Technical and environmental aspects of oil shale assessment for western U.S. deposits

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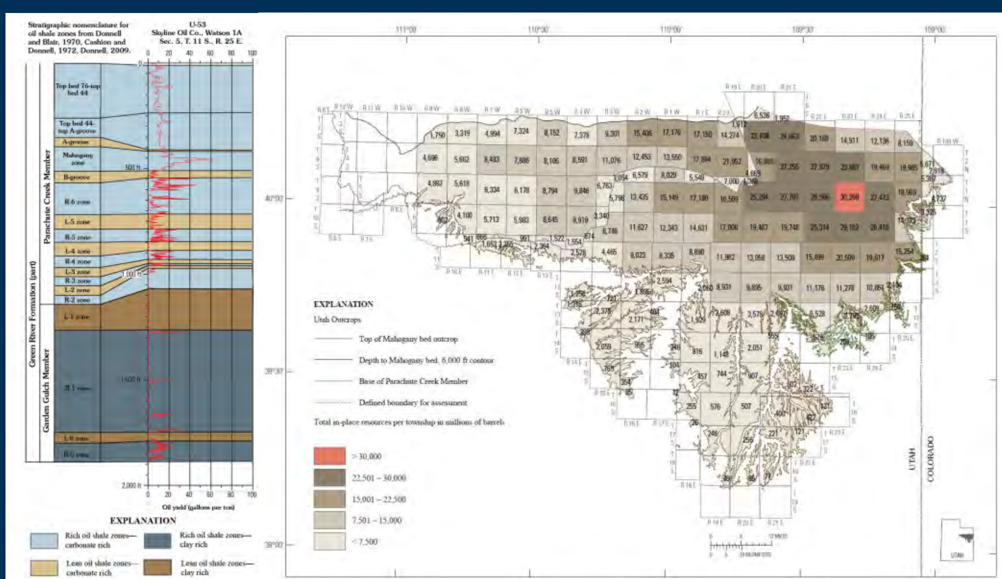
Shale oil resource-in-place assessment

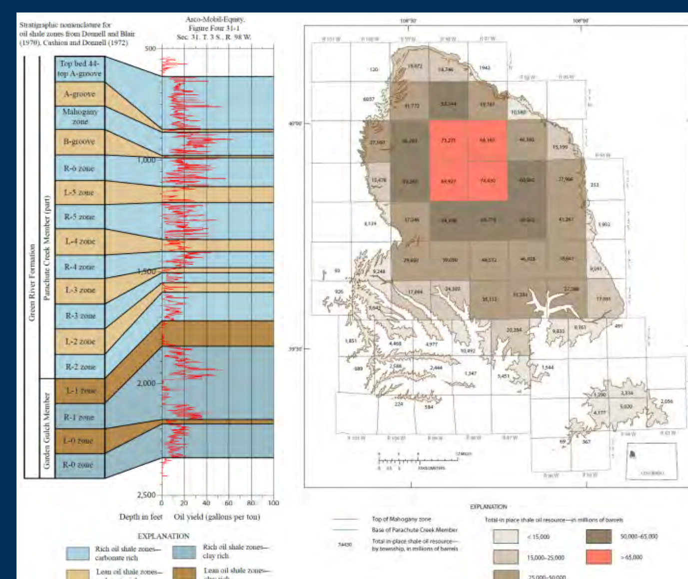
The "oil-in-place" estimates of the latest USGS Western Oil Shale Assessment Team provide an excellent resource on Green River Formation oil shale deposits.

Using Fischer Assay data from hundreds of thousands of analyses, total in-place resources have been estimated and GIS tools are being developed to make using this data simpler (e.g., the Oil Shale Calculator).

Uinta Basin



Piceance Basin



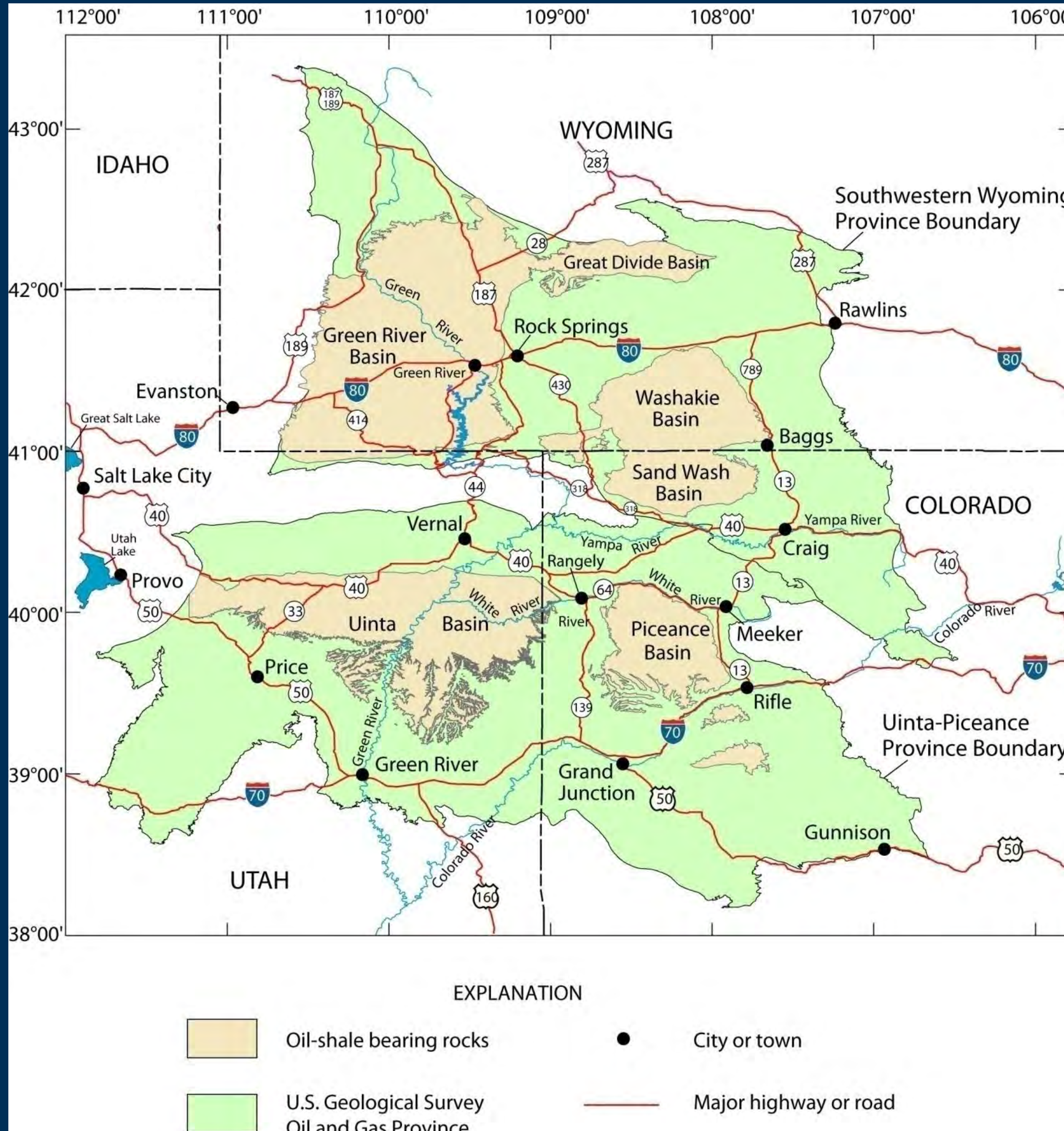
Major Green River Formation Deposits

Piceance Basin:
1,335 mi^2 (3,458 km^2).
In place resource:
1.52 trillion barrels

Uinta Basin:
3,834 mi^2 (9,930 km^2).
In-place resource:
1.32 trillion barrels

Greater Green River Basin:
5,500 mi^2 (14,244 km^2).
In-place resource:
1.44 trillion barrels

Johnson et al., 30th OSS, 2010.



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“Has oil shale become a technically and economically viable alternative to conventional oil?”

J. Bartis, 26th Oil Shale Symposium, October 2006

“The prospects for oil shale development in the United States remain uncertain.”

J. Bartis, Testimony on S. 937 The American Alternative Fuels Act June 2011

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Environmental Impacts of an Oil Shale Industry

Land Use	• Significant land use and ecological impacts (more so from surface retorting than in-situ conversion)
Air Quality	• Early plants could prevent future industry growth • Studies from the 1980s are no longer relevant
Climate Change	• Significantly higher CO2 emissions than with conventional oil operations • Controlling emissions will lead to higher costs
Water Quality	• Salts and toxics may leach from spent shale into the Colorado River drainage basin
Water Consumption	• 3 barrels of water needed for each barrel of shale oil • Competes with other demands for water from the greater Colorado River Basin

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J. Bartis, 26th Oil Shale Symposium, October 2006

Next stage of USGS oil shale assessment

Database GIS products developed during the resource-in-place assessment provides a basis for the next stage – estimating the recoverable resource.

But the recoverable resource is tricky to define:

- What will be the grade cut-off for different processes?
- Include liquid hydrocarbons and gas?
- How will recovery vary with different utilization approaches?
- Is the unrecovered resource lost?

Recoverable resource estimate range (2006): 500-1100 billion barrels of 1500-1800 billion barrels in place (RAND)

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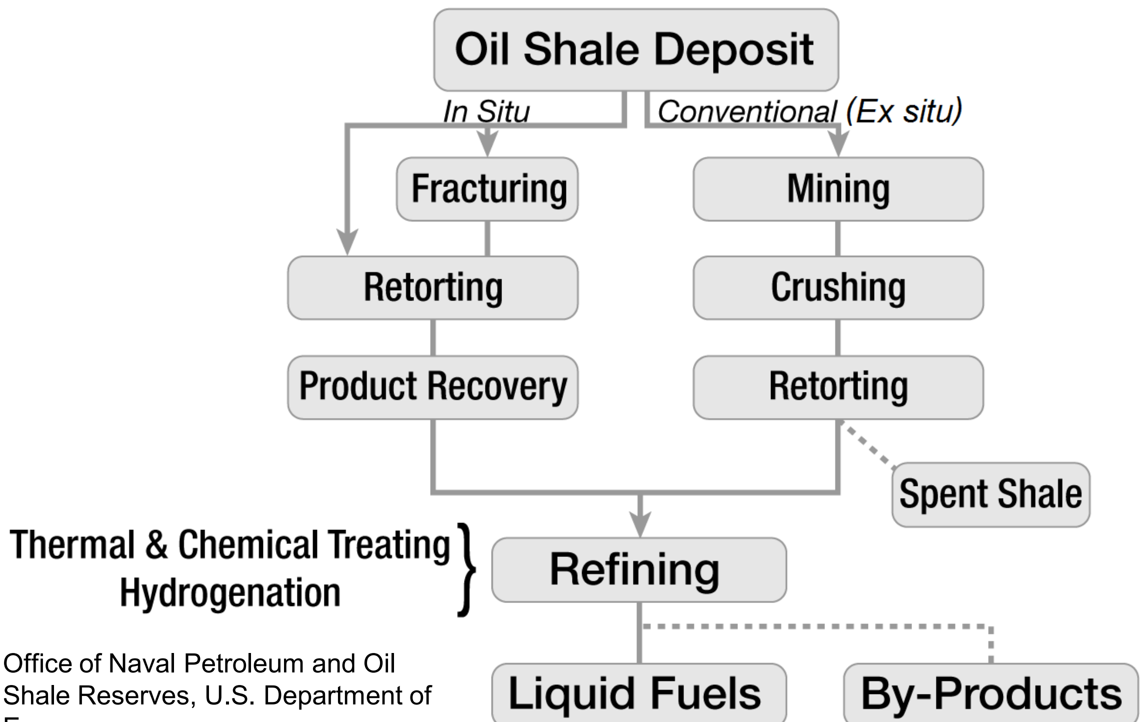
How will oil shale be utilized?

A wide range of technologies are available for oil shale utilization. Generation of liquid hydrocarbons (and gas) by retorting is the most common approach discussed for western US oil shale utilization.



Office of Naval Petroleum and Oil Shale Reserves, U.S. Department of Energy

- What resources are amenable to mining & surface retorting?
- How will *in situ* approaches be applied to different deposits?
- How do environmental impacts differ when different approaches are applied to a specific location?

Retorting conditions will determine the **yield and quality** of products generated from oil shale.

Technically recoverable resources

Define resources:
Retort-generated hydrocarbon liquids and gas

Methods for estimating **Recovery Factors** are needed for oil and gas products, with compositional estimates based on laboratory and pilot scale tests.

This is needed for representative technologies that are expected to be implemented.

These estimates could change as new technologies are developed.

Minable Resources – *Surface retorting*

How does it work?

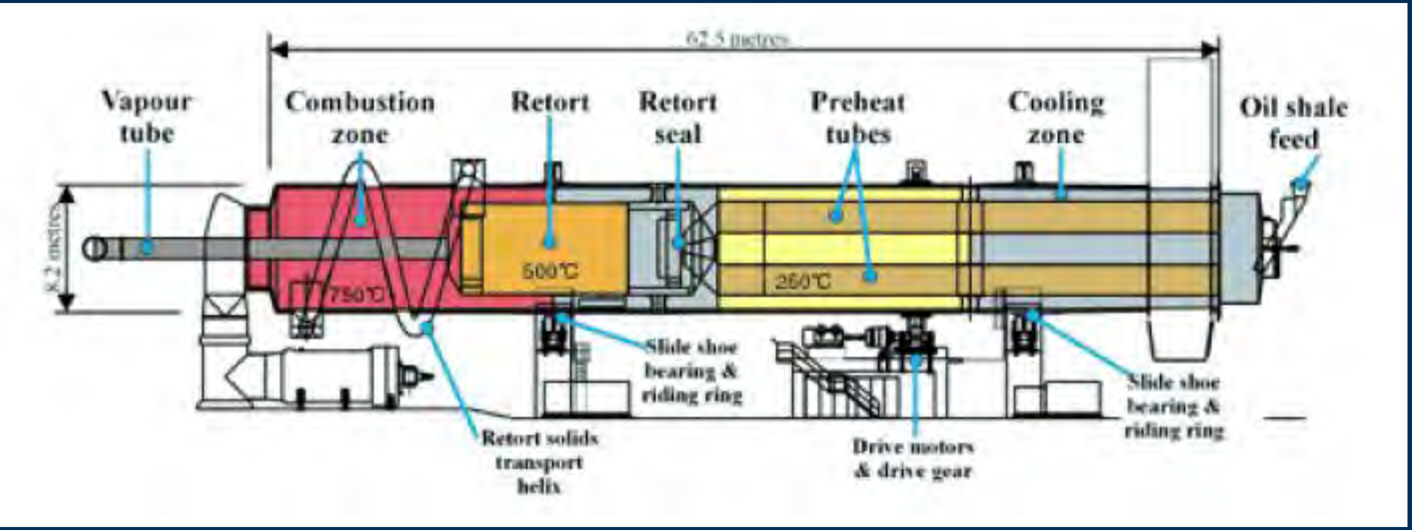
- Mine, crush and heat oil shale – rock residence times ~1 h
- Rapid heating to >500°C to convert kerogen to oil & gas

Advantages

- High yields
- Proven technology

Concerns

- Disposal of spent shale
- Product requires significant upgrading



Alberta-Taciuk Process (horizontal rotary kiln)
(Fact Sheet: Oil Shale Conversion Technology, DOE Office of Petroleum Reserves – Strategic Unconventional Fuels)

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Applicability of different retort methods

Much of the oil shale in the Green River Formation cannot be economically accessed by surface or underground mining and is more amenable to *in situ* approaches

In situ Methods:

Vadose zones – unsaturated deposits either deep enough to make mining impractical or utilized by *in situ* approaches because of advantages related to product quality, surface disturbance, etc.

Groundwater zones – will require site isolation to prevent GW contamination (freeze wall, grouting, etc.)

Sub-aquaclude zones – deep enough that GW issues are less relevant

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In-situ retorting

How does it work?

- Isolate and dewater retort
- Insert heater and production wells
- Gradually heat deposit to convert kerogen to oil & gas

Advantages

- Minimal surface disturbance
- Access deep resources
- Higher quality oil product

Concerns

- Pyrolysis residues
- Impacts on groundwater

Shell's *In-situ* Conversion Process
(Vinegar, H. 26th Oil Shale Symposium, 2006)

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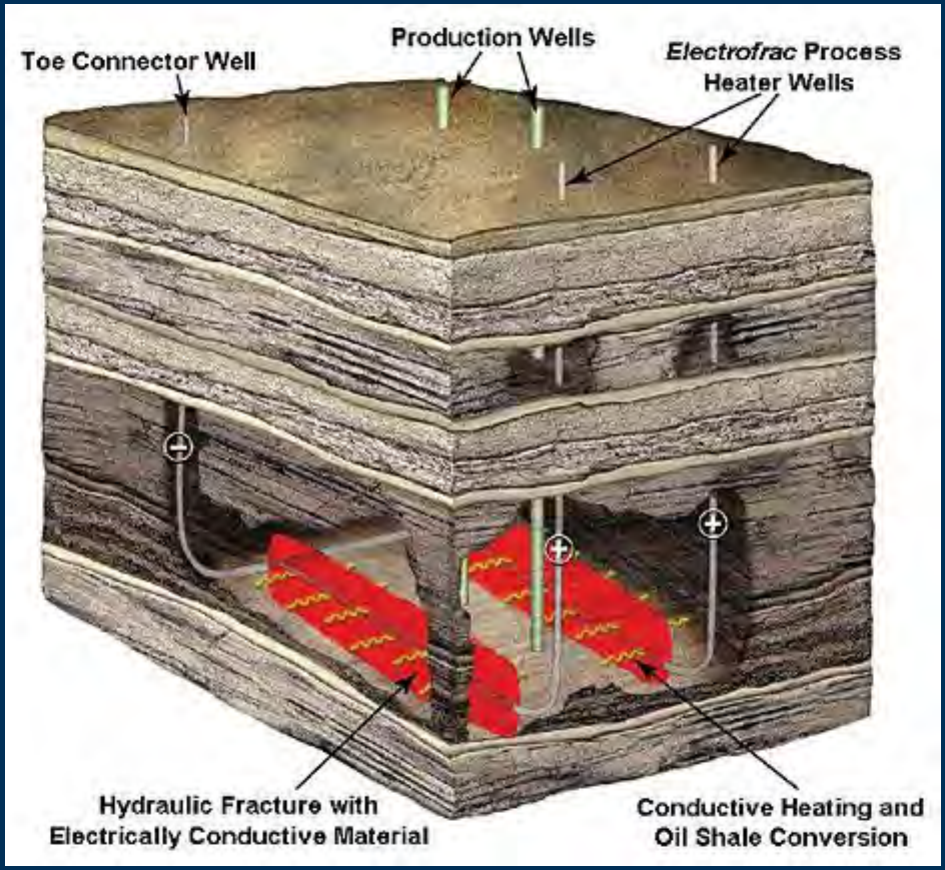
In-situ retorting



ExxonMobil Electrofrac Process
(Meurer et al., 28th Oil Shale Symposium, 2008)

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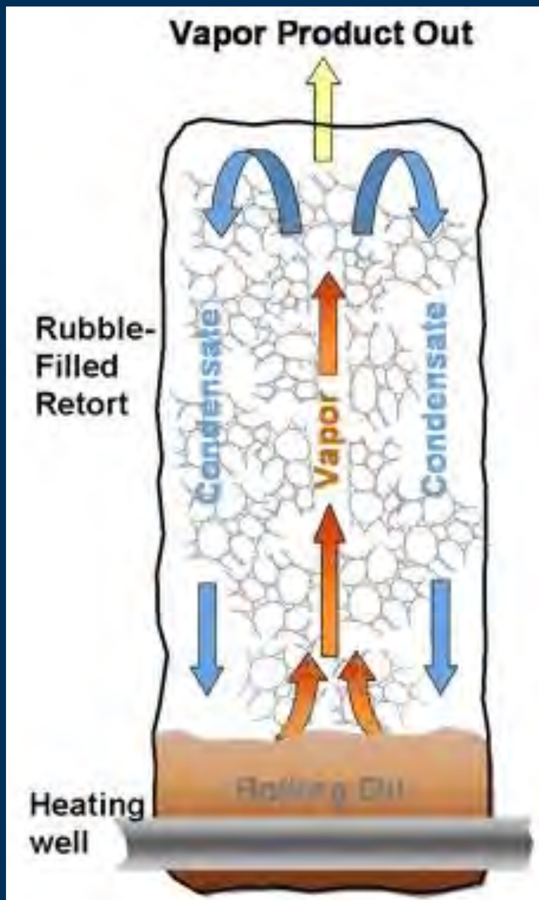
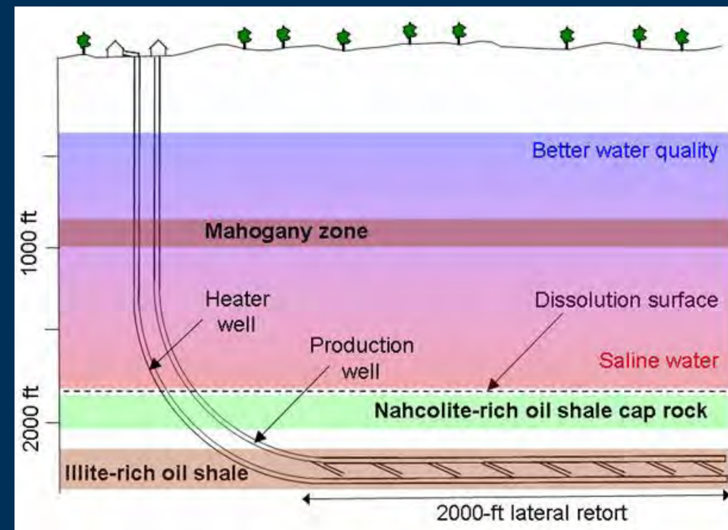
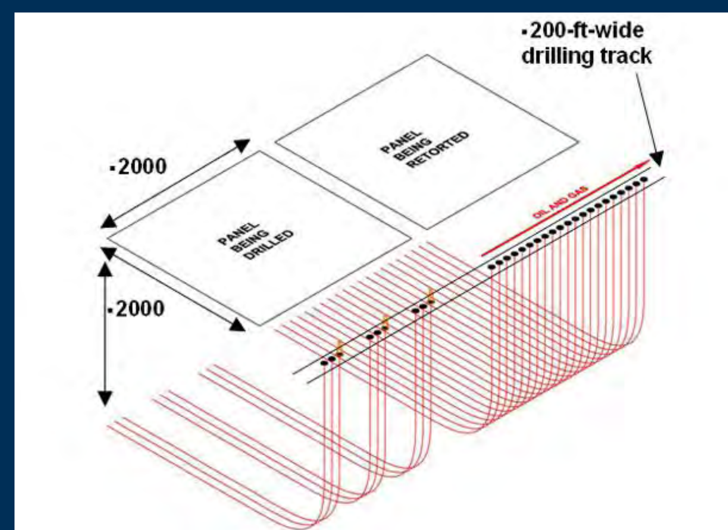
In-situ retorting







AMSO *In-situ* Conversion Process
(AMSO website)

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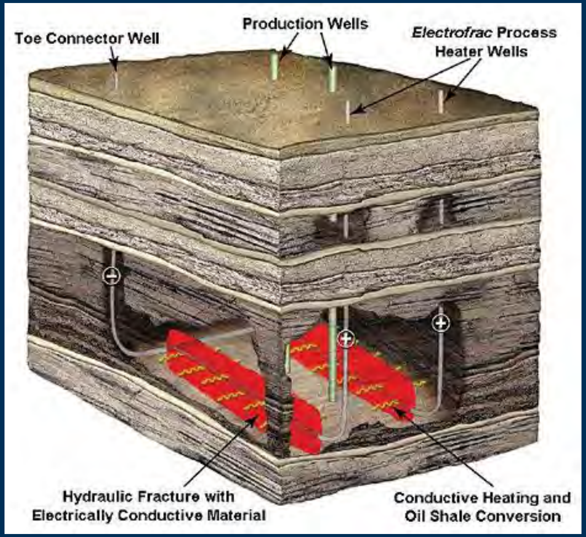
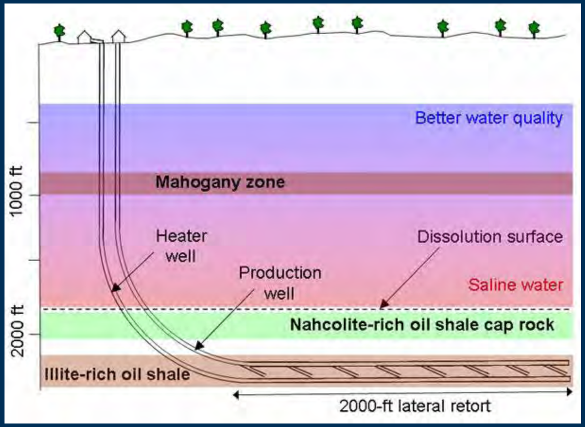
Applicability of different retort methods

Need to determine what, if any, limitations there are for applying particular *in situ* methods to the various resources in the GRF





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Product characterization

Oil composition

Gas composition

Residue composition

Will vary depending on the particular retorting technology applied

Oil and gas processing

Spent shale disposal or reclamation

Is the same true for these development issues?

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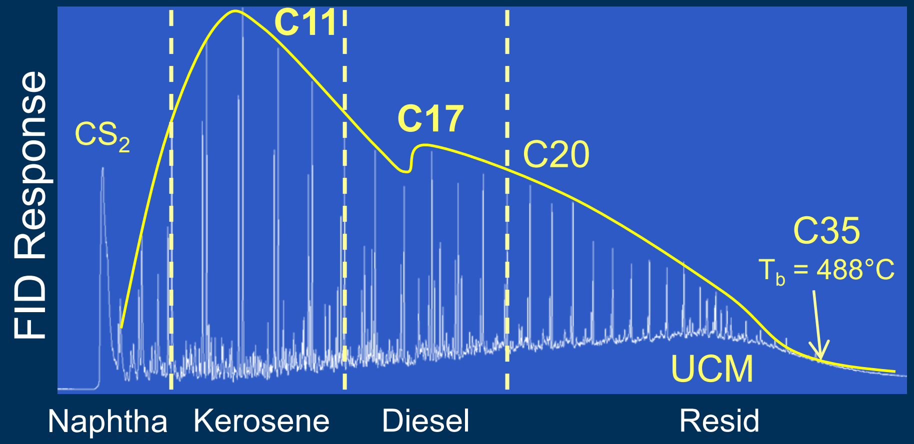
Oil Composition (Mahogany zone oil shale)

Fischer Assay, 500°C, 1 h; API = 23.0°



Volatiles (<C15)	**9.5**
Saturates	**35.3**
Aromatics	**22.2**
Resins	**29.1**
Asphaltenes	**3.9**

Elemental Ratios

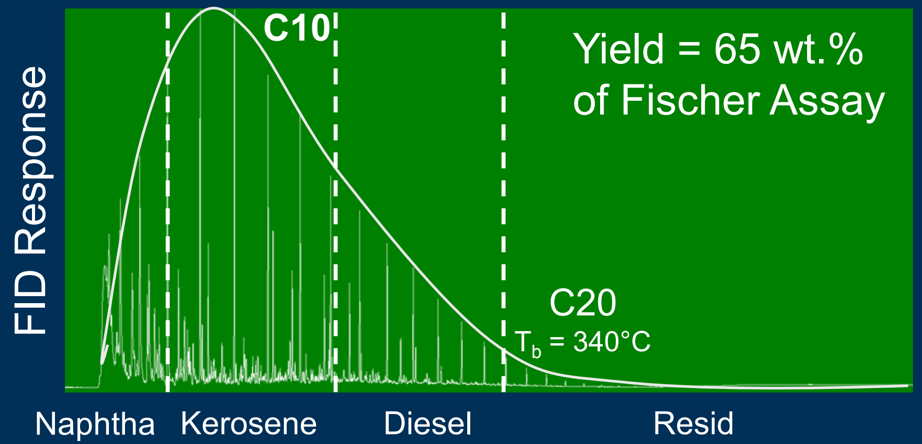
H/C = 1.61, N/C = 0.023, O/C = 0.014

Volatiles (<C15)	**60.7**
Saturates	**25.4**
Aromatics	**6.6**
Resins	**5.9**
Asphaltenes	**1.4**

Elemental Ratios

H/C = 1.85, N/C = 0.013, O/C = 0.006

In-situ Simulator, 360°C, 120 h; API = 50.0°



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Mitigation or prevention of environmental impacts

Water Use

CO_2 release

Surface impacts

Groundwater protection

Spent shale disposal or reclamation

Do we have a better under-standing of these issues now than we did in 2006?

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Other issues

Energy Return on Investment

Co-existing Mineral Resources

Nahcolite

Dawsonite

Reclamation

Long-term Monitoring

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Your input

We are currently developing our approach for this Task.

Input from industry, academia and other government agencies would be greatly appreciated.

Thanks for your attention.

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