

# **Sixth Annual Conference on Carbon Capture & Sequestration**

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*Geologic Storage MMV(2)*

*Application of Exploration Geochemical Methodology  
to CO<sub>2</sub> Monitoring*

Victor T. Jones, Exploration Technologies Inc.

and

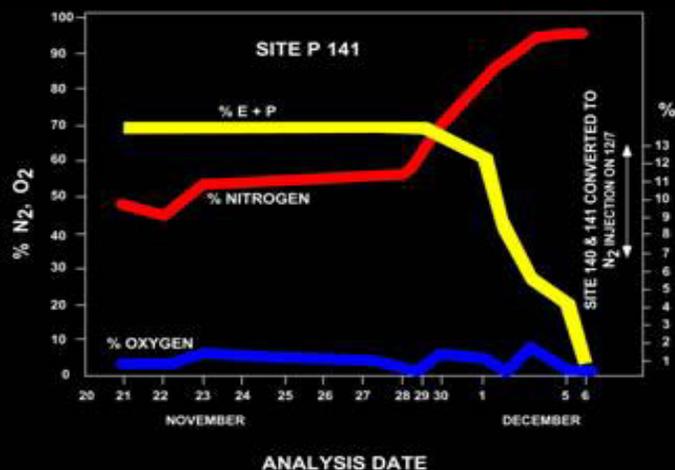
Robert J. Pirkle, Microseeps Inc.

May 7-10, 2007 • Sheraton Station Square • Pittsburgh, Pennsylvania

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# *Application of Exploration Geochemical Methodology to CO<sub>2</sub> Monitoring*

**May 7 - 10, 2007**  
**Sheraton Station Square Hotel**  
**Pittsburgh, Pennsylvania**



*Presented by*  
**EXPLORATION TECHNOLOGIES, Inc.**  
**7755 Synott Road**  
**Houston, Texas**  
*Victor T. Jones, III, PhD..*

*Co-authored by*  
**MICROSEEPS, Inc.**  
**Gulf Lab Road**  
**Pittsburgh, Pa**  
*Robert J. Pirkle, PhD..*

**Applications of Petroleum Exploration and Environmental Geochemistry to Carbon Sequestration**  
poster paper presented at the 5<sup>th</sup> Annual CO<sub>2</sub> Carbon Sequestration Conference  
supported by **Sally Benson** at **The Lawrence Berkeley National Laboratory**  
under LBNL Subcontract No. 6804108

available at <http://www.eti-geochemistry.com/FinalVersion1.10.htm>

## **Yes** Reservoirs Leak? Let's Consider 140 Years of History

**1859 Edwin L. Drake drilled first oil well on macroseep**

**1959 Centennial issue Oil & Gas Journal confirms drilling on seeps has found more oil than any other method**

**1981 JOHN HUNT at the AAPG San Francisco Annual Meeting  
70% of Known Reserves Related to Seeps**

**1972-1983 Gulf Research & Development Company  
conducted an extensive surface and marine geochemical  
exploration program that established the compositional  
relationships of surface seepage to their associated  
reservoirs**

**2003 LARRY CATHLES Cornell University published article in  
Geotimes: "Raining Hydrocarbons in the Gulf"**

**JEAN WEHLAN 99 % of Hydrocarbons Generated in Subsurface  
Are Expulsed and are not Trapped in Reservoirs**



How can reservoir leaks be found?  
 Measure mobile reservoir gases:  
 methane, ethane, propane and butane

V.I. GONZALEZ AND H.G. DROZ

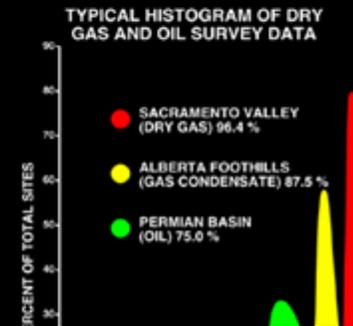
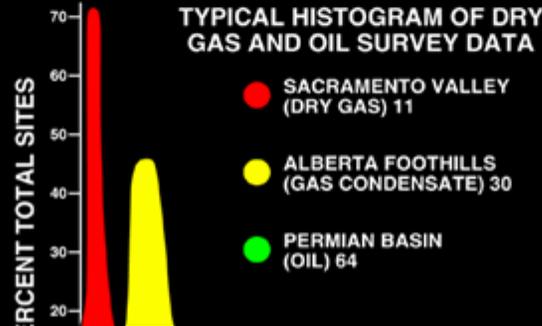
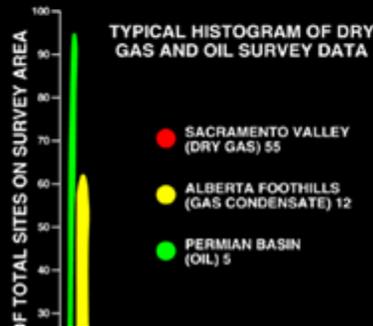
COMPOSITIONS OF TYPICAL C1 TO C4  
 RESERVOIR HYDROCARBONS

LOCATION OF GAS, OIL AND CONDENSATE SURVEYS



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

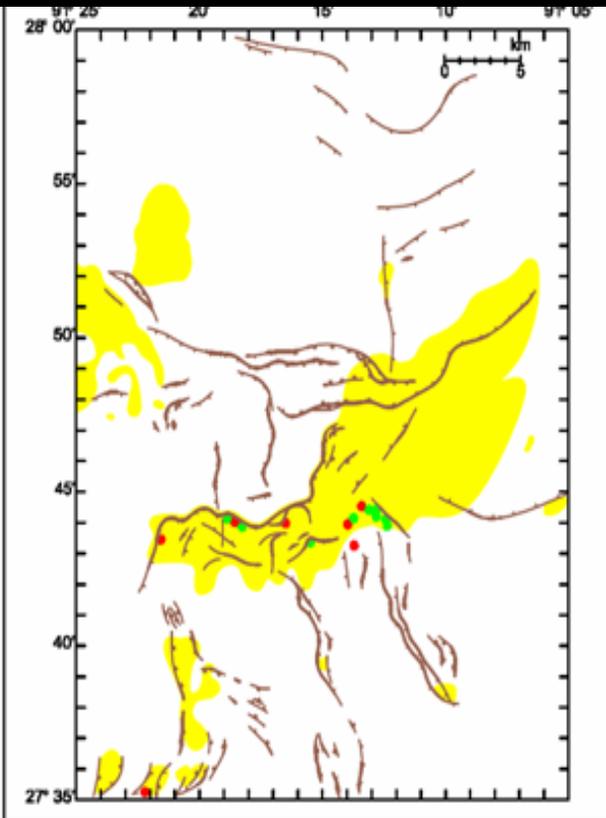
*\*In mole fractions. After Katz and Williams (1952)*



# Mud Logging

# Soil Gases

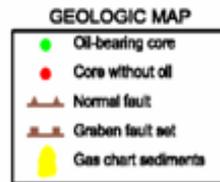
# Reservoir Gases



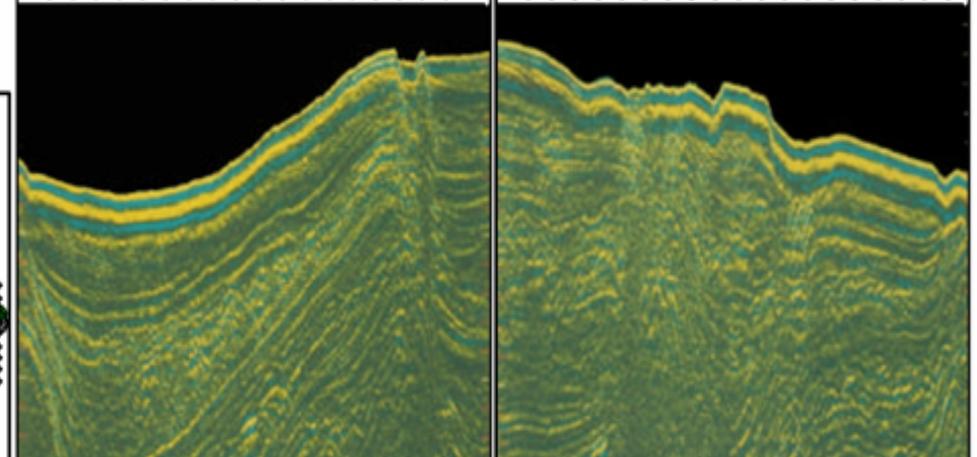
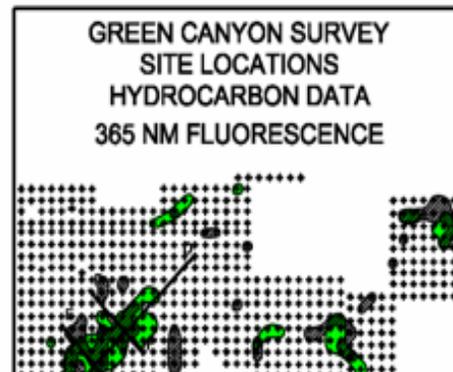
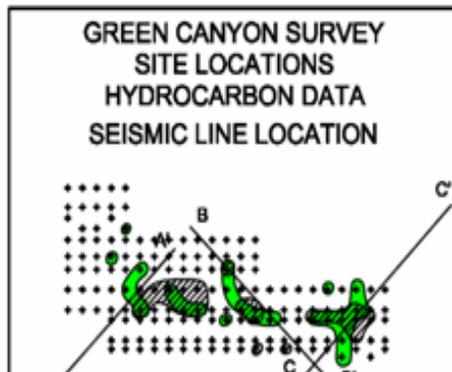
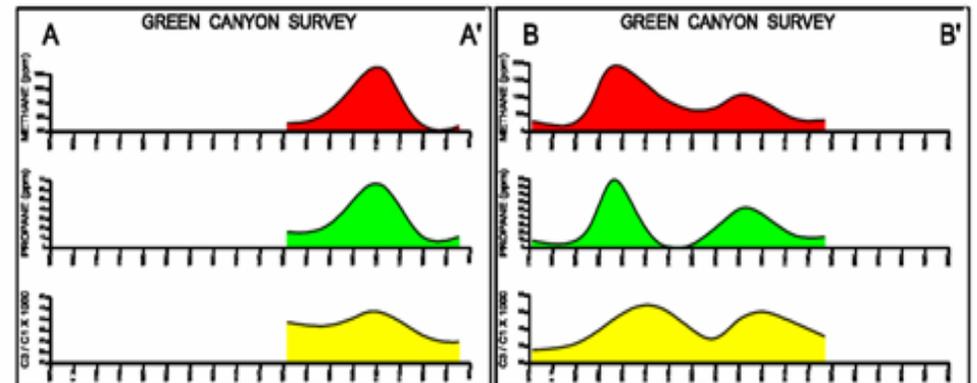
## DEEP WATER MARINE GEOCHEMICAL CORING

### Data Example: Green Canyon, Gulf of Mexico

Regional marine coring programs were used to map the locations of oil and gas seepage in the Green Canyon area prior to extensive drilling. Anomalous headspace gas light hydrocarbon and sediment extract fluorescence results confirmed that seeps were associated with seabed faults, salt structures, gas charged zones and other migration pathways from source formations and reservoirs at depth. Macro oil and gas seeps were also identified. Subsequent exploration drilling has resulted in the discovery of significant petroleum reserves.



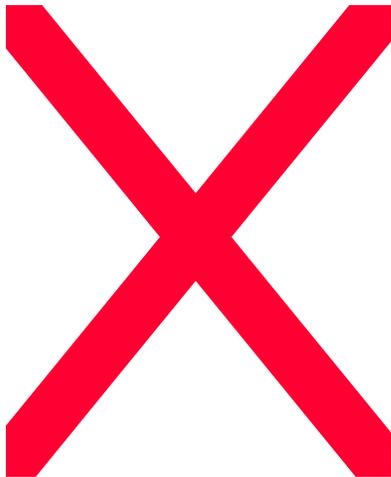
UT INSTITUTE FOR GEOPHYSICS  
UPPER-SLOPE OILSEEP STUDY  
E. W. Behrens, Dec. 1983



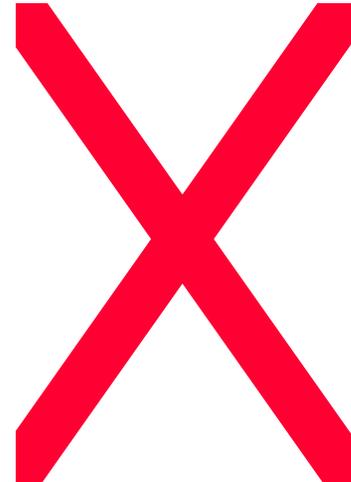


## What are the conduits for vertical migration ?

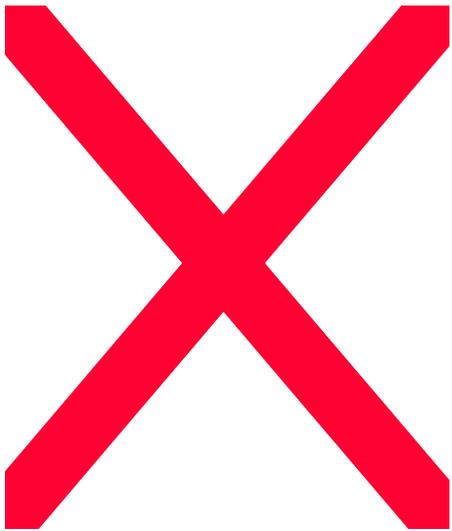
Macroseeps -  
Bedding planes/major faults



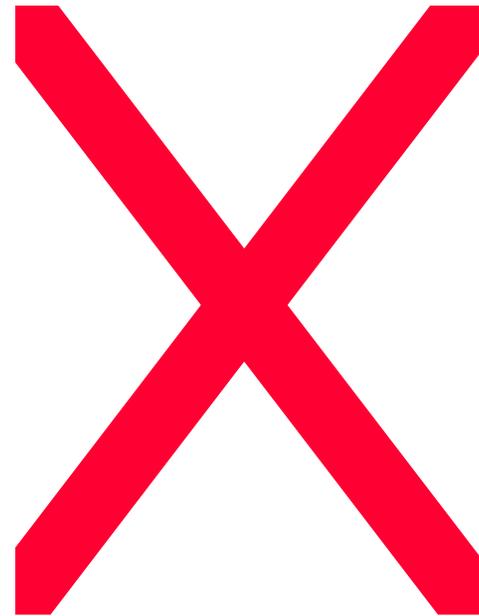
Microseeps  
minor faults/fractures/joints



Macro



Micro



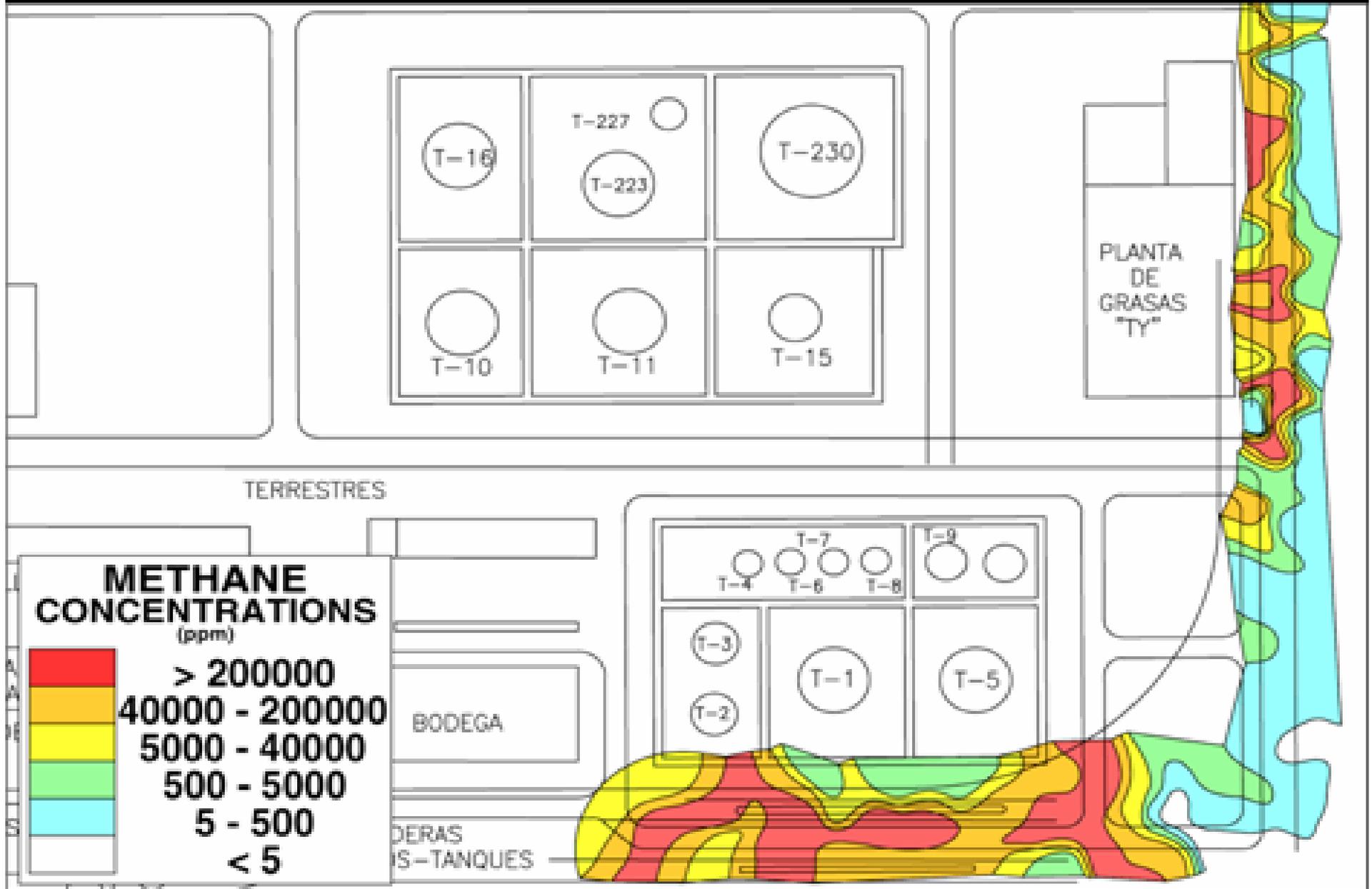
**1976 First Soil Gas Discovery in Powder River Basin**  
**Hartzog Draw 2<sup>nd</sup> Biggest Field in a Mature Basin**



# 1979 Macro Seeps Found Directly over Green Canyon Oil Field

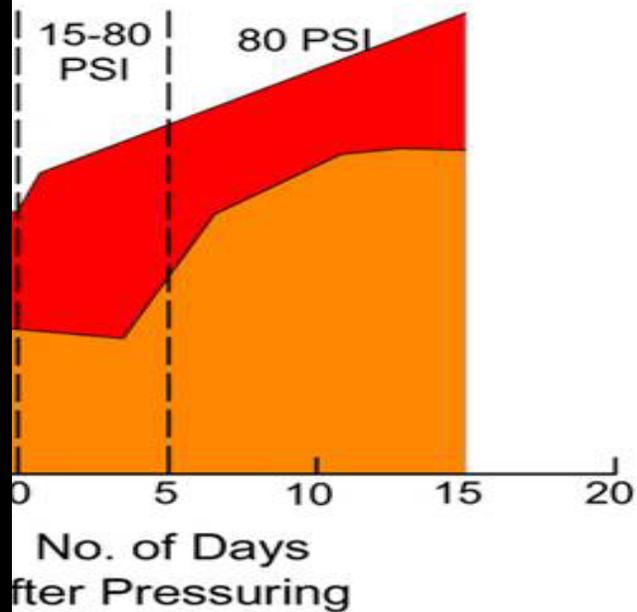


# 1987 Soil Gas Survey Discovers 35 MMB Kansas Stateline Field

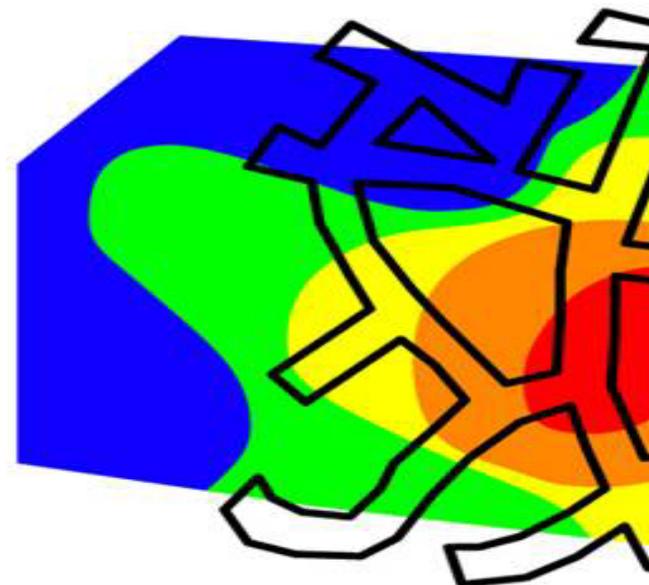


# MAGNITUDE RELATED TO PRESSURE AND PERMEABILITY

PROPANE RECHARGE ABOVE  
PROPANE STORAGE CAVERN  
OCTOBER 1981



No. of Days Until  
Propane Builds

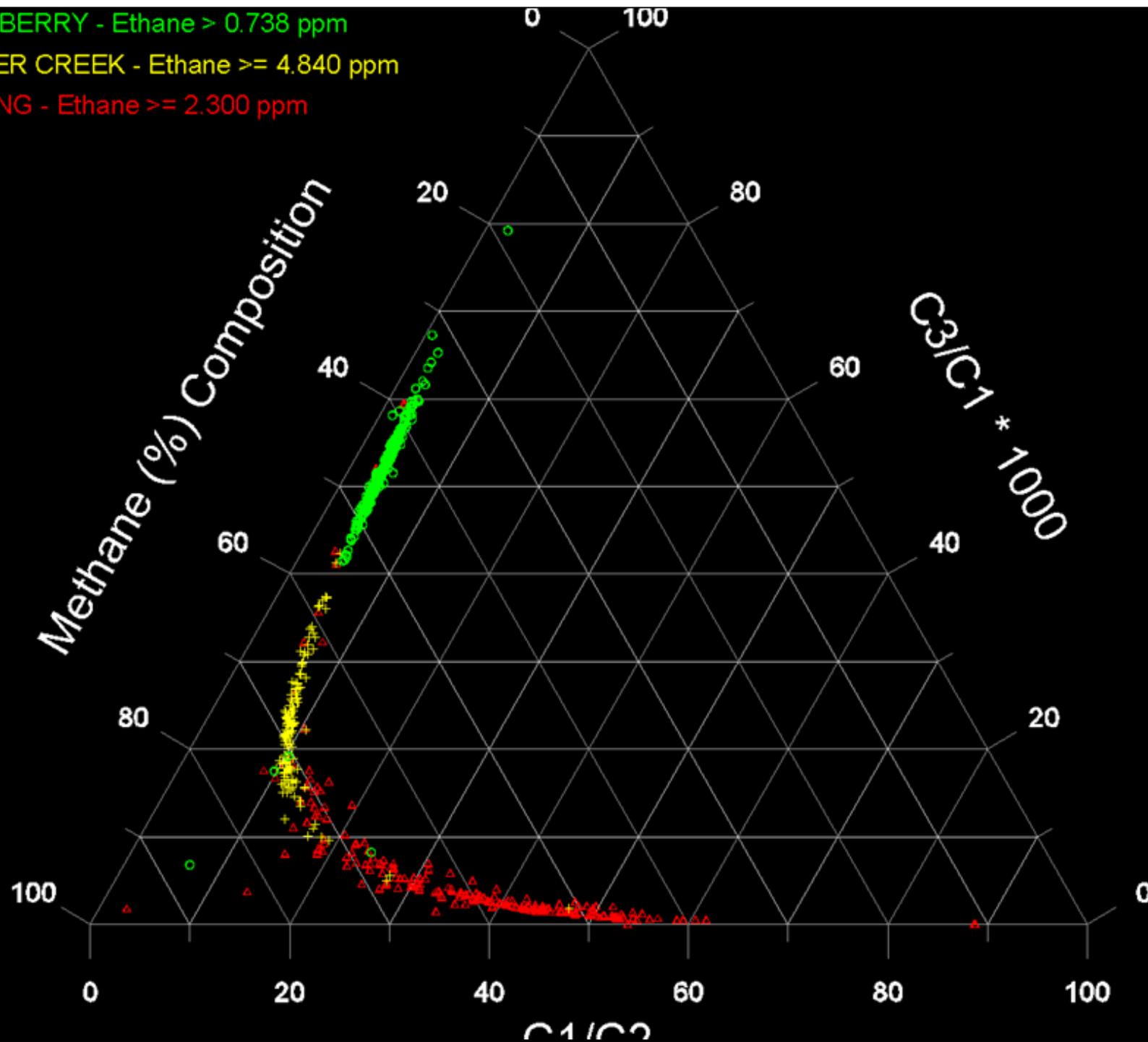


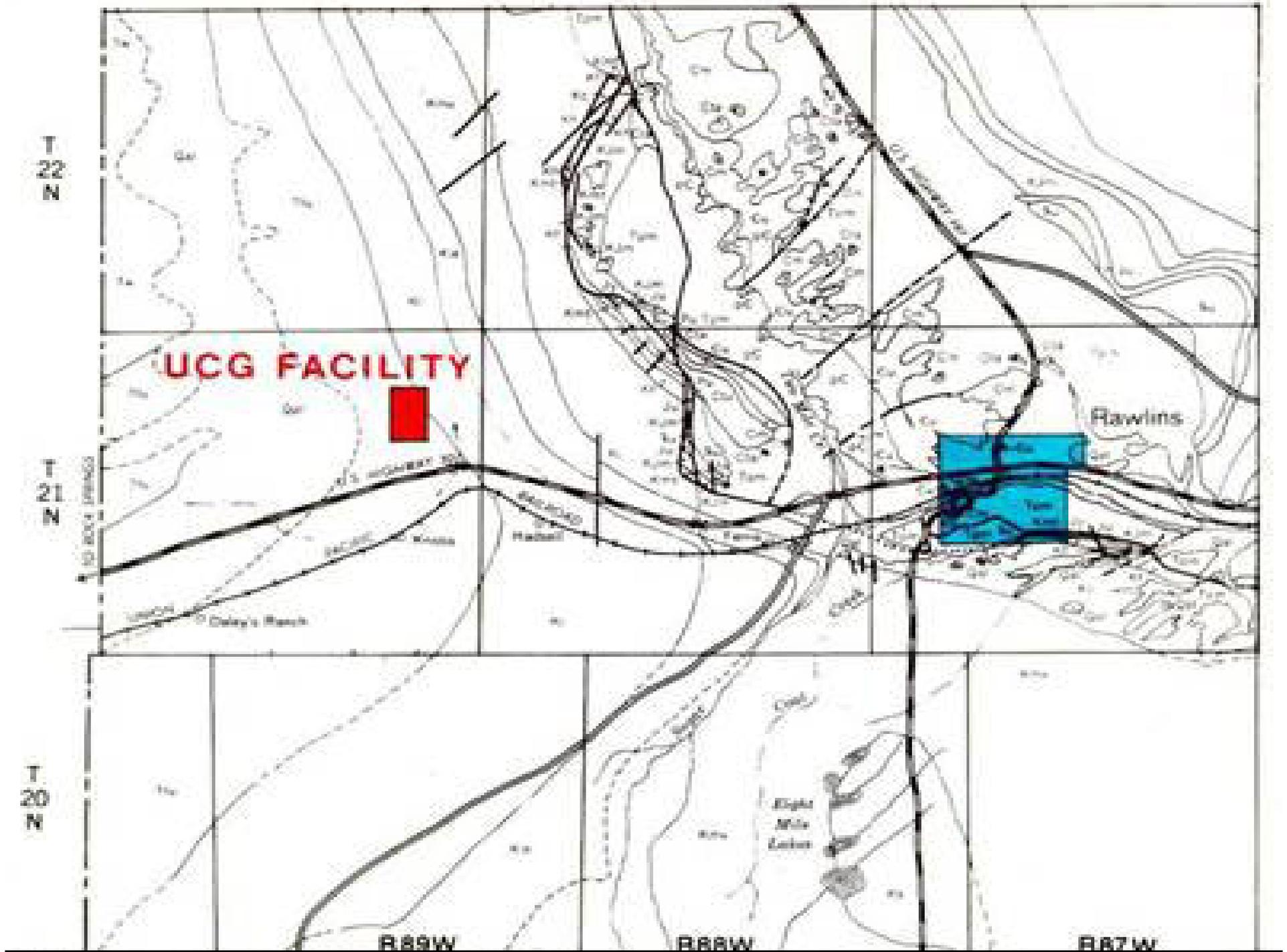
5 - 8

SPRAYBERRY - Ethane > 0.738 ppm

PINCHER CREEK - Ethane >= 4.840 ppm

CORNING - Ethane >= 2.300 ppm



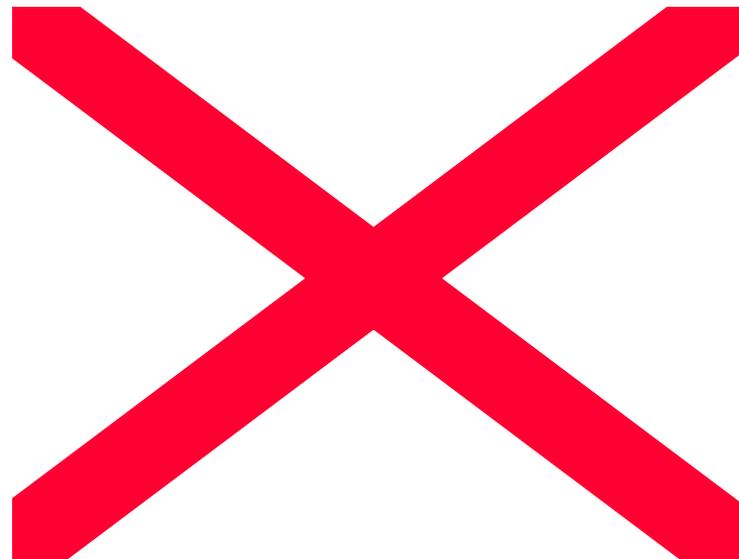




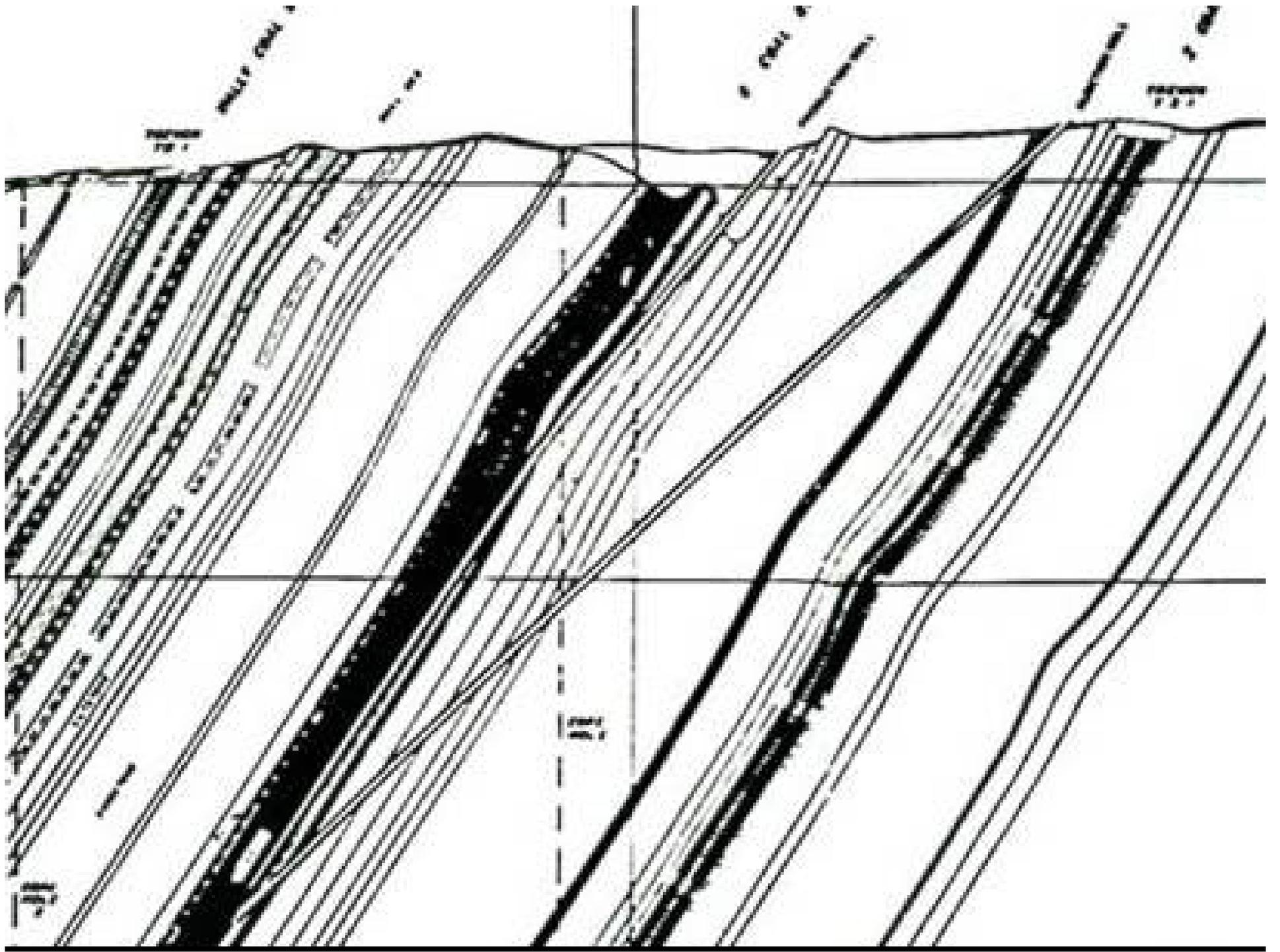




**85% OF HYDROCARBONS GENERATED ARE NOT TRAPPED  
THEY ARE EXPLUSED, AND THIS IS WHAT WE MEASURE**



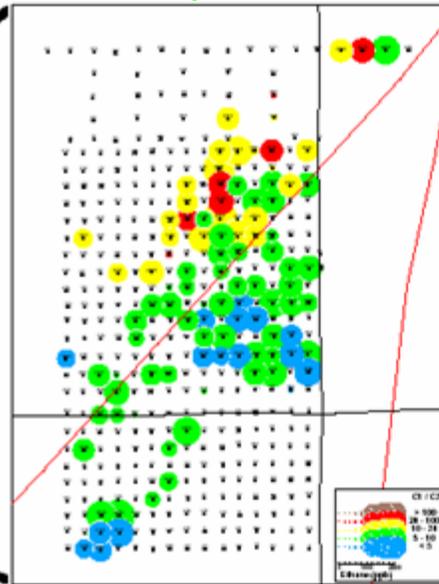
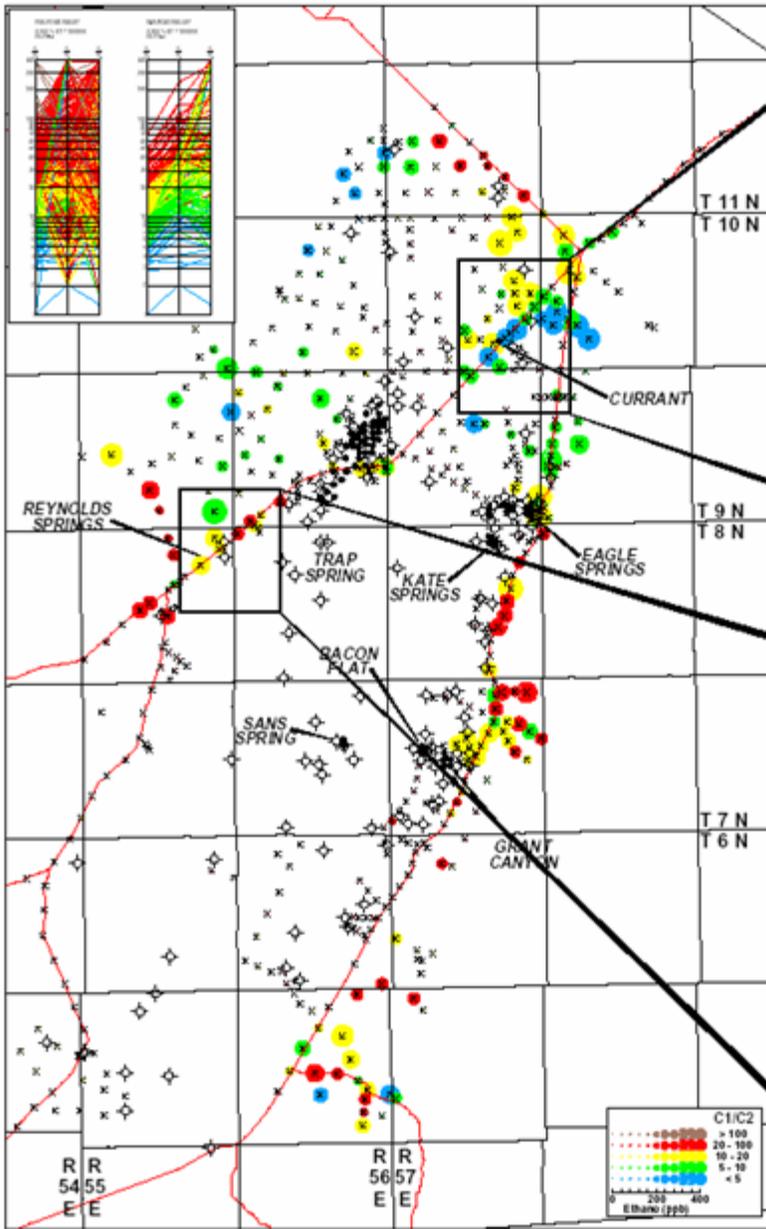




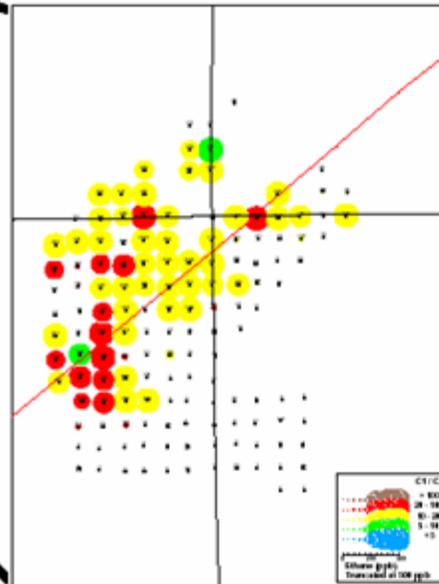
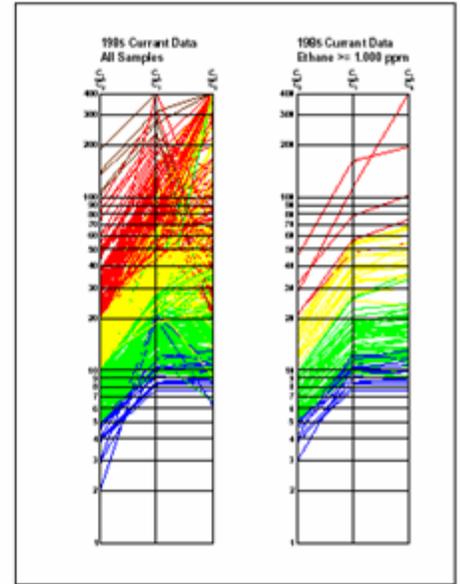
1984

# Reproducibility

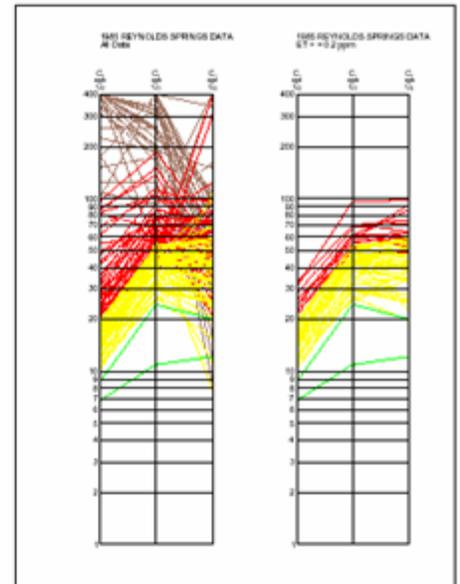
1985



**CURRENT AREA**  
1,000' Centers - Survey Conducted in 1985

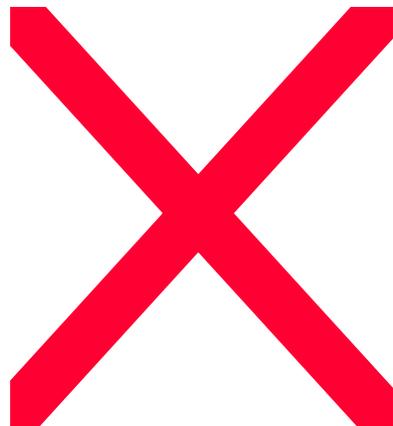
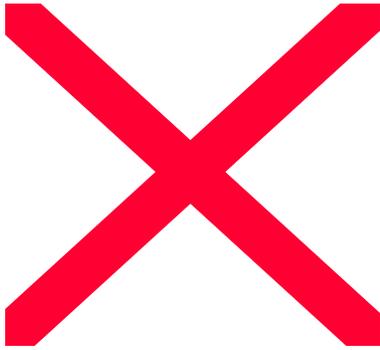


**REYNOLDS SPRINGS AREA**  
1,000' Centers - Survey Conducted in 1985

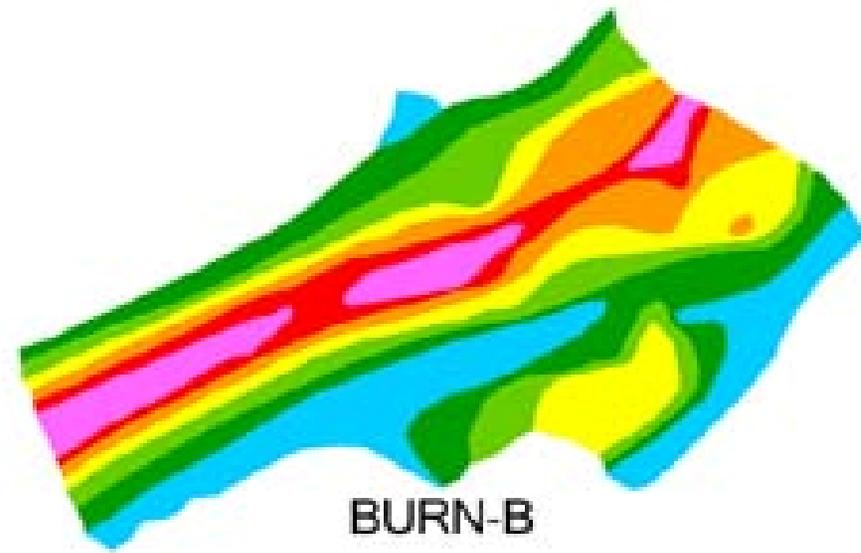
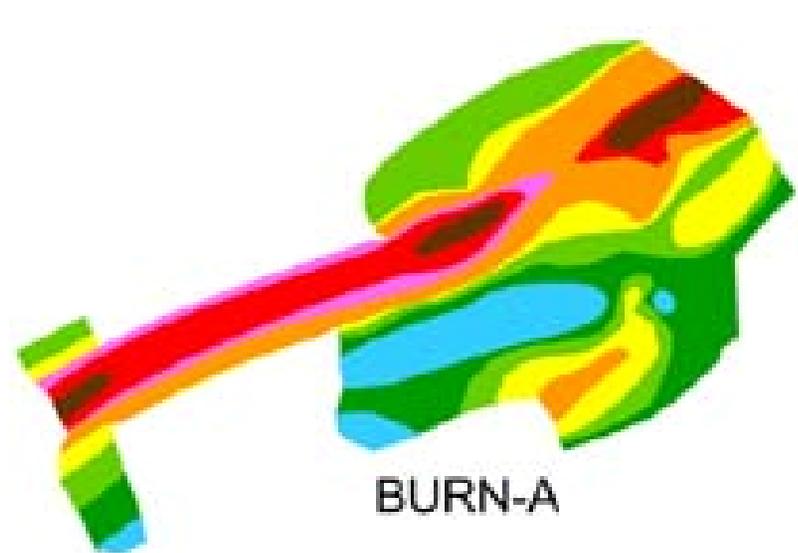
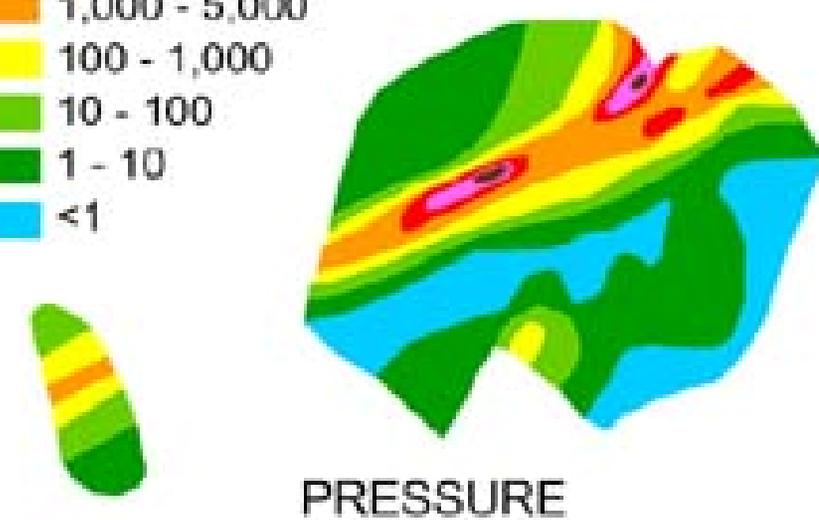
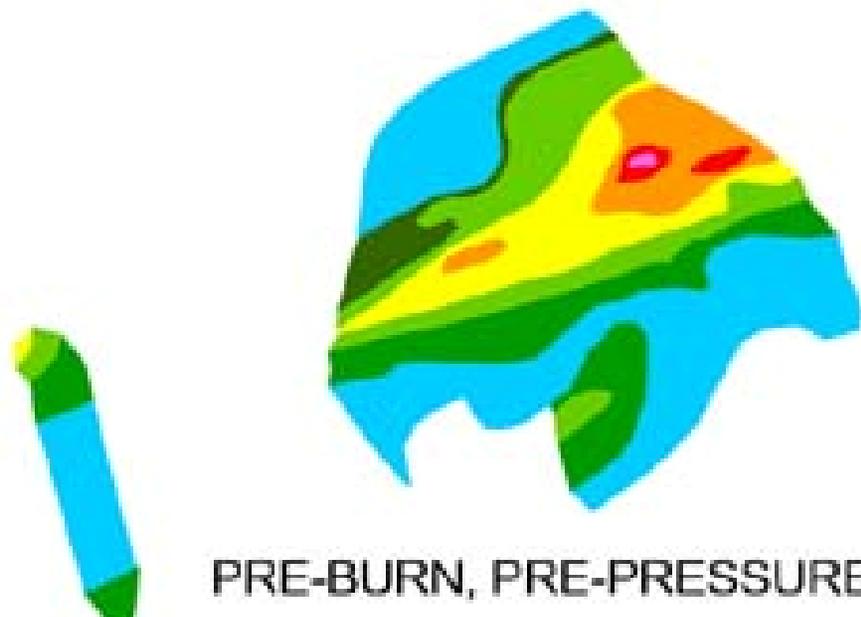
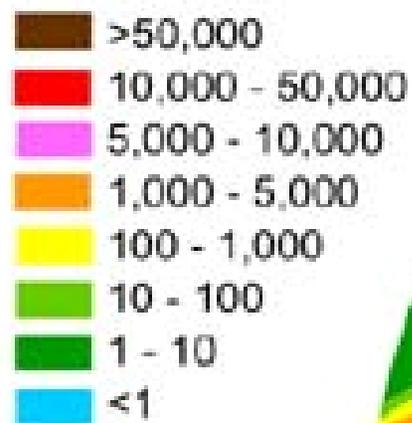


**How Long does it take for migrating gases to reach the surface ?**

**2 to 15 days from 1000 feet in depth**



METHANE - PPM



**TOPOGRAPHIC MAP  
UCG FACILITY  
NORTH KNOBS ROAD  
WYOMING**

CONTOUR INTERVAL = 2'  
SCALE IN FEET  
0 50 100 150 200

—+— LOCAL BASE LINE



EAST LINE SECTION 11 AND FACILITY BOUNDARY

NORTH FACILITY BOUNDARY (11+00')

BASE MIDDLE 'G' COAL

SOUTH FACILITY BOUNDARY (11+00')

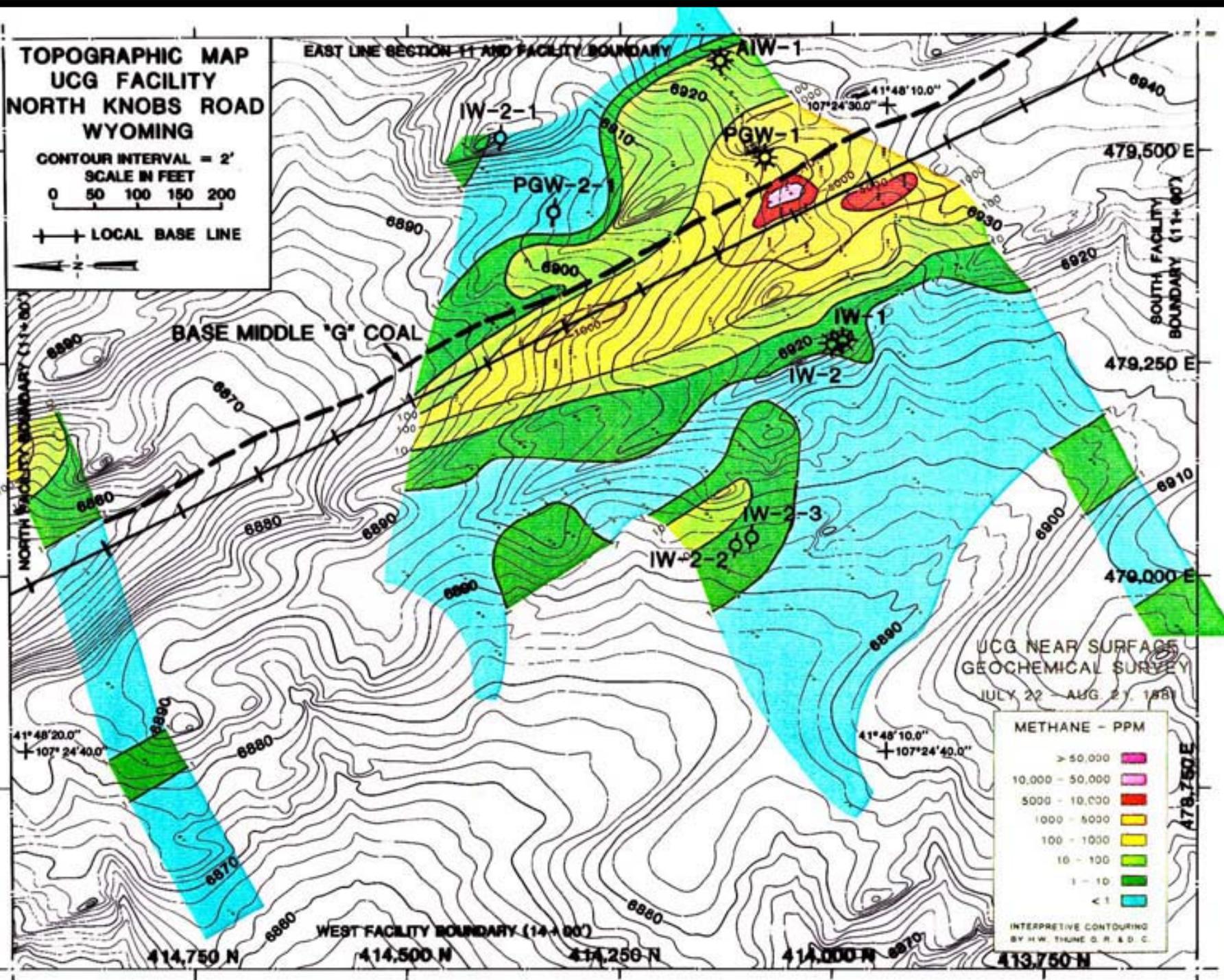
WEST FACILITY BOUNDARY (14+00')

UCG NEAR SURFACE  
GEOCHEMICAL SURVEY  
JULY 22 - AUG 2, 1988

METHANE - PPM

- > 50,000
- 10,000 - 50,000
- 5000 - 10,000
- 1000 - 5000
- 100 - 1000
- 10 - 100
- 1 - 10
- < 1

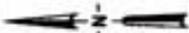
INTERPRETIVE CONTOURING  
BY H.W. THANE G.R. & D.C.



**TOPOGRAPHIC MAP  
UCG FACILITY  
NORTH KNOBS ROAD  
WYOMING**

CONTOUR INTERVAL = 2'  
SCALE IN FEET  
0 50 100 150 200

LOCAL BASE LINE



EAST LINE SECTION 11 AND FACILITY BOUNDARY

NORTH FACILITY BOUNDARY (14-80)

SOUTH FACILITY BOUNDARY (11-80)

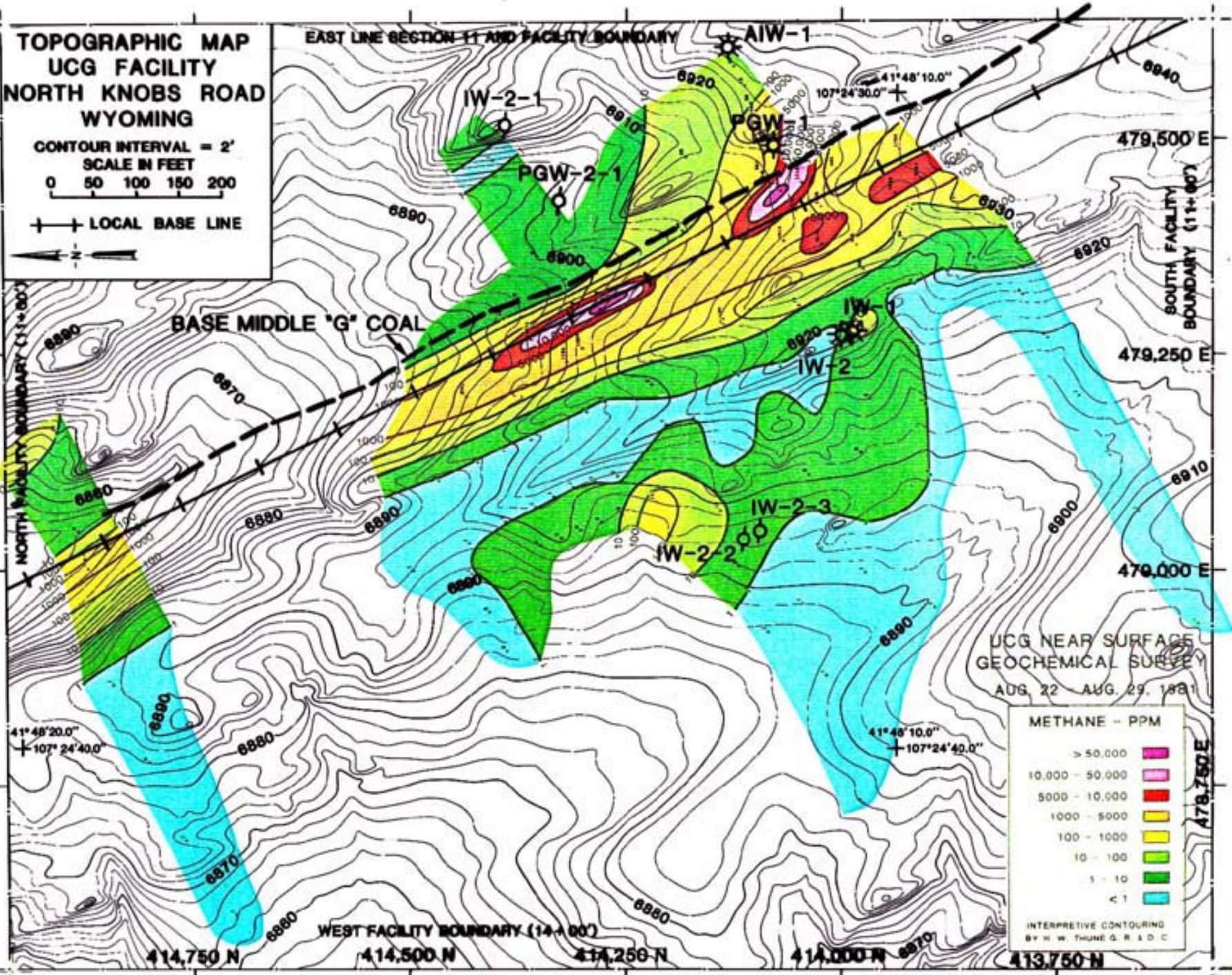
BASE MIDDLE "G" COAL

UCG NEAR SURFACE  
GEOCHEMICAL SURVEY  
AUG. 22 - AUG. 29, 1981

**METHANE - PPM**

> 50,000	
10,000 - 50,000	
5000 - 10,000	
1000 - 5000	
100 - 1000	
10 - 100	
1 - 10	
< 1	

INTERPRETIVE CONTOURING  
BY H. W. THUNE & R. L. D. C.



**TOPOGRAPHIC MAP  
UCG FACILITY  
NORTH KNOBS ROAD  
WYOMING**

CONTOUR INTERVAL = 2'  
SCALE IN FEET  
0 50 100 150 200

LOCAL BASE LINE



EAST LINE SECTION 11 AND FACILITY BOUNDARY

AIW-1

IW-2-1

PGW-1

PGW-2-1

IW-1

IW-2

IW-2-3

IW-2-2

BASE MIDDLE "G" COAL

NORTH FACILITY BOUNDARY (11-00)

SOUTH FACILITY BOUNDARY (11-00)

WEST FACILITY BOUNDARY (14-00)

UCG NEAR SURFACE  
GEOCHEMICAL SURVEY  
AUG. 30 - SEPT. 25, 1988

41°48'20.0"  
107°24'40.0"

41°48'10.0"  
107°24'40.0"

METHANE - PPM

> 50,000	(Pink)
10,000 - 50,000	(Light Pink)
5000 - 10,000	(Red)
1000 - 5000	(Yellow)
100 - 1000	(Light Green)
10 - 100	(Green)
1 - 10	(Light Blue)
< 1	(Cyan)

INTERPRETIVE CONTOURING  
BY H. W. THUNE S. R. B. D. L.

414,750 N

414,500 N

414,250 N

414,000 N

413,750 N

479,500 E

479,250 E

479,000 E

478,750 E

**TOPOGRAPHIC MAP  
UCG FACILITY  
NORTH KNOBS ROAD  
WYOMING**

CONTOUR INTERVAL = 2'  
SCALE IN FEET  
0 50 100 150 200

LOCAL BASE LINE



EAST LINE SECTION 11 AND FACILITY BOUNDARY

AIW-1

IW-2-1

PGW-1

PGW-2-1

479,500 E

SOUTH FACILITY BOUNDARY (11+807)

BASE MIDDLE 'G' COAL

IW-1

IW-2

479,250 E

IW-2-3

IW-2-2

479,000 E

UCG NEAR SURFACE  
GEOCHEMICAL SURVEY  
SEPT 26 DEC 12 1981

METHANE - PPM

> 50,000	Dark Pink
10,000 - 50,000	Light Pink
5,000 - 10,000	Red
1,000 - 5,000	Orange
100 - 1,000	Yellow
10 - 100	Light Green
1 - 10	Green
< 1	Cyan

INTERPRETIVE CONTOURING  
BY H. W. THANE S. R. E. D. C.

WEST FACILITY BOUNDARY (14+807)

414,750 N

414,500 N

414,250 N

414,000 N

413,750 N

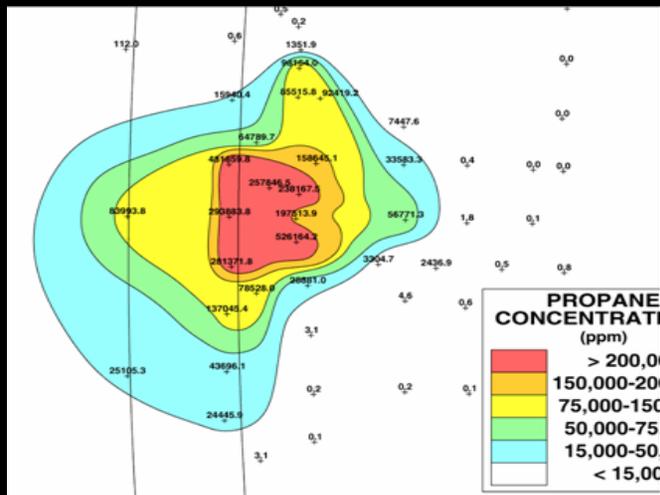
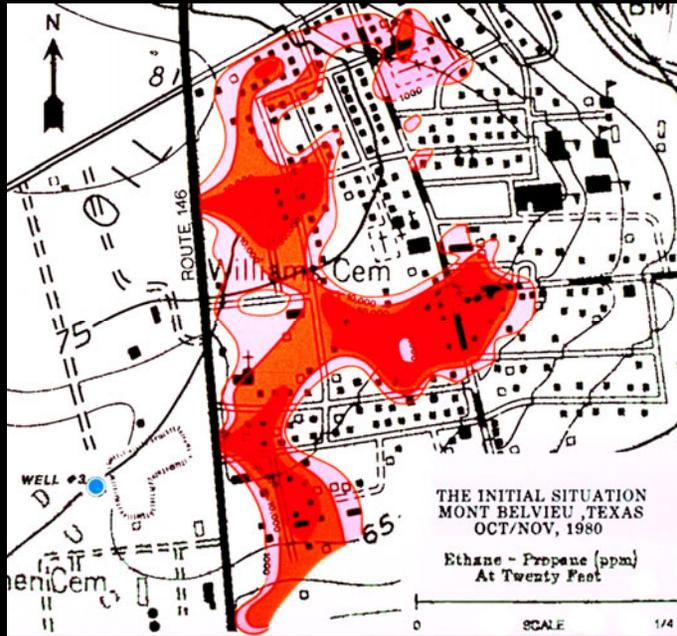
478,750 E

41°48'20.0"  
107°24'40.0"

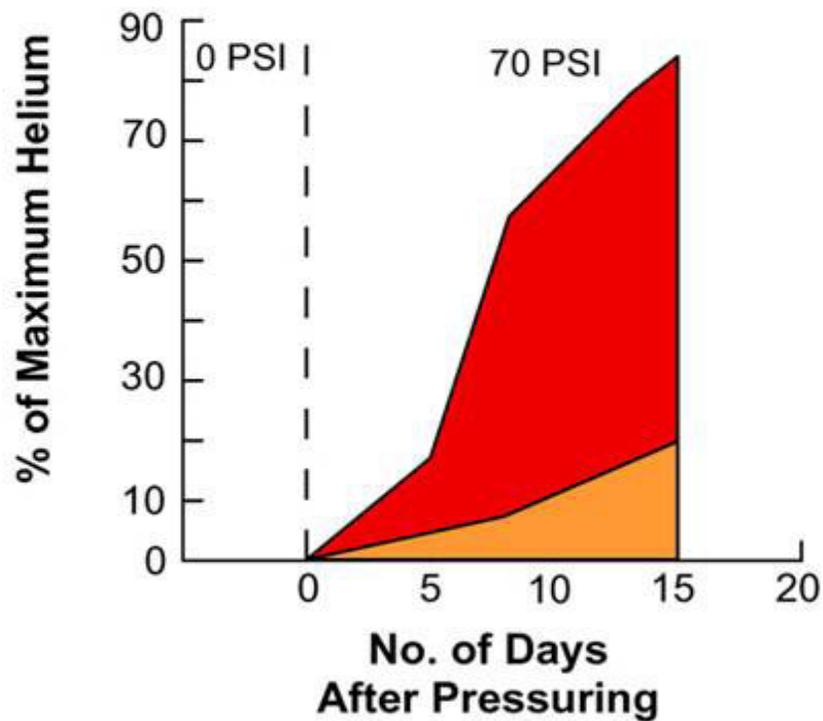
41°48'10.0"  
107°24'40.0"

NORTH FACILITY BOUNDARY (1+807)

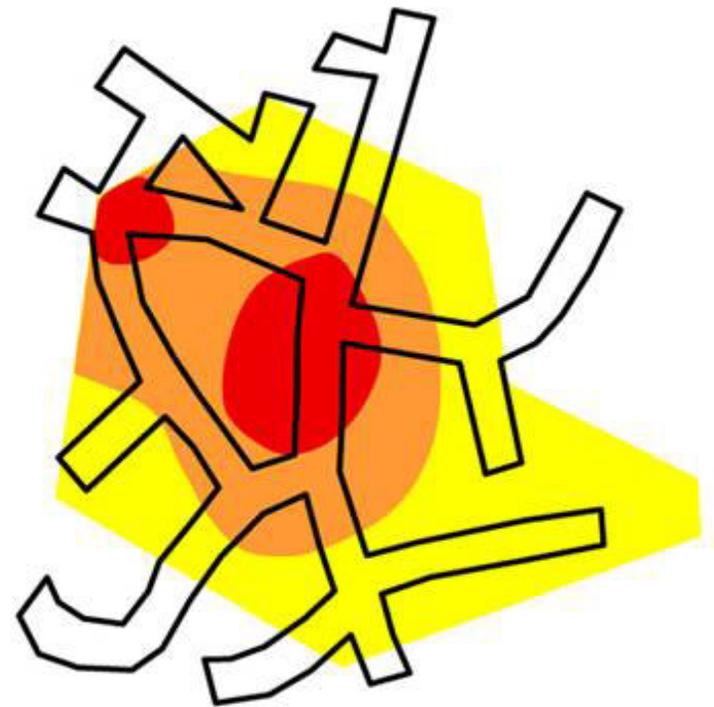
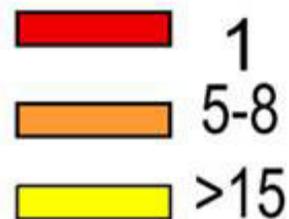
# 1980 Gulf Oil Continuous Monitoring Systems Established in Mount Belvieu, Texas for Monitoring Underground Gas Storage Wells

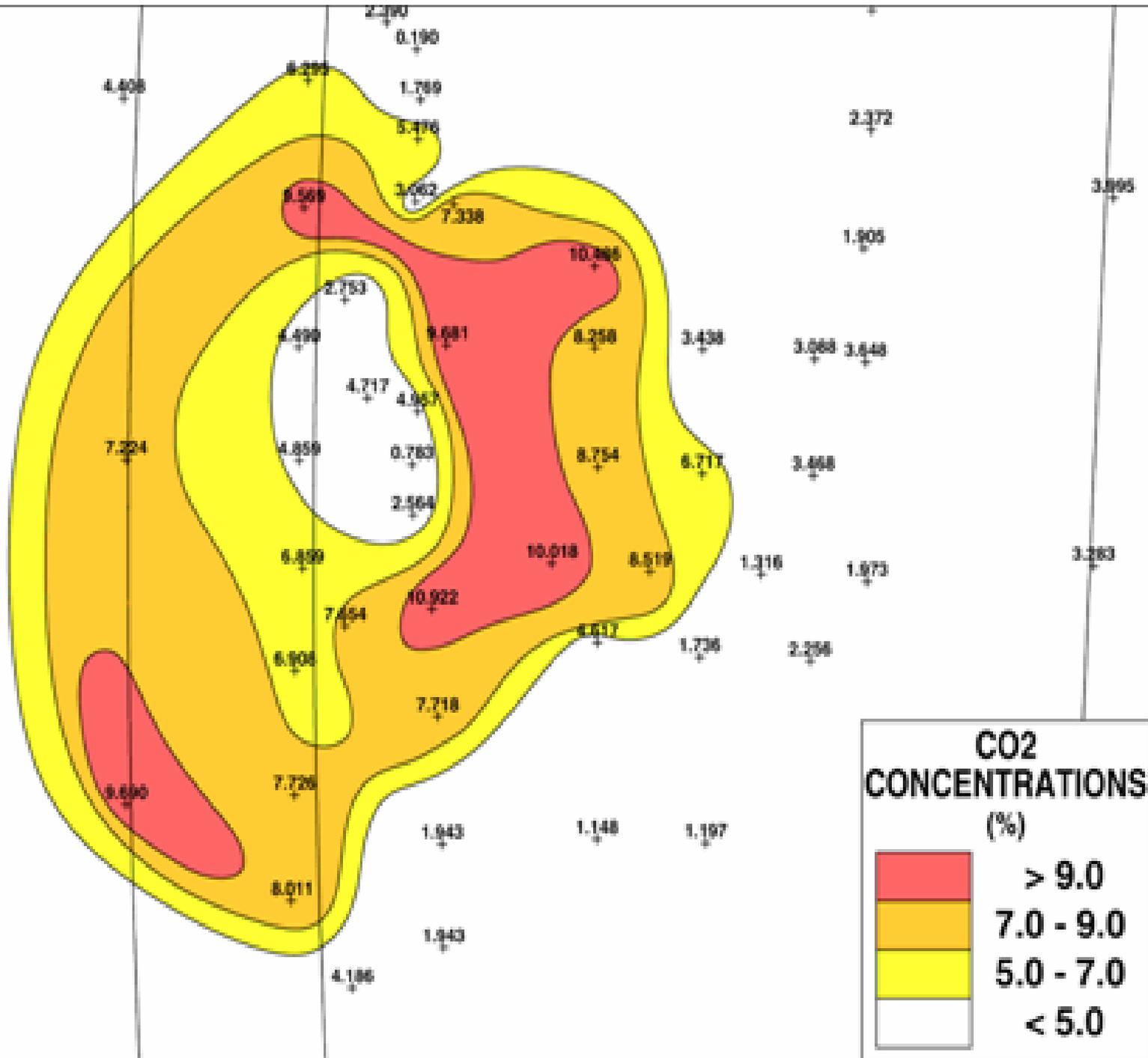


# HELIUM RECHARGE ABOVE PROPANE STORAGE CAVERN OCTOBER 1982



No. of Days Until  
Helium Builds





4.408

2.290

0.190

1.700

8.299

5.490

2.372

8.569

3.002

7.338

3.805

1.905

10.386

2.753

4.490

9.681

8.258

3.438

3.088

3.648

7.224

4.717

4.007

4.859

0.780

2.564

8.754

3.438

3.468

6.717

10.018

1.316

1.973

3.283

6.859

8.519

7.454

10.922

8.617

1.736

2.256

8.690

6.906

7.718

7.718

7.726

1.943

1.148

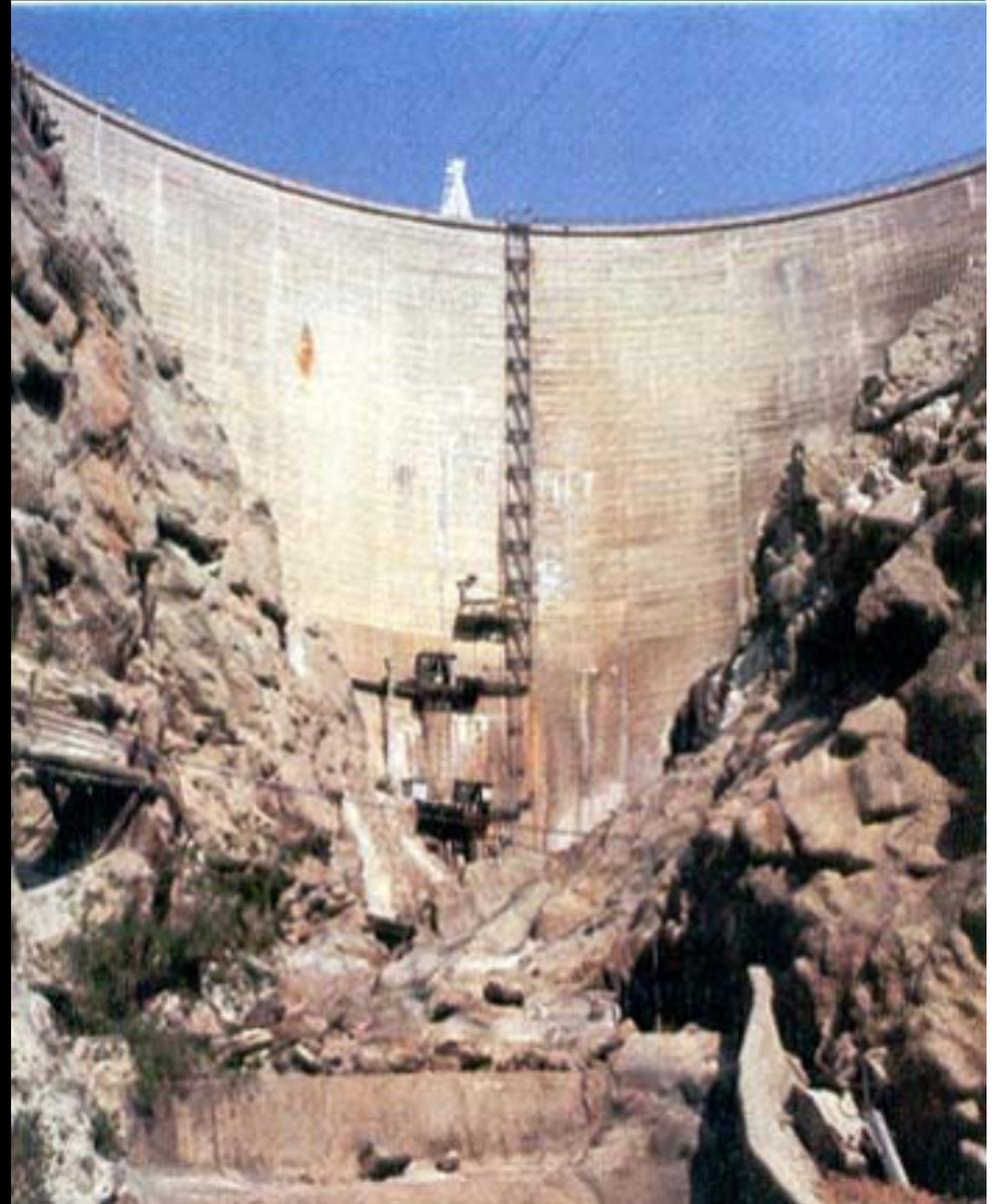
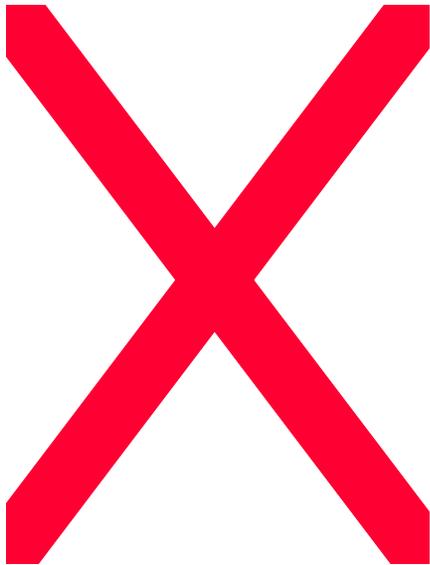
1.197

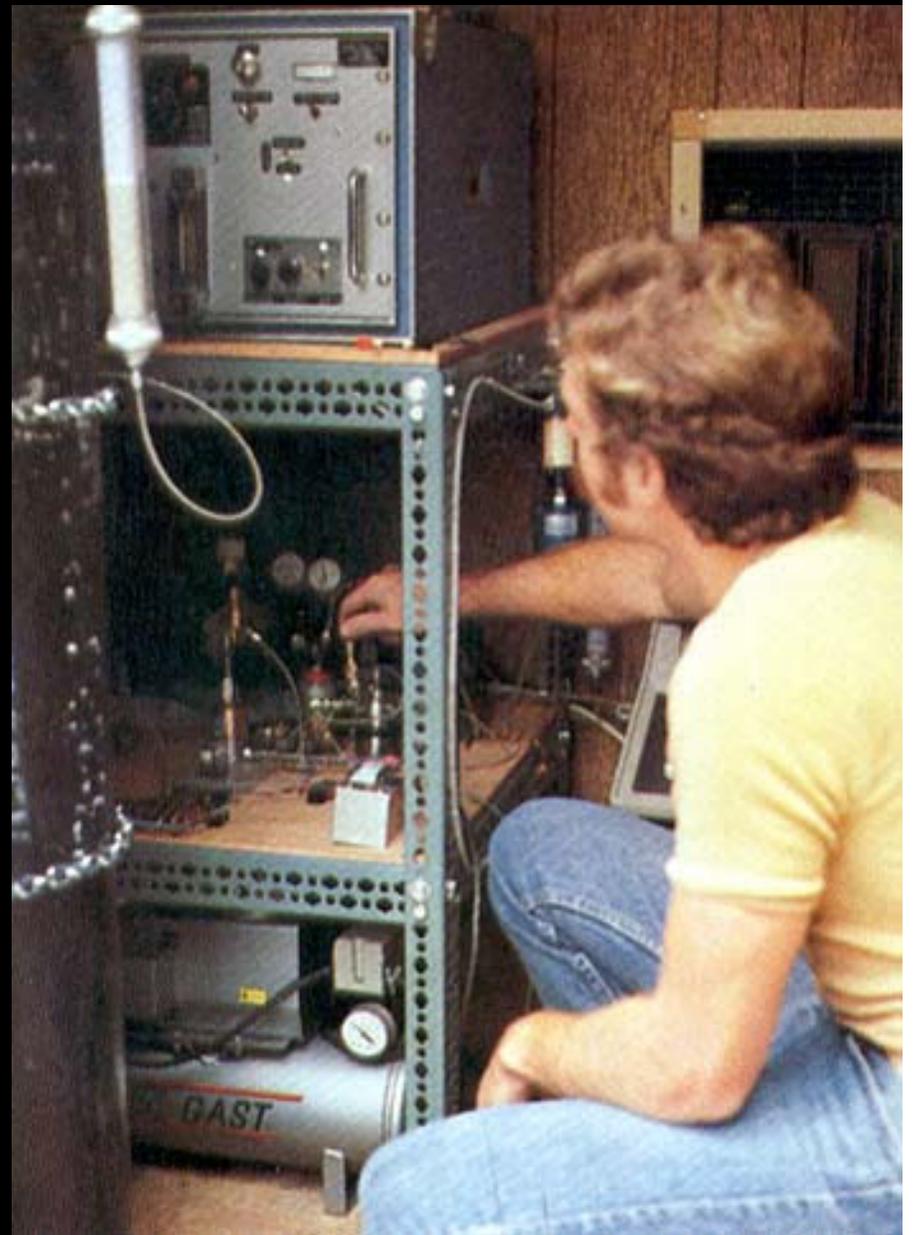
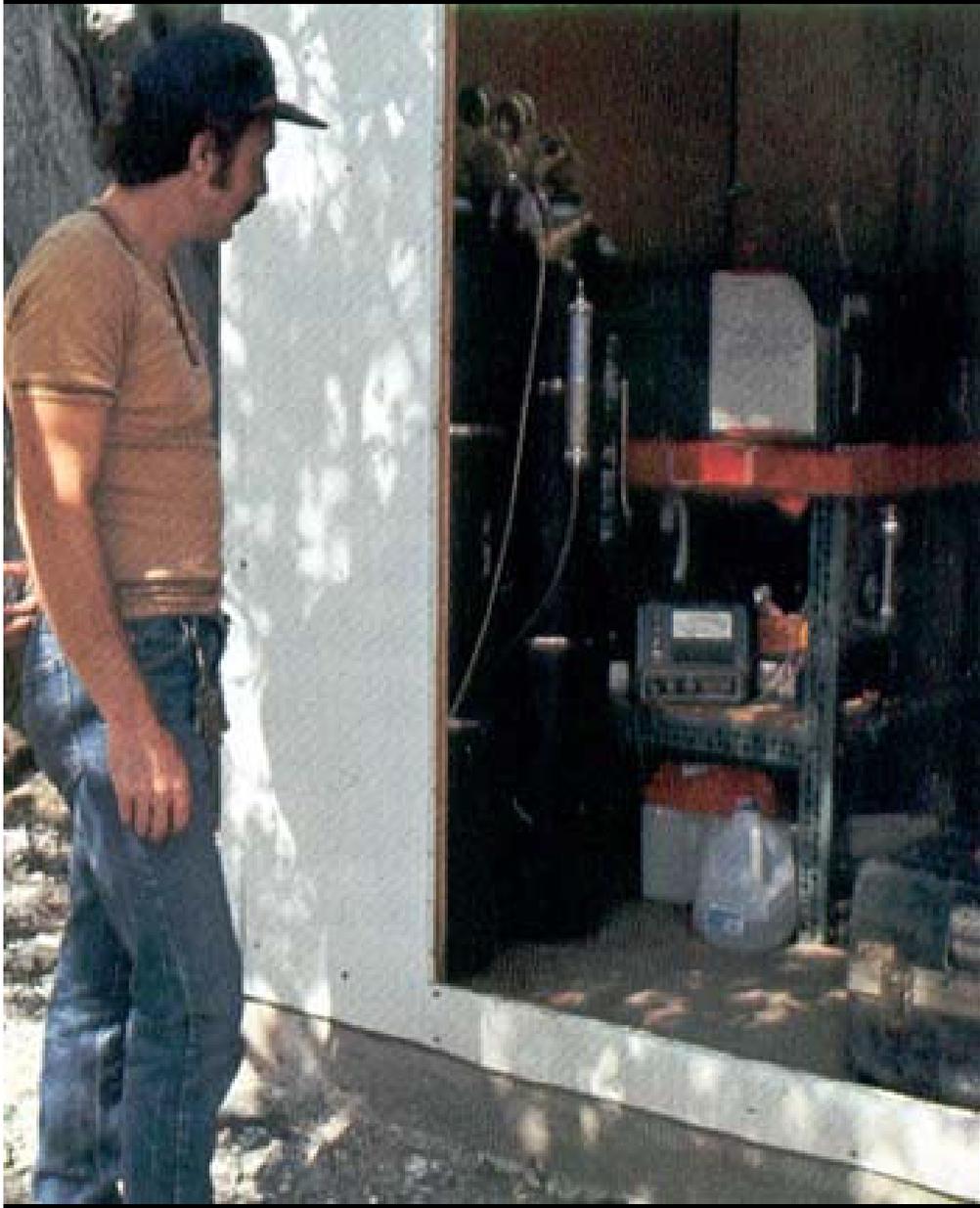
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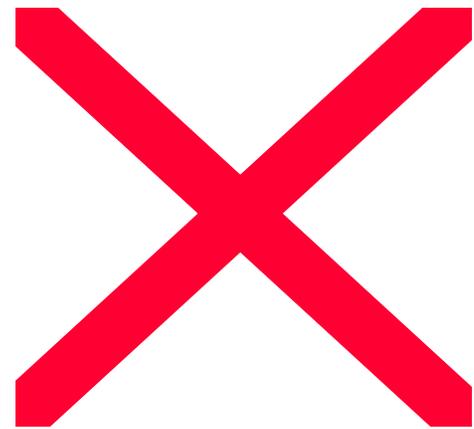
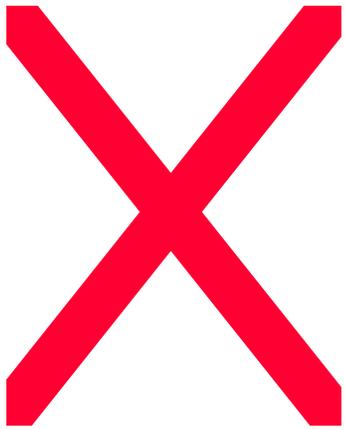
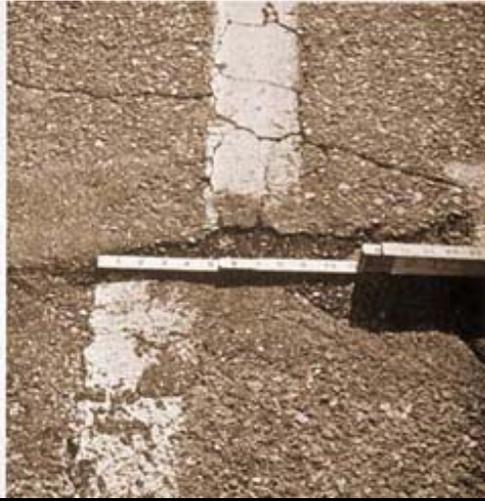
1.943

4.186

**1979 Gulf Oil - CalTech Designed, Built and Operated  
Continuous Monitoring Systems for Earthquake Detection**







# 1981-82 Arrowhead Hot Springs Continuous Monitoring Conducted by Gulf Oil - CalTech Illustrating Natural Variations in Gas Flux over Time

ARROWHEAD SPRINGS DATA  
12/81 TO 12/82  
METHANE (PPM)

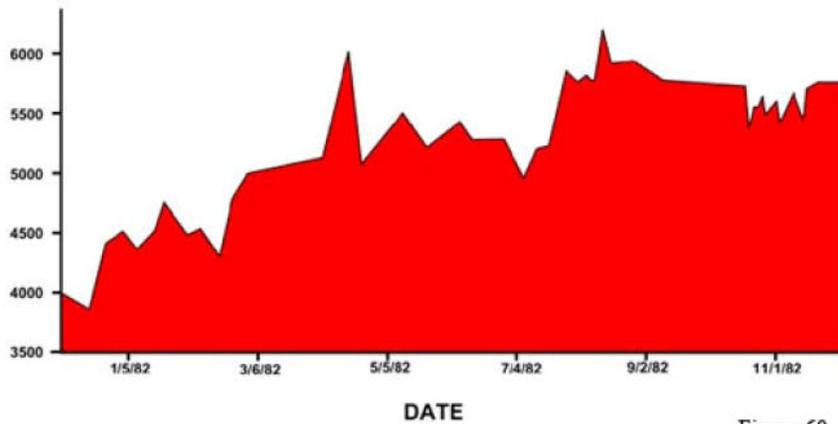


Figure-60

ARROWHEAD SPRINGS DATA  
12/81 TO 12/82  
PROPANE (PPM)

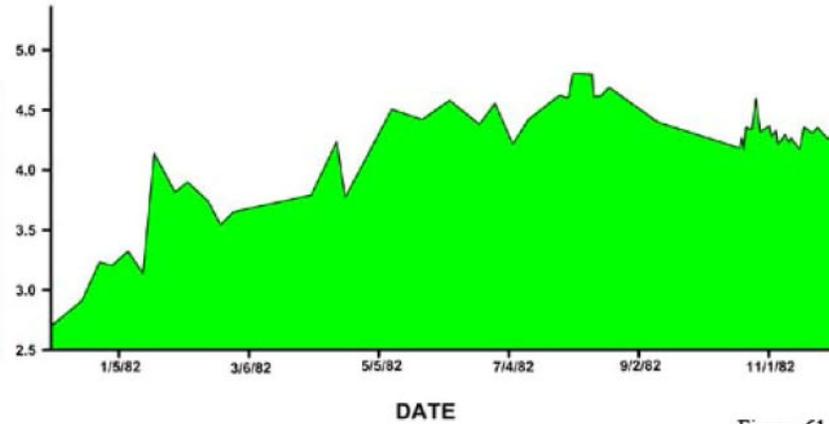


Figure-61

ARROWHEAD SPRINGS DATA  
12/81 TO 12/82  
PROPANE/METHANE X 1000

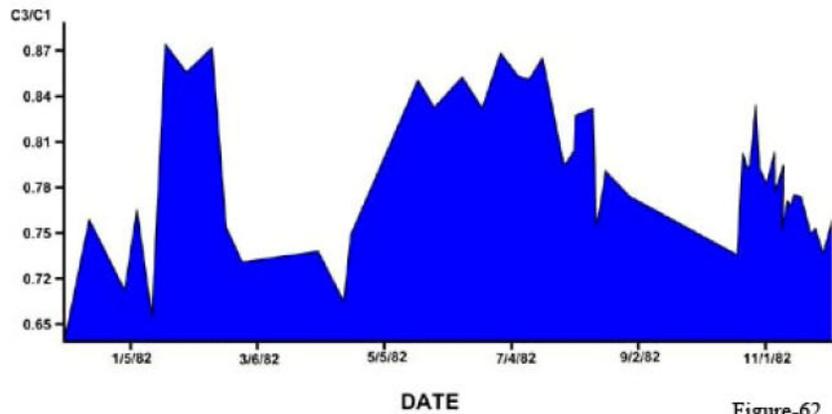


Figure-62

ARROWHEAD SPRINGS DATA  
12/81 TO 12/82  
HELIUM (PPM)

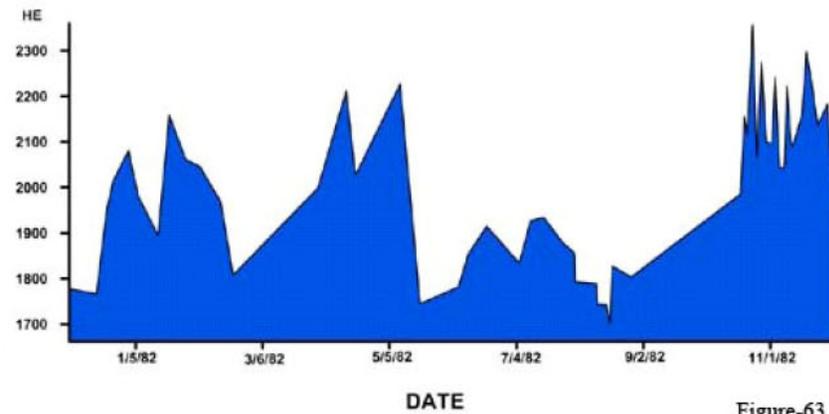
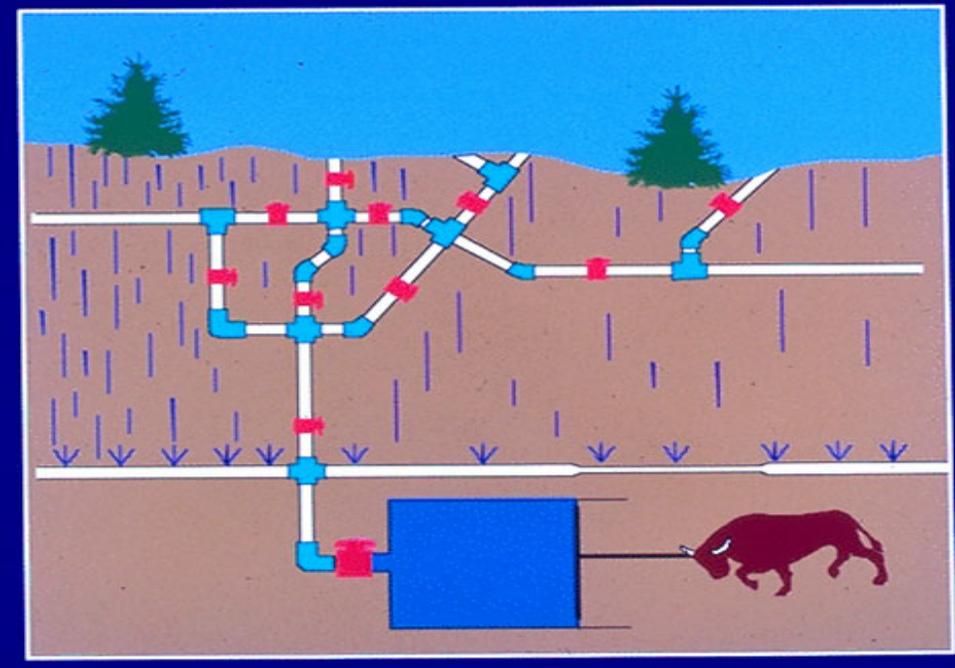
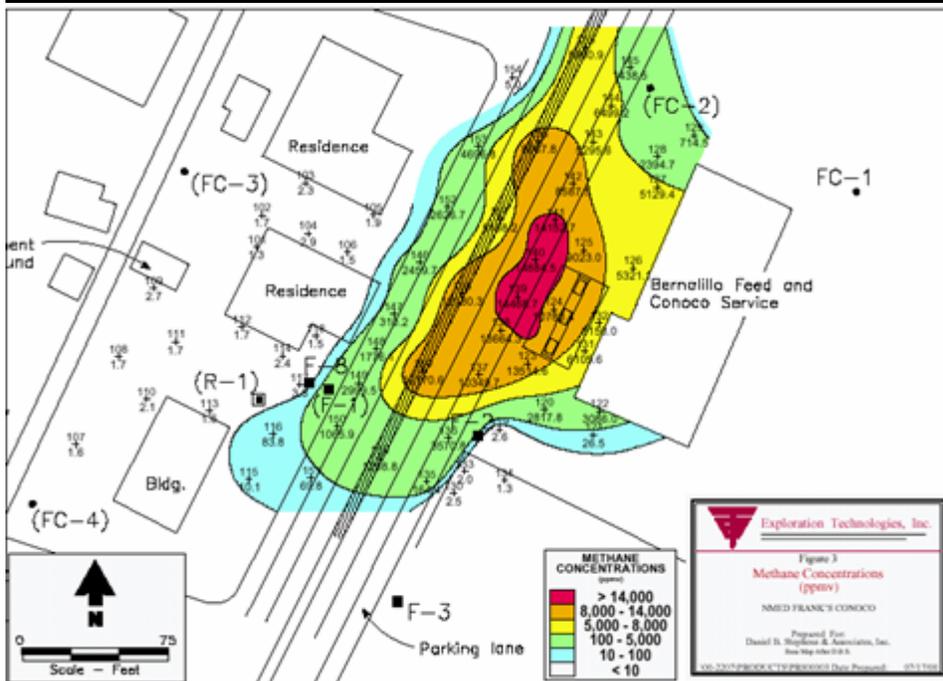
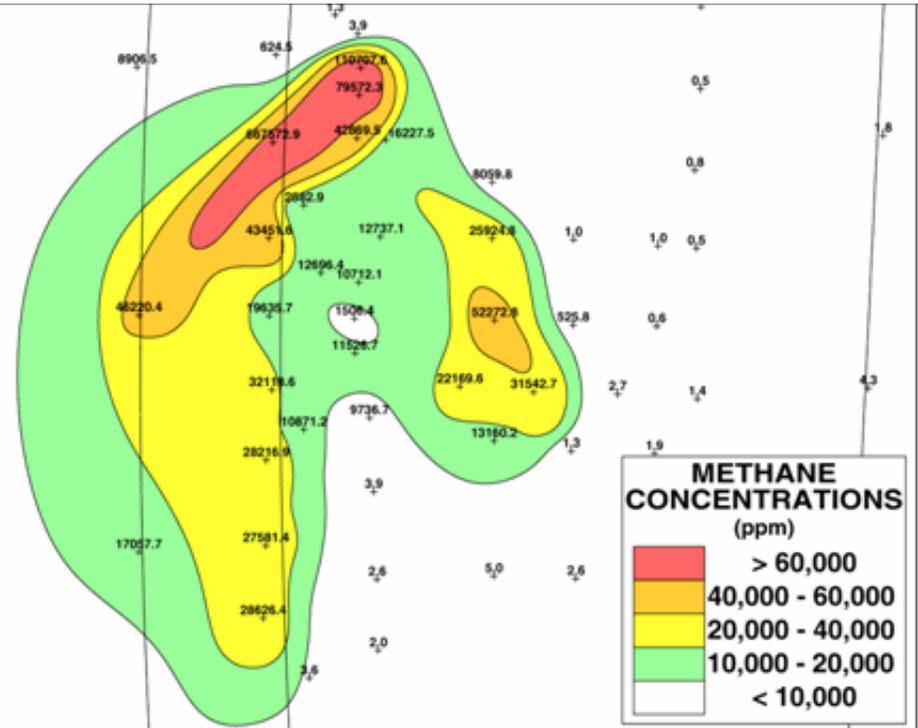


Figure-63

# What is the range and distribution of CO2 and methane Concentrations typically present in near surface soils prior to sequestration?

**Source**  
**Guadalajara Mexico**  
**Cookstove Propane**  
**CO2 10%**  
**methane 10%**



What is the range and distribution of CO<sub>2</sub> and methane Concentrations typically present in near surface soils prior to sequestration?

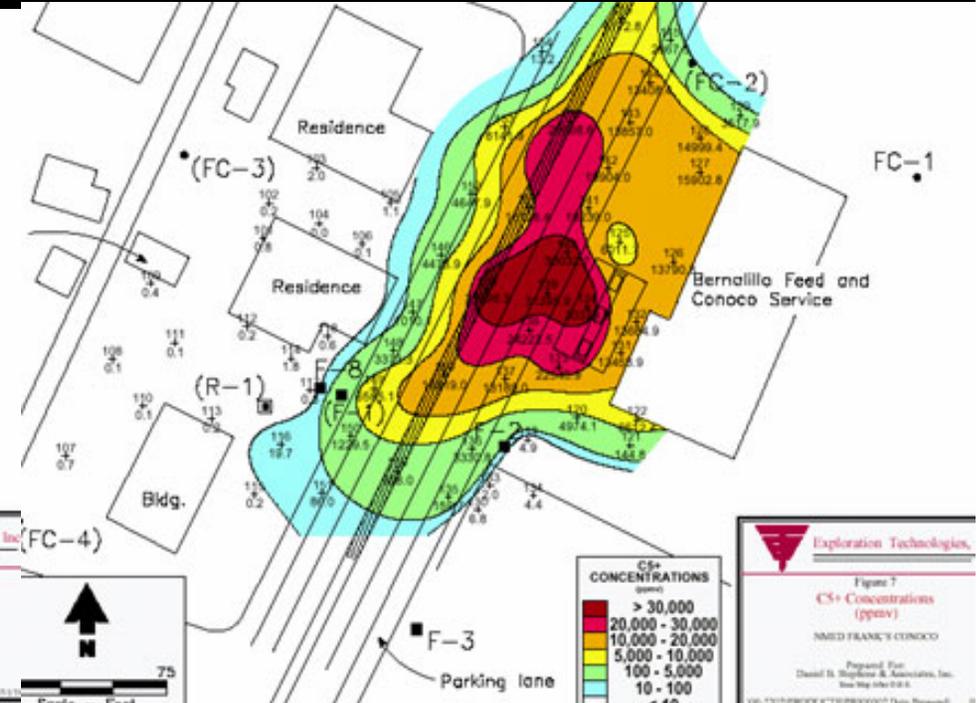
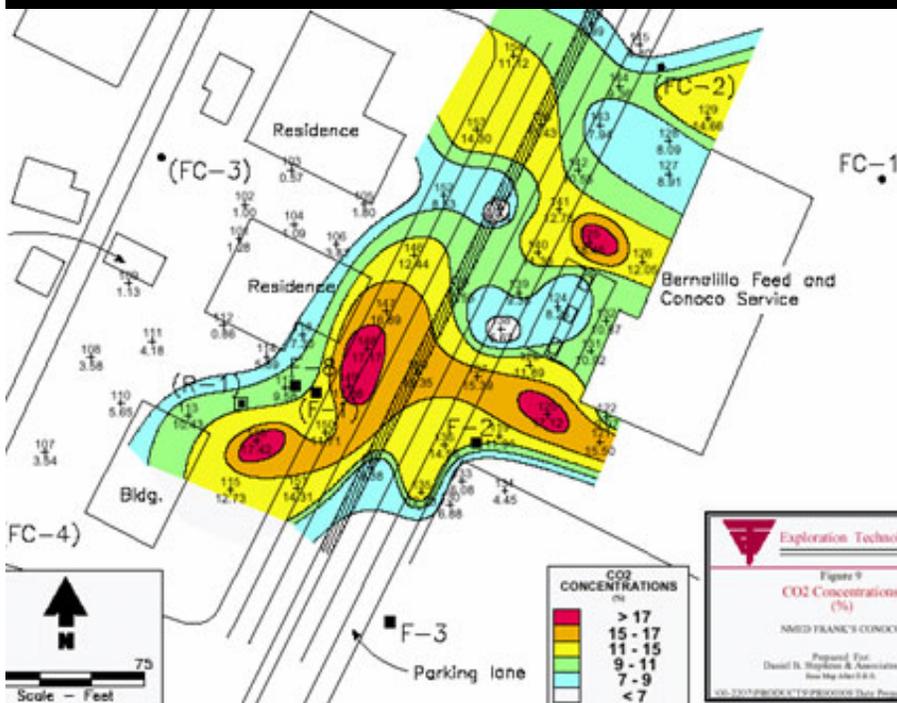
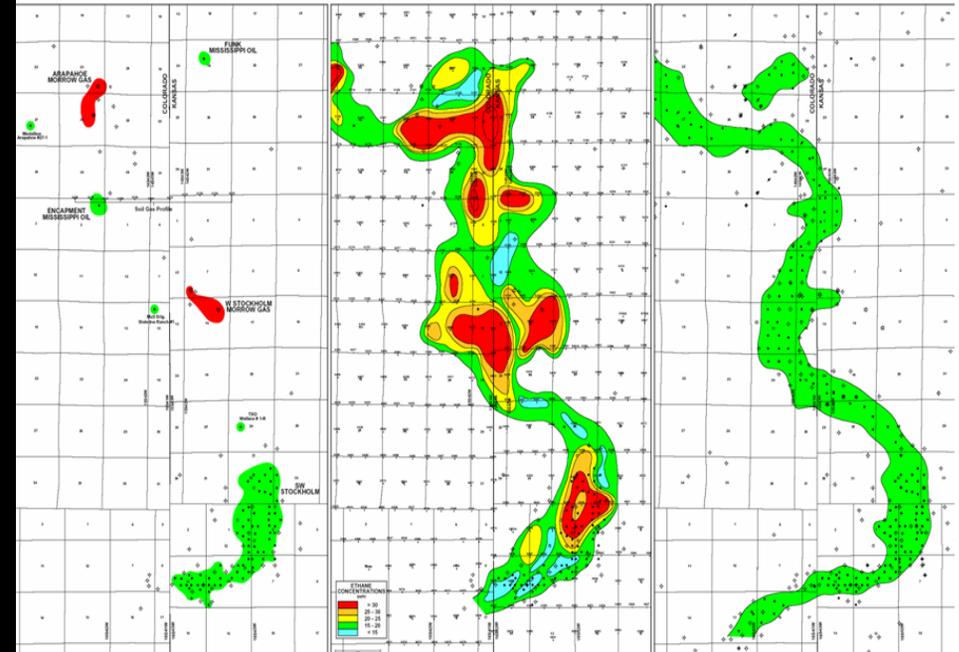
**New Mexico Gasoline Station**

**CO<sub>2</sub> 17%**  
**methane 1.4%**

A. Stateline Complex Development  
January 1987

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

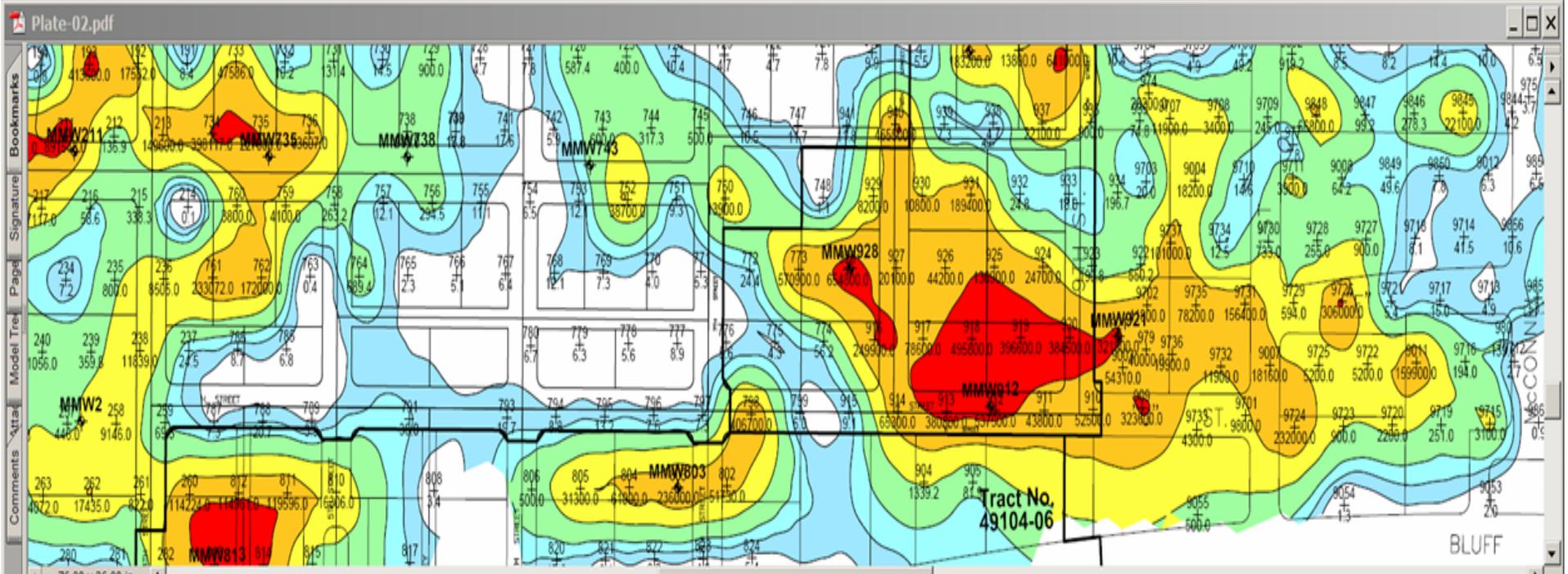
C. Stateline Complex Development  
August 1990



# What is the range and distribution of CO2 and methane Concentrations typically present in near surface soils prior to sequestration?

## Austin, Texas Tanks Farms Groundwater Plume Impacting Public Park

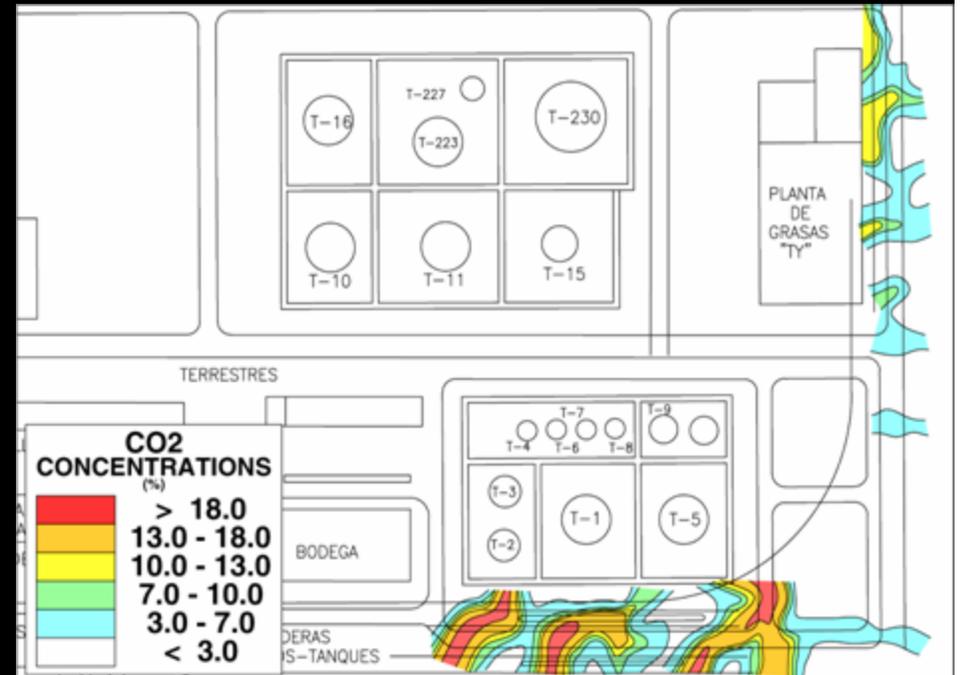
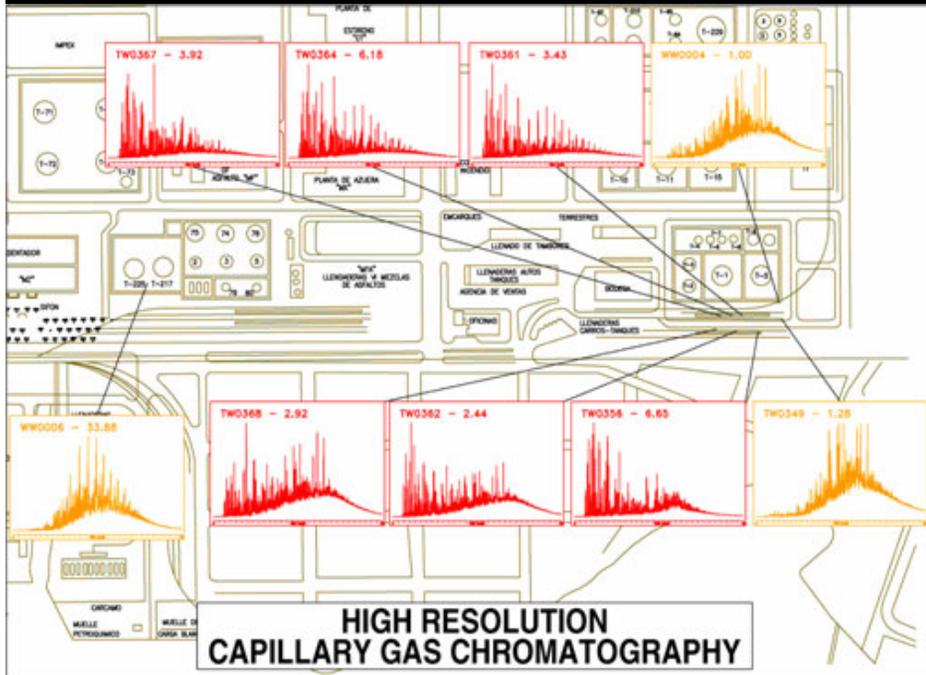
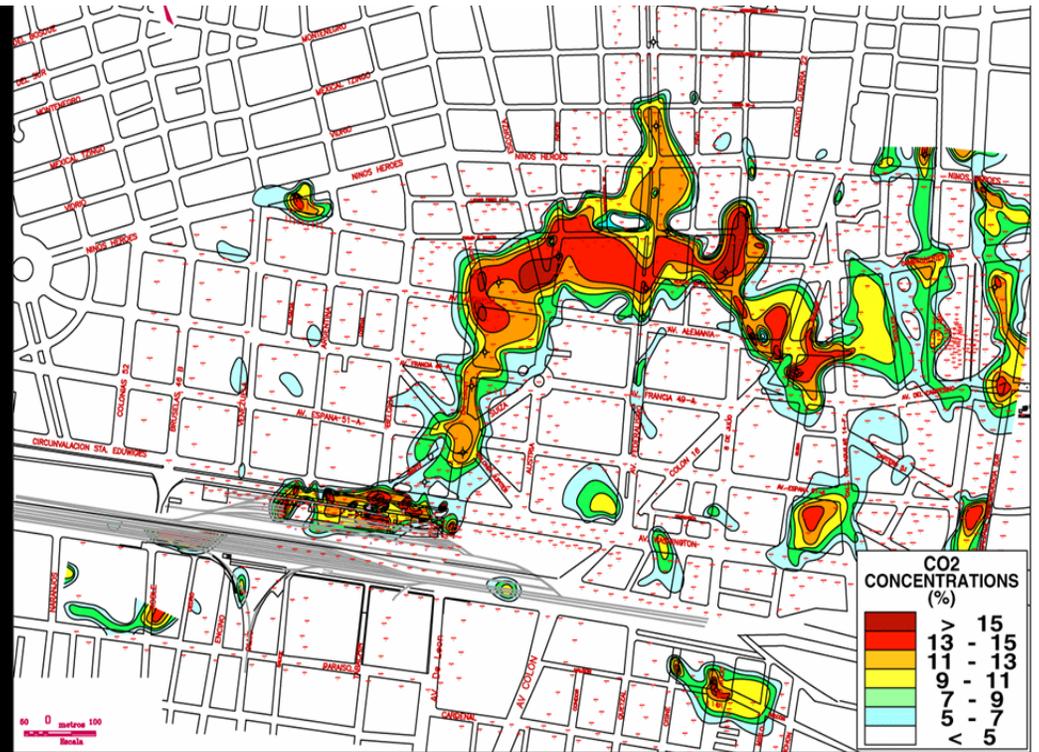
**CO2 14%**      **methane 10%**



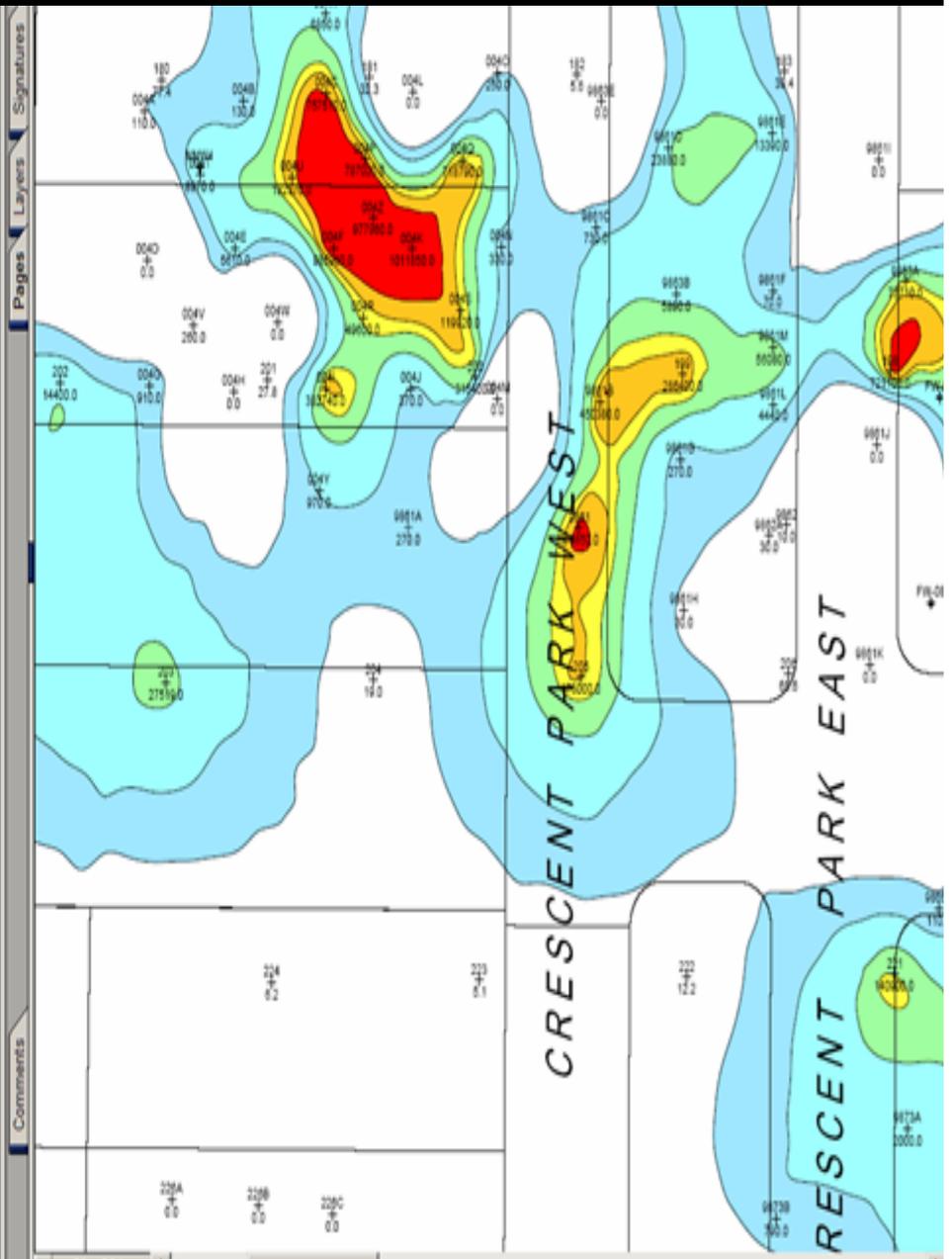
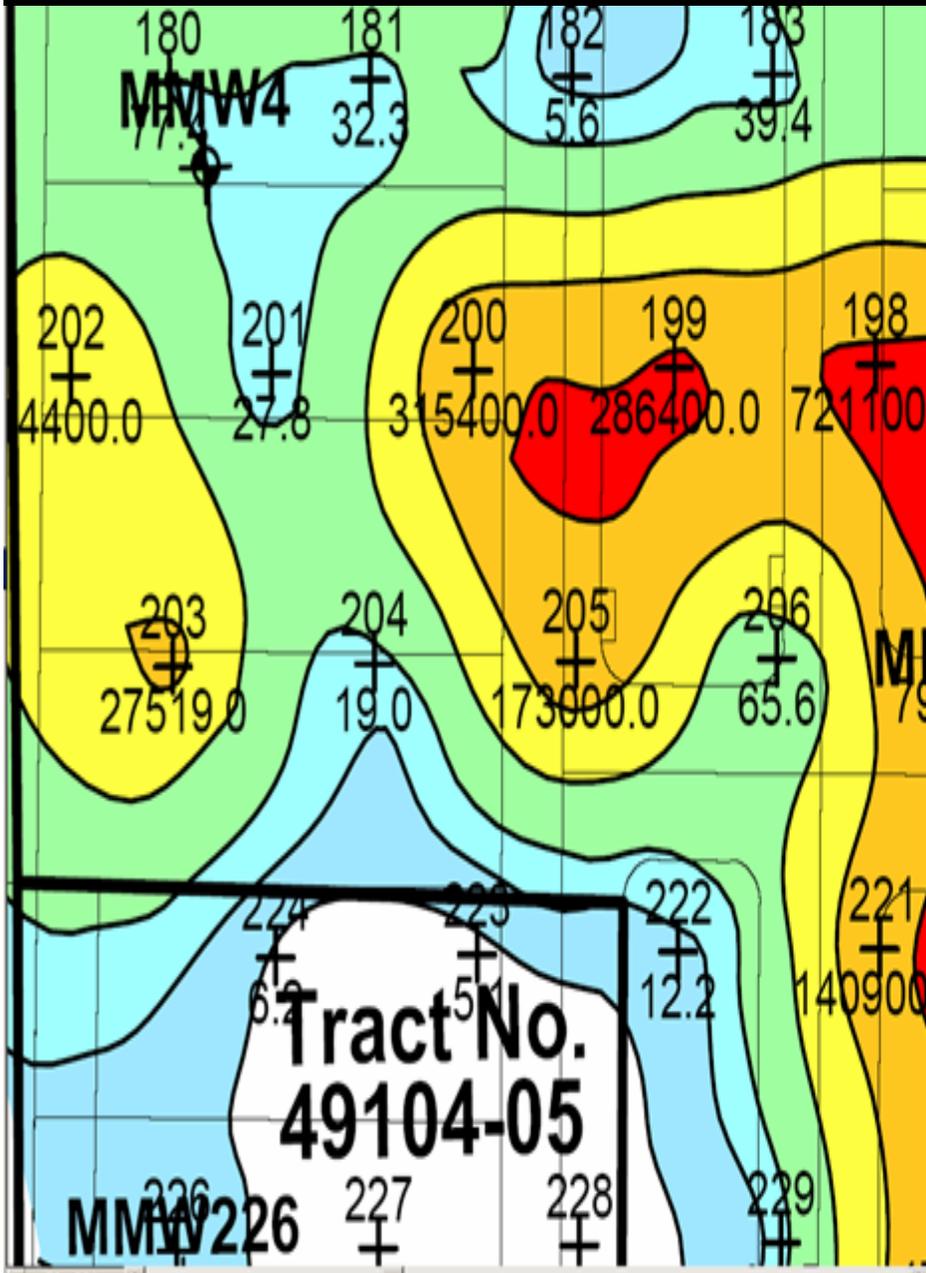
What is the range and distribution of CO<sub>2</sub> and methane Concentrations typically present in near surface soils prior to sequestration?

Tampico Mexico Refinery

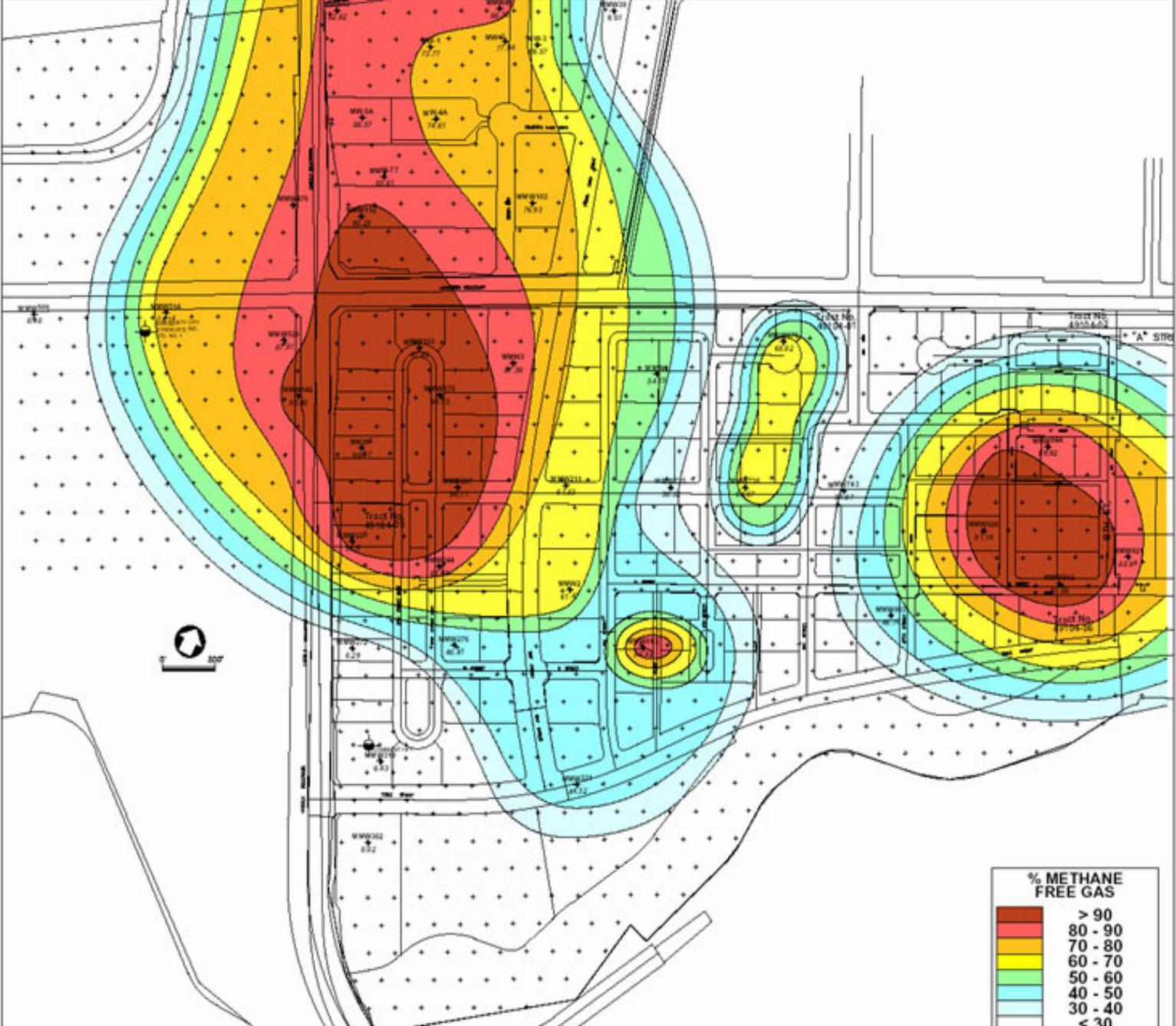
CO<sub>2</sub> 20%  
methane 20%



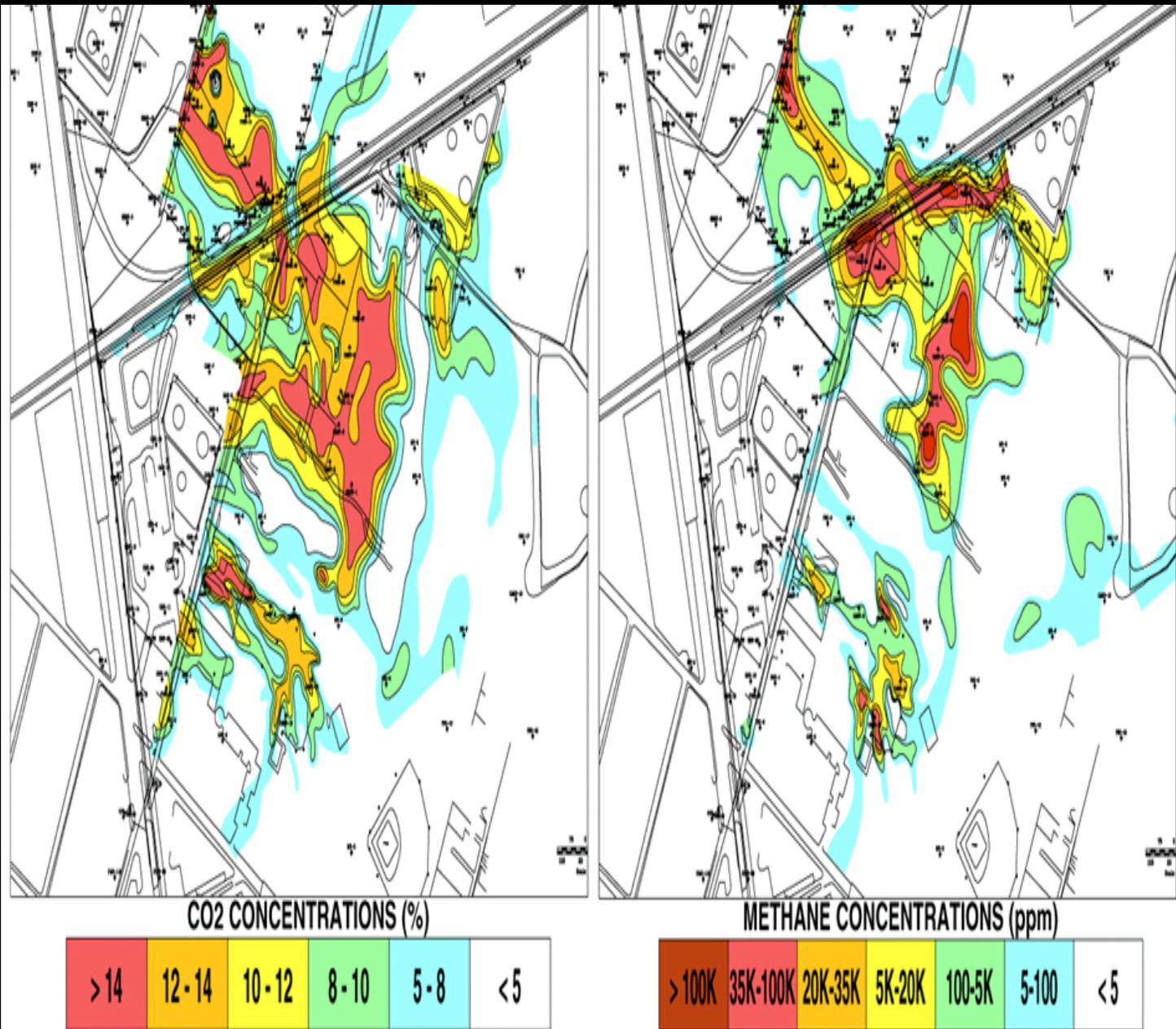
# Guadalajara Mexico Railroad Diesel CO2 15 – 20%



# 2001 Playa Vista California Natural Gas Seepage Defined by Soil Gas Survey

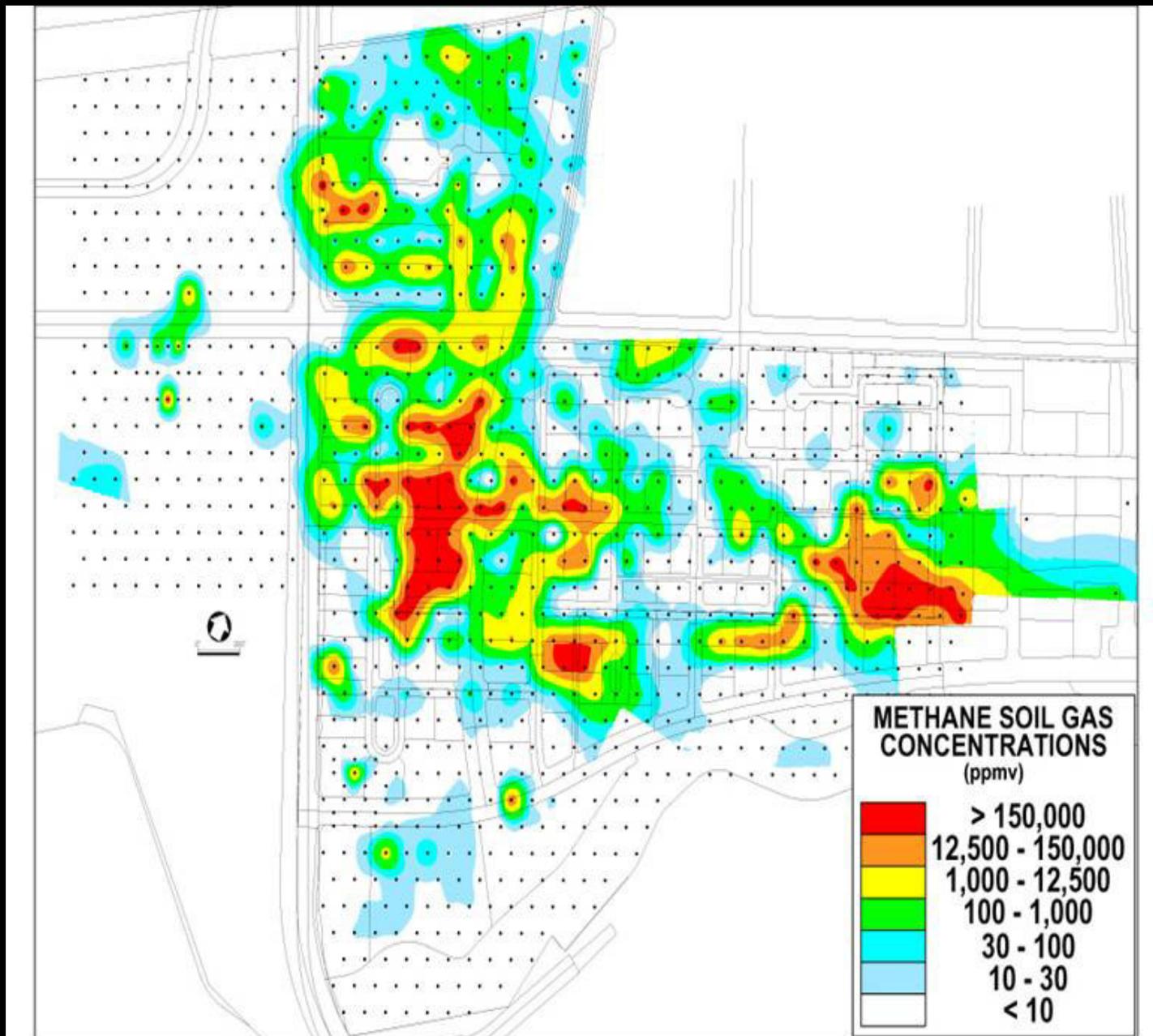


## 2001 Playa Vista California Methane Gas in 60 foot deep Monitor Wells



2001 Playa Vista California

Soil Gas/Groundwater Correlations



# Playa Vista CA Natural Gas Seepage CO<sub>2</sub> 15 – 20%

A.A.P.G. VOL. 67, NO. 6, JUNE, 1983

V.T. Jones and R.J. Drozd

## COMPOSITIONS OF TYPICAL C1 TO C4 RESERVOIR HYDROCARBONS

OF GAS, OIL AND CONDENSATE SURVEYS



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

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

TYPICAL HISTOGRAM OF DRY GAS AND OIL SURVEY DATA

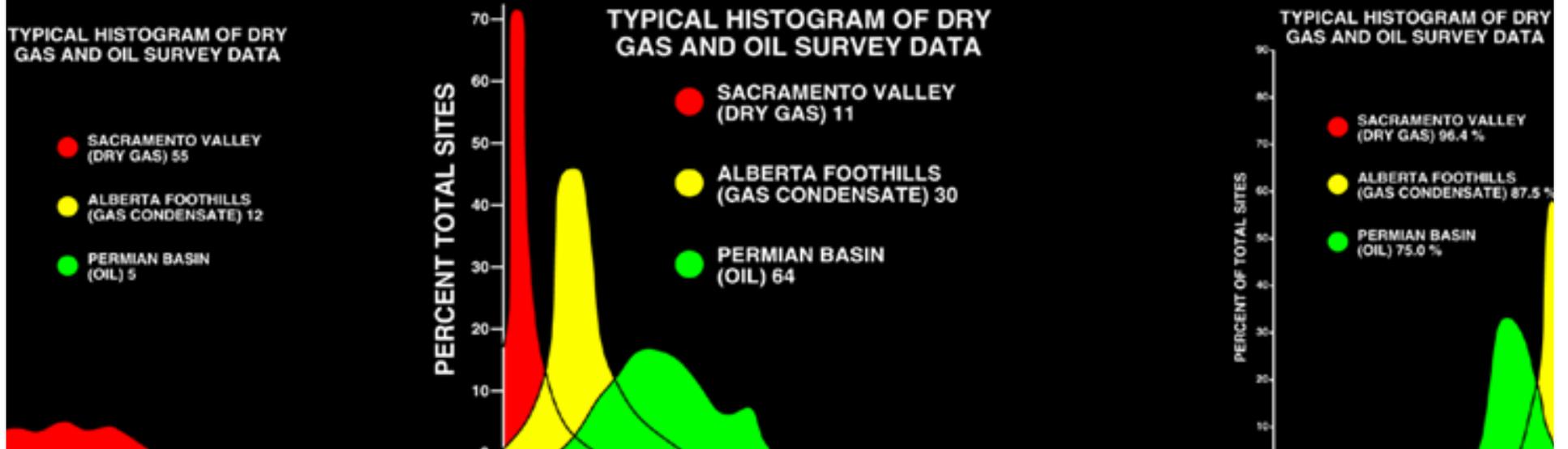
- SACRAMENTO VALLEY (DRY GAS) 55
- ALBERTA FOOTHILLS (GAS CONDENSATE) 12
- PERMIAN BASIN (OIL) 5

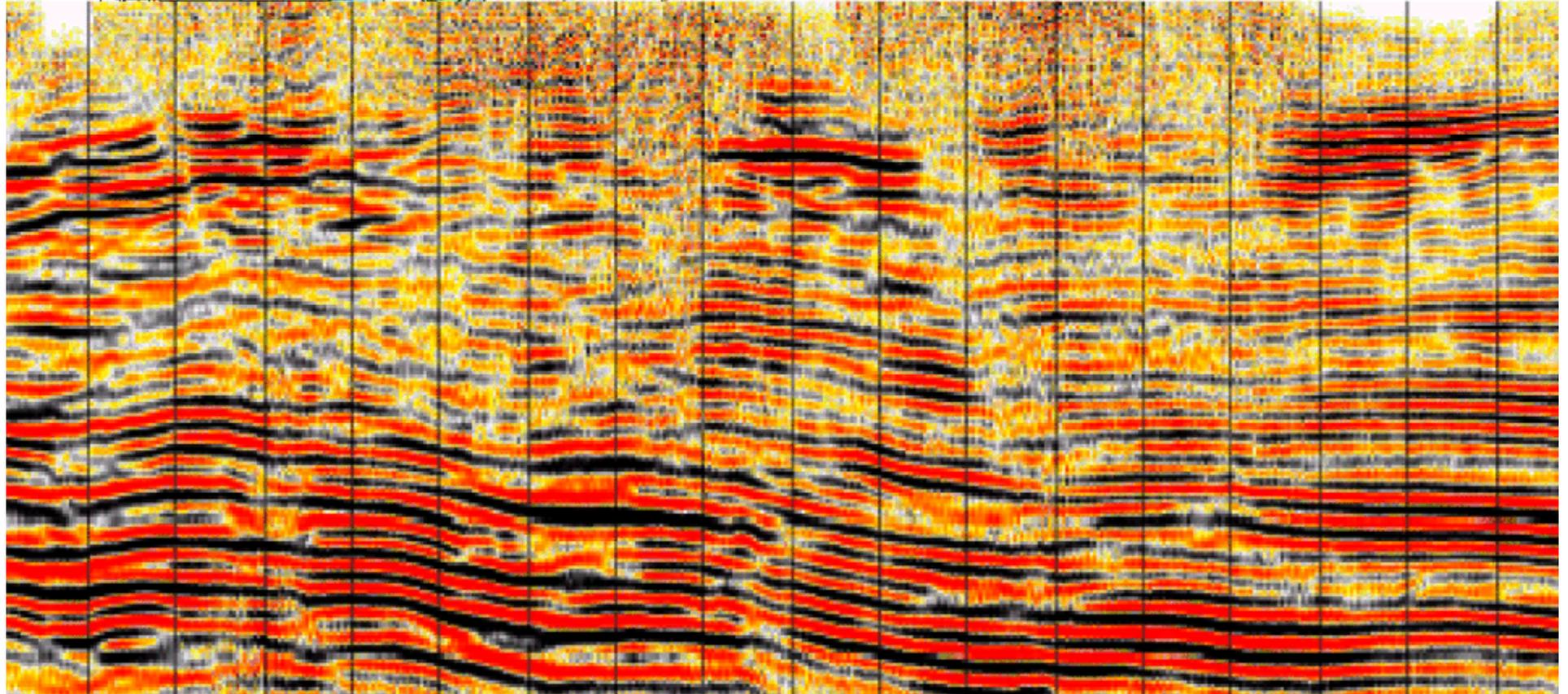
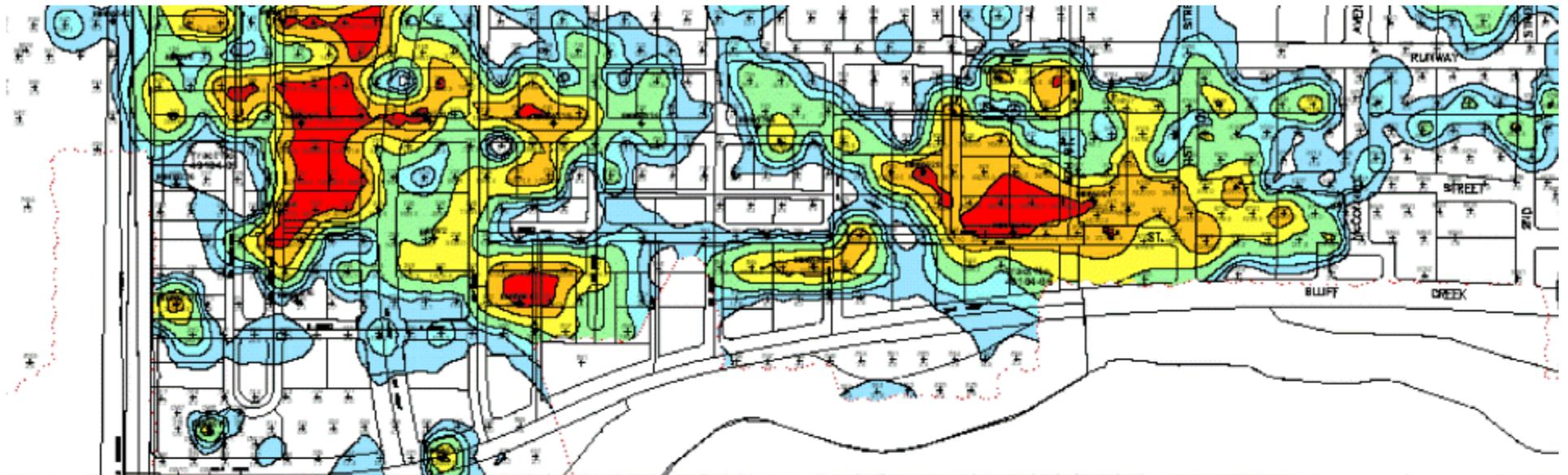
TYPICAL HISTOGRAM OF DRY GAS AND OIL SURVEY DATA

- SACRAMENTO VALLEY (DRY GAS) 11
- ALBERTA FOOTHILLS (GAS CONDENSATE) 30
- PERMIAN BASIN (OIL) 64

TYPICAL HISTOGRAM OF DRY GAS AND OIL SURVEY DATA

- SACRAMENTO VALLEY (DRY GAS) 96.4 %
- ALBERTA FOOTHILLS (GAS CONDENSATE) 87.5 %
- PERMIAN BASIN (OIL) 75.0 %



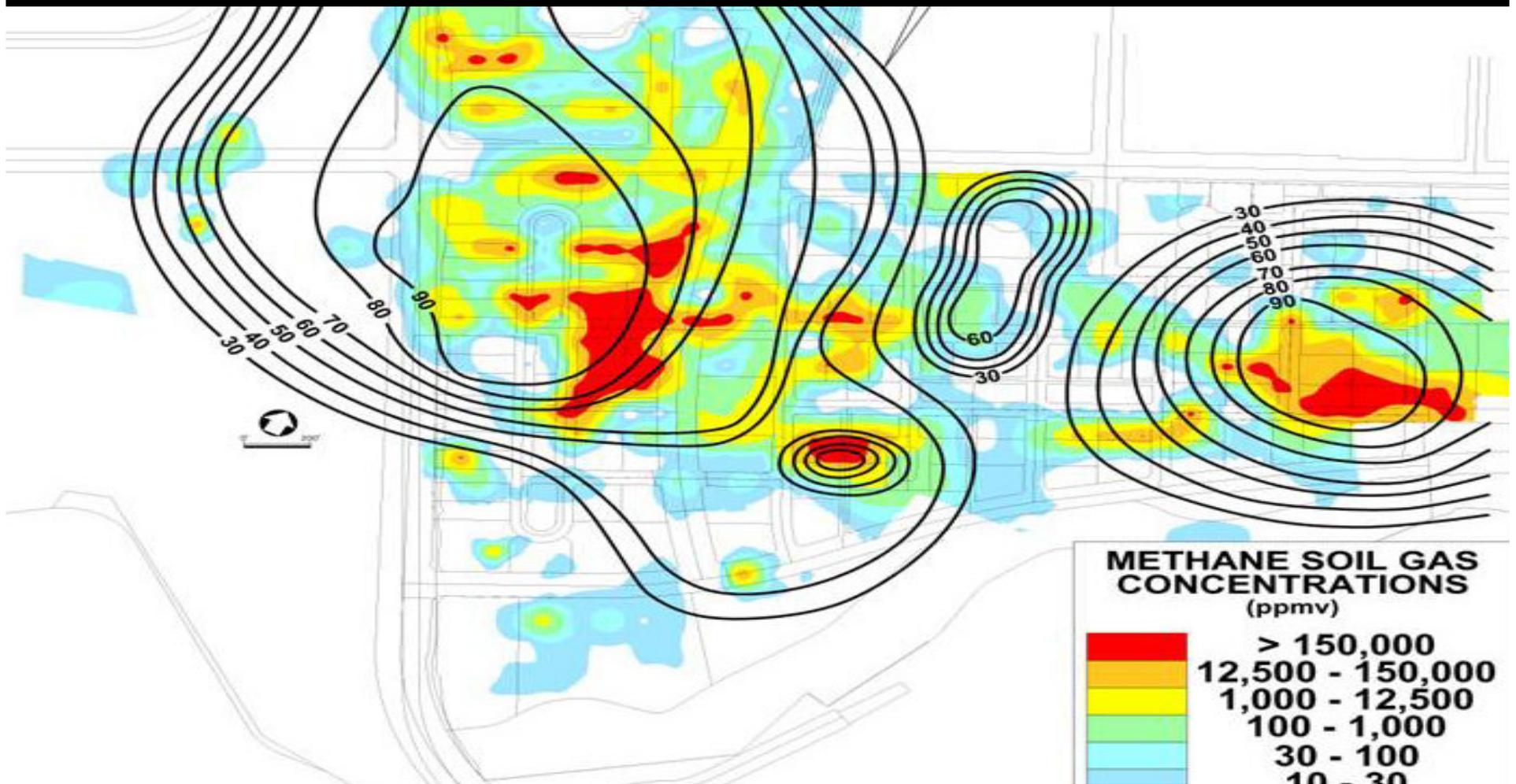


# What is the distribution of soil gas anomalies ?

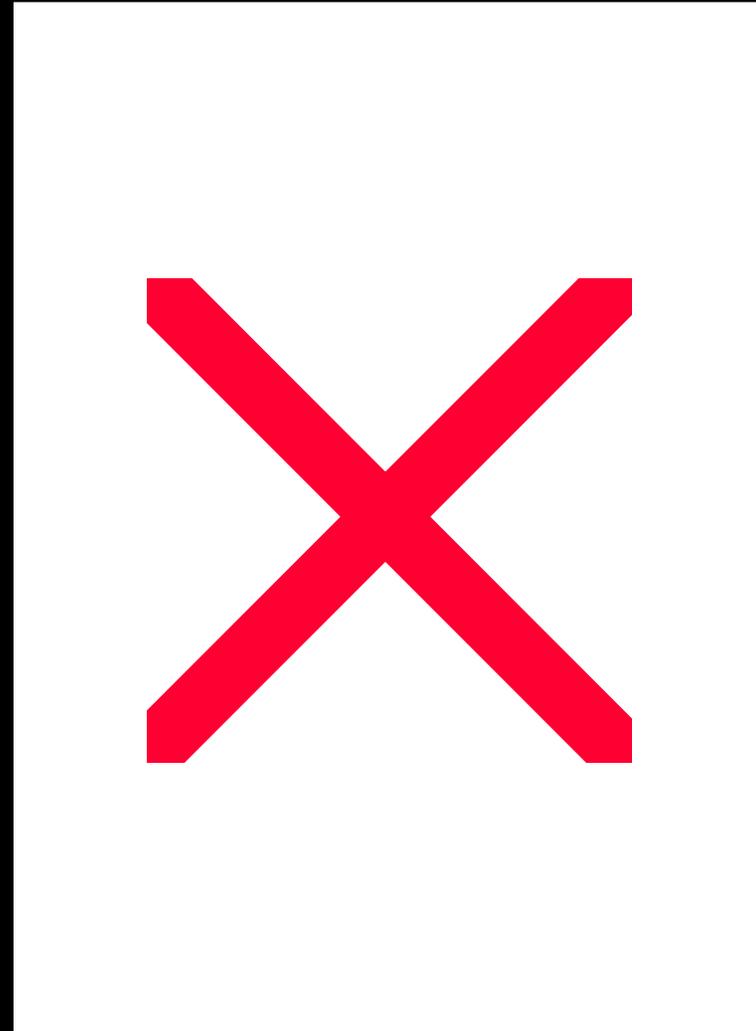
## 2001 Playa Vista, California Soil Gas Surveys

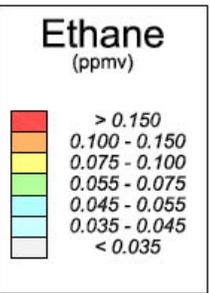
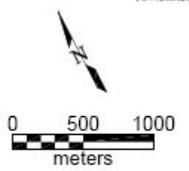
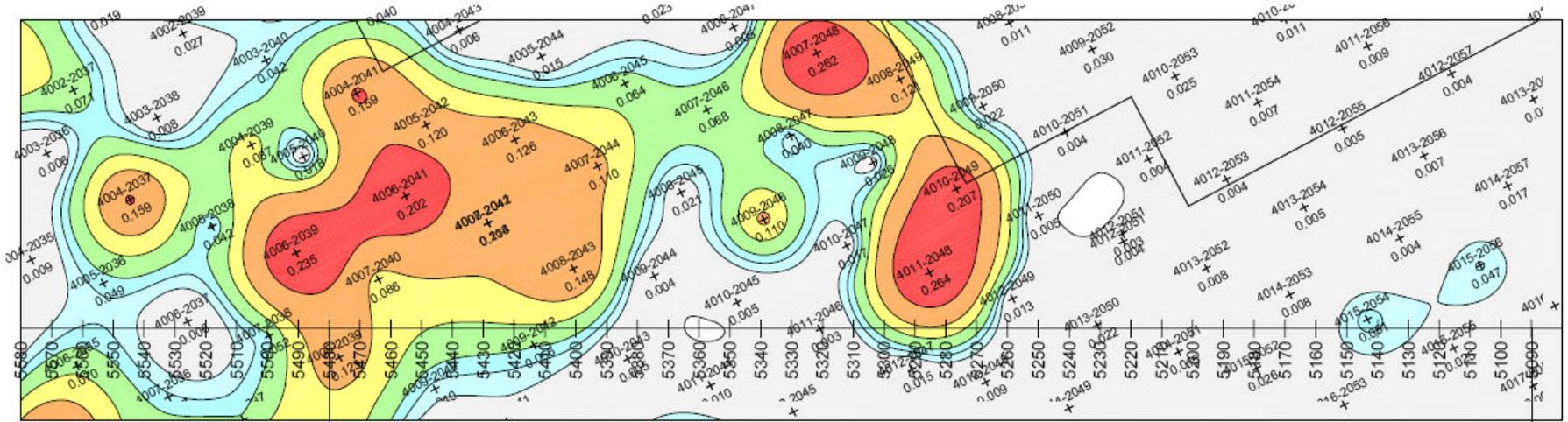
100 foot centers

10 to 50 foot infill



Experience Has Shown That Soil Gas extraction can be obtained by pounding a 4 foot hole in the ground, inserting a probe into the hole that is connected to a clean evacuated bottle and drawing gas into the bottle under vacuum. The gas can be measured in the field or brought into the lab for measurement





Tekirdağ  
Crossline 1020

Figure 18

