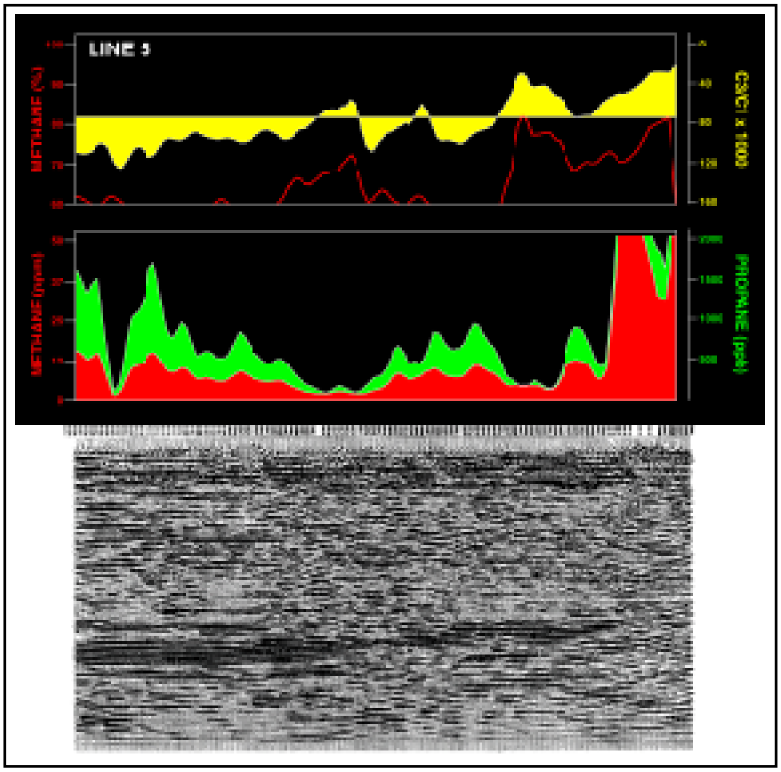


Figure 8. Gomez Line 5 Profile

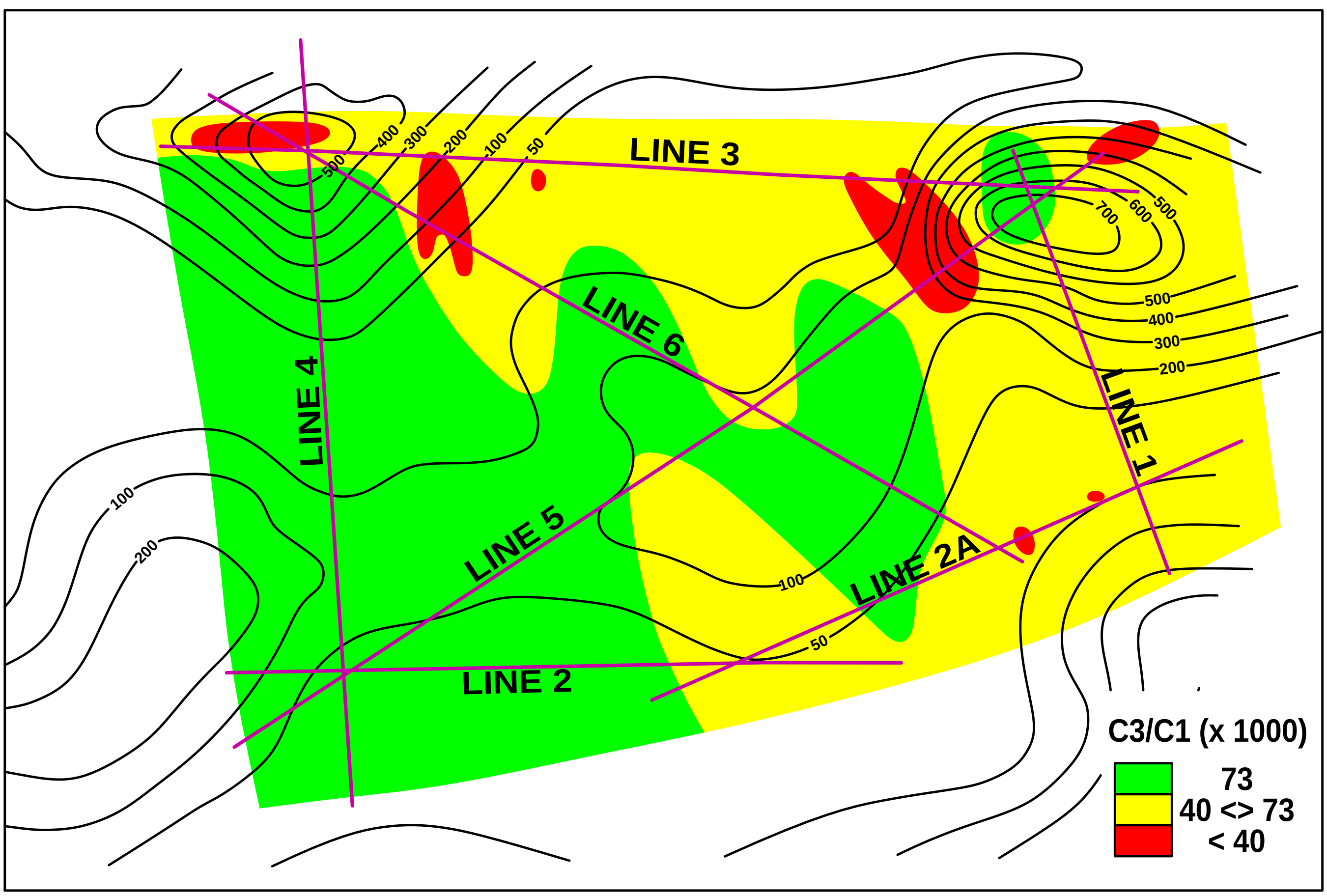


Figure 9. Production Contours for Deep Gas Condensate Wells, Gomez Deep Gas Field

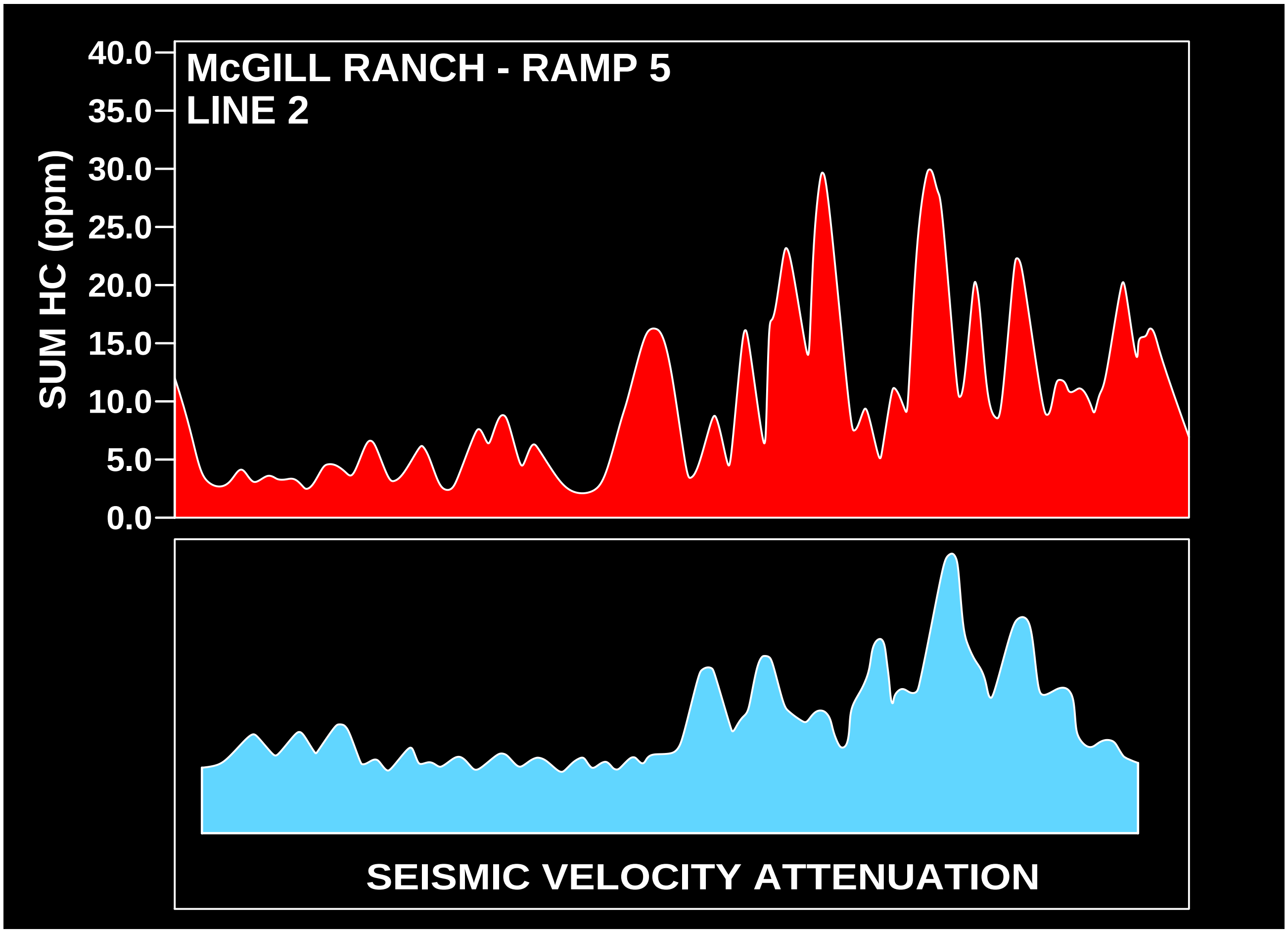


Figure 10. High Frequency Seismic Attenuation