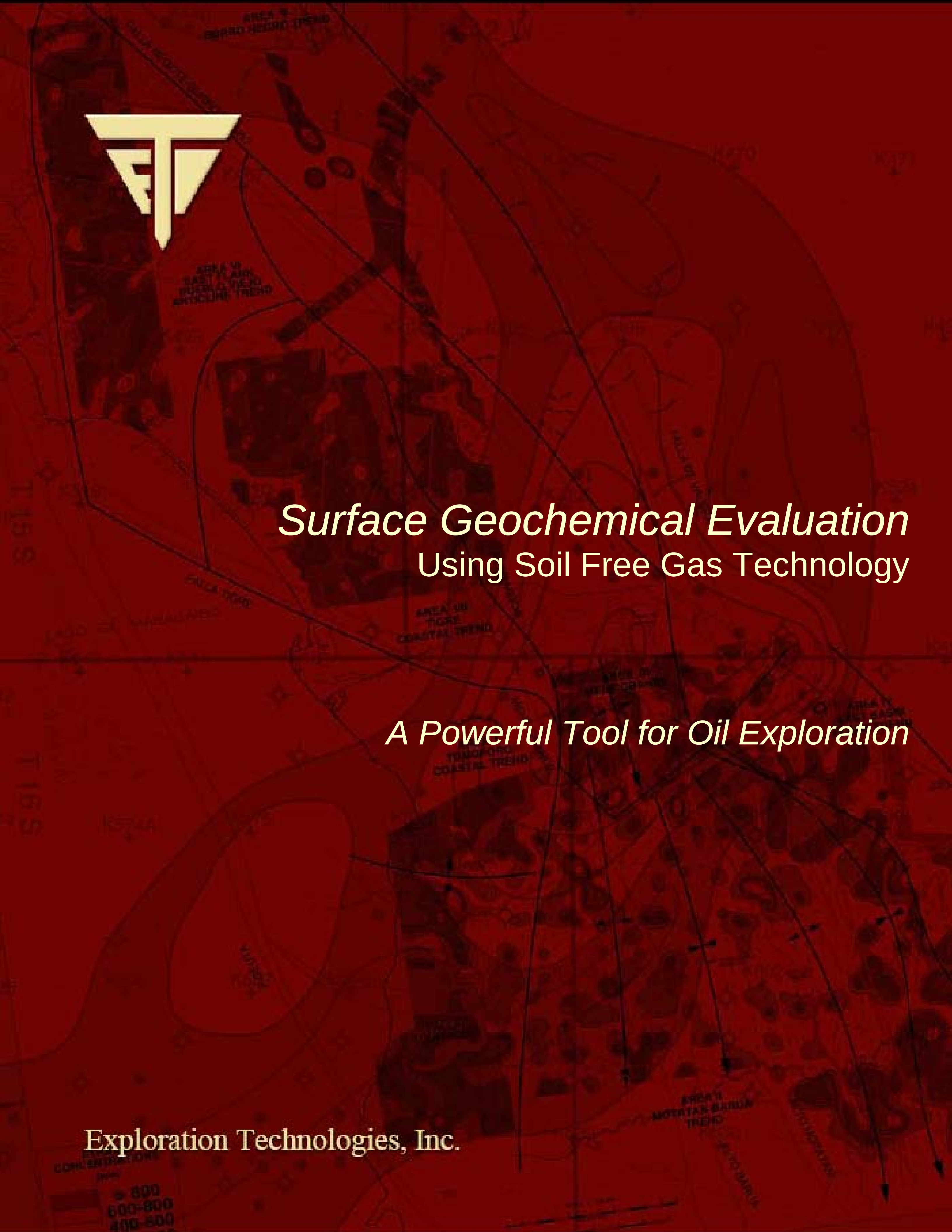
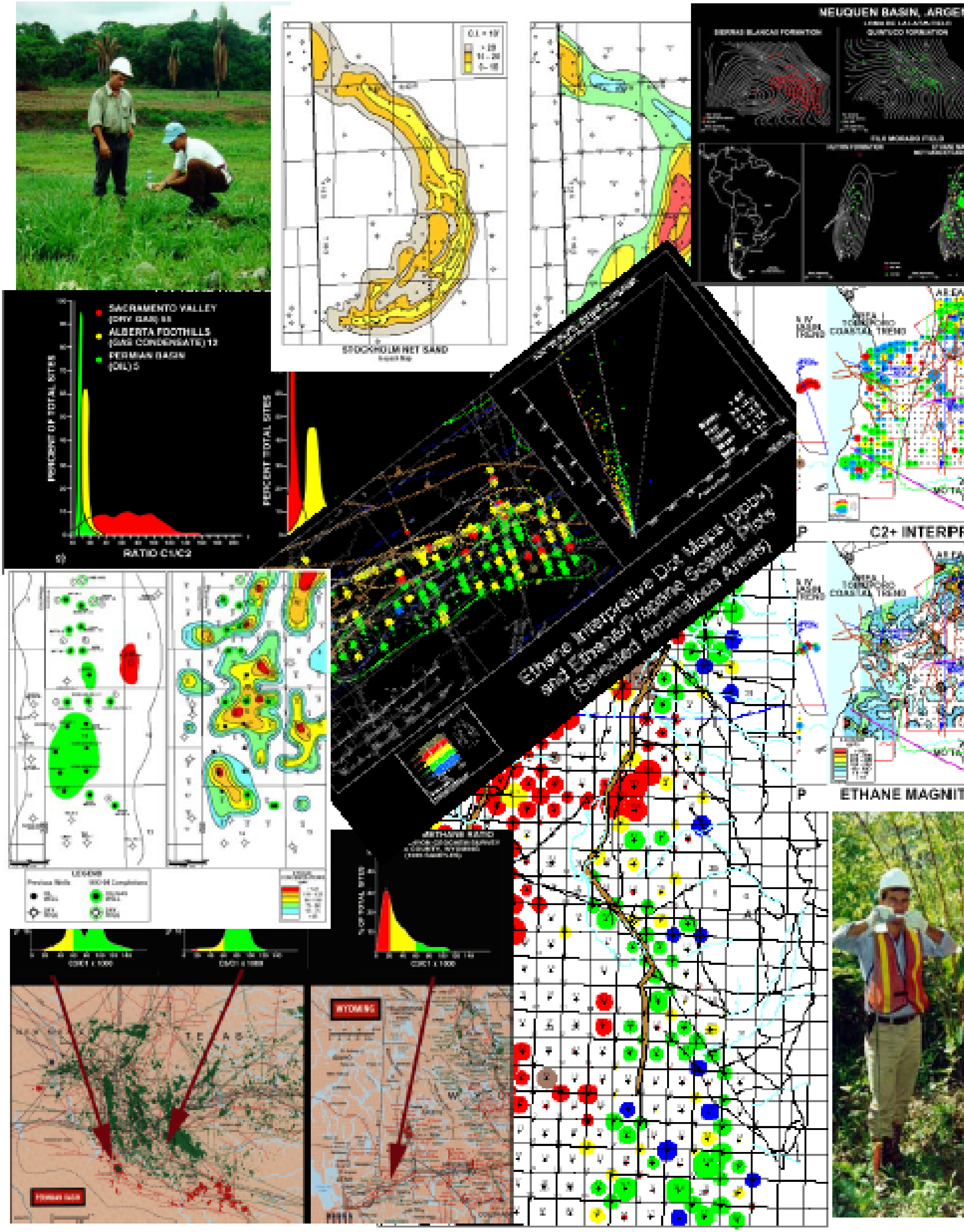


Surface Geochemical Evaluation

Using Soil Free Gas Technology

A Powerful Tool for Oil Exploration

Exploration Technologies, Inc.


NEUQUEN BASIN, ARGEN
SIERRAS BLANCAS FORMATION
QUINTUCO FORMATION
SACRAMENTO VALLEY (DRY GAS) 55
ALBERTA FOOTHILLS (GAS CONDENSATE) 13
PERMIAN BASIN (OIL) 5
PERCENT OF TOTAL SITES
RATIO C1/C2
STOCKHOLM NET SAND
PERCENT TOTAL SITES
Ethane Interpretive Dot Maps (ppbv) and Ethane/Propane Scatter Plots (Selected Anomalous Areas)
COASTAL TREND
C2+ INTERPR
ETHANE MAGNIT
LEGEND
C2/C1 x 1000
TEXAS
WYOMING
PERMIAN BASIN

CONTENT

1- INTRODUCTION

Present day exploration for oil and gas requires a coordinated effort based on the successful integration of geophysics, geology, and geochemistry. Surface geochemical prospecting offers the explorationist a portable, cost effective tool to reduce exploration risk. Specifically, the analysis of light hydrocarbons in soil vapor 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; and
- extend existing productive trends.

The relationship of macroseeps to reservoirs was well established by Link (1952), who stated:

> "A look at the exploration history of the important oil areas of the world proves conclusively that oil and gas seeps gave the first clues to most oil producing regions. Many great oil fields are the direct result of seepage drilling."

Few would argue that the presence of a "macroseep" indicates the presence of petroleum migration or surface source beds. Microseeps, or smaller scale macroseeps, also occur and are usually detectable only by sensitive instruments. These microseeps, although perhaps not as obvious or dramatic as macroseeps, are just as valid for the exploration of undiscovered reserves.

Exploration Technologies, Inc. (ETI) has developed collection techniques and instruments capable of obtaining and analyzing this hydrocarbon signal. The stratigraphic and structural mapping of geological and seismic data, coupled with the measurement of microseeps in the shallow subsurface, provide powerful means of evaluating and ranking prospective trends and traps.

The fundamental assumption of near-surface, geochemical exploration is that thermogenic hydrocarbons, generated and trapped at depth, leak in varying quantities towards the earth's surface in detectable amounts. The close association of near-surface geochemical anomalies to faults and fractures is well known. These fractures act as preferential pathways, focusing the flow of hydrocarbons from the source beds to the reservoir, and from there on towards the surface. Anomalous hydrocarbon concentrations are always real seeps, since active flux is necessary to overcome near surface interfering effects.

The most useful detection technique involves the measurement of the light hydrocarbons: methane, ethane, propane, iso-butane and n-butane. Because of their volatility, these light hydrocarbons are generally found in the free pore space, either in the vaporous or dissolved (in water) state. Worldwide survey results onshore environments have shown that the ratios of these light hydrocarbon components correlate with source maturity and the type of production (oil, gas, or condensate) in a region. Consequently, based on compositions, the technique can be used as a source rock tool applied at the surface.

Near-surface soil gas geochemical investigations require the analysis of free soil gases collected through a probe that is inserted into the ground. Probe sampling can be used in a variety of geologic terrains. The mobility of the soil gas probe sampling opens up large areas to geochemical exploration that are otherwise difficult to sample. Probe sampling is particularly worthy because of the low sampling cost and ease of access in rugged, roadless areas. With this method, small crews of only two persons can obtain large numbers of samples at minimal expense. Public and private landowners are agreeable to probe sampling because there is no surface damage from sample collection. This technique has been used successfully all over the world.

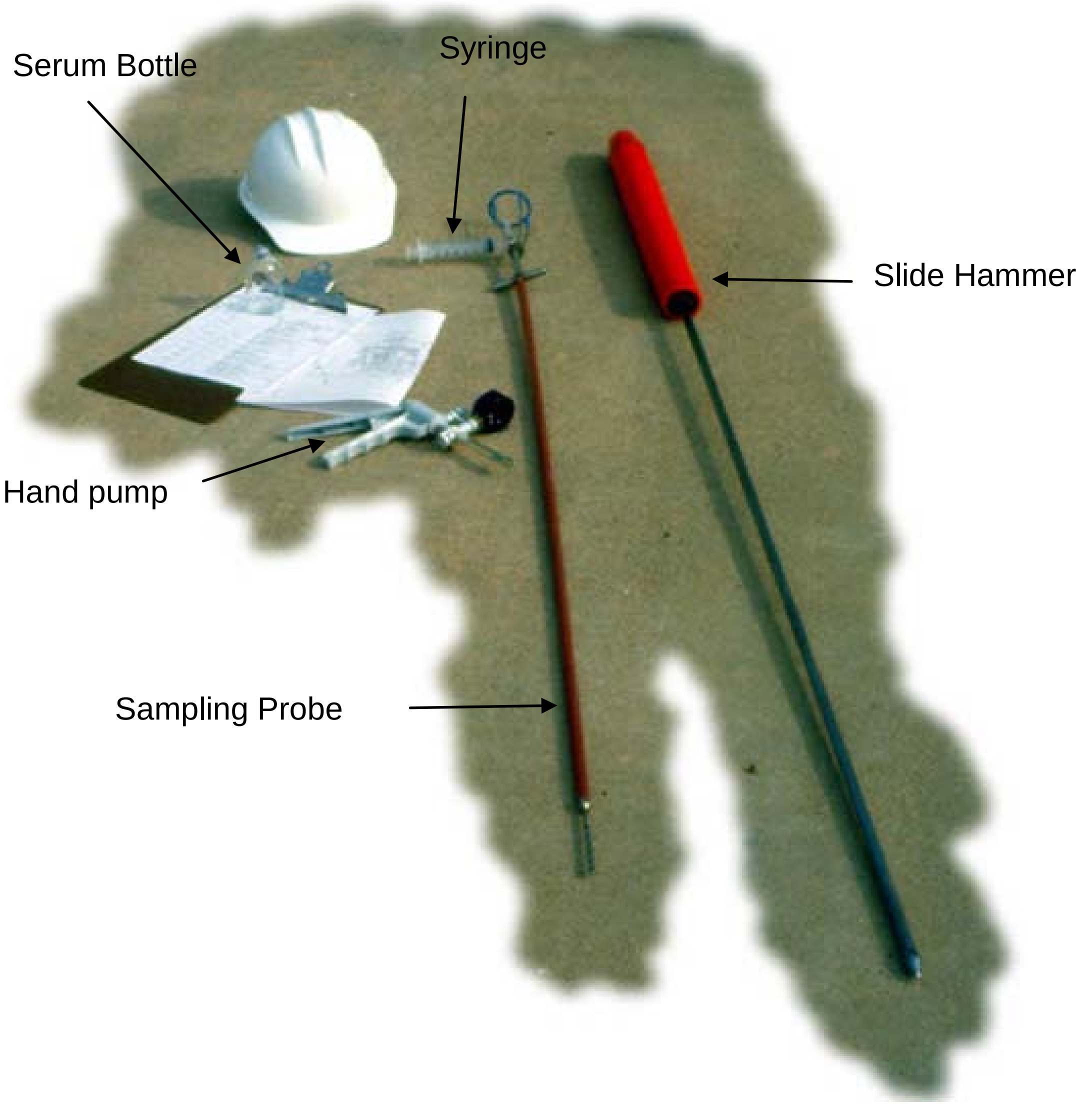
ETI has extensive experience in applying surface geochemical prospecting techniques with seismic surveys. Because of the cost of permitting and surveying, we strongly recommend the measurement of light hydrocarbons along the seismic lines as a way of increasing the exploration information available.

Coupled with more expensive geophysical tools, such as 2D and 3D seismic, surface geochemistry can provide impressive amounts of highly valuable information regarding the oil vs. gas potential of the basin.

Exploration Technologies, Inc. offers state-of-the-art geochemical exploration technology and is the most experienced surface geochemical service company in the world. ETI has collected and analyzed over 150,000 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, Paraguay, Panama, Peru and Honduras. These previous studies are very important for establishing the usefulness of surface geochemical data.

2- SAMPLING EQUIPMENT

Exploration Technologies utilizes our proprietary four-foot manual probe sampling system to collect soil gas samples over the areas of interest selected by the Company.



Each soil gas sample is collected by driving a 1/2 inch diameter 4 foot long slide hammer plunger bar into the soil, and replacing the hammer with an ETI soil gas sampling probe. An evacuated 120 cc serum bottle is then attached to the probe and allowed to draw the soil gas into the bottle. The septum used for these bottles was selected for their lack of emissions of the light C1-C4 hydrocarbons. Using these septa, ethane to butane hydrocarbons can be measured down to approximately 5 to 10 ppb.
All samples are treated using similar methodology to insure consistent results.

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3- THEORETICAL AND PRACTICAL FACTS.

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.

Structural and stratigraphic traps at depth, which originated as brine filled aquifers, eventually filled with petroleum that has been sequestered over substantial periods of geologic time, in some cases hundreds of millions of years. The presence of these stored petroleum reserves at depth were initially discovered by our ancestors from seeps of oil and gas that were found at the surface. These surface manifestations eventually led to the drilling of wells and the development of other more indirect means of exploration. Although all underground geologic traps leak to some extent, the presence of commercial reservoirs indicates that petroleum reservoirs are excellent containment vessels over very long time scales. Depletion has occurred mainly from drilling, suggesting that natural leakage rates are generally quite small by comparison with production, however, as will be discussed below, natural seepage rates can be surprisingly large. 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.

Evidence of reservoir leakage documented by Gulf Research and Development Company (GR&DC) scientists in the 1970's and 1980's over many domestic petroleum basins, numerous foreign fields and over offshore basins on continental shelves has resulted in the establishment of geochemical methods that can accurately and cost-effectively find and document the presence and location of reservoir related seepage (Jones, 1976, Drozd et al. 1981, Jones and Sidle, 1982, Jones and Thune, 1982, Jones and Burtell, 1983, Jones and Drozd, 1983,). Today, with the emphasis placed on geophysics, not everyone is aware of the importance of seeps and of the improvement and developments in monitoring technology and understanding that have occurred over the last 40 years (Jones, 1984, Jones and Bray, 1985, Jones et al., 1985, Jones and Burtell, 1985, Jones et al., 1986, Aldridge and Jones, 1987, Jones, 1987a, 1987b, 1987c, Jones et al., 1988, Jones, 1991, Jones and Burtell, 1994, Jones, 1994, Jones et al., 1996, Jones, 1997, Jones and Agostino, 1998, Jones and Burtell, 1998, Jones 1998, Jones and Agostino, 1999, Jones et al., 2000, Jones, 2000a, 2000b, Jones and Agostino, 2001, Jones and Agostino, 2002, Jones et al., 2002, Jones and LeBlanc, 2004 LeBlanc and Jones 2004a, 2004b and 2004c).

The observation of seeps, both macro and micro, is the oldest method of exploring for oil and gas, including the fact that the first oil well, the Drake well in Pennsylvania, was drilled on a macro-seep. Several well known explorationists have observed that a very significant fraction of the worlds reserves were discovered on the basis of seep observation, including all of the very large fields discovered as late as 1947 in the middle east (Link, 1952, Hunt, 1983).

A significant effort was undertaken to characterize petroleum seeps by Gulf Research and Development Company in the 1970's and 1980's (Jones, 1976, 1984, Mousseau et al, 1979, Weismann, 1980, Mousseau and Glezen, 1980), (Mousseau, 1981a, 1981b, 1983, Jones and Pirkle, 1981, Jones and Drozd, 1983). An important development from the Gulf program was the realization that seeps occur over all petroliferous basins, not only sequestered fluids from the reservoirs, but also fluids that were never sequestered, but migrated vertically from the source rocks at depth. Recently, Larry Cathes at Cornell and Jean Whelan at Woods Hole have suggested that only 1% of the hydrocarbons generated in source rocks may have been sequestered in commercial fields, with the remaining 99% in some state of vertical migration toward the surface. A News Note by Lisa M. Pinsker published in Geotimes (June, 2003) entitled “Raining Hydrocarbons in the Gulf” provides further details of their recent conclusions regarding seeps.

Although many methods have been proposed for mapping petroleum seeps, we have determined from our experience that the best and most reliable method is to measure the light C1-C4 hydrocarbons in the free soil gas, with particular emphasis on the ethane through butanes, since their only source is from thermogenic hydrocarbons at depth. These light hydrocarbons are contained in all reservoirs, including both oil & gas and gas condensate. These gases provide useful information about the reservoirs, whether measured within the reservoir, above the reservoir as part of the exploration process as mud logging components, or even as surface seepage. Extensive experience has demonstrated that valid soil gas measurements can be obtained by pounding a 4 foot hole in the ground, inserting a probe that is connected to a clean evacuated bottle and drawing gas into the bottle under vacuum.

The relationship between near-surface soil gases and deeper reservoir gases was well established by Jones and Drozd (1983) in an extensive soil gas exploration program carried out at the Gulf Oil Research center in the period between 1972 and 1983. They collected many soil gas data sets over many producing fields and over numerous basins throughout the world, Jones and Drozd (1983), Jones et al. (2000). This Gulf Research and Development Company geochemical exploration database was initially established using soil gases collected from 12 foot deep (4 meter) augered holes, and comprised more than 21,000 analyzes covering 16,000 line km (10,000 line miles).

A geochemical distinction between gas-type basins and oil-type basins was first noted from surveys conducted in the Sacramento and San Joaquin basins in California in 1972 and 1974. These compositional results from the first two surveys were confirmed by a third field season in 1975, proving the inherent source rock differences between the Sacramento and San Joaquin Basins was also reflected in the soil gas compositions measured at the surface. Additional surveys were then conducted in southwest Texas which supports the compositional differences noted in California. The results showed the percentage of methane (within the C1 – C4 hydrocarbons) not only reflected the gas versus oil differences within basins, but also indicated the soil gas compositions were repeatable, varied within the basins, yet were still in concert with the oil versus gas content of the individual oil and gas fields. This suggests gridded soil gas surveys could be used to define both regional changes in deep source rock maturity and local, reservoir scale changes in the oil versus gas content of the seepage with their associated reservoirs.

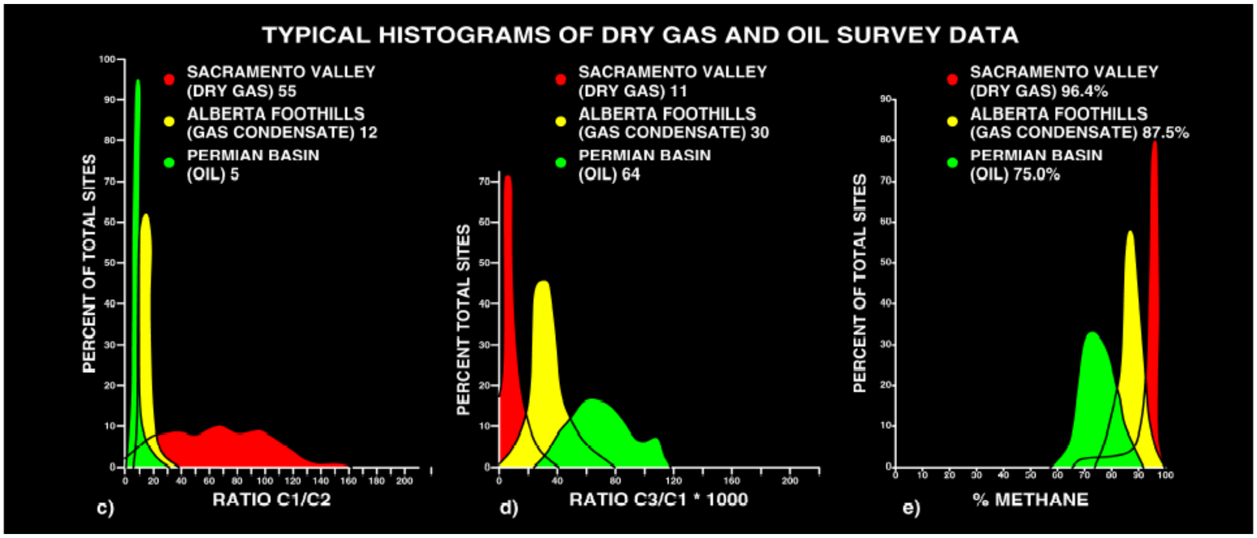
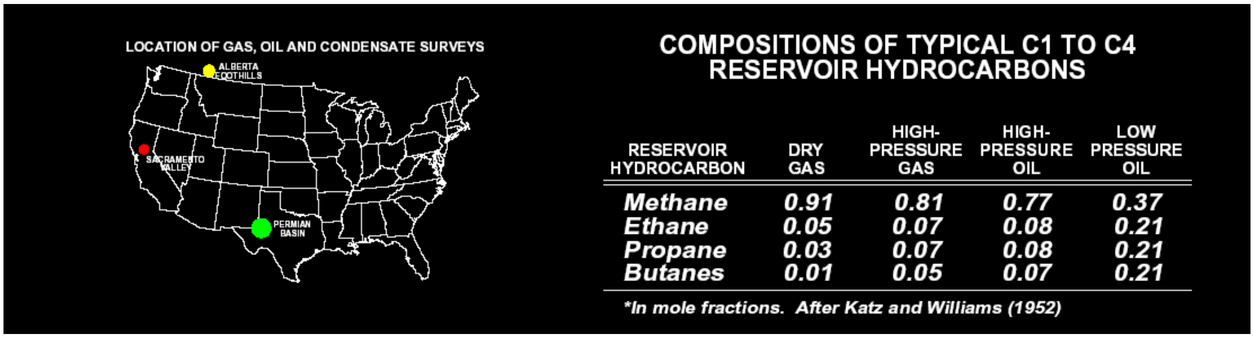


Figure 1

Example soil gas data sets confirming this ability for soil gases to predict the oil versus gas potential of the surveyed basins was published by Jones and Drozd (1983). Histograms of the percent methane, the methane/ethane and the propane/methane ratios shown in Figure 1, respectively, demonstrate statistically valid compositional differences can be provided by soil gas data collected over basins containing all three of the major production types: gas, gas-condensate and oil sources. The histograms in Figure-1 represent data collected within the Sacramento (dry-gas), Alberta (gas-condensate), and Permian (oil and gas) basins. The Sacramento produces only gas, while the Permian produces both oil and gas. Pincher Creek produces retrograde gas-condensate. A map showing the approximate locations of these soil gas surveys is included as Figure 2. Many additional surveys conducted by ETI over the past 30 years have indicated the geochemical compositions of soil gas seepages are repeatable.



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)**

Figure 2

Confirmation of this relationship is easily demonstrated by reservoir gas compositions in the Katz and Williams (1952) petroleum engineering textbook. As shown by Figure 2, the percentage of methane decreases in the trend from a dry-gas deposit to a typical low pressure under saturated oil deposit containing only dissolved gas but no gas cap.

Another independent verification of the relationship of light gases with reservoir type was published by Nikonov (1971), who compiled gas analysis data from 3,500 different reservoirs in the United States, Europe and the USSR. Nikonov grouped his data into sub-populations defined by the production within each basin. Gases from basins containing only dry gas (designated NG) contain less than 5% heavy homologs, whereas gases dissolved in oil pools (designated P) contain an average of 12.5% to 15% heavy homologs. Nikonov included methane and its homologs ethane, propane, butane and pentane in his data base. Histograms of the percent wetness (the inverse of percent methane above) and the methane/ethane ratio shown in Figures 3 demonstrate that the compositional changes in the light gases within the reservoirs are very similar to those associated with near-surface soil gases.

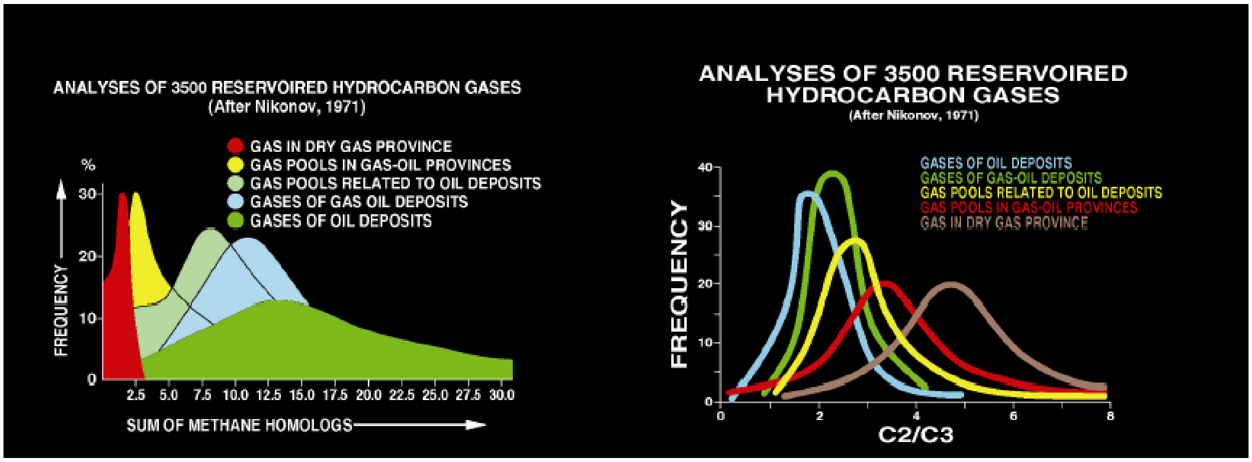
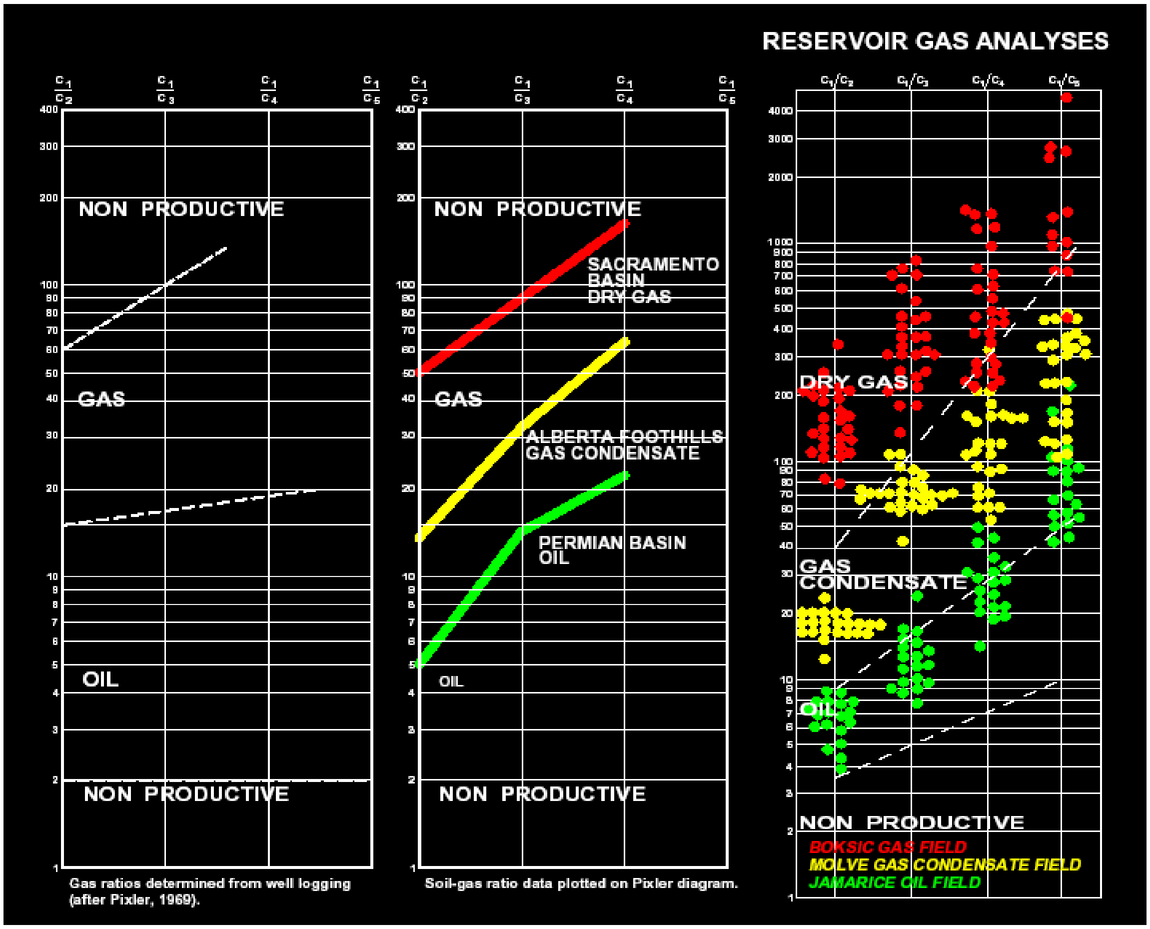


Figure 3

Additional, independent confirmation of these compositional relationships between light gas compositions and reservoir source types has also been published by the mud logging industry. Pixler (1969) found the C1-C5 hydrocarbon gases collected by steam-still reflux gas sampling during routine mud logging could distinguish the type of production associated with the hydrocarbon show. Pixler plotted the ratios of the C2-C5 light hydrocarbons with respect to methane, as shown in Figure 4. Ratios below approximately 2 or above 200 were suggested by Pixler to indicate the deposits were noncommercial. The upper range for these ratios for dry-gas deposits was enlarged by Verbanac and Dunia (1982), who measured the gas compositions from over 250 wells from 10 oil and gas fields. Their data, shown in under the title "Reservoir Gas Analysis" suggest upper limits for dry-gas reservoir ratios of: C1/C2 <350, C1/C3 <900, C1/C4 <1,500, C1/C5 <4,500. These ratios provide approximate boundaries for defining the transition between thermogenic and biogenic gases. Another empirical rule suggested by Pixler is the slope of the lines defined by these ratios must increase to the right; if they do not, the reservoir will be water-wet and therefore non-productive. Verbanac and Dunia (1982) suggested a negative slope connecting individual ratios may result from fractured reservoir zones of limited permeability.



Gas ratios determined from well logging (after Pixler, 1969).

Soil-gas ratio data plotted on Pixler diagram.

Figure 4

An evaluation of the soil gas survey compositions for the three basins described above with the mud logging data can be made by plotting the soil gas data on the Pixler-type diagram, as shown in Figure 4. This direct comparison of these soil gas ratios with mud logging and reservoir data is very striking, and clearly indicates deep source reservoir gases are the source material for surface soil gas seeps. It is important to note migrated gases almost always decrease in the following order: methane > ethane > propane > butane. Thus, in a Pixler-type diagram, soil gas data, like reservoir data, generally plot as line segments of positive slope for the soil gases to represent a typical migrated seep gas.

The histograms and Pixler plots of the soil gas data discussed above have focused mainly on the statistical parameters derived from the means, medians and ranges shown by the data. Another very striking comparison of these three soil gas data sets can be demonstrated by plotting all sample points on a ternary diagram, as shown by Figure-4k. Although there is some overlap of the data sets, it is striking how well they separate according to source type. All three of these surveys are large grids of four to six hundred samples covering several square miles. All three areas contain well-developed soils that are cultivated and would be expected to provide excellent conditions for the generation of biogenic methane.

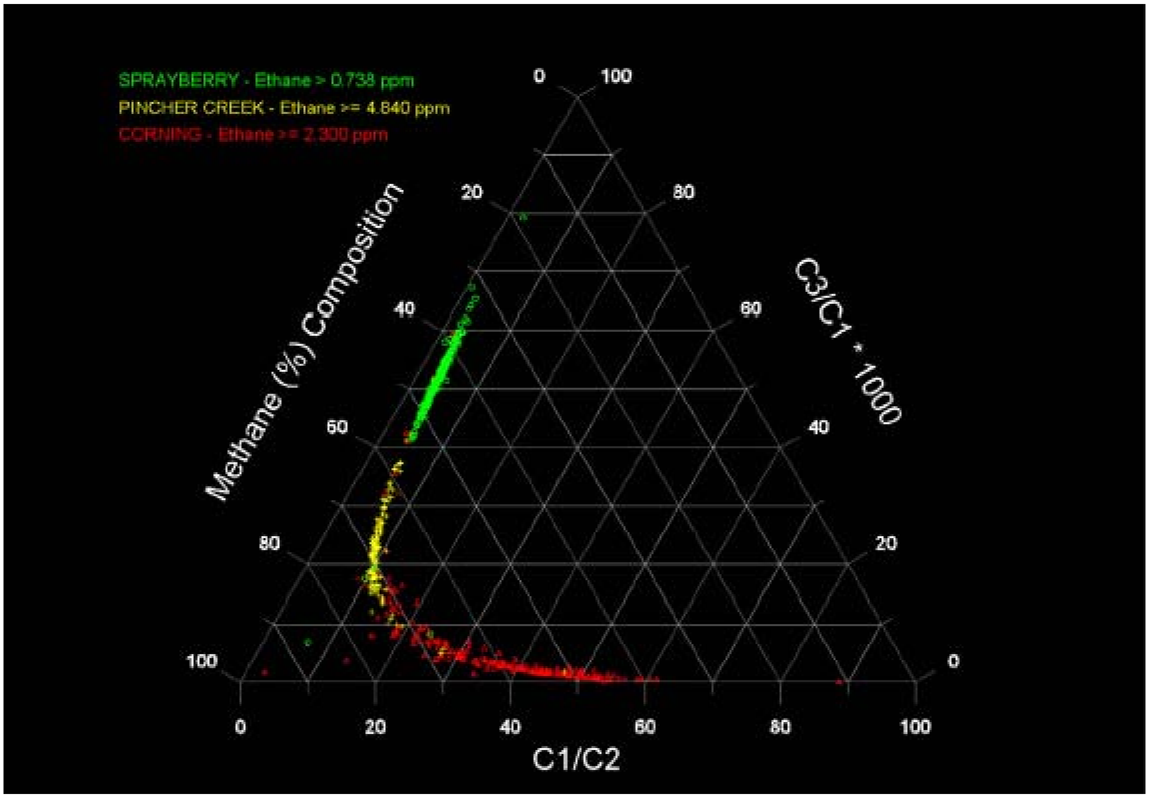


Figure 5

Figure 5 shows there is no sign of any influence from biogenic methane in any one of these data sets. Extensive experience in conducting soil gas surveys over the past 40 years has amplified this conclusion, and proven beyond any doubt the underlying source rocks are the primary source for the light hydrocarbons found in the vadose zone. The most significant aspect of this exploration geochemical research program carried out initially at Gulf Research, and later at ETI is soil gas compositional data can not only be related to the compositions of the known fields surveyed, but is also capable of predicting the oil versus gas potential of an unknown frontier area before drilling. With the exception of environmental contamination, which is always limited in aerial extent, there is less than 2 ppb of ethane plus gases in the atmosphere, and there are no ethane plus hydrocarbons generated via biogenic sources. Thus, essentially all of the ethane plus hydrocarbons have to be sourced from subsurface sources. Although deeper sampling generally provides superior compositional data, later field data gathered, over the past 30 years, by ETI has proven the shallow four foot deep soil gas probe can provide adequate results at a much lower cost than deeper more expensive samples, such as the 12 foot deep augered boreholes initially used by Gulf Oil.

The use of hydrocarbon compositions in soil gas prospecting requires gathering adequate data to allow statistically valid and separate populations to be defined, so a particular geochemical anomaly can be related to a geologic or geophysical objective or province. A percentage composition based on only two or three sites having 85% or 95% methane is not sufficient to define a population. As shown by these illustrations, considerable overlap exists among the intermediate gas-condensate and oil-type and gas-type deposits.

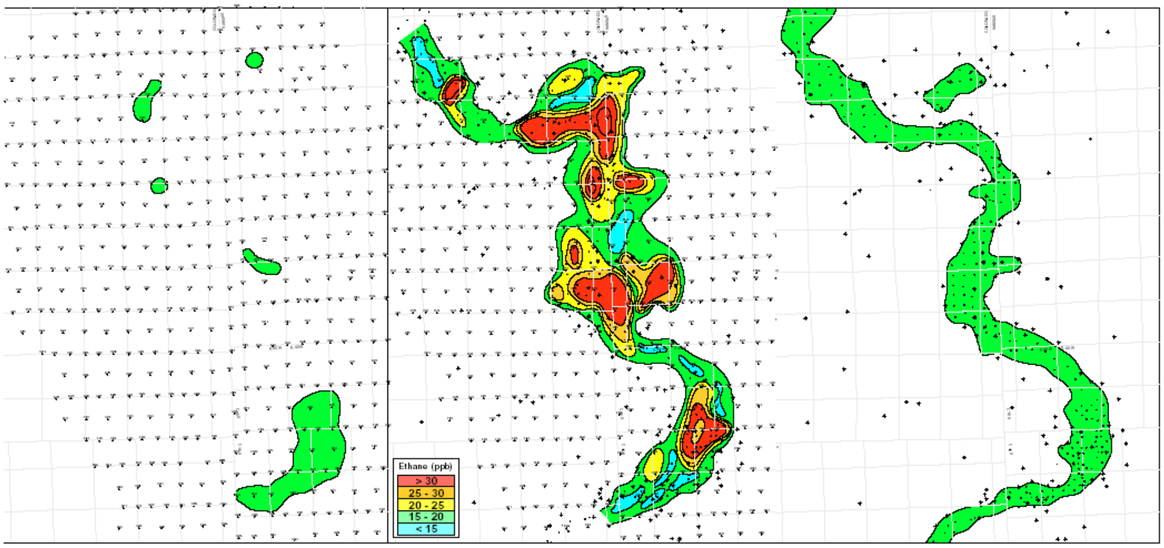
In basins having mixed production, prediction of a reservoir gas-to-oil ratio (GOR) is probably not possible. However, in spite of this limitation, the presence of well-defined, clustered anomalies, having more than 5% ethane plus is a clear and definite indicator of the presence of natural gas liquids.

4- CASES STUDIES

4-1. Stockholm Field, Kansas, USA.

A reconnaissance soil gas survey was conducted on the Kansas-Colorado border in November 1987 over an area of 150 square miles as shown in the center section of Figure 1. Plotted are soil gas ethane magnitudes which were found in the range of 10 – 30 ppbv.

The Stateline Complex is on the northeast flank of the northeast plunging Las Animas Arch, which separates the Denver Basin to the northwest from the Hugoton Embayment to the southeast. Production is from stratigraphic traps at depths ranging from 5000 to 5500 feet in the Lower Pennsylvanian Johannes and Stockholm members of the Morrow Formation. In 1979, Texaco drilled the discovery well for the SW Stockholm Field (and the Stateline Trend) at the location shown on left portion of Figure 1. At this time, there were only four fields in the immediate area. These four fields were discovered as a result of various exploration plays on low-relief structures. By the end of 1986, the SW Stockholm Field had been developed to the extent shown on the left portion of Figure 1. The field contained 53 wells and extended for four miles.



A. Stateline Complex Development
January 1987

B. Soil Gas Survey Conducted - November 1987
Ethane Magnitude Contour Map

C. Stateline Complex Development
August 1990

Figura 1

During 1987 there were three significant developments in the area. These three wells, along with the wells of SW Stockholm Field had, in general terms, defined a Morrow sand oil fairway for a distance of 10 miles in a northsouth direction (see left portion of Figure 1). Based on these discoveries, a decision was made to conduct a reconnaissance surface soil gas survey in the area (November 1987). Subsequent exploration and development drilling has delineated a complex of nine Morrow Sand fields over 25 miles long (see right portion of Figure 1) consisting of over 270 wells which have a cumulative production of over 12 MMBO. It can be clearly seen that as early as 1987, the soil gas survey had accurately defined the general areal extent of the productive Morrow incised valley as would be confirmed by development drilling three years later in 1990 (see central and right portion of Figure 1). A detailed discussion of this example is available (Dickinson et al., 1994, Jones and LeBlanc, 2004, LeBlanc and Jones 2004a and 2004b).

Figure 2 shows a detailed of the SW Stockholm field located at the south portion of the Stateline Trend. The right and left portions of the figure represent the ethane concentration contour map from soil gas samples collected at a depth of 4 foot and the net sand isopach map of the field respectively. It can be observed the perfect correlation between the reservoir boundaries and the superficial expression of the ethane map. The oil field is located in a geological stable area and the absence of structural deformations explains the low concentrations encountered at the surface

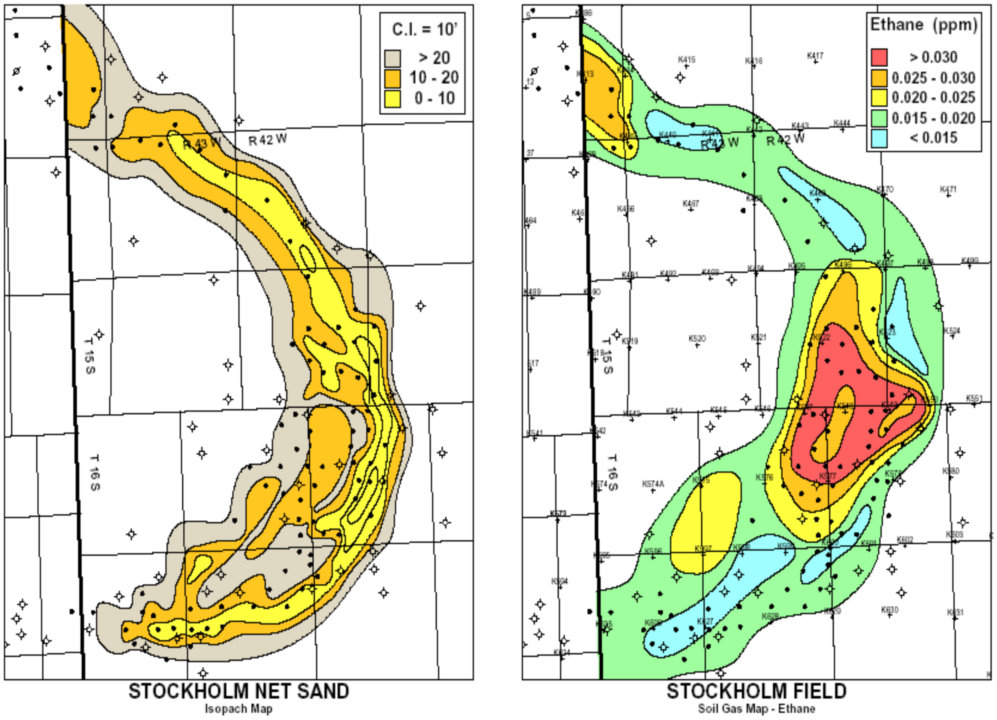


Figura 2

As this example shows, migration conduits need not generate large near surface anomalies in order to be detectable, and even more important, they demonstrate one of the most important conclusions concerning surface prospecting methods, which is that there is no relationship between the magnitudes of seeps and the volume of fluid contained in the associated subsurface reservoir.

4-2. Barua-Motatan Study Area, Venezuela

A surface geochemical survey, consisting of 939 soil gas samples, has been conducted over the Barua - Motatan study area of the Zulia and Trujillo states on the east coast of Lake Maracaibo, Venezuela (Figure 1). The field area is located on the east central flank of the Maracaibo basin in the area of the Barua and Motatan oil fields, which lie south and southwest, respectively, of the Mene Grande field. Mene Grande, Motatan, Barua, and Tomoporo fields account for approximately 1,488 MMB of recoverable oil reserves.

Although magnitudes of the microseepages are strongly influenced by subsurface pressure and migration pathway permeability, the compositions of the light hydrocarbon gases change mainly in response to regional source changes. These changes in compositional signatures appear to be governed by the primary and/or secondary oil migration pathways which have controlled the generation of the reservoired oil in the basin. This influence is clearly demonstrated by the presence of the Barua - Motatan fields, where heavier oils overlie lighter oils and actually provide a seal for the deeper, more volatile oils and condensates. The lack of reservoir pressure in the shallower oil reservoirs, coupled with the absence of lighter gases (methane and ethane with respect to propane and butanes) has directly affected the surface seepage, both in magnitude and composition, resulting in abnormal, very oily ratios for the light gases associated with these fields.

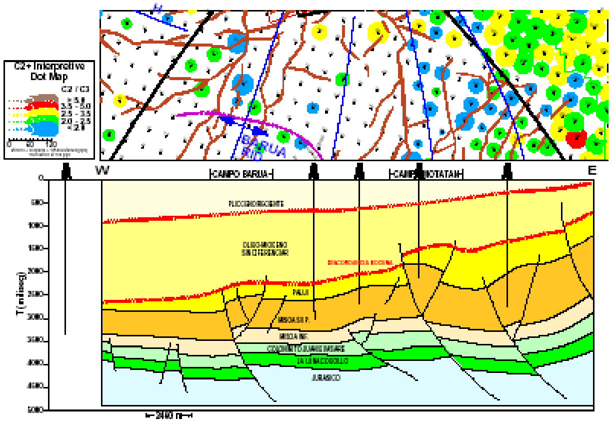
Maturation of the source rocks took place as early as Middle Eocene in kitchens east and northeast of Motatan and Mene Grande fields. Following uplift of the Misoa range in Miocene to Recent times, the maturation kitchen migrated clockwise to the south and southwest of the fields. As a result, two crude oil types have developed. The older oil has an API gravity ranging between 20-25 while the second, younger crude has an API gravity ranging from 30-40 (Zubizarreta and others, 1997).

The surface geochemical data exhibit much larger magnitude seepages directly over the Mene Grande field than over the deeper Barua - Motatan fields to the south. In addition, seepage having a similar oily composition extends eastward for at least 10 kms beyond the known productive area of the Mene Grande field. This seepage trend extends around the eastern portion of the survey area, becoming progressively lighter in composition toward the southeast. These larger magnitudes, gassier seepages are suggestive of deep source potential for lighter oils or condensates trapped in structural and/or stratigraphic reservoirs formed downdip between the Motatan structural ridge and the surface expression of these microseeps.

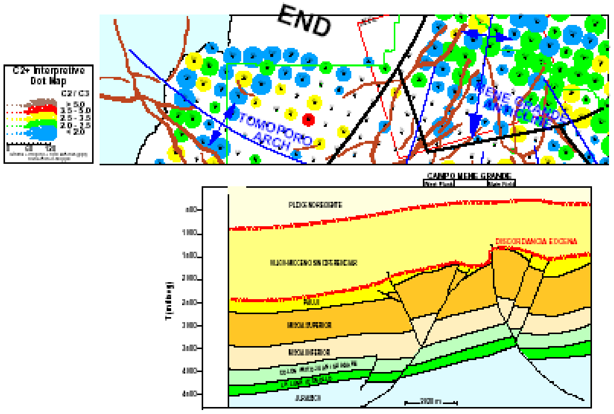
By comparison, seepage levels directly over the Barua-Motatan field are very low because of the very low pressure and the under-saturated nature of the oils produced from the upper reservoirs in these two fields. The overlying oil accumulations which are under-saturated in natural gas may also act as a sink and adsorb or filter out gases which are migrating from the deeper light oil reservoirs. Although of limited areal extent, several moderate magnitude seeps were observed over portions of these two fields. These larger magnitude seeps over the Barua - Motatan field still exhibit fairly oily signatures typical of the medium gravity oils found in this area, suggesting that signatures from the deeper reservoirs are influenced by passage through the upper reservoirs.

In contrast to the Barua-Motatan field areas, much larger magnitude seepages are noted along the western flank of the survey, within the Tomoporo and Ceuta areas. This increase in magnitudes of the surface seepages is very significant, given the much deeper reservoirs in this area. The increase in magnitude of these seeps, in spite of the increased cover thickness implies significant subsurface potential. The northern Tomoporo area has a very oily composition, similar to the adjacent Barua — Motatan fields, but the southern anomaly, which is currently outside the areas of 3D seismic coverage has light gas ratios suggestive of generation from the currently active source kitchen, and of lighter oil potential.

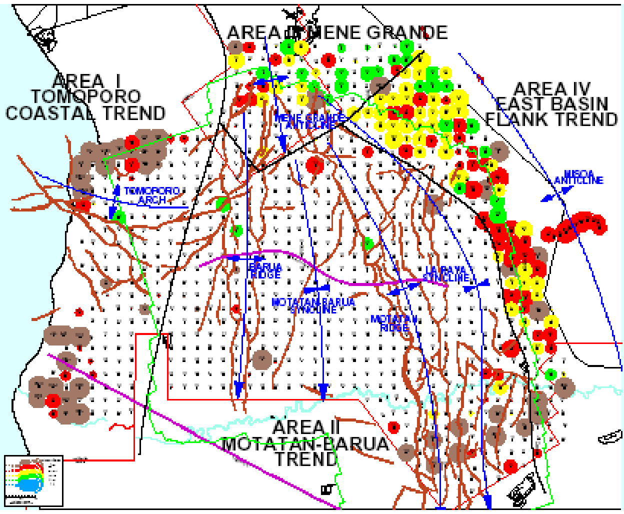
Surface geochemical signatures in the East Basin Flank Trend suggest five anomalous areas. Although seepage magnitudes are expected to be larger because of the bedding plane leakage avenues which influence migration in this area, experience in interpreting geochemical signatures suggests that these micro seepages, compositional signatures are not typical of breached reservoirs. These large magnitude seeps, flanking the eastern margin of the basin suggest significant source potential for both structural and stratigraphic reservoirs located downdip from the surface expression of these seeps. Unfortunately, portions of the geochemical anomalies in this trend are outside the area of current 3D seismic coverage.



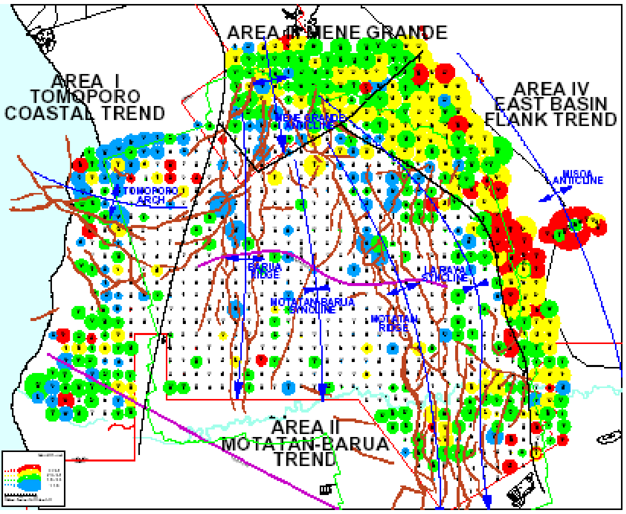
C2+ INTERPRETIVE DOT MAP AND REGIONAL CROSS SECTION



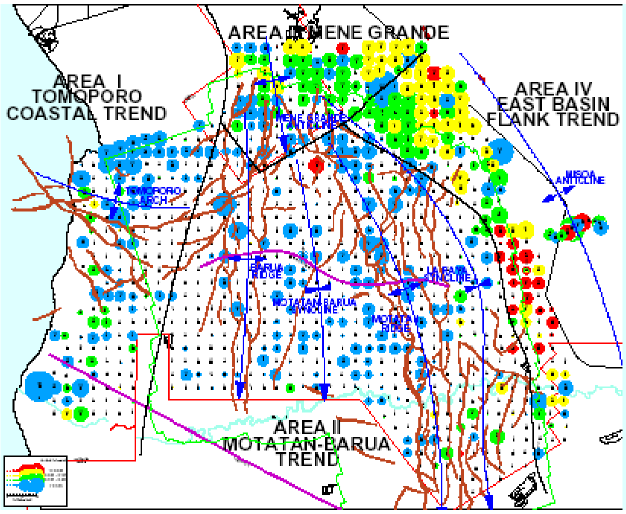
C2+ INTERPRETIVE DOT MAP AND REGIONAL CROSS SECTION



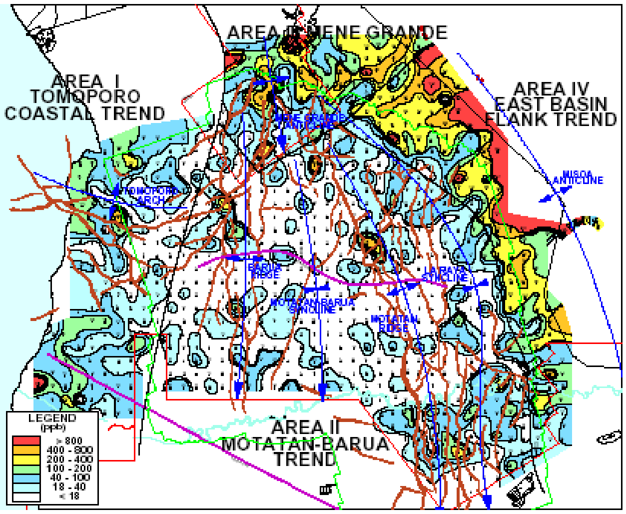
METHANE INTERPRETIVE DOT MAP



C2+ INTERPRETIVE DOT MAP



I-BUTANE INTERPRETIVE DOT MAP



ETHANE MAGNITUDE CONTOUR MAP

Figure 1

4.2.1 Detecting medium-low gravity oil

There is scientific questioning about the chance of molecules in range of condensates and liquid hydrocarbons (C5 to C20) to escape from reservoirs and travel to the surface in vapor phase. The C5+ gases don't migrate to the surface except in liquid form, with water and oil, but not in gaseous form, therefore the C5+ components are not present in the near-surface vapors, except perhaps in the nearby area around a liquid macroseep.

C5+ gasoline range hydrocarbons are often measured in near surface geochemical surveys to identify the locations of areas where seepage of liquid phase hydrocarbons has occurred. C5+ results can therefore be interpreted as mapping active oil seepage or related fluid expulsion from depth where dissolved phase and liquid hydrocarbons can be carried to the surface. Unfortunately given the size of the C5+ molecules and the fact that it is much more difficult to migrate these larger compounds to the surface than light hydrocarbons, C5+ anomalies tend to be spotty, discontinuous and at times difficult to interpret in surveys having only a regional data distribution. Generally C5+ anomalies are identified as small clusters of anomalies within more widely distributed light hydrocarbon seepage zones, which do not necessarily correlate on a one-to-one basis with light hydrocarbon constituents

As have been proof in the previous sections, our soil gas (vapor) technology (sampling and analysis) is capable to detect macro and micro seeps using only C1-C4 hydrocarbons concentration. ETI soil gas compositional data can not only be related to the compositions of the known fields surveyed, but is also capable of predicting the oil versus gas potential of an unknown frontier area.

In contrast to lighter oils, heavier oils will have lower concentrations of the C1 –C5 volatiles (they have lost their volatiles via water washing and/or from poor reservoir seals that have let the C1-C4 gases escape). The other thing that is true about heavier oils is that the gases associated with them are very often composed of only methane, and that is because this is biogenic methane that is actually generated in the reservoir. Pixler Plots for heavier oils some time are very gassy and plotted in the dry gas range.
A high sensitive gas chromatograph is necessary to detect the very low concentration of light hydrocarbons C2-C4.

Barua-Motatan project is one of a several examples of how our free gas soil sample technology can be used to detect fairly oily signatures typical of the medium-low gravity oils. The present API gravities of the Barua - Motatan oil field are in the range of 17^{0} to 25^{0} API.

In contrast to magnitudes, the compositions of the soil gases are often normally distributed over the entire basin, changing in composition in direct response to changes in the subsurface sources. These regional compositional changes are demonstrated graphically by the use of color dot maps as shown in Figure 1.

Because of the regional spacing used for this survey only one contour map was generated. Ethane was chosen because it is the lightest, non-biogenic gas that is associated with subsurface petroleum generation. It is also light (next to methane) and migrates easily from subsurface reservoirs. Although it can be degraded by microbes, it is much less degradeable than propane and normal-butane (James, 1990), so ethane has a slightly greater probability of surviving along the migration pathway and in the near-surface environment.

It is very important to stress again that contour maps (especially at a regional spacing) do not, and cannot truly represent the actual shape and outline of the geologic features which control the soil gas migration pathways. For this reason, the ethane contour map must be considered to be a regional representation of seepage signatures and used only for the purpose of showing the regional distribution of ethane anomalies and, the relative magnitudes of the regional anomalies with respect to one another. Given these reservations, one can draw several significant observations from the ethane contour map. Regionally, the entire study area is sourced with migrated petrogenic light hydrocarbon gases. There are anomalies over or adjacent to all known productive fields. There is a big difference in magnitudes from the Motatan-Barua fields to the Mene Grande and Tomoporo fields and especially to the east basin flank where the gassiest signatures and largest magnitudes are observed. Given the tectonics associated with the Motatan- Barua ridges, one would expect to find large magnitude seeps over these ridges. This absence is explained by the history of oil generation and migration in the basin which has left the upper reservoirs filled with a mixed biodegraded/medium oil, which represents the residual left behind by a significant breaching event. The very low values of the soil gas ethane, and the ethane/propane ratio, clearly reflects this influence. The lack of pressure in these shallow under-saturated oil reservoirs probably makes them an effective seal or sink for light gases generated from deeper light oil sources.

The interpretive dot maps shown in Figure 1 provide a non-biased representation of the regional seepage trend without the need for contouring. Dot colors for these Plates are based on methane/ethane or ethane/propane ratios that reflect the oil versus gas composition of individual sites as a method of mapping regional compositional signatures. These empirical compositional classifications were derived from previous surveys over producing fields, (Jones & Drozd, 1983). The color codes used for the dot maps are:

Methane/Ethane Ratio	Ethane/Propane x 10 Ratio	Dot Color	Predicted Composition
> 100	>50	Brown	Dry Gas
20 - 100	35 - 50	Red	Gas
10 - 20	25 - 35	Yellow	Oil and Gas/ Intermediate
5 - 10	20 - 25	Green	Oil
< 5	< 20	Blue	Heavy Oil/ Degraded

It should be noted that these are only general classifications which provide a starting point for soil gas interpretation within an unknown basin. These classifications need to be reset by actual calibration in the Lake Maracaibo Basin.

As far as magnitudes are concerned, all four dot maps show exactly the same regional magnitude variation as ethane and propane. Propane magnitudes show a high correlation with ethane and butane and were not mapped individually. Instead they were included as part of the C2 plus map. However, the methane map is very striking in one special regard. ***This map shows significant number of large brown dots where the methane/ethane ratio is greater than 100. Only deep thermal gases and biogenic gases have ratios this large*.** Most soil gas surveys find a fairly low percentage of biogenic sites where the methane was generated from near-surface source material (i.e. glacial till, etc.) and these sites almost always occur at random. This is particularly true when sampling on a regional grid where the samples are 3300 feet (1 km) apart. Inspection of the methane dot map and visual comparison with contour and dot maps shows that these extra large methane observations do correlate fairly well with the heavier gases, which do not have biogenic sources. Clearly these large methane sites have some form of association with the ethane to butane gases, which are sourced from the subsurface oil generating sources.

Many recent measurements made in areas impacted by macro-seepage and/or contamination (which has a similar effect) have demonstrated that bacteria biodegrade oil anaerobically and produce copious quantities of biogenic methane which is derived directly from the macro-seepage Marrin (1987) and Jones (1995). This biological process occurs not only in the near-surface but has also been demonstrated to occur in the reservoir at depth, Connan (1996). Given the degraded nature of the shallower oils reservoired in the known fields in this study area, it is entirely reasonable to expect biogenic methane to be generated in association with these biodegraded oil reservoirs.

Thus the interpretation of the methane dot map suggests that these methane emanations represent biogenic methane generated from degraded oils at depth.

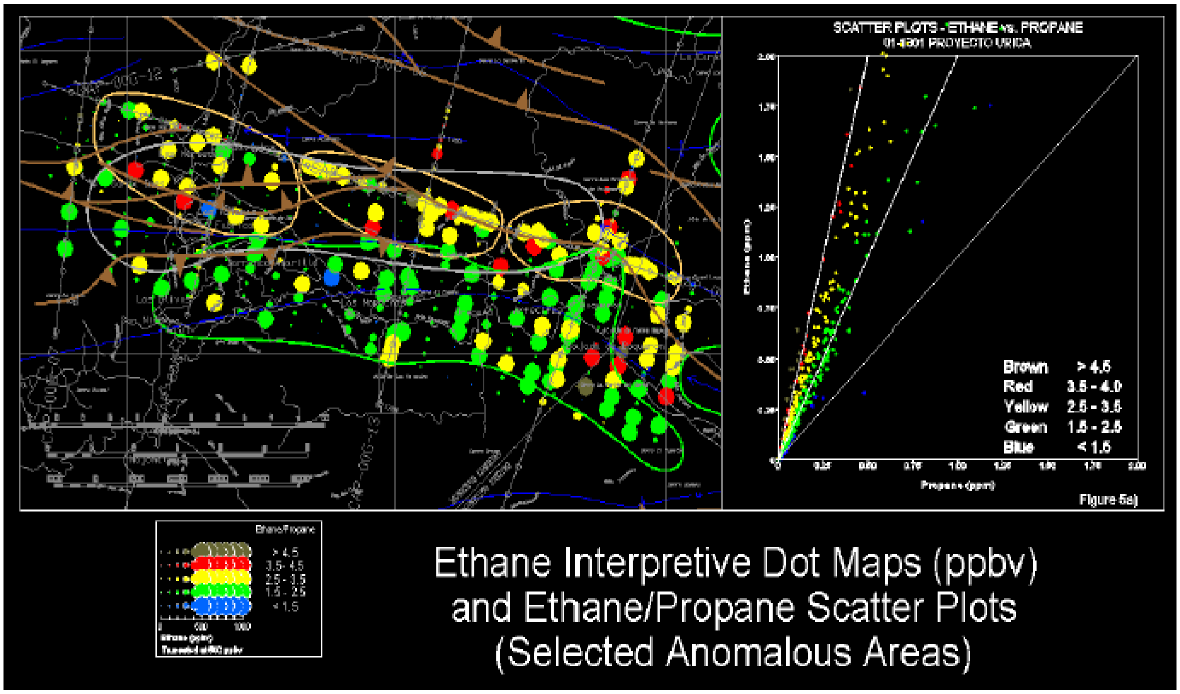
Then, significant oil potential may exist within the areas outlined by the brown dots. This interpretation is confirmed by the other petrogenic C2 plus components, propane and ethane plus maps which show a distribution of anomalies similar to methane, confirming that significant levels of petrogenic hydrocarbons are migrating to the surface in these areas. As a further check to determine the origin of the high magnitude of methane, selected samples were analyzed for their stable carbon isotopes

4-3. North-eastern Mountain Front, Venezuela.

A soil gas geochemical survey was conducted over an area in the north-east of Venezuela. The purpose of this survey was to identify the magnitude and composition of near surface light hydrocarbon seepage in the area of interest and to use this geochemical information for interpretation of the subsurface hydrocarbon potential of the area. A total of 1455 samples were collected on 500 meter centers on north-south regional lines located approximately 1000 meter apart and along several regional seismic lines of specific interest.

The soil geochemical data confirms the presence of an active petroleum system in the study area 9Figure 1). The soil gas exhibits actively migrating light hydrocarbons at magnitudes that are very large when compared to other petroliferous basins. Compositional ratios indicate oily sources. As has been discussed before, the ethane/propane ratio is the most stable, non-biogenic ratio available, and was selected to show regional changes in source maturity over the study area.

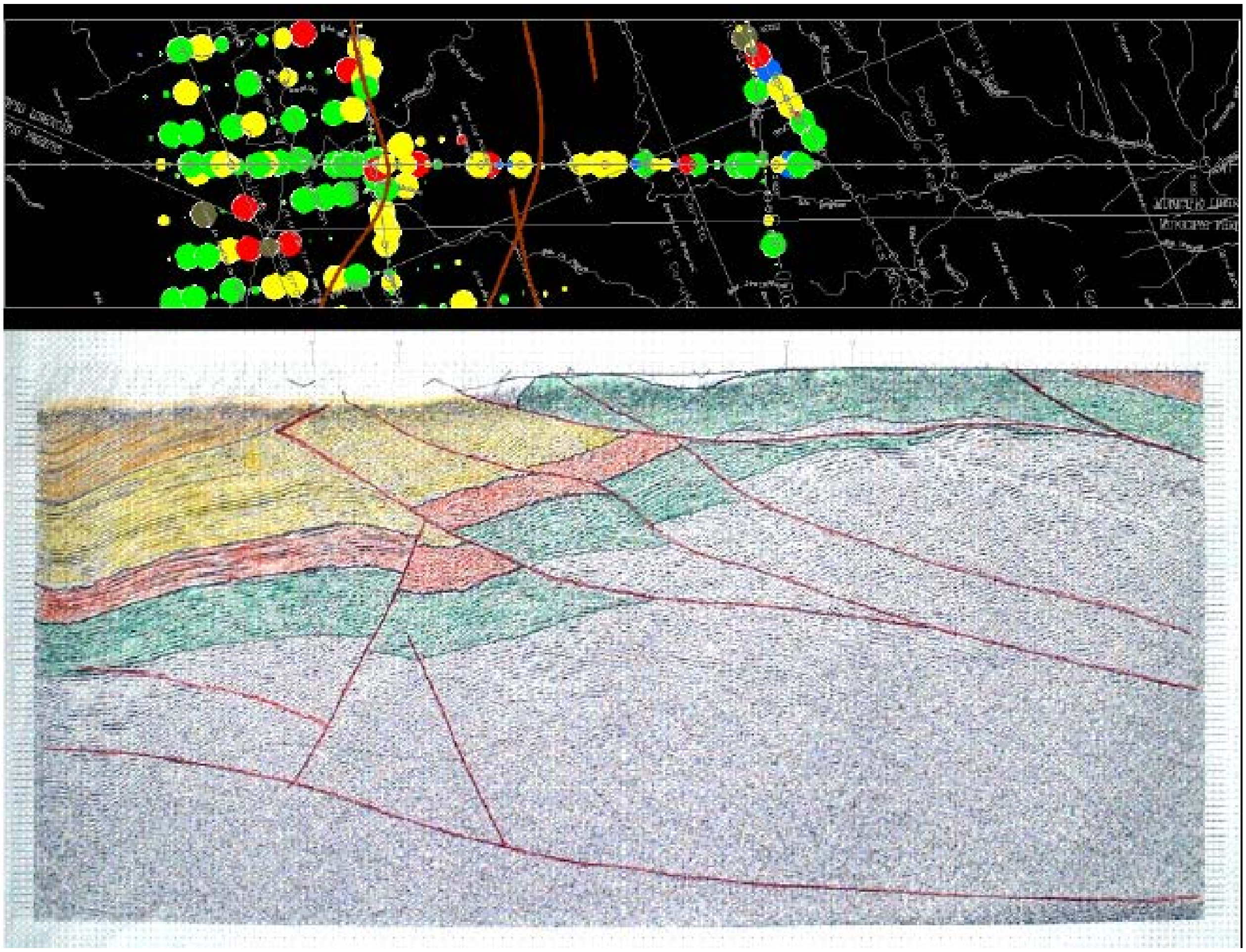
Several oily leads occur directly over known anticlinal structures. Clusters of anomalous soil gas samples appear to be highlighting excellent leads for future prospecting. Compositional variations suggest the presence of multiple oil and gas sources within the survey area and appear to be capable of confirming the presence and distribution of these different sources.



Ethane Interpretive Dot Maps (ppbv)
and Ethane/Propane Scatter Plots
(Selected Anomalous Areas)

(Figura 1)

Subcrops of Oligocene faults appear to provide boundaries along which deeper source gases impact the surface soil gas seepage (Figure 2). These Oligocene fault boundary soil gas anomalies suggest the existence of deep source light oils or condensates are in contact with the fault boundaries.



(Figura 2)

4-4. Neuquen Basin in Argentina, Argentina

Detailed soil gas geochemical surveys were conducted for calibration purposes over two fields, Filo Morado and Loma de La Lata in the Neuquen Basin in Argentina (Figure1) during November, 1989 as part of a larger regional exploration program. These two fields were chosen for this calibration study because of their differences in both reservoir composition and entrapment mechanisms.

Filo Morado is an anticlinal oil field producing from the Agrio-Huitrin Formations at a depth of 3,000 meters (9,843 feet), while Loma de La Lata consists of two stratigraphically trapped reservoirs formed on a homocline which dips to the northeast.

At the Loma de La Lata field, the shallowest oil pool produces from the Quintuco Formation at 2,000 meters (6,562 feet) and is partially underlain by a separate gas to gas condensate reservoir producing from the Sierras Blancas formation at 3,000 meters (9,843 feet). Both the updip facies change, and downdip water-hydrocarbon contact of this lower reservoir are plotted along with the productive gas condensate wells. The three separate reservoirs from these two fields provide two different oil reservoirs and one deeper gas to gas condensate reservoir for compositional calibration of the soil gas geochemical surveys.

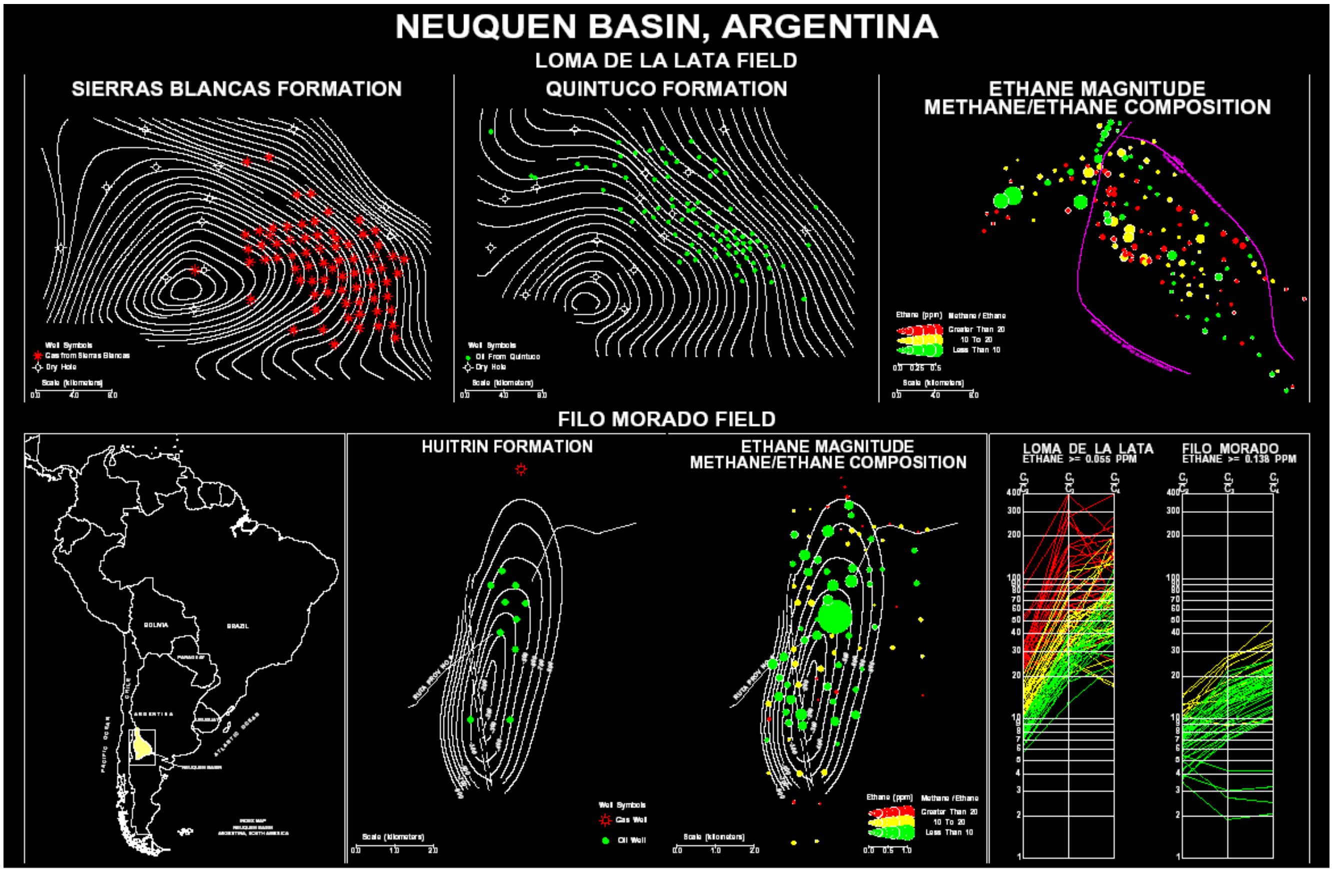
The geochemical data consists of 239 four foot deep soil gas samples collected on 500 meter grids placed directly over these two fields, with 95 sites collected over Filo Morado and 144 sites collected over Loma de La Lata. The free soil gases were analyzed for light hydrocarbons; methane, ethane, ethylene, propane, propylene, iso-butane, and normal butane by flame ionization gas chromatography.

In order to illustrate the distribution and compositions of the light hydrocarbon seepage, color compositional dot maps which combine both the light hydrocarbon magnitudes and compositional information into a single map have been generated for Filo Morado and for Loma de La Lata. Each dot is color coded to reflect the composition of soil gases as being indicative of oil (green dot), gas (red dot) or intermediate (yellow dot) based on the C1/C2 ratio. The dots vary in size according to the ethane magnitude, including even those localities with only background magnitudes.

The color compositional subdivisions used are derived from the published literature (Nikonov, 1971, and Jones & Drozd, 1983). The color of each of these clustered anomalies suggests the oil versus gas potential of the anomaly according to these empirical divisions alone. Ratios of methane/ethane, methane/propane and methane/total butanes for all soil gas sites are plotted on a Pixel graph for all sites in order to provide a visual illustration of the compositional differences in the larger magnitude sites. The bimodal nature of the Loma de La Lata soil gas data is clearly shown by the red (gas) and green (oil) populations. Filo Morado stands in stark contrast with its unimodal oily (green) population and by the lack of gas type anomalies.

A single oil source is predicted at Filo Morado, in agreement with the known oil field. Much gassier soil gas data is noted over the Loma de La Lata Field where there exists an oil and gas field underlain by a deeper gas condensate reservoir.

In addition, a very striking change to fairly large magnitude oil type compositional anomalies occurs directly over the northwestern portion of the Loma de La Lata survey data where the Quintuco oil reservoir is the only known producing horizon. This change in composition from oil to gas condensate type signatures over the Loma de La Lata Field occurs across a permeability pinchout at depth which controls the updip limits of the deeper gas condensate reservoirs. Thus the geochemical soil gas data exhibits clearly defined compositional subpopulations which match the composition of the underlying reservoirs and change in direct response to the major structural and/or stratigraphic features which control the location of these subsurface reservoirs. Predictions of oil versus gas from these soil gas data are in excellent agreement with published soil gas and reservoir data, Jones and Drozd (1983).



4-5. Moore-Johnson Field, Kansas

Introductión

A high-density soil gas survey was conducted in the vicinity of Moore-Johnson field in 1992. The survey was conducted after the discovery of the field and initial development attempts, all by the same major oil company, which resulted in a total of 10 wells (3 oil wells, 7 D&A). A second attempt to extend the field, starting in 1992, was conducted by six independent oil companies. One of the companies used an integrated approach of combining subsurface geology and seismic with a detailed geochemical soil gas survey. The remainder of the companies used industry-standard Morrow exploration techniques acquired from 1978 to 1990 during development of Morrow oil fields to the north.

A high-density soil gas survey was conducted over a four square mile area of interest. Integration of geochemistry, geology, and geophysics resulted in a compatible, unified interpretation that the field could be extended to the north.

The company utilizing the soil gas survey completed the first well to extend the field with a 4700-foot stepout. This company completed eight consecutive successful Morrow wells in the field before drilling a dry hole. After drilling 10 wells, the company had a 90% success rate. A total of 34 wells were drilled to both define the limits of the field and develop the Morrow reserves. By only drilling 29% of the total wells, the company utilizing soil gas geochemistry acquired 47% of the reserves produced to date. Success rates for the remainder of the other field operators were 0%, 30%, 50% and 67%.

The Morrow sands in these wider incised valleys are of smaller areal extent, in cross section, and more compartmentalized. Correspondingly, the average reserves per well are smaller than the northern fields. Although reserves are lower in the downdip facies, employing soil gas geochemistry can improve the relatively low success rates now being encountered in this area.

This documentation of a successful application of a detailed soil gas survey demonstrates how the method could be used to delineate other areas of Morrow incised valley-fill systems in areas of untested potential. Additionally, the method would also be applicable in incised valley-fill systems of other geologic ages in Midcontinent and Rocky Mountain basins.

Soil gas geochemistry is not a panacea for Morrow exploration, exploitation, or development drilling, but is an integral part of a thorough exploration program. Applying the recently related concepts of Morrow sequence stratigraphy will undoubtedly be a tremendous advantage in future Morrow exploration and development drilling ventures, reservoir maintenance, and in secondary recovery operations. Using soil gas geochemistry in tandem with this concept would provide a very powerful synergistic effect to Morrow exploration and development projects.

Discovery of Moore-Johnson Field.

Moore-Johnson field in Greeley Co., Kansas was discovered by Amoco in October 1989 (Adams, 1990). The Amoco Mo-Jo #1 was discovery well for the field. The well was completed in the sands of the V-7 valley fill sequence of the Morrow Formation. The Amoco combined geological and seismic conceptual model was that of a northwest-southeast oriented Morrow sand body (Figure 1). By May 1990, Amoco had extended the field to include two successful wells (Figure 2); the Brewer #1and Brewer #2.

As shown in Figure 2, attempts to extend the field to the south and farther to the northwest by Amoco in 1990 resulted in six dry holes (Mo-Jo#2, Linn #1, Sell #1, Keller #1, Keller #2, Brewer #3). Amoco also drilled another dry hole to the northeast (Lawson #1). The overall success rate, at the end of 1990, for development drilling in the Moore-Johnson field area was a disappointing 33%. This was considerably below previous industry standards in the Morrow Trend. Success rates for development of Frontera, SW Stockholm and Second Wind fields of the Stateline Trend were 73%, 68%, and 56%, respectively. There was no further drilling in the field area during all of 1991.

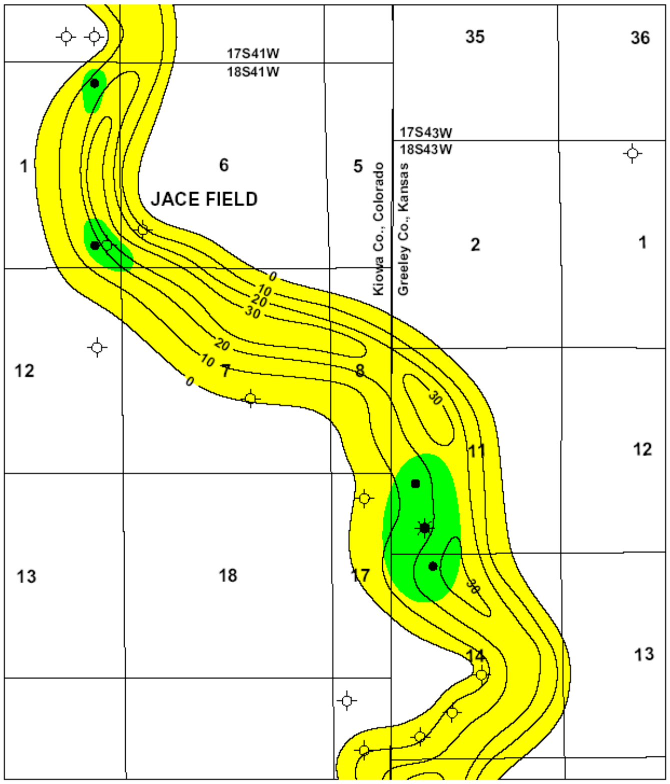


Fig 1- Geological and seismic conceptual model

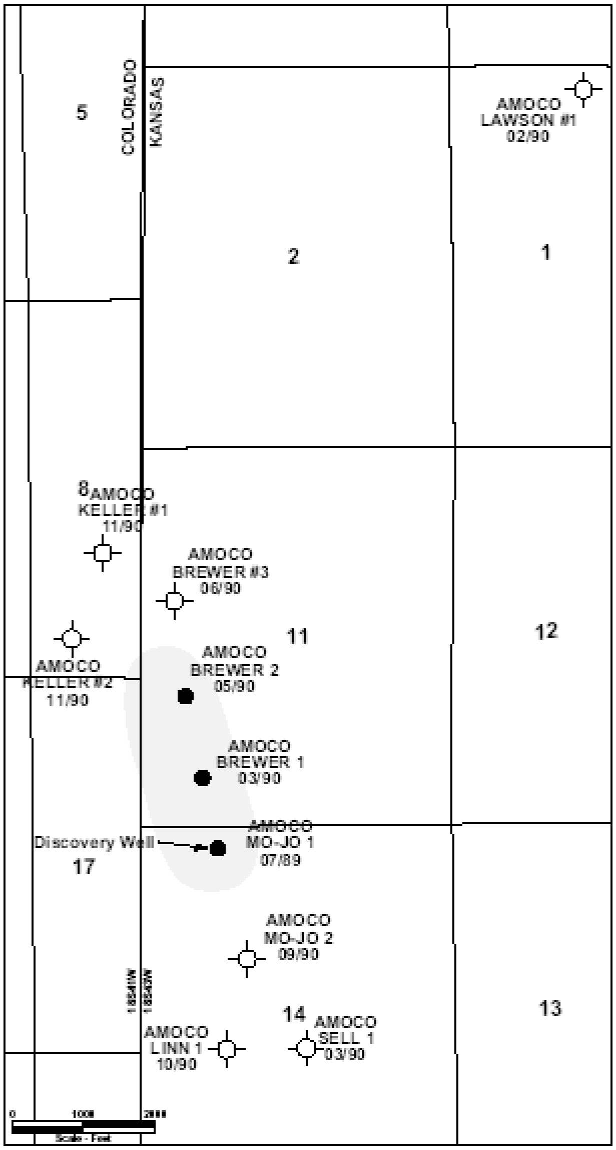


Fig 2-Drilling schedule during 1990

Surface Geochemical Survey

En April 1992 Axem/Murfin decided to contract ETI for performing a Surface Geochemical Survey on the Stateline Trend using free soil gas samples technology.
A soil gas calibration survey was first conducted over the three-well field and in the area of the 6 dry holes. An ethane magnitude contour map of the soil gas data in the calibration area is shown in Figure 3 (left portion). As shown on the ethane magnitude contour map, low ethane magnitudes were observed in areas where the dry holes were drilled and the anomalous ethane values corresponded to the area of the three Morrow oil wells. There was no problem with reservoir pressure depletion at the time of the survey because of the limited production at that time. The soil gas contour map for the calibration survey also indicated other areas of anomalous microseepage to the east and northeast of the three productive wells. The more detailed soil gas survey was extended into those areas to aid in further development drilling at Moore-Johnson field. The initial sample grid of 16 sample sites per section was increased with infill soil gas sites as shown in Figure 3, right portion. A total of 106 soil gas sites were sampled within the map area.

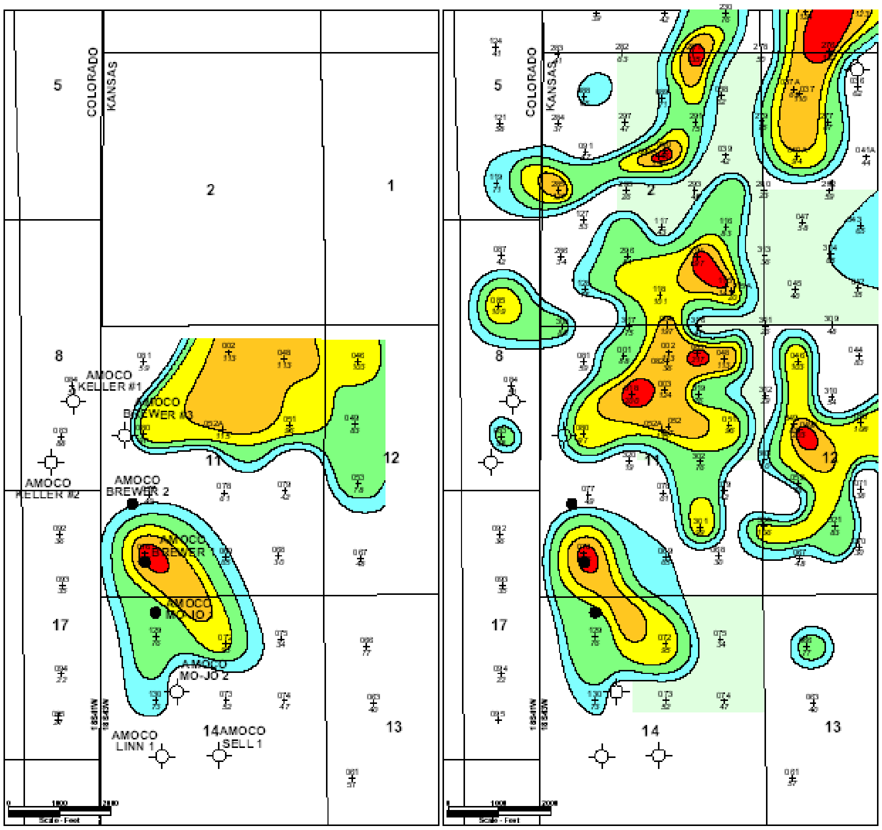
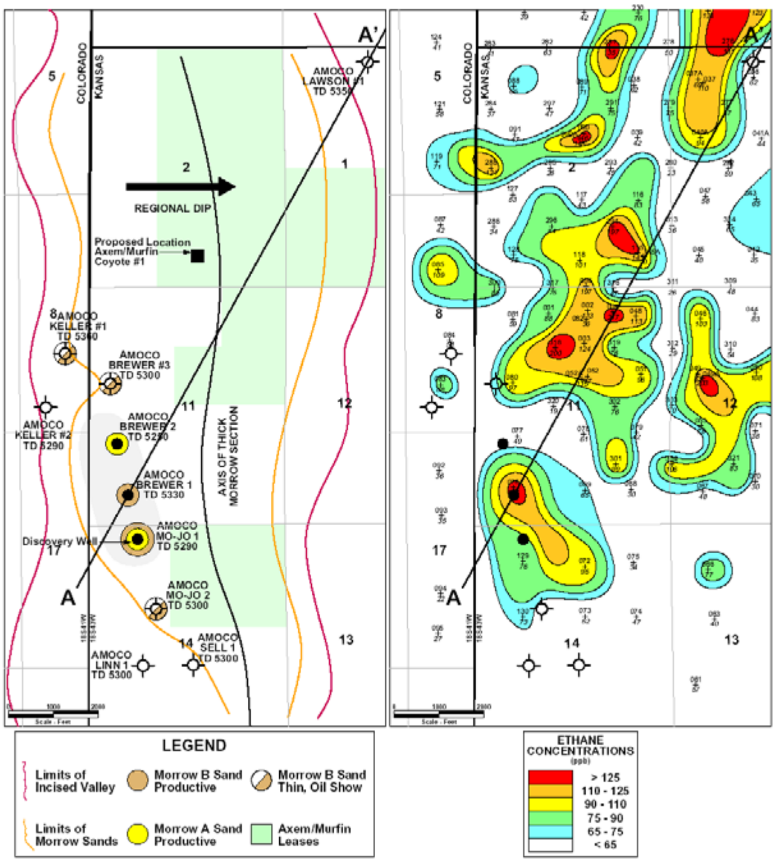


Fig.3- Surface Geological Survey

The infill sample data significantly increased the detail of the microseepage anomaly pattern from that of the original calibration survey, as evidenced by comparing the two contour maps. Ethane magnitudes ranged from 22 ppb to 205 ppb within this area. The ethane magnitude contour map indicated anomalous microseepage over the Axem Resources and Murfin Drilling (Axem/Murfin) lease block in sections 2, 11, and 14.

Integration of Subsurface Geology, Seismic, and Surface Soil Gas Geochemistry



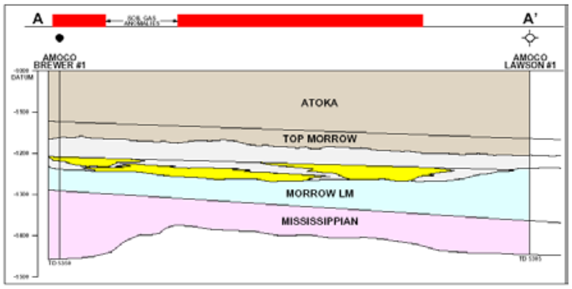


Fig. 4

During the first half of 1992, Axem/Murfin integrated the combined subsurface geology and seismic interpretation with the surface soil gas data. The conceptual model for the Morrow trend, derived from the all the development of the northern Stateline Trend fields, was that the Morrow section (base of Atoka to top Morrow Limestone) was observed to thicken in the areas of maximum Morrow sand development and productive wells. In contrast, the Morrow section was much thinner, with non deposition of Morrow sands, on the east and west flanks of the Morrow fields. This was the Axem/Murfin conceptual model at the Moore-Johnson area interpreted from the available well control and seismic data (Figure 4, left portion). Subsurface data from the Amoco wells in the area and seismic interpretation provided the Axem/Murfin concept of the Morrow incised valley boundaries, regional dip, and general axis of the depocenter of the Morrow valley as indicated on Figure 4. The expected areal distribution of Morrow sands was interpreted as shown on the map. Axem/Murfin had interpreted the Morrow sands to be oriented north-south in the area as opposed to the previous Amoco concept of a northwest-southeast alignment. In the new interpretation, the Amoco productive wells were interpreted to be at the west, updip limits of a Morrow stratigraphic trap. The interpretation of the soil gas survey data is shown on Figure 4 at center. The ethane magnitude contour map indicated that the maximum gas microseeps were observed in the central portion of the expected Morrow incised valley and within the expected Morrow sand fairway. The geochemical, geological, and geophysical data were all compatible with the conceptual model for a Morrow stratigraphic trap. A location was staked for Coyote #1 in section 2. The well was spudded July, 25, 1992.

1992 Drilling Schedule

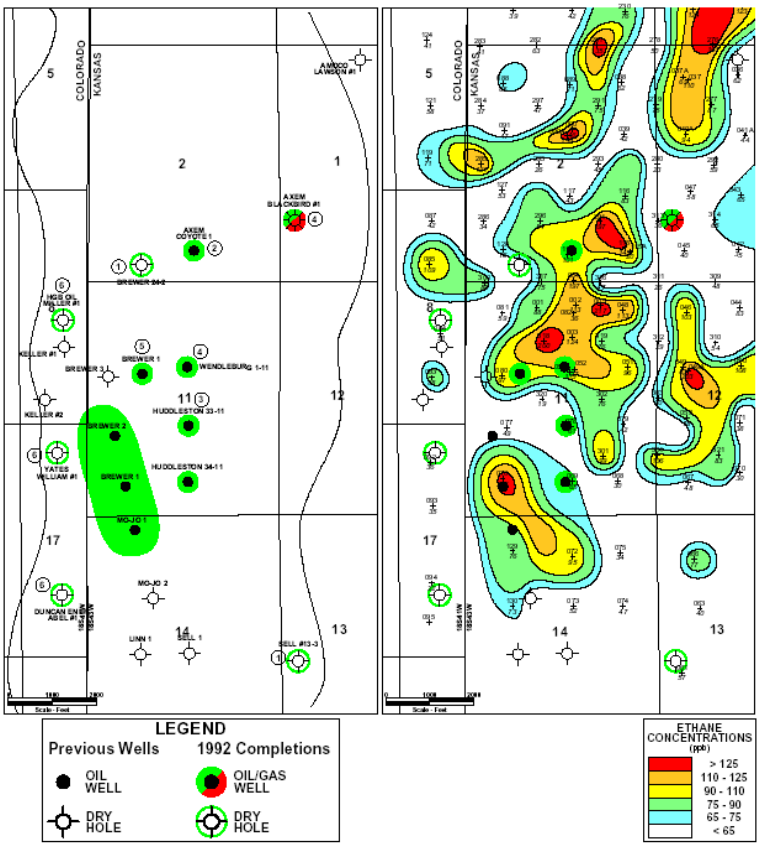


Fig.5

Eleven wells were drilled in 1992 by 5 oil companies. Only Axem/ Murfin used the integrated approach of soil gas geochemistry with geology and seismic to select well locations. The locations of the wells drilled in 1992 are shown on Figure 5, left.
La secuencia de perforación fue la siguiente:

1) In April and May 1992, MW Pet. drilled two Morrow dry holes with the Brewer #24-2 and Sell #13-31 Both well locations are in areas of background soil gas concentrations. No further wells were drilled by this company in this area

2) In August 1992, Axem/Murfin drilled their first well and completed the Coyote # 1 The well location was supported by a strong soil gas anomaly. The well confirmed the conceptual model established.

3) Duncan Energy completed two direct offsets in October and November to the Amoco Brewer #1 and #2 producing Morrow wells (Huddleston 33-11 y 34-11). These two wells were only 1500-foot offset locations.

4) In November 1992, Axem/Murfin completed two Morrow wells with the Wendleburg #1-11 and Blackbird #1 wells. The Wendleburg #1-11 location was supported by a strong soil gas anomaly.

5) In December 1992, HGB Oil completed the Brewer #1. This location had been proven by the preceding surrounding wells to the west, east, and south.

6) HGB Oil, Yates, and Duncan Energy each drilled a dry hole attempting to extend field production updip and to the west. There were now five dry holes in Colorado to the west of the field. All five well locations are in areas of low magnitude soil gas data. By the end of 1992, Moore-Johnson field had produced 512,714 BO.

1993 and 1994 Drilling Schedule

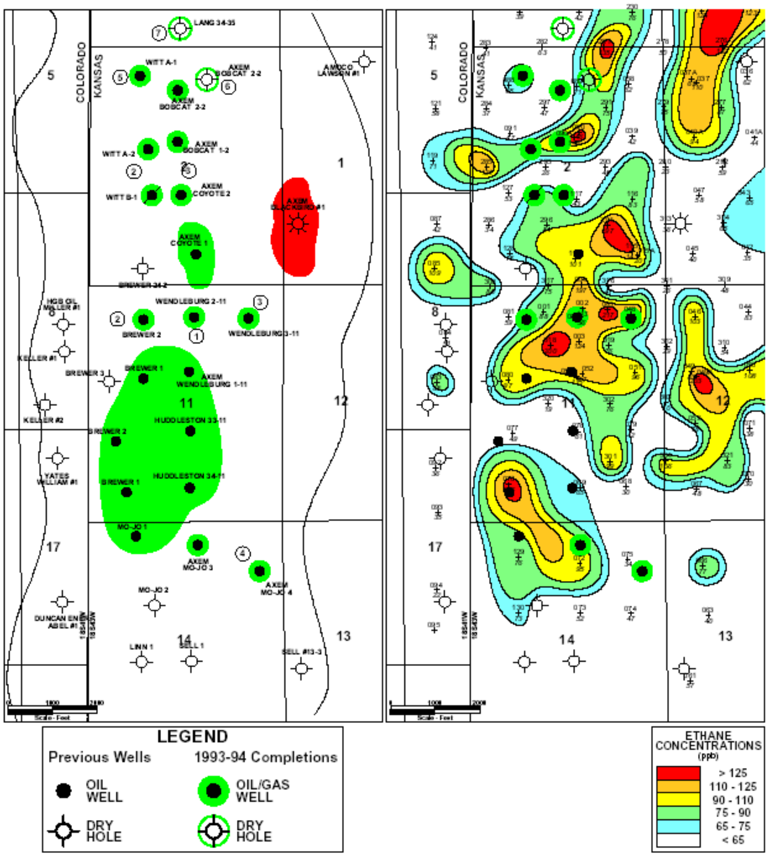


Fig. 6
The locations of all the wells previously drilled through 1992 are shown on Figure 6 (left) An ethane magnitude contour map (right) illustrates the basis of Axem/Murfin decisions in selecting well sites. The following are the 1993 wells that were drilled:

1) Marathon completed the Wendleburg #2-11 as a Morrow oil well in February 1993. This well was a direct offset to the Axem/Murfin Wendleburg #1-11 drilled three months previously in November 1992. This was the only lease Marathon held in the field area.

2) HGB Oil drilled three Morrow oil completions from March through July 1993 (Witt #A2, Witt #B1, Brewer #2). The wells were on the updip, west side of the field.
The Witt #B1 only produced 1745 BO and is considered to be a dry hole.

3) Axem/Murfin drilled three Morrow oil wells in the north area with the Bobcat #1-2, Coyote #2, and Wendleburg #3-11. The Bobcat and Wendleburg well locations were in areas of anomalous microseeps.

4) Axem/Murfin drilled two Morrow oil wells in the south area with the Mo-Jo #3 and Mo-Jo #4 wells. The Mo-Jo #3 well was completed in August 1993 and was located in an area of anomalous ethane concentrations.
By the end of 1993, Moore-Johnson field contained 17 Morrow oil wells and extended for 11,000 feet in a north-south direction and 3000 feet in width. Axem/Murfin had completed seven successful Morrow wells without a dry hole. At the end of 1993, cumulative production at the field was 780,549 BO.

In 1994, four wells were drilled by three oil companies in the north area of the field. The following are the 1994 wells that were drilled:

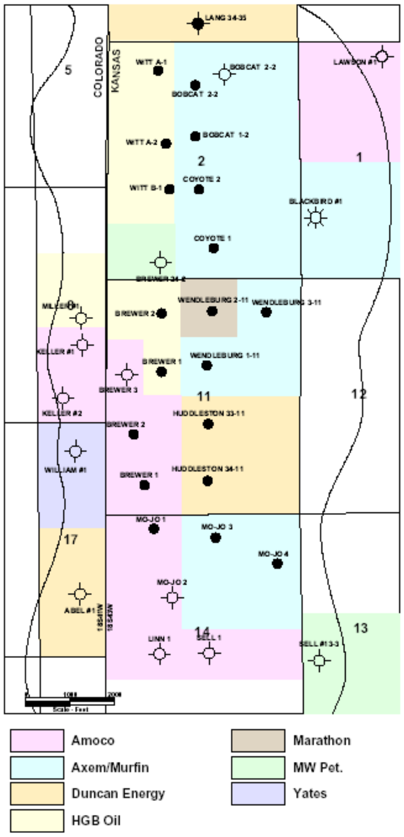
5) HGB Oil drilled the Witt #A1 as a Morrow oil well in January 1994. The well location was on trend and 1500 feet from their Witt #A2 completion 6 months earlier.

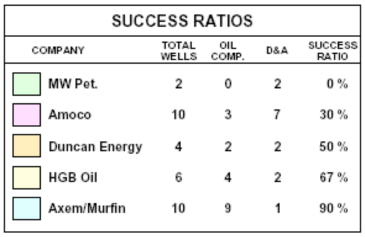
6) Axem/Murfin drilled their first dry hole in the Bobcat #2-2 in January 1994. A 700-foot offset to the southwest, however, resulted in a Morrow oil completion. The Bobcat lease, to date, has produced a total cumulative of 170,646 BO from two wells.

7) Duncan Energy completed a marginal Morrow well with the Lang #34-35 in March 1994. After only producing 477 BO, the well was converted to an injection well.

Moore-Johnson field was fully defined by 34 wells. The major extension of the field only took 24 months. This is one of the shortest development periods for a comparative size field in the whole Morrow trend. By the end of 1994, the cumulative production from the 19 Morrow wells in Moore-Johnson field was 980,152 BO.

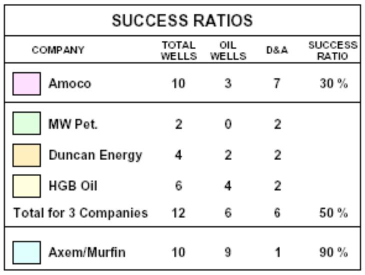
Moore-Johnson Field: In Retrospect





SUCCESS RATIOS

COMPANY	TOTAL WELLS	OIL COMP.	D&A	SUCCESS RATIO
MW Pet.	2	0	2	0 %
Amoco	10	3	7	30 %
Duncan Energy	4	2	2	50 %
HGB Oil	6	4	2	67 %
Axem/Murfin	10	9	1	90 %



SUCCESS RATIOS

COMPANY	TOTAL WELLS	OIL WELLS	D&A	SUCCESS RATIO
Amoco	10	3	7	30 %
MW Pet.	2	0	2	
Duncan Energy	4	2	2	
HGB Oil	6	4	2	
Total for 3 Companies	12	6	6	50 %
Axem/Murfin	10	9	1	90 %

Fig.7

The major advantage of using detailed soil gas surveys for exploitation/development drilling is to increase the success rate (risk reduction). A total of 34 wells were drilled both to define the limits of the field and to develop the Morrow reserves in Moore-Johnson Field culminating with 19 producing wells and 15 dry holes. An initially completed well at the north end of the field (Lang #34-35) was a marginal well (447 BO) which was converted to an injection well and later into a salt water disposal well and is considered as a dry hole. This represents an overall success rate of 56%, which at the end of 1994, was on the low side of the industry average in the Morrow Trend.

To characterize the success rate at this field in this way is somewhat misleading. The drilling statistics are severely hampered by the dismal Amoco success rate of 30% and, on the other hand, strengthened by the exceptional Axem/Murfin success rate of 90%. A better way of characterizing the success rate at Moore-Johnson Field is to look at the individual drilling statistics of five companies. The major lease blocks held by the operators in the field, along with the completed wells, is shown on the map on the far left. Marathon and Yates each drilled only one Morrow oil well and one dry hole, respectively, in the field area and are not discussed further.

As shown in the Table 1 on the left, the success rates for the six companies, that drilled at least 2 wells, ranged from 0% (MW Pet.) to 50% (Duncan Engin.) to 90% for Axem/Murfin. The chief reason for the high success rate of Axem/Murfin was that they used an integrated approach of surface geochemistry,subsurface geology and geophysics.

This analysis, however, uses widely varying populations of drilled wells. If the Duncan Ener., MW Pet., and HGB Oil wells are grouped together, then an even comparison can be made to Axem/Murfin and Amoco with the groups each having drilled 10 or 12 wells. As Table 2 indicates, Amoco and the Duncan – HGB Oil – MW Pet. group had a success rates of 30% and 50%, respectively, (without using geochemistry) and the Axem/Murfin group had a 90% success rate.

Axem/Murfin drilled 9 successful Morrow wells which accounted for 47% of the total Morrow oil wells in the field. HGB Oil and Duncan Ener. both gained valuable subsurface control from these Axem/Murfin wells which ultimately helped increase their success rate. The Axem/Murfin Coyote #1 and Wendleburg #1-11 were very early Morrow completions which greatly aided HGB Oil in evaluating their southern leases.

Besides discussing success rates, the benefits of using surface soil gas geochemistry can also be illustrated by considering discovered oil reserves. Cumulatives for the 3 companies are listed on Table 3. By drilling 10 wells Duncan Energy and HGB Oil had a cumulative production (to 2003) of 418,429 BO. By drilling the same number of wells, Axem/Murfin wells had produced 749,800 BO. This is almost twice as much production. By drilling only 29% of the total wells (34), Axem/Murfin wells, to date, have produced 47% of the produced reserves. The ultimate recoverable reserves for Moore-Johnson Field are estimated at 2,000,000 BO.

5. SOIL GAS COLLECTION METHOD

The proposed sampling equipment is portable, inexpensive and can be used to rapidly sample large areas in a variety of environments. Soil gas samples will be collected by driving a 1/2 inch diameter 4 foot long slide hammer plunger bar into the soil, and replacing the hammer with an ETI soil gas sampling probe. A 15 cc volume of background air will be extracted from the probe and discarded to draw soil gas into the probe. An evacuated 125 cc serum bottle is then attached to the probe and allowed to draw the soil gas into the bottle. An additional 60 cc of soil gas will be added to the bottle to give a positive pressure and provide adequate sample for laboratory analysis.
All samples will be collected using same procedure to insure consistent results.

After sample collection each bottle is properly identified with a label and sealed with 100% silicon rubber cement to guard against leakage during storage and transportation prior to analysis. The sample probe will be flushed extensively with ambient air after each sample to reduce the possibility of cross contamination between sample locations.

As a part of the quality control program air sample (Field Blanks) are taken every day (2 per day/per crew).

6. LABORATORY ANALYSIS

On receipt in the lab samples will be run for methane, ethane, propane, iso-butane, normal butane, ethylene and propylene by computer controlled, flow-through, flame ionization detector (FID) gas chromatography. Samples will also be simultaneously analyzed for helium and hydrogen by thermal conductivity detector (TCD) gas chromatography. Results will be reduced and soil gas magnitudes calculated as parts per million (ppm) by volume.

As part of the quality control program, air blanks will be analyzed for about 5% of the soil gas samples. Also every bottle tray contain one trip blank to assure no cross contamination has occur during the trip from and to Houston, Texas. All trip blank are also analyzed.

As a further check to determine the origin of the high magnitude methane samples, selected samples will be analyzed for their stable carbon isotopes to help differentiate biogenic versus petrogenic sources for the gases and the relative source rock maturity. The 13C/12C (del C13) ratio will be determined using a stable isotope ratio mass spectrometer. It is anticipated that 10 of the samples could be large enough for isotope analysis.

7.-DATA ANALYSIS AND REPORT PREPARATION

Final survey results will be compiled into a summary report discussing the distribution and composition of light hydrocarbon seepage in the study area to highlight geochemical trends and anomalies suggestive of subsurface petroleum migration pathways and accumulations. As appropriate and feasible the following deliverable products will be generated:

Data Tables:

- Summary statistics including maximum, minimum, mean, standard deviation/mean for light hydrocarbon magnitudes, percentage composition and compositional ratios. Correlation coefficients between pairs of gases
- Light hydrocarbon magnitude listing files.
- Light hydrocarbon compositional ratios.
- Pixler Ratio Values
- Stable isotope ratio 13C/12C (if any)
- Position Coordinates

Illustrations:

- Histograms of light hydrocarbon magnitude and compositional components.
- Pixler ratio plots.
- Compositional Crossplots

Plates:

- Sample location map.
- Interpretive dot maps and/or contour maps to highlight the magnitude and composition of light hydrocarbon seeps

Report:

- Discussion of field and laboratory methodology.
- Summary of field activities.
- Summary of results.
- Interpretation of light hydrocarbon seepage distribution and composition.

8. REPRESENTATIVE GEOCHEMICAL EXPLORATION EXPERIENCE

4 FOOT PROBE SOIL GAS SURVEYS

2011	Turkey	150 site soil gas survey, Turkey
2011	Turkey	185 site soil gas survey, Turkey
2011	Turkey	150 site soil gas survey, Northern Turkey
2011	Turkey	50 site soil gas survey, Northern Turkey
2011	Turkey	200 site soil gas survey, Southern Turkey
2011	Montana	1700 site soil gas survey, Valley County
2011	Colombia	300 site soil gas survey, Carbonera Prospect
2010	Montana	300 site soil gas survey, Tendoy Mountains, western extension, phase 2
2010	Colombia	640 site soil gas survey, Catutumbo Basin, Santa Cruz Block, phase 2
2010	Colombia	700 site soil gas survey, Cubrio Block
2010	Texas	600 site soil gas survery, La Mesa
2009	Colombia	127 site pilot survey, Gaban & Cabiona Blocks
2009	Senegal	708 site soil gas survey, Tamnia
2009	Colombia	802 site soil gas survey, Catutumbo Basin, Santa Cruz Block
2009	Kansas	260 site soil gas survey, SW Kansas
2009	Kansas	797 site soil gas survey, 6 projects
2009	Mauritania	1360 site soil gas survey, Tauodani Basin
2008	Kazakhstan	1703 site soil gas survey, Block 36
2008	Colorado	460 site soil gas survey, Baca County
2008	Senegal	2010 site soil gas survey, Sebikhotane and Tamna Blocks
2008	Canada	537 site soil gas survey, North Central Alberta

2008	Paraguay	240 site soil gas survey, PG&E Block
2008	Paraguay	1777 site soil gas survey, Boqueron Block
2007	Paraguay	262 site soil gas survey, Gabino Mendoza Block
2007	California	476 site soil gas survey, Antelope, Bitterwater Valley, Carneros Creek Areas
2007	Montana	204 site soil gas survey, Beaver Head County
2007	Colorado	325 site soil gas survey, Baca County
2007	Argentina	1196 site soil gas survey in San Jorge Basin
2007	California	476 site soil gas survey in San Joaquin Basin
2006	Turkey	1366 site soil gas survey for evaluation in Muratli Block in Thrace Basin
2006	Turkey	1076 site soil gas survey for evaluation in Havsa Block in Thrace Basin
2006	Turkey	1895 site soil gas survey in Erzurum Area
2006	Colorado	Phase 3 – 325 Infill Detail soil gas sites – Peoria Field
2005	Turkey	765 site soil gas survey in Mesutlu-Hamitabat area in Thrace Basin
2005	Holbrook Basin, Az	244 site Helium Survey over Navajo Springs Field
2005	Turkey	291 site Edmemit Area soil gas survey
2005	SE Texas	53 site soil gas lease evaluation in Houston Salt Basin
2005	Turkey	251 site soil gas survey in Bafra Basin
2004	Colorado	Phase 2 – 207 Infill Detail soil gas sites added to – Peoria Field
2004	Turkey	Pilot program – 200 soil gas sites in Thrace Basin
2004	Belize	96 samples – water samples
2004	Colorado	Phase 1 – 200 sites soil gas sampling program – Peoria Field
2003	Mississippi	Phases 2 & 3 – 537 sites soil gas sampling program, Black Warrior Basin
2003	Kazakhstan	2000 site soil gas sampling program, Turgay Basin

2003	Georgia	200 site soil gas sampling program, Block 12, Kura Basin
2003	Ecuador	1000 site soil gas sampling program, Oriente Basin
2003	Oklahoma	67 site soil gas sampling program, Bryan County
2002	Mississippi	Phase 1 - 271 site soil gas sampling program, Black Warrior Basin
2002	Republic of Senegal	520 site soil gas sampling program
2001	Peru	834 site soil gas sampling programs over 2 blocks
2001	Venezuela	1390 site soil gas sampling program
2001	Argentina	1091 site soil gas sampling program
2001	Peru	300 site pilot program over two areas
2000	New Zealand	Exploration pilot program
2000	Argentina	125 site soil gas sampling program in Cerro Cochiquito
2000	Texas	65 samples from the Hockley Dome
2000	Argentina	585 site soil gas sampling program in La Rebelde/La Antena
2000	Argentina	175 site soil gas sampling program in Puesto Molina Norte
2000	Republic of Yemen	443 site soil gas sampling program over two blocks
1999	Argentina	164 site soil gas sampling program in Neuquen
1999	Saudi Arabia	540 site soil gas sampling program
1999	Texas	Samples run from Valverde County
1999	Australia	101 site soil gas sampling program
1999	Wyoming	20 site soil gas sampling program over Mocroft Ranch
1999	Wyoming	Coal bed samples run for CH4
1998	Argentina	180 site soil gas sampling program in Arroyo Butaco
1998	Argentina	200 site soil gas sampling program in El Tranquilo
1998	Texas	314 site soil gas sampling program in Dimmit County

1998	Wyoming	10 sites Wyoming
1998	Wyoming	72 site soil gas sampling program in Red Desert
1998	Wyoming	35 site soil gas sampling program in White River
1998	Canada	150 site regional soil gas sampling program
1997	Greece	263 site regional soil gas sampling program
1997	Peru	510 site regional soil gas sampling program
1997	Italy	1390 detailed soil gas samples collected over two study areas.
1997	Colombia	350 sample regional surface geochemical evaluation in an undrilled basin
1997	Argentina	200 sample detailed soil gas study
1997	Venezuela	2595 soil gas samples collected over 4 regional study areas.
1997	Italy	865 sample regional soil gas study
1997	Venezuela	649 sample detailed grid in-fill study to follow-up 1996 sampling program.
1997	Colorado	223 sites regional soil gas survey to cover prospect areas in sub-basin.
1996	Italy	1114 sample regional soil gas sampling program.
1996	North Dakota	487 sample soil gas study over calibration and prospect areas.
1996	Venezuela	1840 sample regional soil gas study over frontier areas including close spaced sites on seismic lines and roads.
1996	Canada	150 sample soil gas calibration study.
1995	Michigan	970 samples collected on 1/4 mile spacing along roads and country trails to high-grade 2 prospect areas.
1995	Texas	420 site regional survey over known production and the rest of the lease acreage.
1995	Yemen	96 site survey on specific targets in a rank frontier area to highgrade prospects.
1995	Yemen	315 samples collected on 1km spacing in 3 prospect areas to rank the prospects.

1995	Egypt	305 samples collected along known faults and on top of mountain range.
1995	Texas	100 sites collected on 1/4 mile spacing over known gas field to delineate potential producing area.
1995	Alaska	3000 site regional survey designed to cover producing fields, seismic crosscuts, wildlife areas to delineate regional fairways and oil vs. gas potential.
1994	Mississippi	200 site seismic geochemical survey over salt dome area.
1994	Wyoming	99 samples collected in and around drilling prospect.
1994	Texas	150 site combination soil gas and seismic shothole samples on a regional survey.
1994	Egypt	186 samples collected on 1km spacing to highgrade a lease to determine best potential area to search.
1994	India	883 samples collected on 1km spacing to highgrade a large basin to determine oil vs. gas potential.
1994	Alabama	197 Coal bed samples run for CH4
1993	Africa	203 site reconnaissance soil gas survey over a 10,000 km area.
1993	Argentina	153 site added to detail prospect over large frontier block.
1993	Honduras	200 site detail survey to further define drillable prospects.
1993	Kansas*	245 site regional and detail survey over the Kansas/ Colorado Morrow Trend.
1993	Ethiopia	3000 site soil gas survey in conjunction with a 1400 line km seismic survey over selected areas
1993	Argentina	275 site soil gas survey along regional roads in the NW Bolsones Area.
1993	Wyoming	134 site soil gas regional 4' probe survey over a 90 square mile area in the Chimney Butte Area.
1993	Texas	228 site regional soil gas survey over a 5 square mile area in Comanche County, Texas.
1993	Nevada*	209 site soil gas survey in the Overland Pass Area, White Pine County, Nevada.

1993	Texas	110 site soil gas survey in Henderson County, Texas in the Cross Roads Area.
1993	Argentina	359 sites soil gas survey in the Chubut Area.
1993	Argentina	608 site soil gas survey to further define drillable prospects.
1993	Wyoming	265 site soil gas survey over 140 square miles in the Big Piney Area to expand the geochemical evaluation to an area surrounding a previous survey of 134 sites.
1993	India	800 site soil gas survey in the Pranhita -Godavari Basin, India.
1992	Argentina	300 site added to detail prospect (1991) over large frontier block.
1992	Seattle, Washington	265 site survey to highgrade coal-bed methane prospect area.
1992	Colorado/Kansas Morrow Sand Trend*	313 site detail survey to further define drillable prospects.
1992	Colorado/Kansas* Morrow Sand Trend	428 site survey to highgrade acreage and rank prospects.
1992	Nacogdoches County, Texas	172 site detail survey to delineate prospect area.
1992	Sheridan County, Montana	103 site reconnaissance survey to evaluate prospective acreage.
1992	Van Zandt County, Texas	428 site reconnaissance survey to highgrade large acreage block.
1992	Comanche County Kansas	208 site detail survey to further delineate seismically defined prospects.
1992	Uvalde/Medina Counties, Texas	149 site reconnaissance survey to evaluate prospect areas
1992	Stuben County, New York	300 site reconnaissance survey to highgrade large acreage position.
1992	Lawrence County	540 site detail survey to further Ohio delineate drillable prospects.
1992	Ethiopia	558 reconnaissance survey to test geochemical methods and techniques.
1992	Yemen	345 site reconnaissance survey to highgrade five (5) prospective areas.
1992	Argentina	1651 site reconnaissance survey to evaluate a rank frontier area for exploration

1991	Argentina	275 site regional reconnaissance grid.
1991	Argentina	72 site regional reconnaissance grid.
1991	Panama	186 site soil gas reconnaissance survey conducted along Changuinola River using free, dissolved and adsorbed gases in rain forest environments.
1991	Lawrence County	392 site reconnaissance geochemical Ohio survey.
1991	Lawrence County	176 site calibration grid survey over Ohio Greasy Ridge Oil Field in Ohio.
1991	Rio Blanco County	136 site soil gas reconnaissance Colorado survey over Weber Prospects.
1991	Argentina	1500 4 ft. soil gas probe survey conducted over large regional frontier block.
1991	Wyandot County	387 site soil gas survey using 4 ft. Ohio probe technique.
1991	South Butte Valley, Nevada	200 site prospect detail.
1991	Tuscaloosa Prospect Survey	559 site soil gas survey over Tuscaloosa prospect in St. Helena Parish, Louisiana.
1990	Calibration Survey Cook County, Texas	125 site soil gas calibration over North Walnut Bend Oil Field, Cook County, Texas.
1990	Calibration Surveys	387 site soil gas calibration over Baywood and Beaver Dam Creek Fields in Beaver Dam Creek St. Helena Parish, Louisiana.
1990	Argentina Chaco Basin	300 site grid of soil gas and sediment cores for free gas, disaggregation gas, and 3-D and synchronous fluorescence.
1990	Argentina	1000 soil gas samples on regional grid in for pre-lease evaluation.
1990	Newark Valley, Nevada*	250 site gridded detail over selected blocks.
1990	Huntington Valley, Nevada*	918 site regional grid analyzed for C1-C4 hydrocarbons.
1990	Tunisia	800 site regional grid consisting of sediment disaggregation gas analyzed for C1-C4 and C5 plus gasoline range hydrocarbons and 2-D and synchronous fluorescence of aromatic hydrocarbons.
1989	Argentina Neuquen Basin	1250 4 ft. probe soil gas sites placed regional grid in Neuquen Basin to evaluate 1 million acre block.

1989	Argentina, Neuquen Basin Calibration Study*	244 site soil gas calibration survey over Filo Morado and Loma de Lata oil and gas condensate fields.
1989	Tyler, Texas	125 site soil gas study to locate Paluxy sand trends.
1989	Tunisia	220 site regional study consisting of soil and sediment disaggregation gas analyzed for C1-C4 and C5 plus gasoline range hydrocarbons and 2-D and synchronous fluorescence of aromatic hydrocarbons.
1989	North Yemen	556 4 ft. probe soil gas study.
1989	Argentina	655 4 ft. probe soil gas study of concession study.
1989	Midland, Texas	92 4 ft. probe soil gas study over known field.
1989	North Carolina	450 4 ft. probe soil gas study in Triassic Basin.
1989	California	200 4 ft. probe gridded study over 2 producing fields.
1988	Northeast Texas	500 4 ft. soil gas probe sample study over producing trend.
1988	Western Overthurst Belt*	1690 4 ft. probe soil gas locations, regional study.
1988	Triassic Basins, Maryland	1200 4 ft. soil gas probe samples in a regional grid of eastern Maryland
1988	Great Basin, Nevada*	4650 4 ft. soil gas probe study in a regional survey of six valleys
1988	Western Kansas*	1100 4 ft. soil gas probe samples for a regional grid study.
1987	Pine Valley, Nevada*	950 4 ft. probe sites for a regional evaluation of Pine Valley, Nevada
1987	Loreto, Italy	190 4 ft. probe samples over prospective leases, Loreto Area, Italy.
1987	Western Overthrust Belt*	2000 4 ft. soil gas probe sample in a regional grid.
1987	Railroad Valley, Nevada	175 4 ft. soil gas probe studies Northern Railroad Valley
1987	North White River Valley	150 4 ft soil gas probe samples.
1987	Western Kansas*	800 4 ft. soil gas probe samples for a regional grid study.
1987	North East Texas	500 4 ft. gas probe samples in a regional grid.
1987	Triassic Basins	280 4 ft. probe site soil gas study.
1987	Skull Valley, Utah*	160 soil gas sites.
1986	Upper Magdalena Valley	501 4 ft probe site geochemical survey in the Upper

	Colombia	Magdalena Valley, Colombia, South America.
1986	Jakes Valley, Nevada	260 4 ft. probe sites for a regional evaluation of Jakes Valley, Nevada.
1986	White River Valley Regional*	500 4 ft. probe sites for a regional of White River Valley.
1986	White River Valley	90 4 ft. probe sites along seismic line.
1986	White River Valley	1000 4 ft. probe sites for a regional study of White River Valley.
1986	Central Kentucky	300 4 ft. probe sites in regional and prospect evaluation studies in central Kentucky.
1986	Michigan	120 4 ft. probe sites along seismic prospect, Michigan.
1986	Central Ohio	210 4 ft. probe sites over prospective areas of productive trend.
1986	Triassic Basins	150 4 ft. soil gas probe test study in the Triassic Basins.
1985	Wilson County, Texas	100 sites over Austin/Chalk Budda trend prospects.
1985	Rocky Mountain Regional Study	200 4 ft. probe sites in four Rocky Mountain Basins for technique verification.
1985	Railroad Valley, Nevada*	450 4 ft. probe samples in 1/10 mile grid on a regional geochemical anomaly, Currant area of Railroad Valley, Nevada.
1985	West Texas	300 4 ft. probe sites over four prospect areas in west Texas.
1985	Southeast Texas*	370 4 ft. probe sites for a regional survey along a producing trend in southeast Texas.
1985	Wyoming, Utah Overthrust Belt	250 4 ft. probe sites along Airborne spectrometer survey lines.
1985	Sweetwater Arch Wyoming*	1250 4 ft. probe sites for a regional survey of the Overthrust Belt.
1985	Nevada Regional*	2150 4 ft. probe sites for a regional survey of four valleys in central Nevada.
1984	Railroad Valley, Nevada*	450 4 ft. probe sites in a regional grid of Railroad Valley.
1984	Stoney Point Field Michigan	200 4 ft. probe sites for calibration of soil gas seepage over the Stoney Point Field.
1984	Albion Scipio Trend Michigan	160 4 ft. probe sites to delineate prospective areas.

1984	Central Ohio	300 4 ft. probe sites over prospect area in central Ohio.
1984	Garden Valley Nevada	225 4 ft. probe samples collected along seismic lines.

12 FOOT DRILL SOIL GAS SURVEYS

1985	Uinta Basin Utah*	550 12 ft. drill sites in regional survey of a portion of the Uinta Basin.
1985	East Granite Mountains Wyoming*	275 12 ft. drill sites on regional lines and seismic lines and seismic lines to delineate hydrocarbon trends.
1985	North Garden Valley Nevada*	315 12 ft. drill and 4 ft. probe sites along regional seismic lines as continuation of 1984 program.
1985	Grant Canyon Field Railroad Valley, Nevada*	200 12 ft. drill sites on regional lines and seismic lines to delineate hydrocarbon trends.
1984-1985	San Joaquin Valley, California*	1600 12 ft. drill sites in regional survey of the central and north central San Joaquin Valley. All samples were analyzed in mobile field laboratory.
1984	East Texas	300 12 ft. drill sites collected to supplement seismic exploration data acquisition. All samples run on site in laboratory van.
1984	Four Corners, Arizona*	200 12 ft. drill and 4 ft. probe sites on a regional grid. All samples were analyzed in a mobile field laboratory.
1984	Garden Valley, Nevada*	225 12 ft. drill and 4 ft. probe samples collected along seismic lines. Samples analyzed for C1-C4 by gas chromatography, He by leak detector.

**** Indicates Surveys Available for Resale***

9. CLIENT REFERENCE LIST

- AMOCO PRODUCTION COMPANY
- ANADARKO PETROLEUM CORP.
- APACHE CORPORATION
- ARCADIS G&M
- BEASON ENERGY
- BELL ENERGY, CORPORATION
- BROKEN HILLS PROPERTIES
- BROWN AND CALDWELL
- CALIK ENERGY
- CANADIAN OCCIDENTAL PETROLEUM
- CDS, ENERGY
- CENTURION PIPELINE
- CLIVEDEN PETROLEUM
- CNG CONSOLIDATED GAS COMPANY
- CORPOVEN
- CONOCO-PHILLIPS
- DCH ENVIRONMENTAL
- ENRON OIL & GAS COMPANY
- ENTERPRISE OIL
- ENSR
- EOG CANADA
- EXXON COMPANY, USA
- FORTESA INTERNATIONAL
- FRONTERA RESOURCES
- FUGRO-McCLELLAND MARINE
- GEOSCIENCES, INC.
- GME CONSULTING
- HINDUSTAN OIL EXPLORATION CO.
- HUNT OIL COMPANY
- ILLINOIS INSTITUTE OF TECHNOLOGY
- LOPER GROUP
- MAGNUM HUNTER
- MARATHON PETROLEUM EGYPT, LTD.
- MARATHON OIL COMPANY
- MARAVEN
- MATRIX ENVIRONMENTAL
- MAYFAIR PETROLEUM, LTD.
- MERIDIAN OIL COMPANY
- MOBIL OIL CORPORATION
- MITCHELL ENERGY CORPORATION
- NIMIR ENERGY SERVICES
- ORIENT PETROLEUM
- OXY USA INC.
- OXY INTERNATIONAL PETROLEUM
- PETROLEOS DE VENEZUELA (PDVSA)
- PETROLEOS MEXICANOS (PEMEX)
- PERENCO ECUADOR LTD.
- PHILLIPS PETROLEUM COMPANY
- PLAINSMEN PARTNERS
- SAMSON RESOURCES
- SHELL OIL COMPANY
- TERRACON
- TEXACO OVERSEAS HOLDINGS, INC.
- TEXACO PRODUCING, INC.
- TEXACO USA
- TEXAS A&M UNIVERSITY –
- TYLER ROCKIES
- GEOCHEMICAL & ENVIRONMENTAL
- TOLUNAY-WONG
- RESEARCH GROUP
- TOTAL FINA ELF
- TREND ARGENTINA, S.A.
- TRINITY GAS CORPORATION
- TURKIYE PETROLLERI A.O.
- UNION OIL COMPANY OF CALIFORNIA
- UNION TEXAS PETROLEUM CORP.
- YEMEN HUNT OIL COMPANY
- ZINN PETROLEUM COMPANY