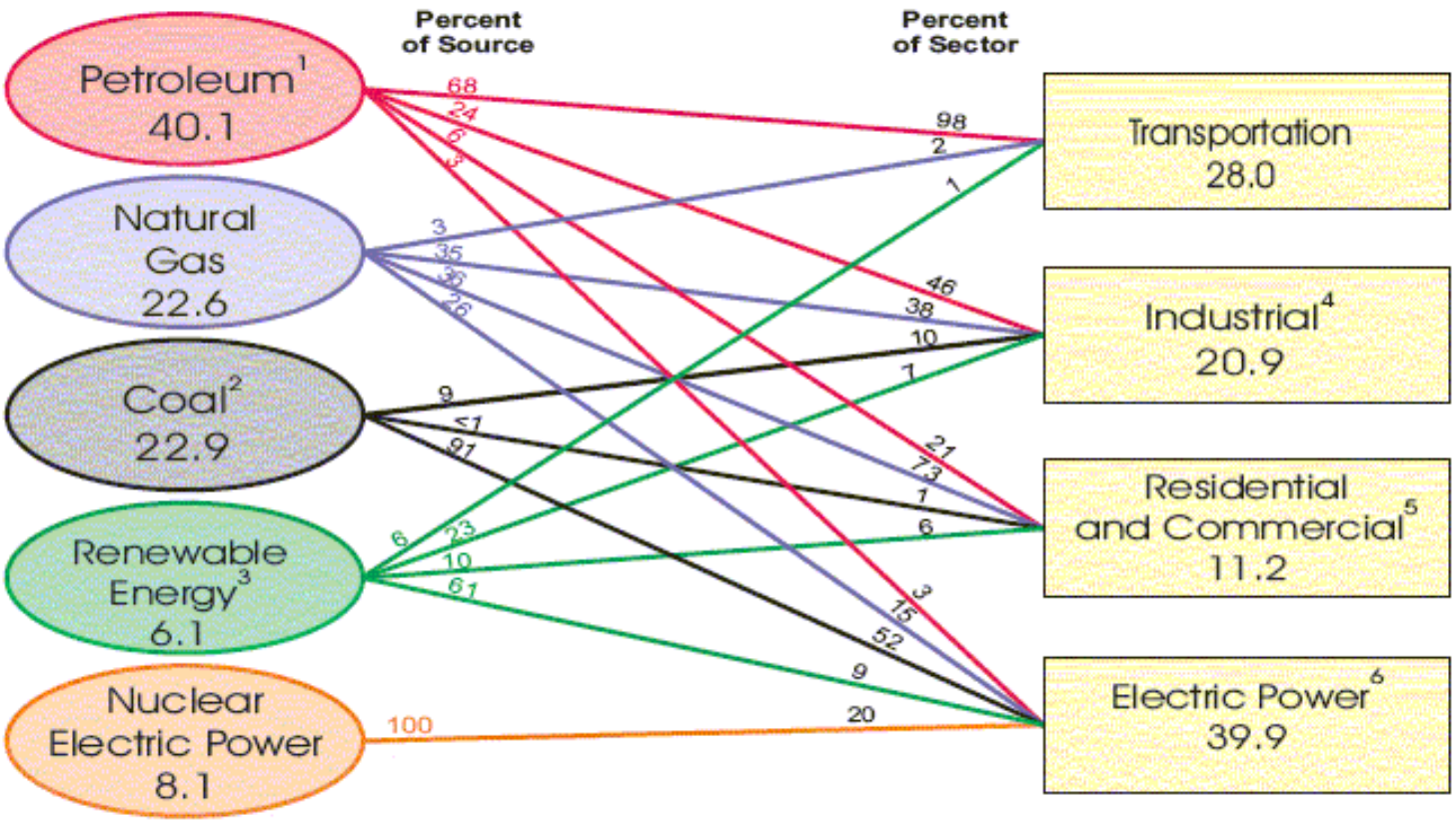
Advantages of In-situ Gas Extraction

Dr. Kevin Shurtleff
Dr. Milind Deo

MOUNTAIN WEST ENERGY

2007 Oil Shale Symposium
Colorado School of Mines
October 16, 2007

U.S. Energy Facts



U.S. Primary Energy Consumption by Source and Sector, 2005 (Quadrillion Btu).

MWE's Oil Shale Strategy

"Those who do not learn from the past are doomed to repeat it."
[George Santayana]

"I've missed almost 9,000 shots. I've lost almost 300 games. I've failed over and over again in my life. And that is why I succeed."
[Michael Jordan]

We are fortunate to learn from the failures and build on the successes of the those that have blazed the path.

Oil Shale Issues

- The quantity of oil shale is well documented.
- Oil from oil shale is technically feasible.
- Critical issues today are economic and environmental.
- Commercial viability requires the following:
  1. Low capital and operating costs.
  2. Fast return on investment (ROI).
  3. Low environmental impact.

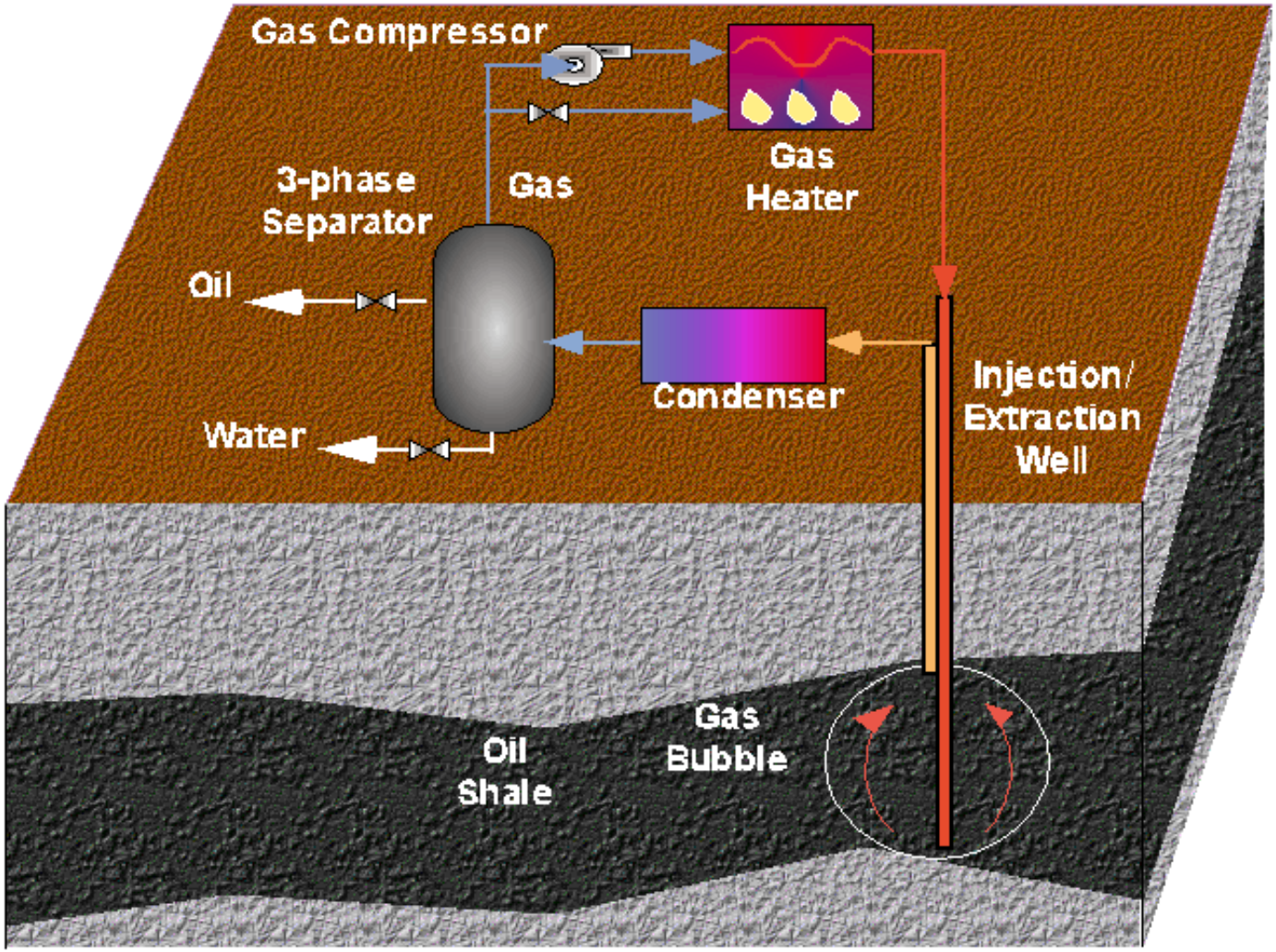
Why in-situ?

- Lowest cost
- Lowest environmental impact
- Safest

In-situ methods produced 289,000 bbls/day of oil from Canadian oil sands in 2005.

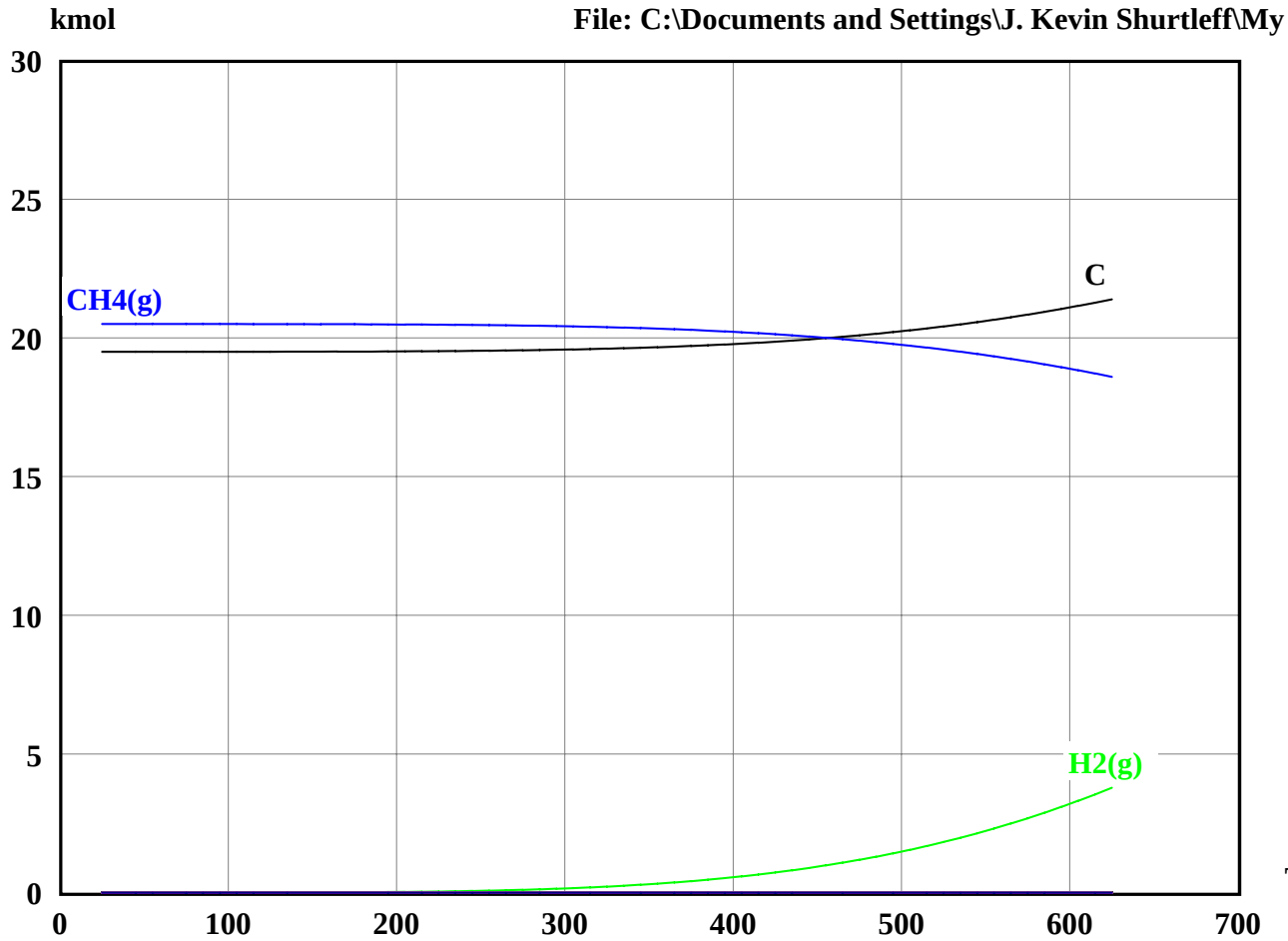
The in-situ conversion process (ICP™) showed us the possibilities for oil shale.

MWE In-situ Gas Extraction



- Closed loop, re-circulating gas.
- Faster heating by convection.
- Oil vapor (not liquid).
- Inverted flow (extraction point above injection point.
- Single well.

Pyrolysis Thermodynamics

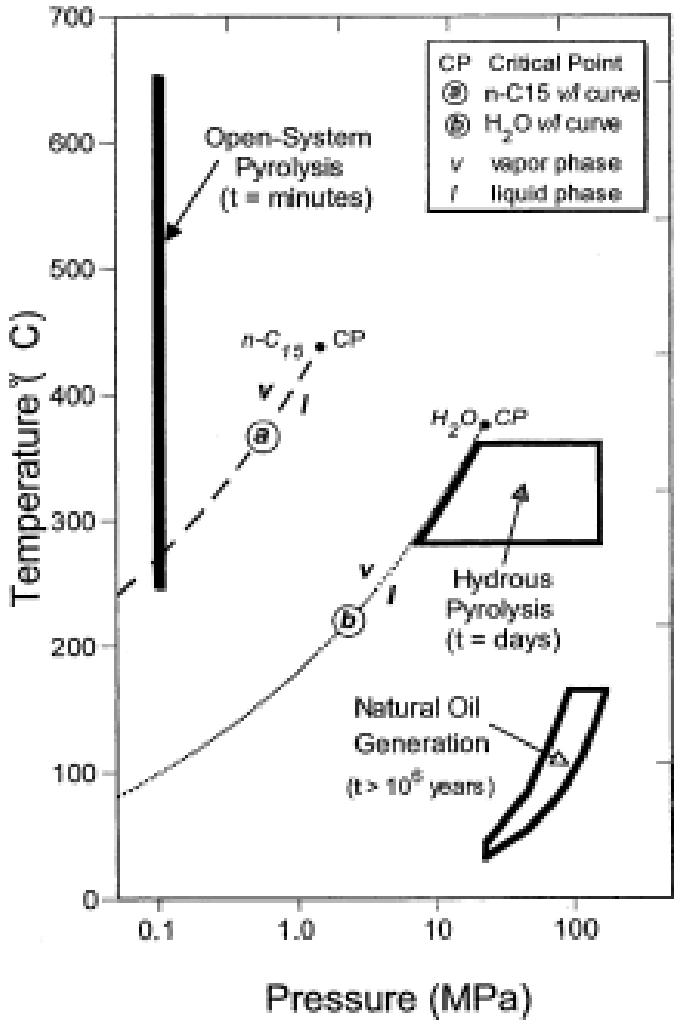


Thermodynamic equilibrium calculations using HSC (Outokumpu Research).

Pyrolysis of a large paraffin molecule (C40H82) at 1300 psia.

Pyrolysis is kinetically limited.

Pyrolysis Kinetics



M.D. Lewan and T.E. Ruble, Organic Geochemistry, 33, (2002), 1457-1475

Slow, low temperature, high pressure, natural process produces the highest quality oil.

Fig. 19. Temperature-pressure plot showing conditions employed by open-system pyrolysis, hydrous pyrolysis, and natural oil generation relative to the vapor-liquid (v/l) phase curves and critical points (CP) for *n*-pentadecane (a) and water (b).

Pyrolysis Energy Requirements

1 acre of oil shale (235 ft diameter x 100 ft thick)

= 291,500 tons (long)

= 168,013 GJ to heat to 350 C with 10% heat loss (not including heat of cracking/reaction).

= 1.95 GW over a day, 2.66 MW over two years, 1.07 MW over five years.

= Natural gas cost of ~ $955,471 ($6 per mmBtu) or electricity cost of ~ $2,800,209 ($0.06 per kWhr)

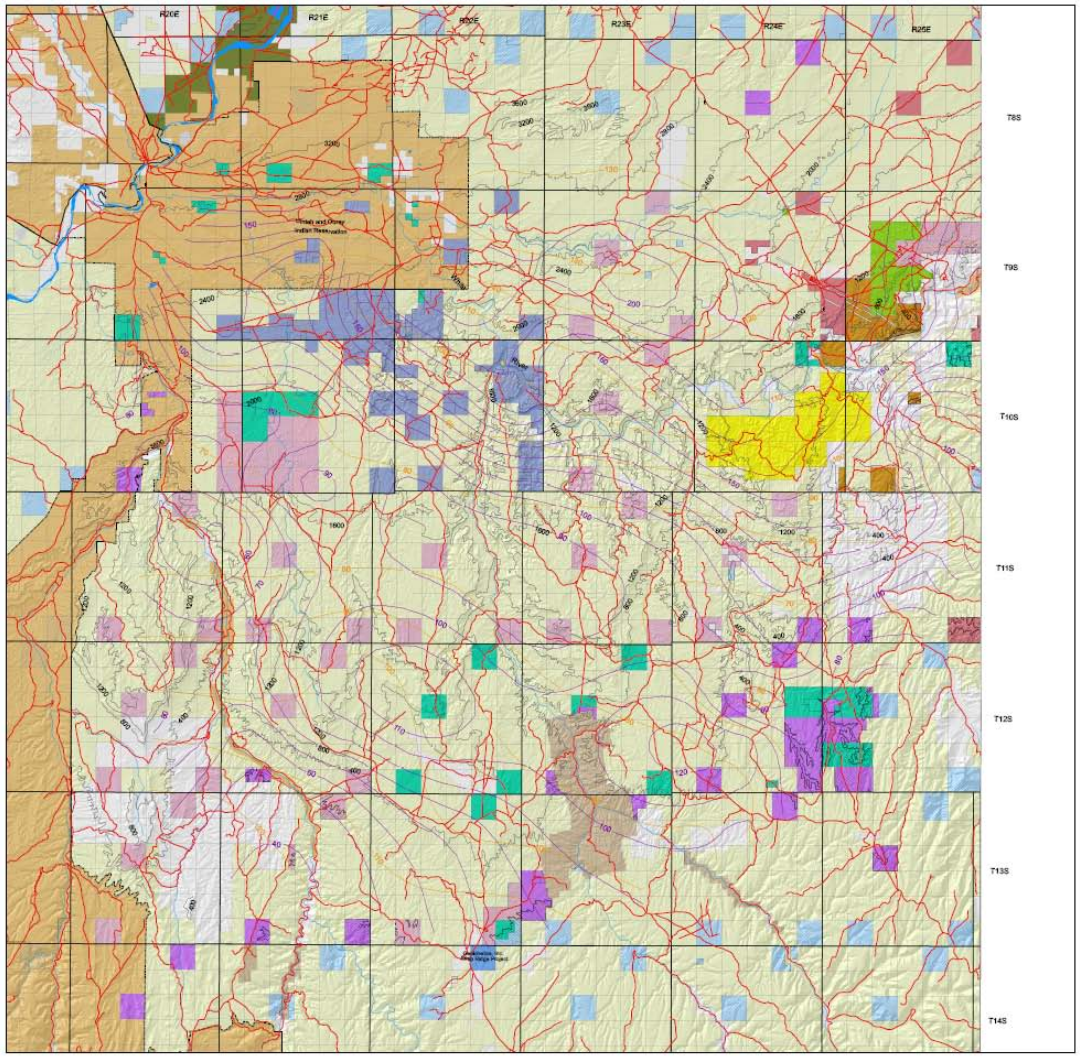
= Potential to produce ~152,700 bbls of oil (22 gal/ton).

Single Well Process

- Low surface impact (chemistry underground).
- Each well covers ~ ¾ acre
- Oil extracted over 2 years (fast recovery).
- 60,000+ barrels per well at 50% extraction efficiency.
- Total direct costs for a single well project ~ $800,000.

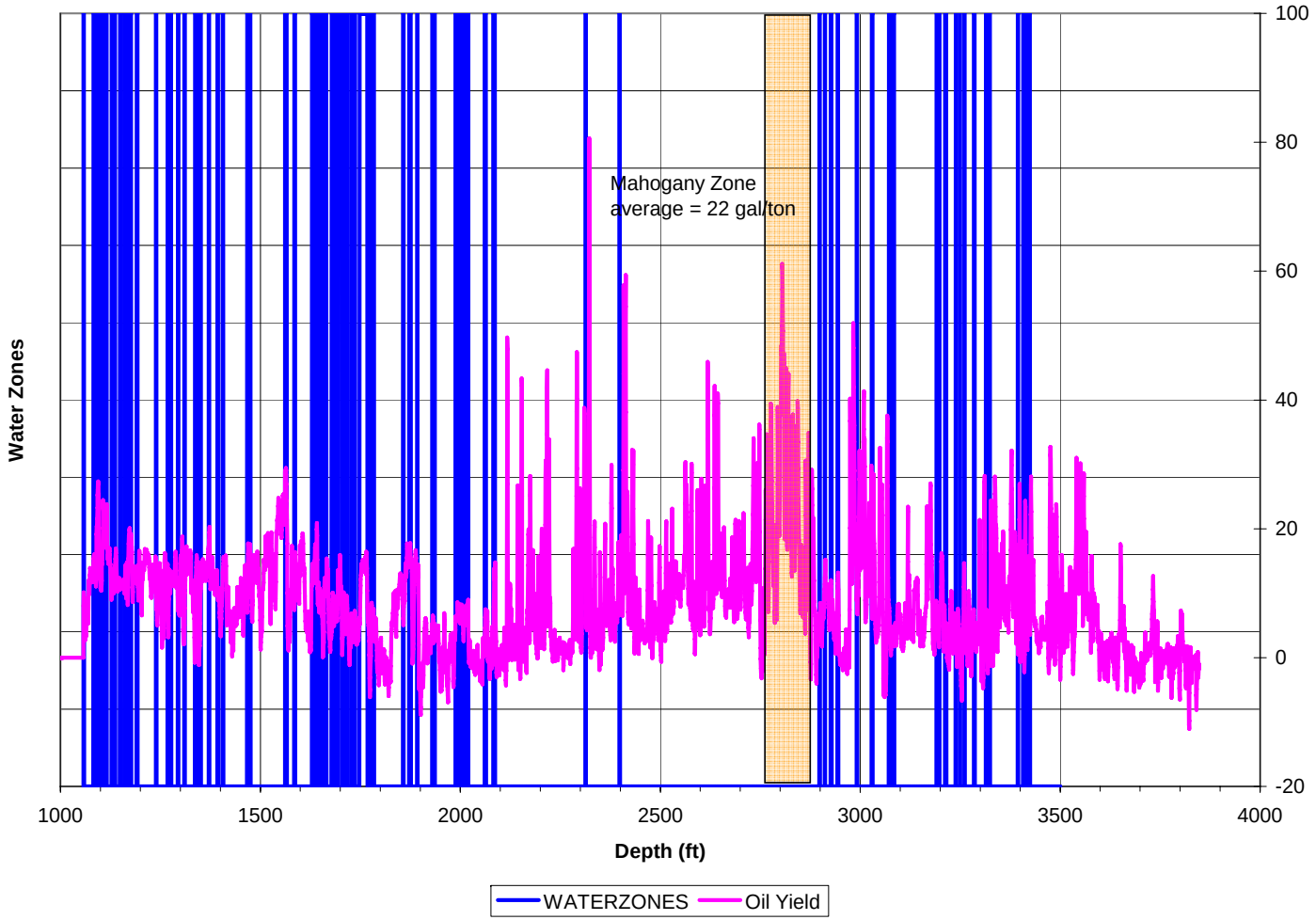
(Illustrative well)

Why Utah?


R20E
R21E
R22E
R23E
R24E
R25E
T8S
T9S
T10S
T11S
T12S
T13S
T14S


UTAH TRUST LANDS
Oil Shale Resources
Uintah County, Utah
LEGEND
Trust Lands Oil Shale Leases
ConocoPhillips
Sutton Monarch Mining, Inc.
Oil-Tech, Inc.
Retamco Operating, Inc.
Cliffs Synfuels Corp.
Sunger/Great Western Energy
Other Oil Shale Leases
Unleased Oil Shale Trust Lands
Trust Lands Minerals
All mineral ownership
Partial mineral ownership
Other Land Ownership
Other Trust Lands
BLM Administered Lands
Tribal Lands
Private Lands
State Wildlife Lands
U.S. Fish & Wildlife Lands
1,000's Barrels Oil Per Acre In The 25 GPT Mahogany Zone
Mahogany Oil Shale Zone Thickness in Feet
Overburden Thickness In Feet Above The Mahogany Zone
Surface Erosion of The Mahogany Zone
April, 2006

Preventing Groundwater Contamination



Density and sonic log analysis according to John Dyni, et al, USGS Open File Report 91-285.

(Brian Black)

Environmental Impact

- IGE requires 14 wells to cover a 10 acre plot.

Almost 300 wells, spaced 8 ft, are required to surround a 10 acre plot.

- Natural gas heaters for IGE will produce 9,341 metric tons of carbon dioxide (90% conversion efficiency).

Electric heaters will produce 37,217 metric tons of carbon dioxide from a coal fired power plant (40% conversion efficiency).

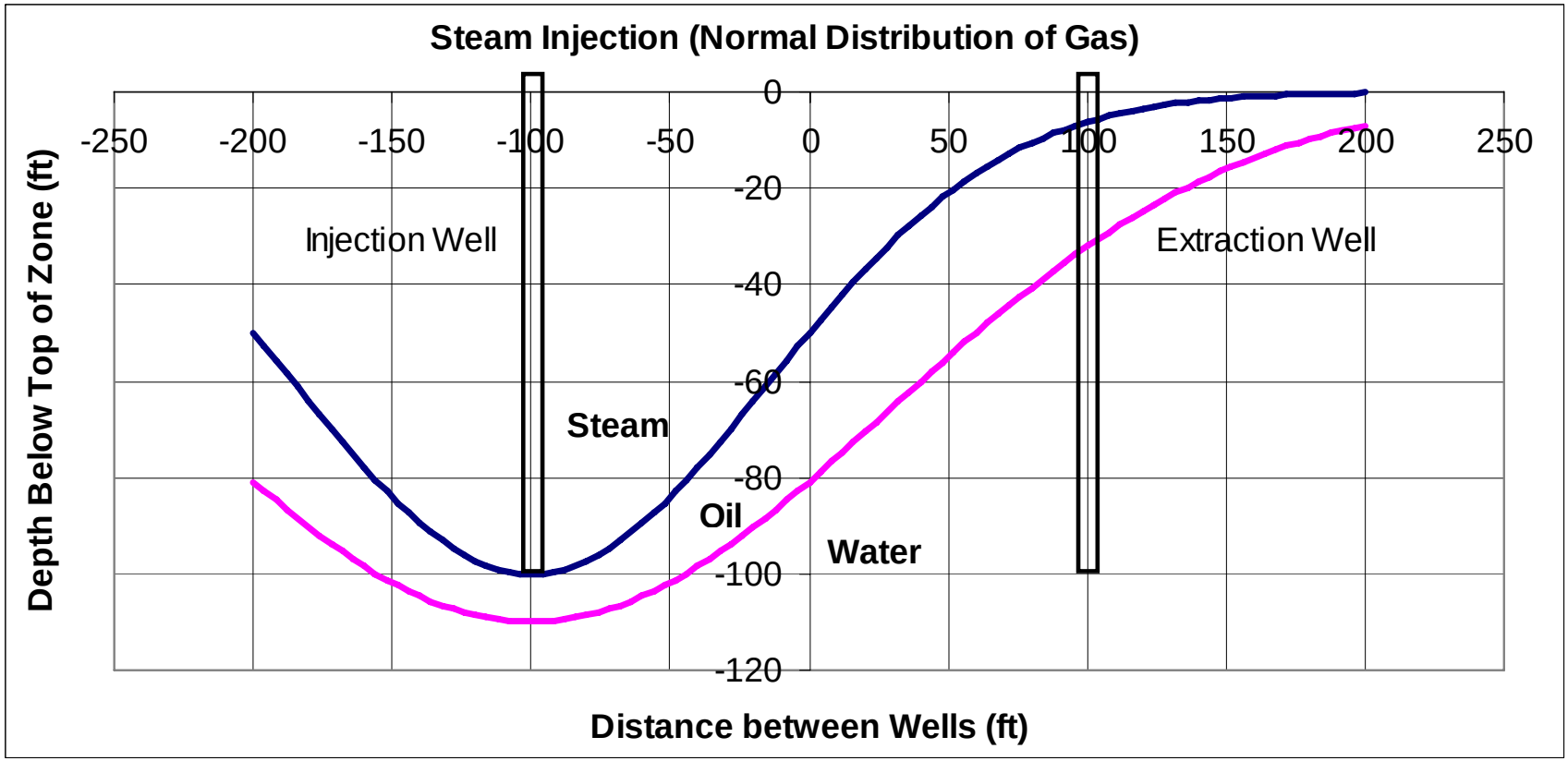
- IGE enables heat capture from previously depleted zones, to reduce energy costs and emissions.
- IGE could use solar thermal heating to reduce energy costs and eliminate most emissions.

Why Natural Gas?

- Natural gas is readily available near oil shale deposits in the Uintah Basin of Utah.
- Natural gas produced during pyrolysis can be re-circulated without separation.
- Natural gas produced by pyrolysis can be directly burned to generate heat for the process.

Carbon dioxide would work, but requires additional equipment for separating natural gas from the re-circulating gas.

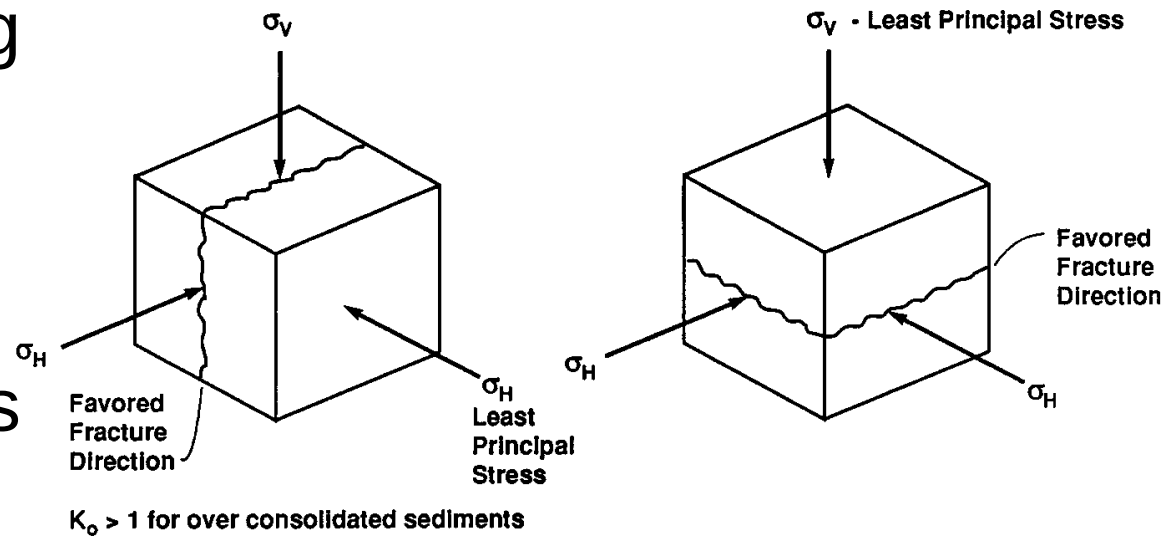
Why not steam?



Steam is a better heat carrier (heat of vaporization), but condenses to liquid in the formation. Does the oil float?

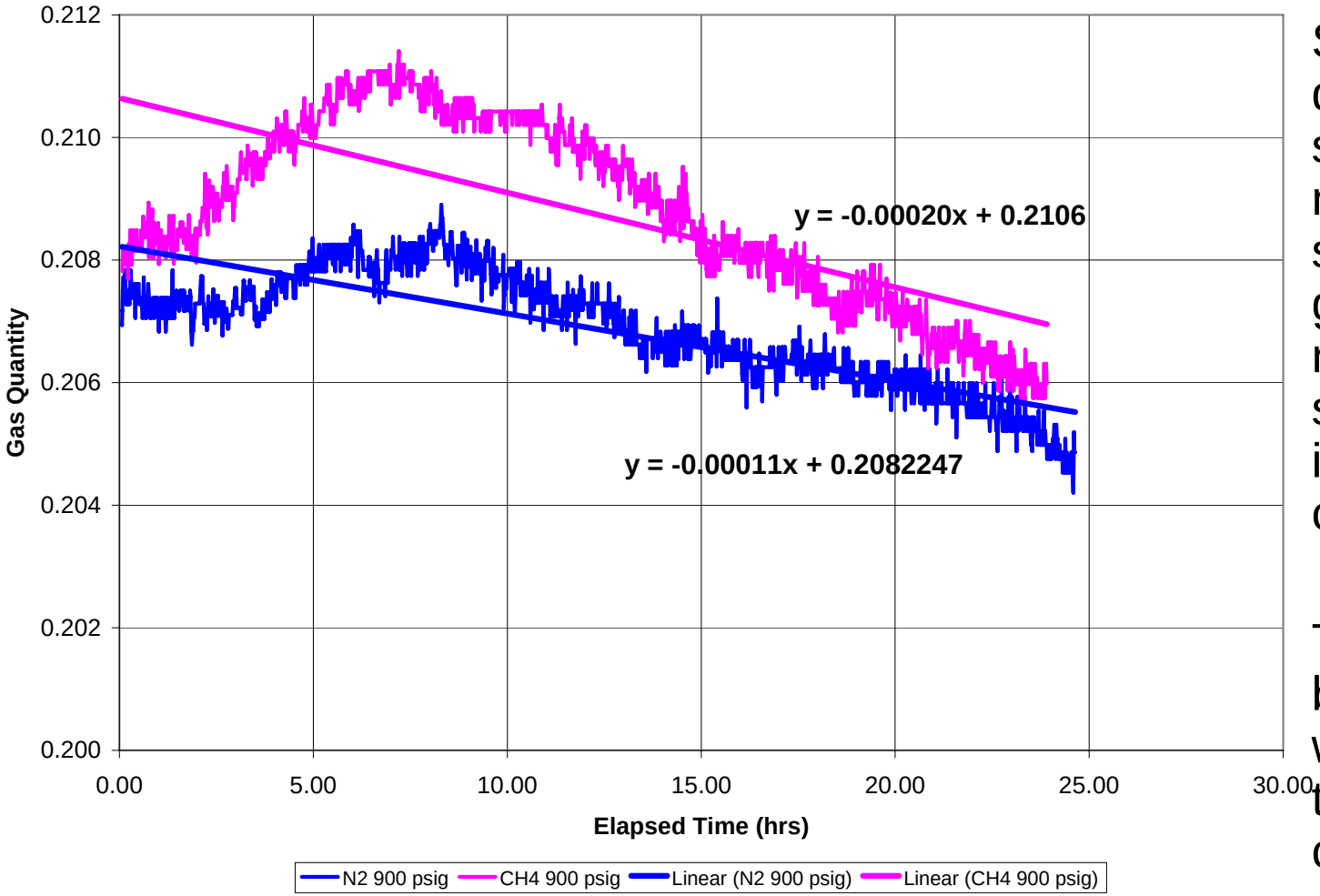
Fracturing for Gas Flow

- Thermal fracturing
- Hydraulic stimulation
- Gas Gun™
- High pressure gas fracturing
- Methane solubility – No fracturing required?



Fracturing occurs perpendicular the least principal stress. In shallow oil shale formations, this may result in horizontal fractures.

Methane Solubility in Oil Shale



Slope differences suggests methane solubility is ~2x greater than nitrogen solubility (non-isothermal conditions).

Test system has been enhanced with constant temperature controller.

Laboratory Scale System

- Functioning system.
- Parameters

1.8 kg of Utah oil shale
99% recirculating methane
Gas temp. = 350 - 400 C

- Results

0.11 kg of oil (6 wt%)
API gravity 18-21
Sulfur content 0.5-1.0 wt%
Wax content 3.9 wt%
Hydrogen/Carbon ratio 1.6
(Conventional oil = 1.9)

- Experimentation is on-going

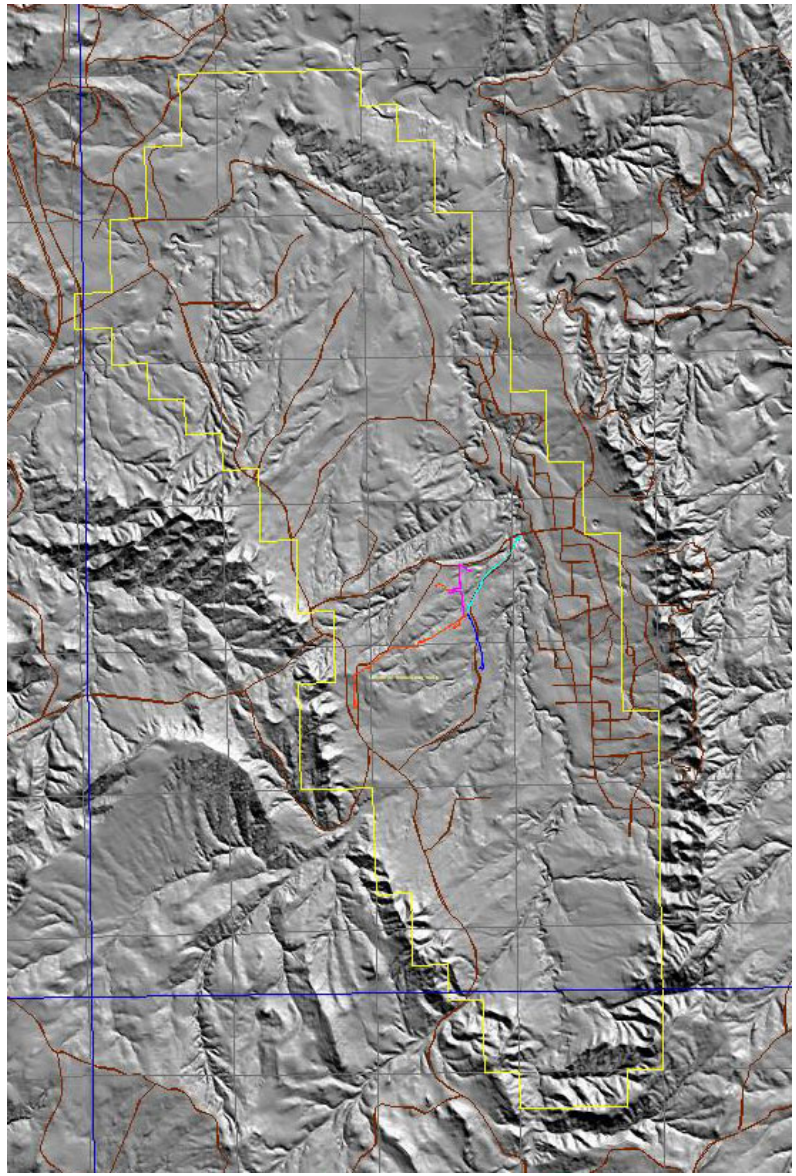
RMOTC Project

Naval Petroleum Reserve #3, Teapot Dome, Shannon Formation

Phase 1 – gas flow testing

Phase 2 – heating and oil extraction

Starting Fall 2007



U.S. Department of ENERGY
Fossil Energy Program

MWE's Competitive Advantages

- Lowest capital and operating costs.
- Scalable by replication.
- Faster return on investment.
- Marketable oil without upgrading.
- Low environmental impact.
- Five patents in process.

(Low cost truck mounted rig)

Acknowledgements

- Brian Black - RMOTC
- Ben Cahoon - MWE
- Harvey Cahoon - MWE
- Stewart Cowley - MWE
- Dave Glazier – Kirton and Mcconkie, PC

Questions