Finding and Protecting Energy Resources with 21st Century Geochemical Tools

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Organic and inorganic geochemical analyses of various sample media are used to reduce risk in oil & gas exploration and development. More specifically, the methods help to focus land acquisition, seismic surveys and drill targets in petroleum exploration. Additionally the geochemical methods are used for documenting baseline environmental conditions before and after development of an energy resource to prevent potential litigation and complaints down the road.

The results of unique geochemical exploration surveys from the following areas will be presented:

(1) **Albion-Scipio Oil Field (Michigan)** – Crude oil microseeps, which are compositionally identical to produced oil, guided the drilling of commercial oil wells in the 4,000-foot deep, Ordovician Trenton hydrothermal dolomite reservoir.

(2) **Devonian Carbonate Oil Field (Illinois)** – Passive gas anomalies at surface are compositionally linked with a 2,000-foot deep oil reservoir.

(3) **Grant Canyon Oil Field (Nevada)** – Lithium and magnesium anomalies in soils are compositionally linked to water in the 5,000-foot deep carbonate oil reservoir.

Baseline environmental surveys are done before and after the development of an energy resource to document groundwater quality and natural hydrocarbon seeps. This documentation is important for avoiding future potential litigation and complaints from landowners and regulatory agencies. Groundwater from domestic and stock wells near proposed oil and/or gas wells are tested for dissolved C_1-C_7 hydrocarbons, carbon and deuterium isotopes of detected hydrocarbons, cations and anions, and pathogenic and non-pathogenic bacteria to document general water quality before and after stimulation of an oil and/or gas reservoir. Examples of baseline environmental surveys from the DJ and Ration Basins will be presented. Forensic isotopic evidence from shallow aquifers and produced water in the DJ Basin will be shown to emphasize the lack of fluid mixing between oil and gas reservoirs and shallow groundwater aquifers.

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Outline of Presentation

- **Finding Energy Resources with Geochemical Tools**
  - **Sampling and Analytical Methods**
  - **Linking Reservoir Fluids with Surface Seeps Using Hydrocarbons and Major/Trace Elements**

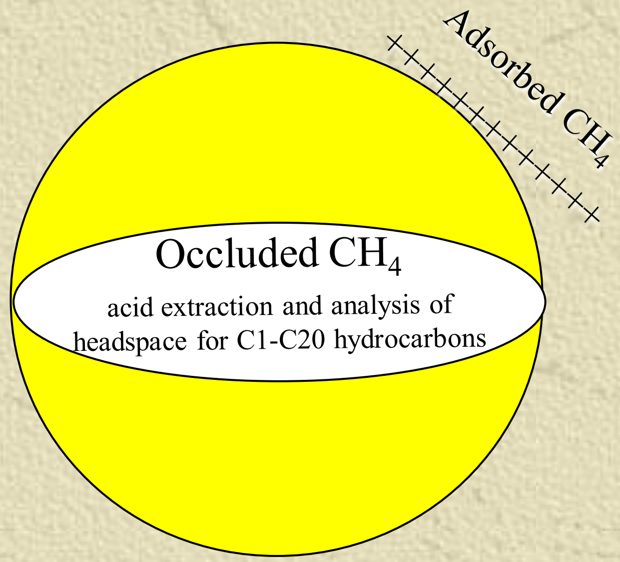
- **Protecting Energy Resources with Geochemical Tools**
  - ***Why Baseline Surveys?***
  - ***Geochemical Tools Used in Baseline Surveys***
  - ***Denver Basin Case Study***
  - ***Summary***

Sample Media Collected

Shallow Soils

Shot-Holes

Lake Sediments



Sediment or soil particle

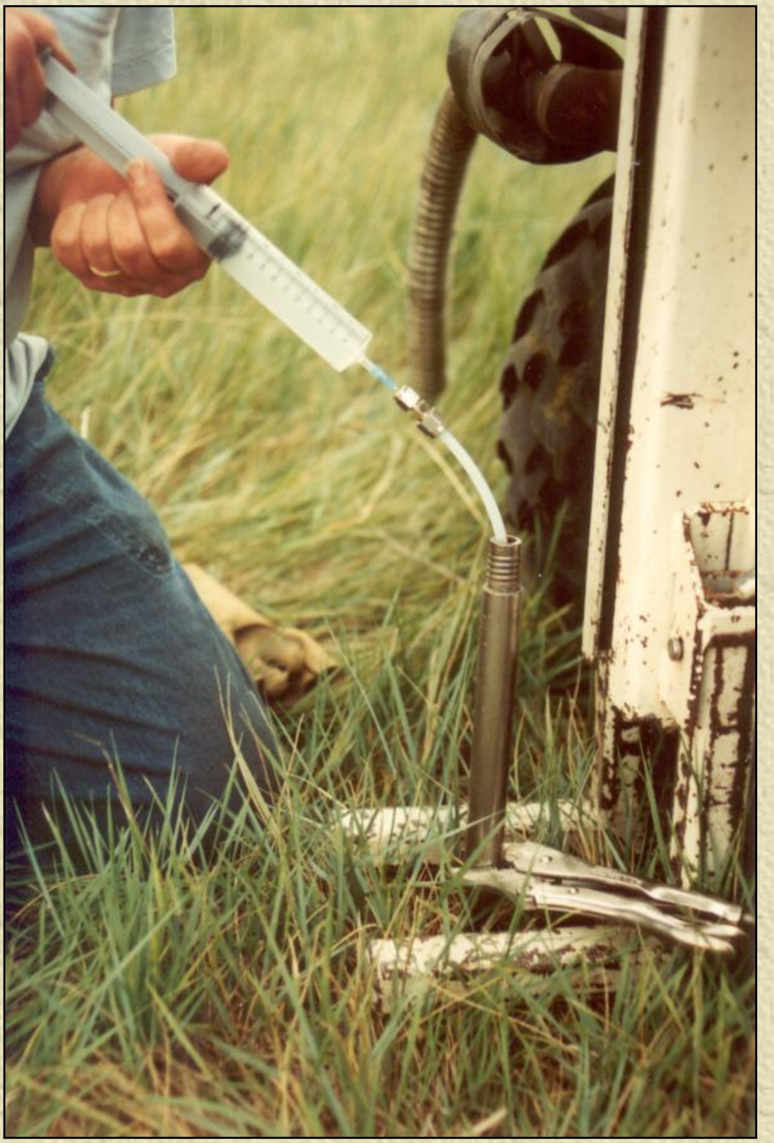
HC Extraction Methods

- Heat
- Acid
- Organic Solvent

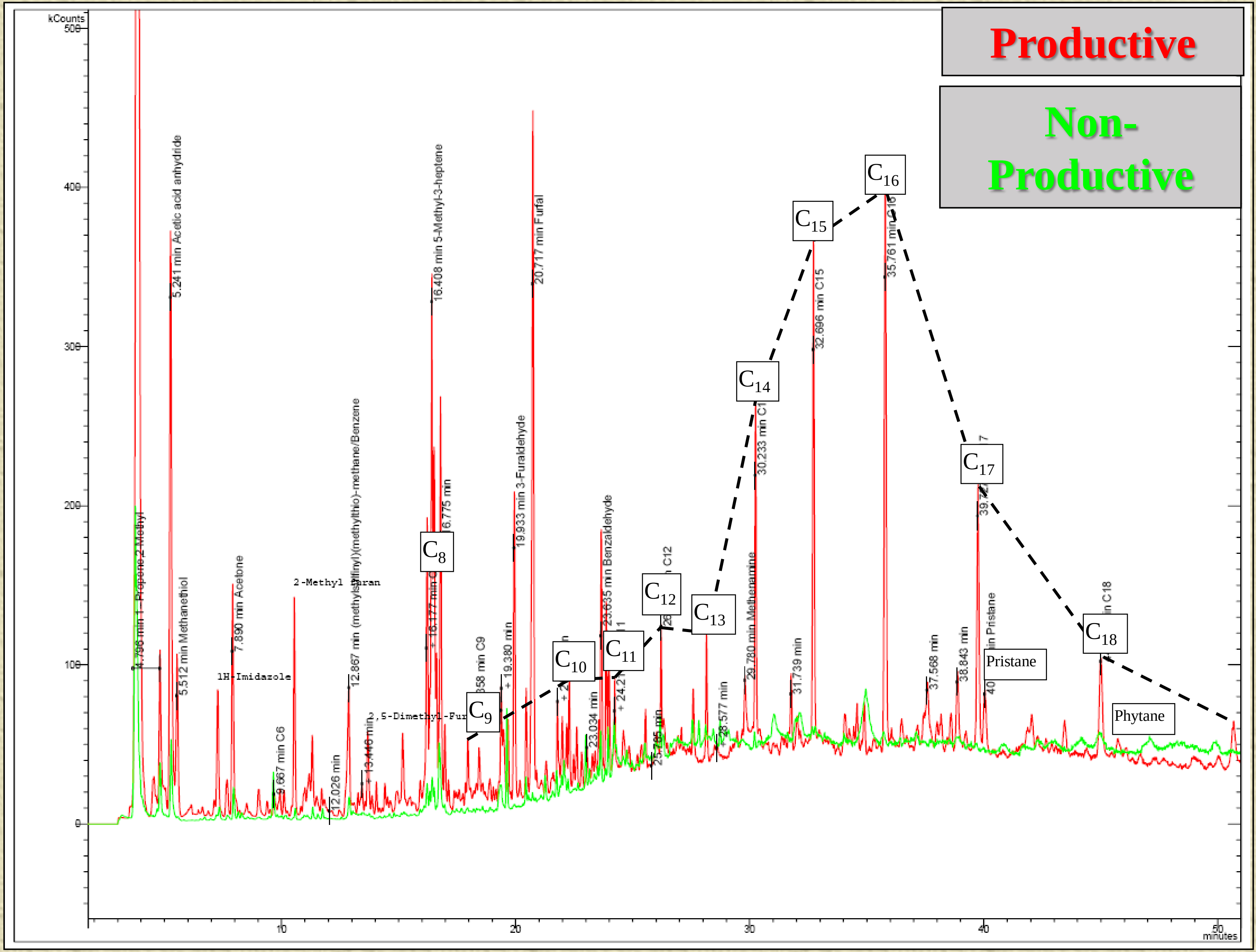
Deep Soils & Soil Gas

Passive Soil Gas

Active Soil Gas



Chromatography of Oil Microseeps in Surface Soils



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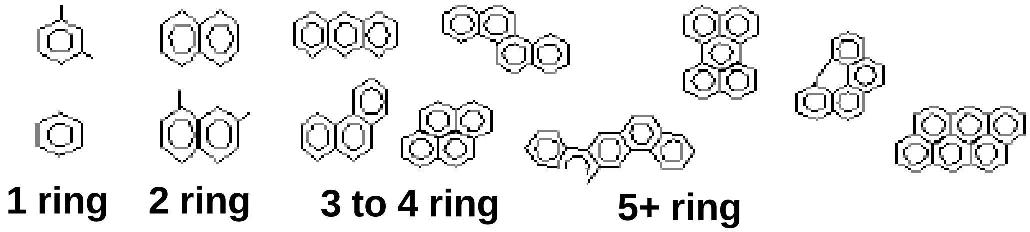
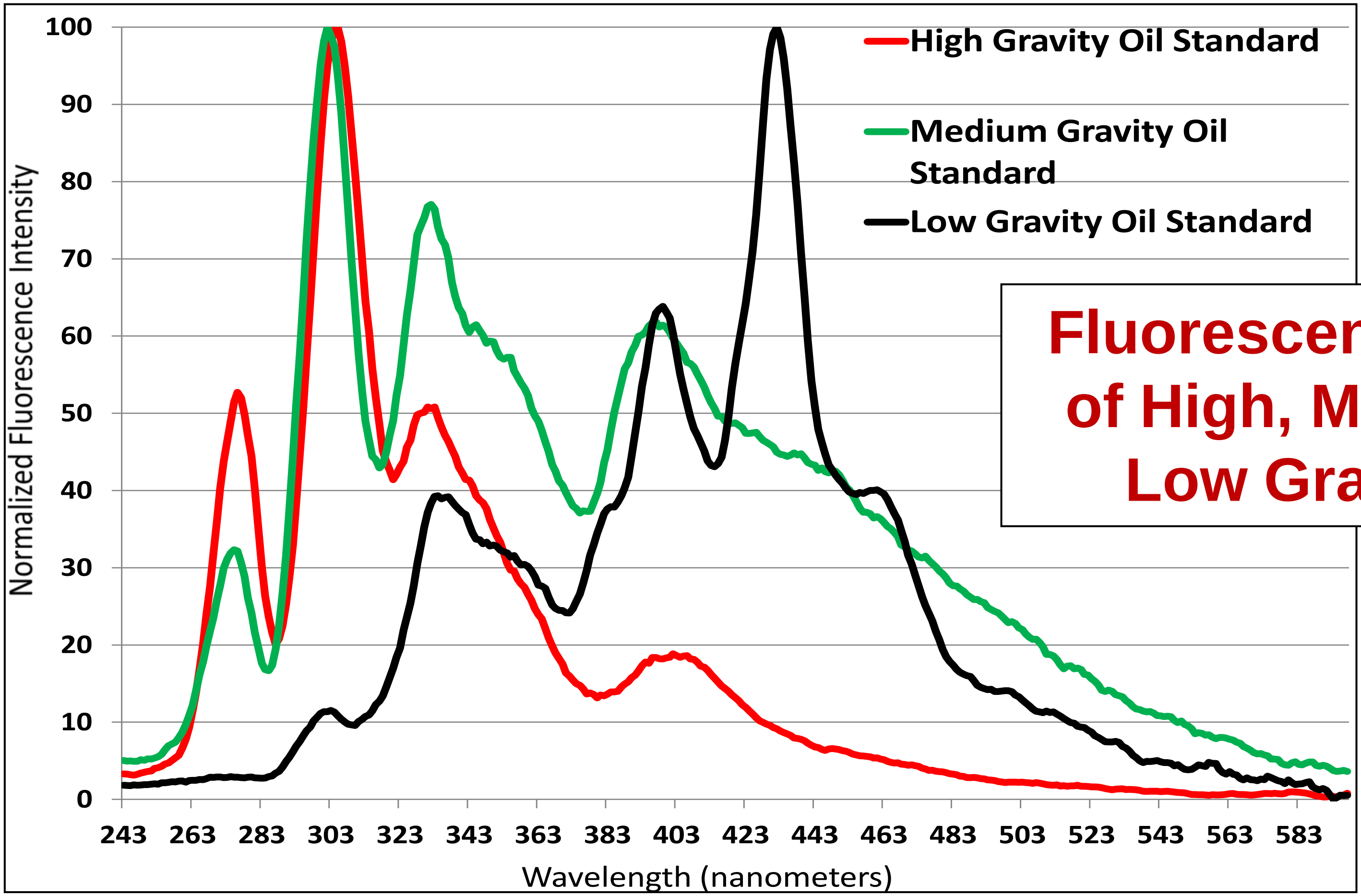




Fluorescence Spectra of High, Medium and Low Gravity Oils

<u>1 ring (270-275nm):</u> *Benzene, Xylenes*

<u>2 rings (300-305nm):</u> *Naphthalene, Methyl Naphthalene*

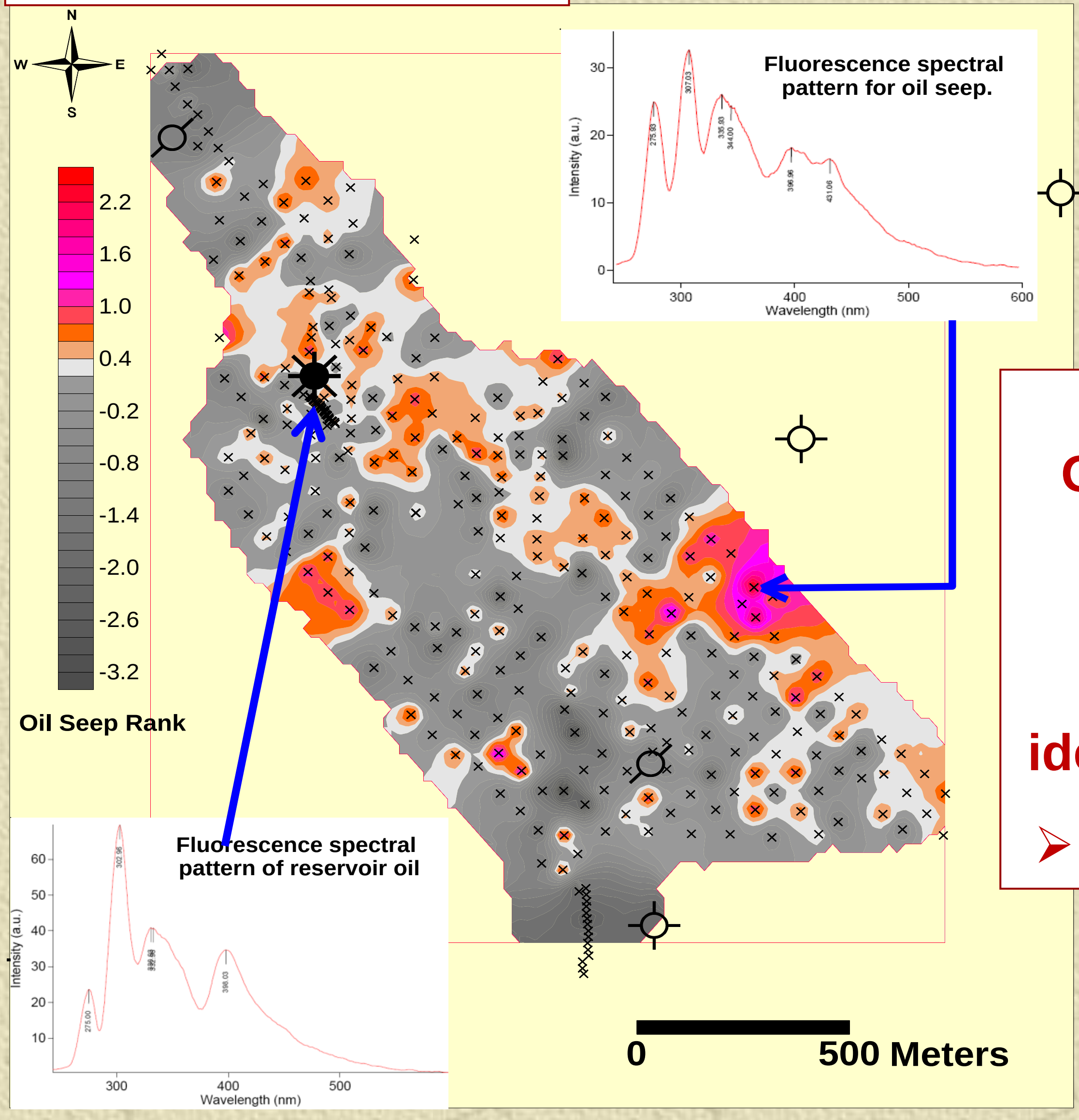
<u>3-4 rings (325-335m):</u> *Phenanthrene, Anthracene, Benzo(a)anthracene, Chrysene, Pyrene*

<u>5+ rings (390-600nm):</u> *Anthanthrene, Dibenzo(a,h)anthracene, Coronene, Benzo(g,h,i)fluoranthrene, Perylene*

Linking Oil Microseeps with an Albion-Scipio Oil Reservoir

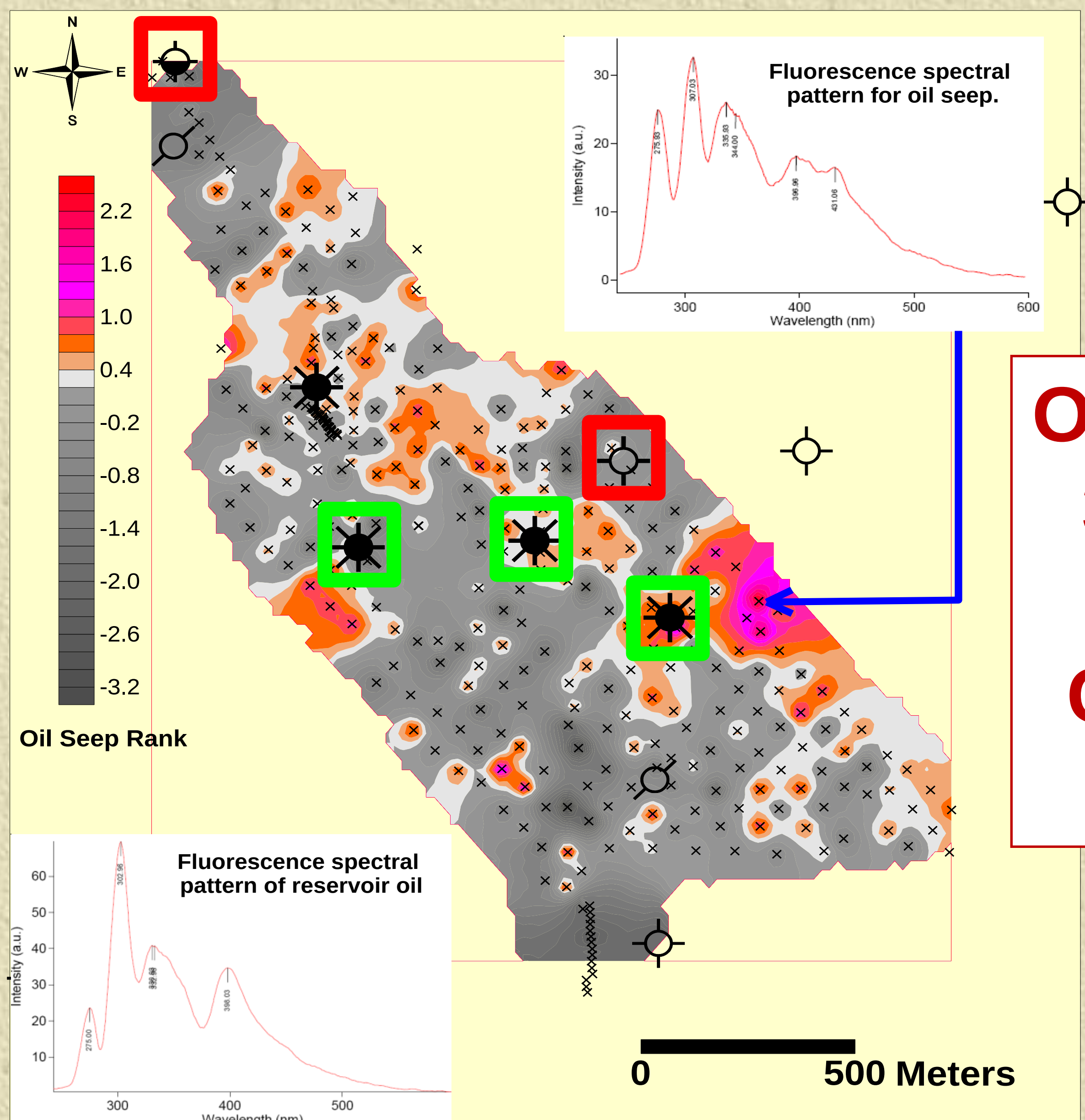
Oil Microseeps in Michigan Basin, USA

Before Drilling



- ➢1,200 m deep Ordovician carbonate reservoir
- ➢Oil seeps are compositionally identical to produced oil
- ➢ Seeps at 50 cm depth

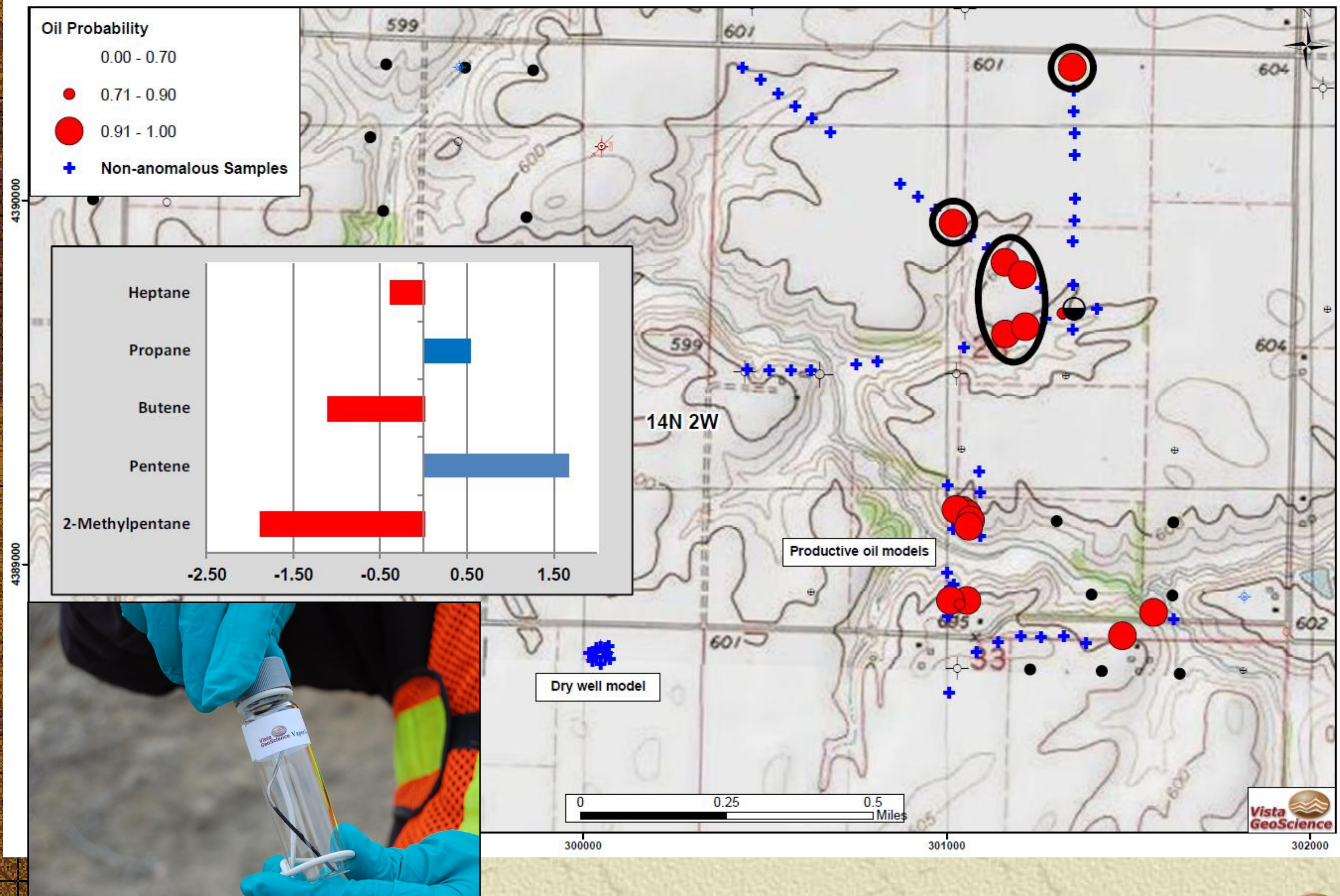
After Drilling



Oil Seeps and 3D Seismic Predict Commercial Oil Wells

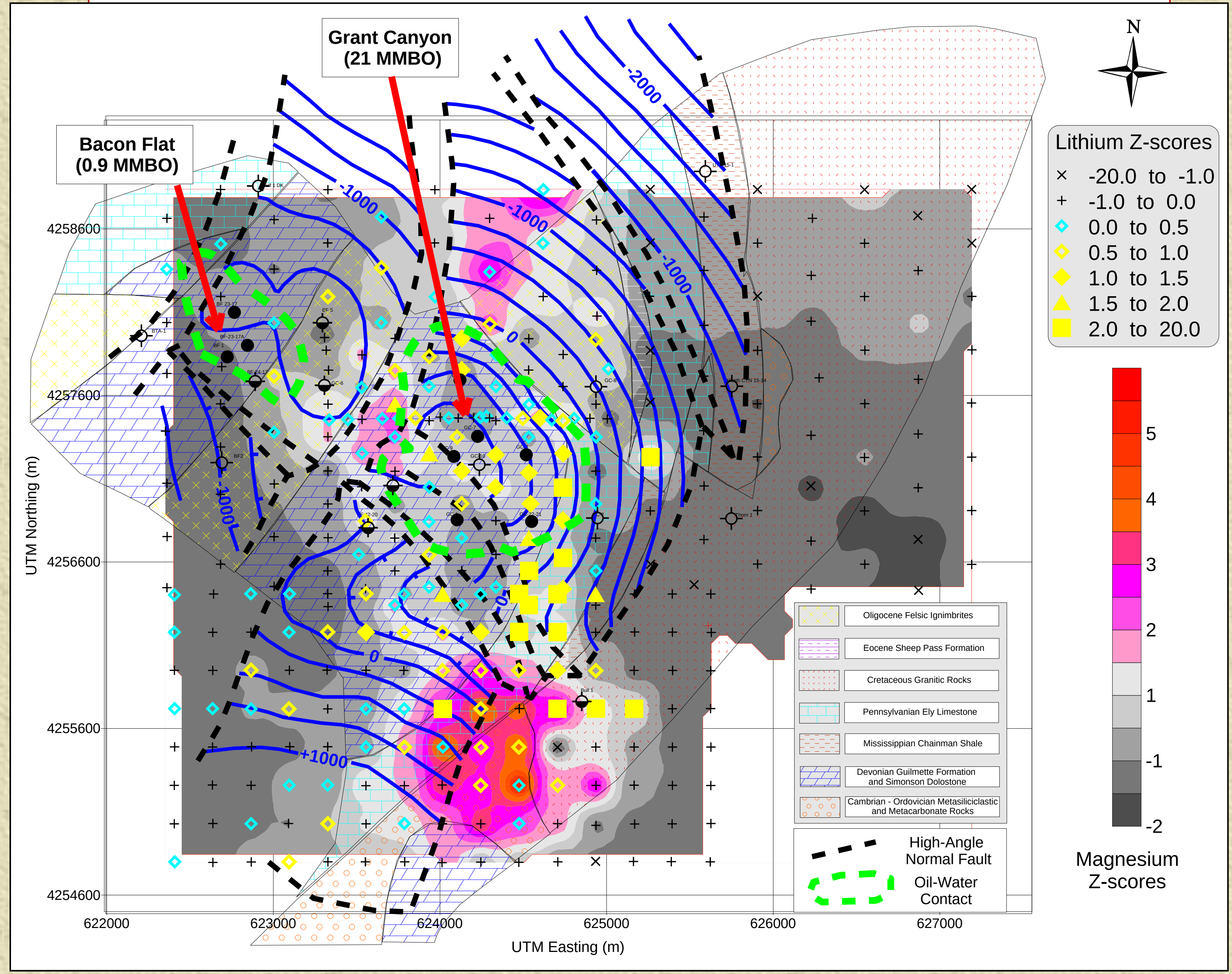
Linking Gas Microseeps With Devonian Carbonate Oil Reservoir

Passive Gas Anomalies Over Oil-charged Carbonates



Linking Major/Trace Element Anomalies With Grant Canyon Oil Reservoir

Magnesium and Lithium Anomalies in Soils



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Grant Canyon Produced Water Composition

Hulen et al (1994)

Concentrations (mg/kg)	GC #3 Oil Well	WGC Dry Well 21-31
K	72	14.6
Ca	56.3	31.8
Mg	7.2	3.4
Sr	1.07	0.93
Br	4.86	0.63
Li	1.8	0.21
Cs	0.058	0.025
Rb	0.31	0.09

Google Images (1st page) Fracking, Water

Benefits of Baseline Surveys to the Oil & Gas Industry

- **Document Environmental Conditions Before and After Oil & Gas Development**

- **"Insurance Policy" Against Future Landowner and Regulatory Agency Complaints and Litigation.**

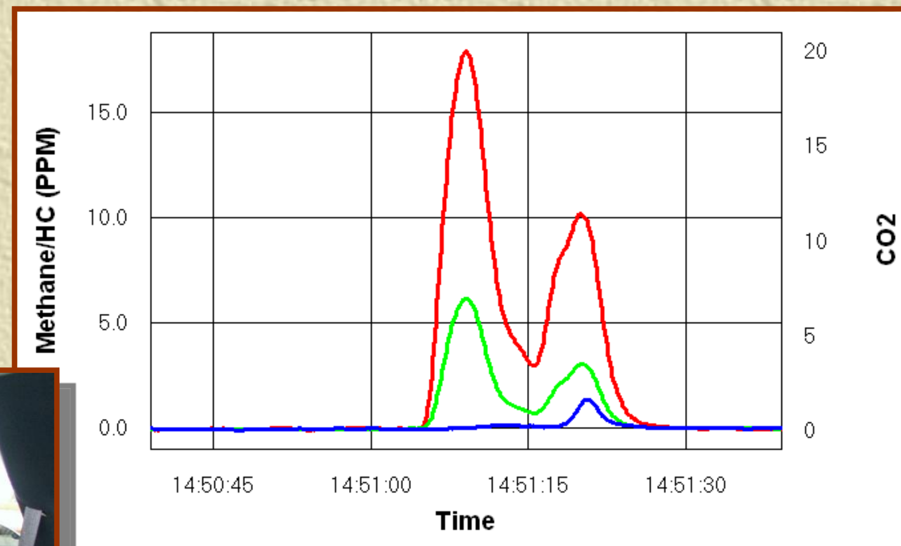
- **Improve Community Relationships**

Phases of a Baseline Environmental Survey

- Map Existing Oil, Gas and Water Wells
- Examine Air Photos, Geology Maps and Interview Residents
- Map Stressed Vegetation, Probable Faults and Gas Seeps Noted by Landowners
- Conduct Regional and Detailed Hydrocarbon Seep Survey (P&A wells, springs, water wells etc.)
- Sample and Analyze Soil Gas Seeps and Water Wells for Organics and Inorganics.
- Determine Source of Hydrocarbons and Groundwater Through Forensic Geochemical Methods.

Ambient Air Methods - Infra-Red Spectrometer

- Real-time sub-ppm airborne CH_4 , C_2+, CO_2
- <1ppm sensitivity



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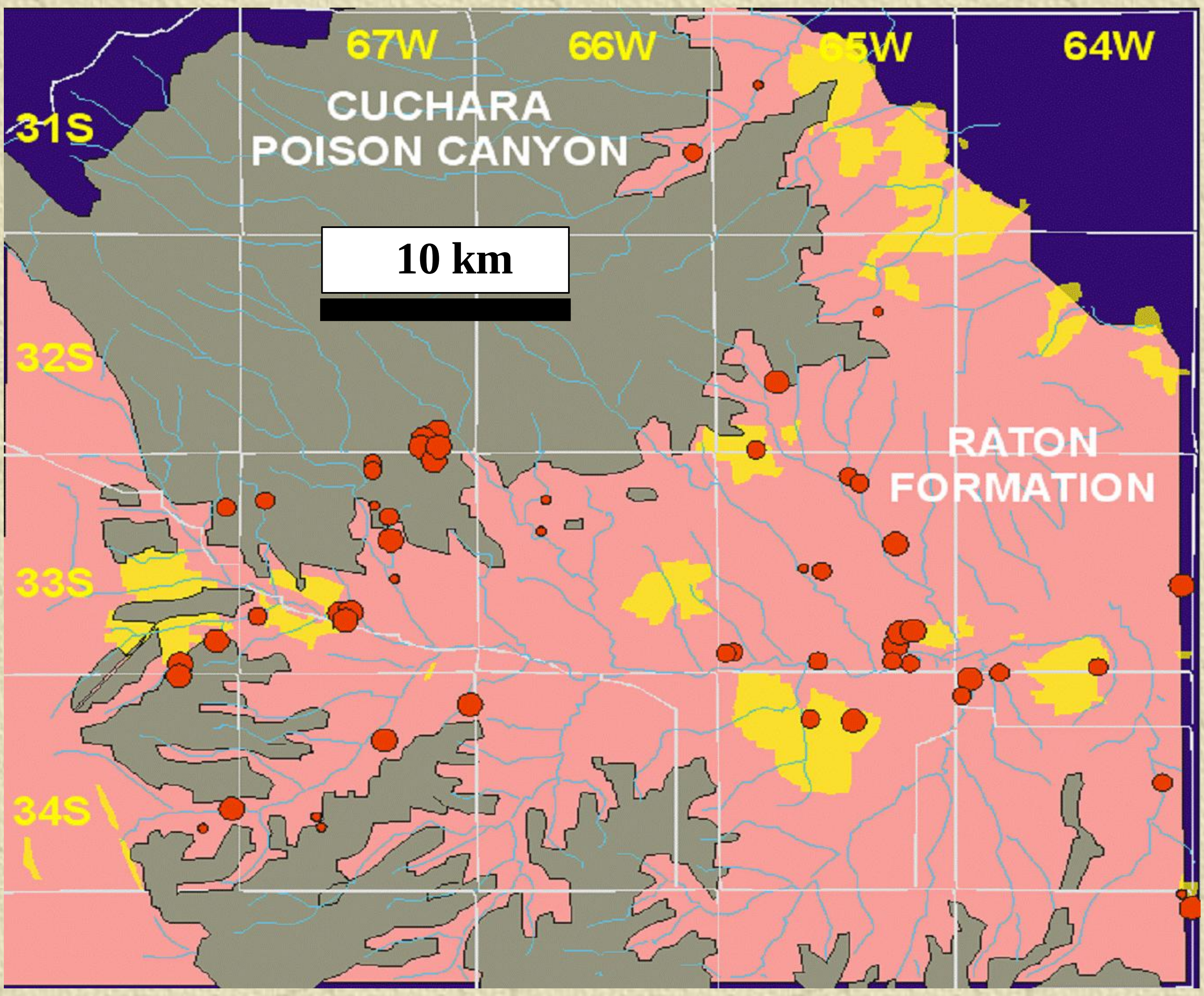
Regional Hydrocarbon Seep Survey in Raton Coal Basin, Colorado, USA



Locate Source of Seeps on Foot

- **Flame Ionization (FID)**
  - Sees all hydrocarbons
  - **1 ppm CH_4 sensitivity**
- **Photo Ionization (PID)**
  - Aromatics, alkenes, heavies
- **Modified for surface detection to replace probing & intrusive methods, avoiding utilities**
- **Continuous data transects**
- **Calibrated daily, multi-point**
- **LEL meters lack sensitivity**

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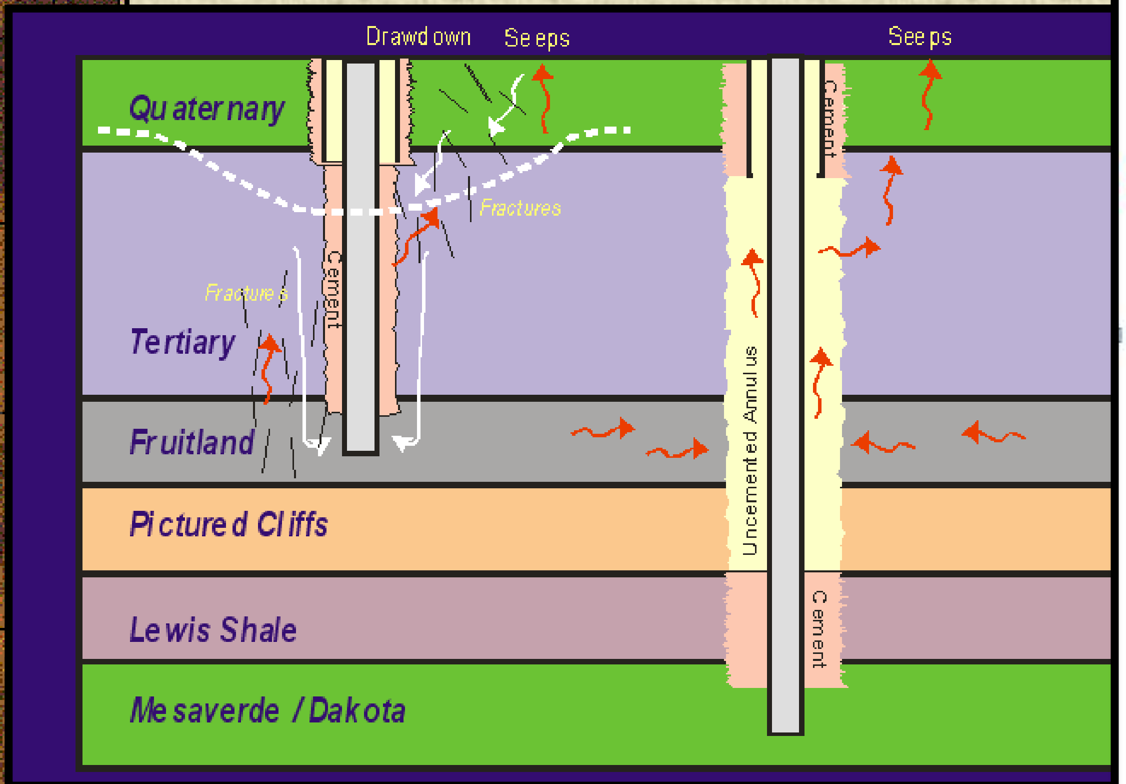
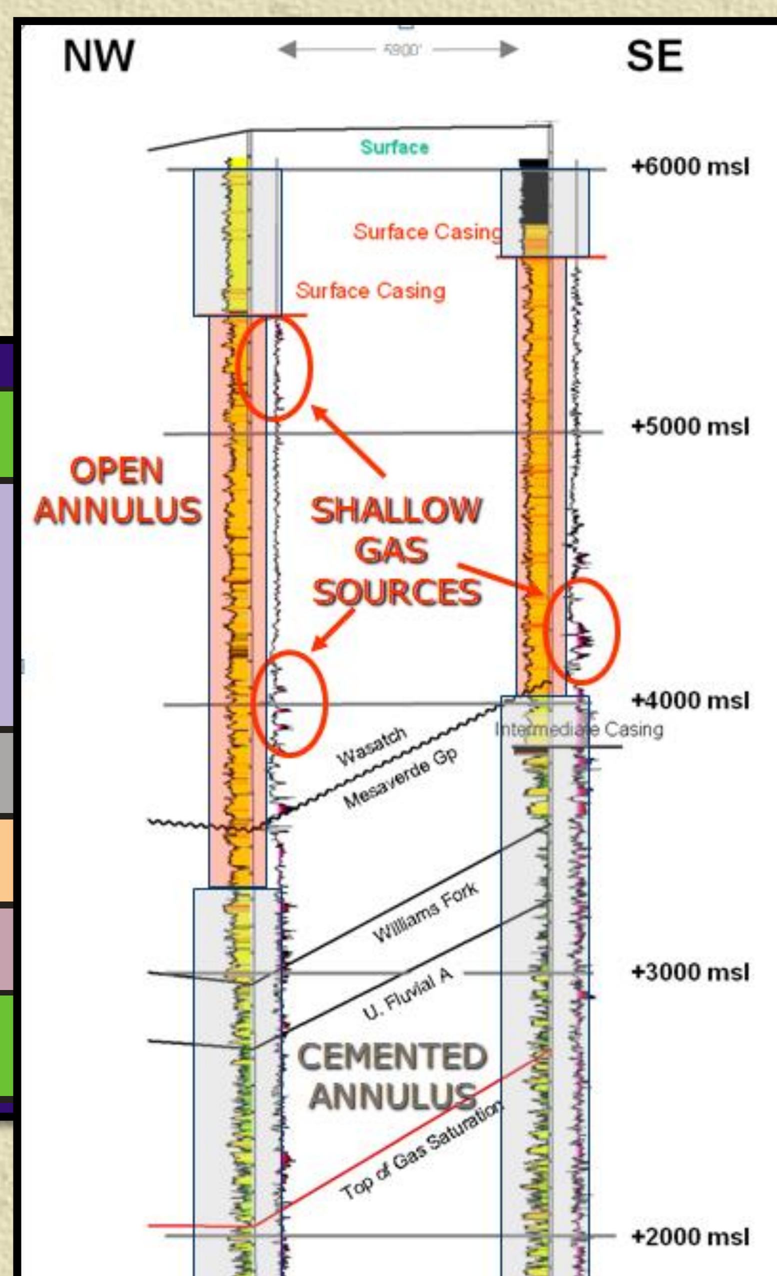
Leaking O&G Wells

- **Well Casing Leaks**
  - Historic, Old & New





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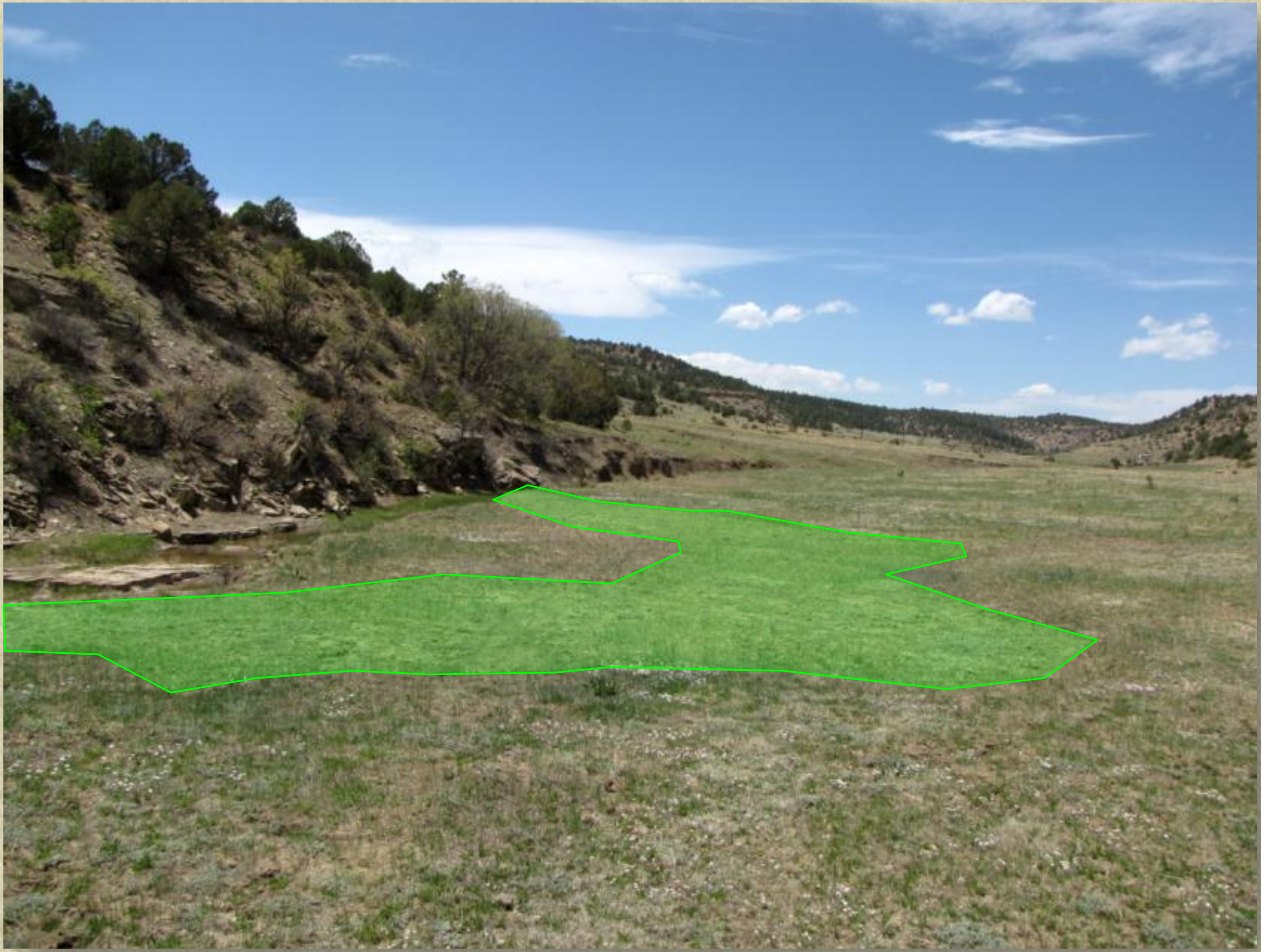
Map Seep Features (Stressed Vegetation, Salt Crusts, etc.)



Collect Gas Samples

- If gas seeps are detected, samples are required for C_1-C_6, fixed gases (CO_2, O_2, He, H_2) and carbon and deuterium isotopes of CH_4

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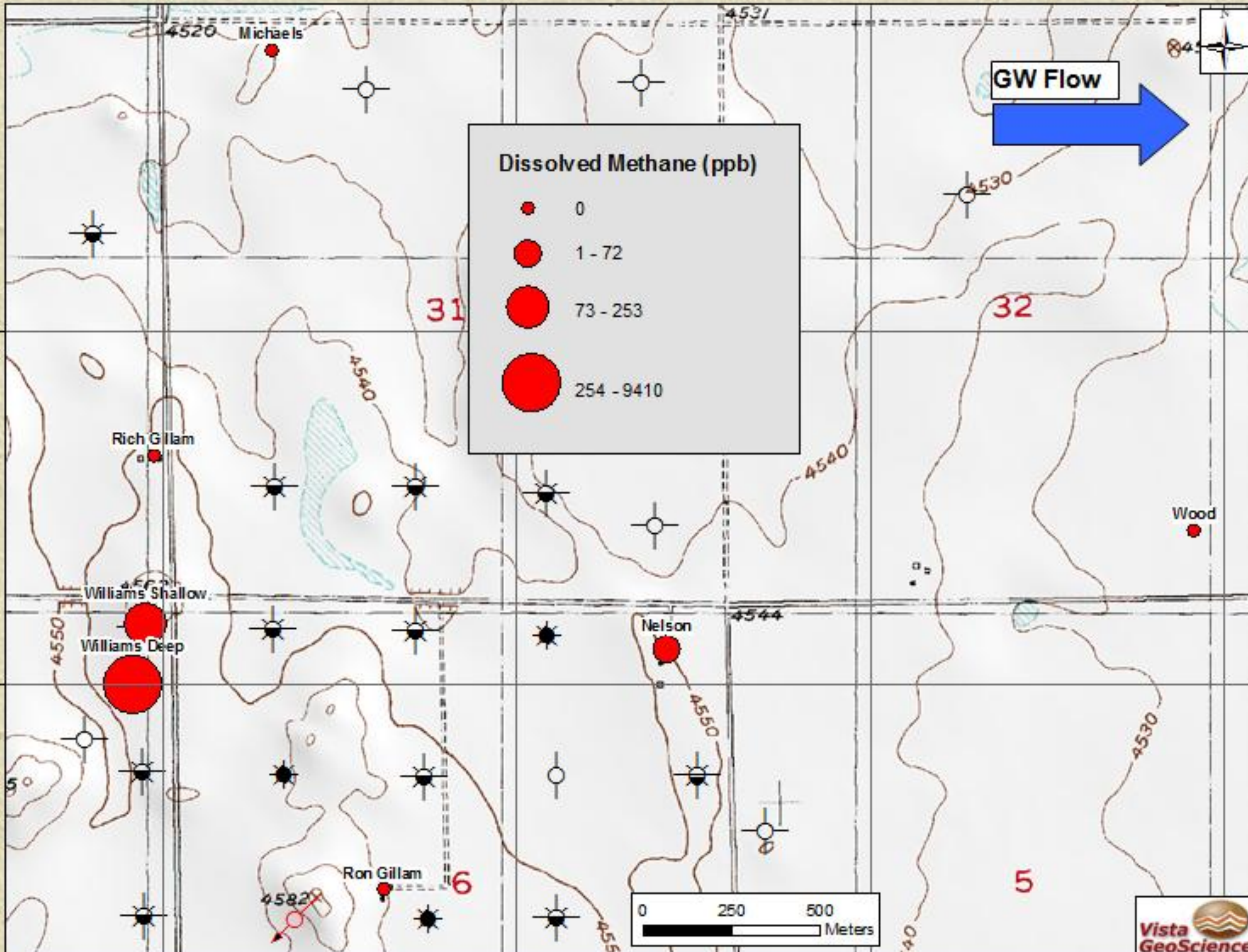
Collect Water Samples (wells, springs etc.)

Water Quality Parameters and Dissolved Hydrocarbon Analysis (COGA List)

pH	**Dissolved Gases**
Specific Conductance	Methane
Total Dissolved Solids	Ethane
Alkalinity (total bicarbonate, and carbonate; as CaCO3	Propane
Major Anions	**BTEX Compounds**
Bromide	Benzene
Chloride	Toluene
Sulfate	Ethylbenzene
Nitrate and Nitrite as N	Xylenes (o-xylene, m-p-xylene, total xylene)
Phosphorous	**If dissolved CH4 > 1 mg/L**
Major Cations (Dissolved)	Fixed gases and C1-C6 hydrocarbons
Boron	Stable isotopic concentration of the carbon (^{12}C and ^{13}C) and hydrogen (^{1}H and ^{2}H) in the methane
Calcium	**BART Bacteria Analysis**
Iron	Sulfate-reducing bacteria (SRB)
Magnesium	Iron-related Bacteria (IRB)
Manganese	Slime Forming Bacteria (SLYM)
Potassium	
Selenium	
Sodium	
Strontium	

Source of Anomalous Methane in Fox Hills Aquifer?



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ERA	Period	GEOLOGIC EPOCH/AGE	FORMATION NAME	TYPE WELL M. Segelke # 1 NENE Sec. 27 T11N R53W API 05-075-09050
Recent		Holocene Pleistocene	Alluvial & Dune Sand	0 - 50 ft
	TERTIARY	Pliocene	Ogallaha	0 - 180 ft
		Miocene	Arikaree	0 - 80 ft (Not present in area)
		Lower Oligocene	White River	25 - 100 ft
		Late Maestrichtian	Laramie Fox Hills	400 - 550 ft
MESOZOIC	CRETACEOUS	Maestrichtian Campanian	Pierre	3150 ft
		Campanian Coniacian	Niobrara & Fort Hays	350 ft
		Turonian	Carlile	195 ft
			Greenhorn	250 ft (Storage Caprock)
		Cenomanian	Graneros Shale	
		Albian	Dakota "D"	50 ft (Storage Zone)
			Huntsman	65 ft
		Aptian	Dakota "J"	104 ft (Storage Zone)
			Skull Creek	115 ft
			Lytle	104 ft
	Jurassic		Morrison	420 ft
PALEOZOIC	PERMIAN	Guadalupian	Cedar Hills - Blaine	205
		Leonardian	Stone Corral	104 ft
			Lyons	46 ft
			Wellington - Lower Satanka	44 ft
		Wolfcampian	Wolfcamp	328 ft
	PENNSYLVANIAN	Virgilian	Virgil	352 ft
		Missourian	Missouri	135 ft
		Desmoinesian	Marmaton Cherokee	165 ft
		Atokan	Atoka	200 ft
		Morrowan	Morrow	165 ft
Precambrian			Precambrian	Unknown

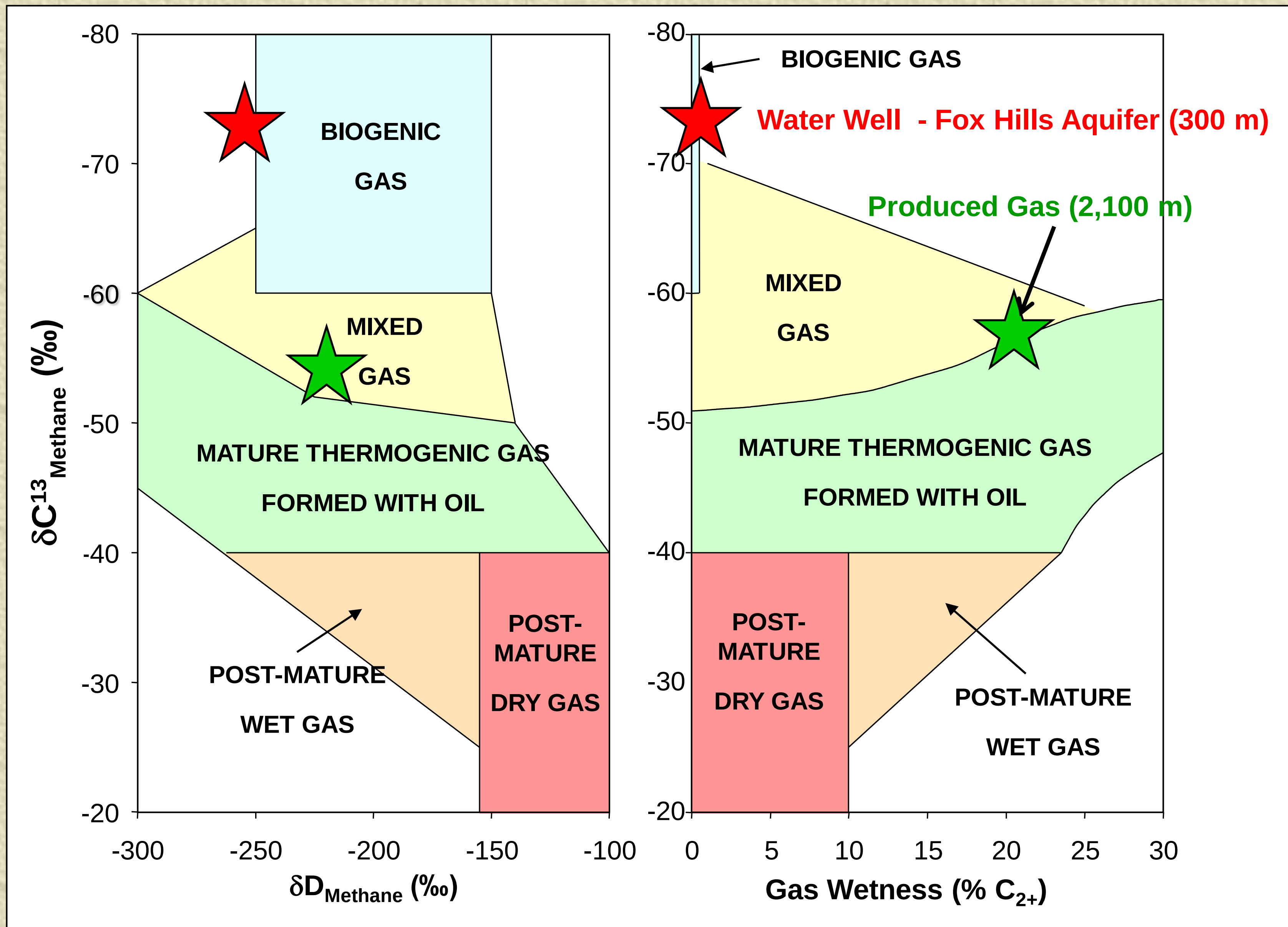
Ogallala Aquifer (80 m)

Fox Hills Aquifer (300 m)

O&G Reservoir (2,100 m)

Denver Basin Baseline Survey, Colorado, USA

Biogenic Methane in Aquifer is Not Produced Gas



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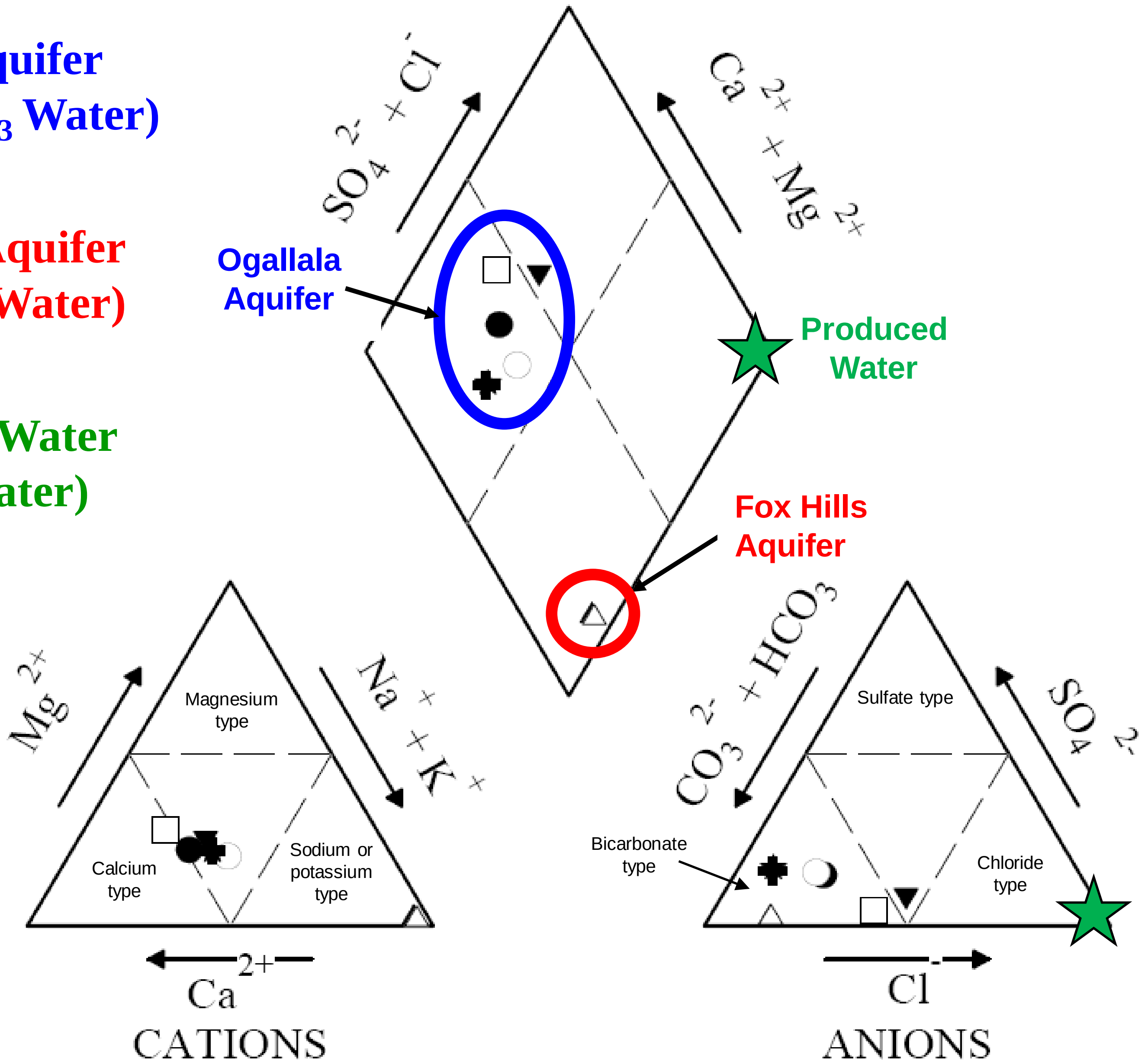
No Mixing of Groundwater and Produced Water

Ogalla Aquifer ($CaMgHCO_3$ Water)

Fox Hills Aquifer ($NaHCO_3$ Water)

Produced Water (NaCl Water)



SUMMARY

- Surface geochemical methods reduce exploration risk for energy resources.
- Important to link surface seeps with reservoir fluids.
- Baseline environmental surveys can help protect energy resources from potential complaints and litigation.