Fuel and Energy

Oil Shale

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Definition

- Oil shales are diverse fine-grained rocks, which contain refractory organic material that can be refined into fuels.
- Soluble bitumen fraction constitutes about 20% of this organic material, whereas the remainder exists as an insoluble kerogen.
- Oil shale is a compact, laminated rock of sedimentary origin, yielding over **33%** of ash and containing organic matter that yields oil when distilled, but not appreciably when extracted with the ordinary solvents for petroleum
- The organic matter in oil shale contains both bitumen and kerogen.
- Bitumen content in oil shale constitutes only a minor portion.
- It is soluble in most organic solvents, it is not difficult to extract it from oil shale.
- The bulk of the organic matter is composed of kerogen, which is insoluble and inert.

Composition

Oil shale
- Inorganic matrix
  - Quartz
  - Feldspars
  - Clays (mainly illite and chlorite)
  - Carbonates (calcite and dolomite)
  - Pyrite and other minerals
- Bitumens (soluble in CS_2)
- Kerogens (insoluble in CS_2) (containing U, Fe, V, Ni, Mo)

General scheme of the oil-shale components

Composition

Average chemical composition **of** Green River oil shale, as determined by the writers for several samples from Rifle, Colorado.

FeS_2	0.86%		Mineral matter 86.2%	Oil shale
$NaAlSi_2O_6 \cdot H_2O$ (analcite)	4.3%		Mineral matter 86.2%	Oil shale
SiO_2 (quartz)	8.6%		Mineral matter 86.2%	Oil shale
$KAl_4Si_7AlO_{20}(OH)_4$ (illite) montmorillonite muscovite	12.9%		Mineral matter 86.2%	Oil shale
$KAlSi_3O_8$ (K-feldspar) $NaAlSi_3O_8$-$CaAl_2Si_2O_8$ (plagioclase)	16.4%		Mineral matter 86.2%	Oil shale
O	22.2%	$CaMg(CO_3)_2$ (dolomite) and calcite 43.1%	Mineral matter 86.2%	Oil shale
Ca	9.5%	$CaMg(CO_3)_2$ (dolomite) and calcite 43.1%	Mineral matter 86.2%	Oil shale
Mg	5.8%	$CaMg(CO_3)_2$ (dolomite) and calcite 43.1%	Mineral matter 86.2%	Oil shale
C	5.6%	$CaMg(CO_3)_2$ (dolomite) and calcite 43.1%	Mineral matter 86.2%	Oil shale
S, N, O	1.28%	bitumen 2.76 %	Organic matter 13.8%	Oil shale
H	1.42%	kerogen 11.04%	Organic matter 13.8%	Oil shale
C	11.1%	kerogen 11.04%	Organic matter 13.8%	Oil shale

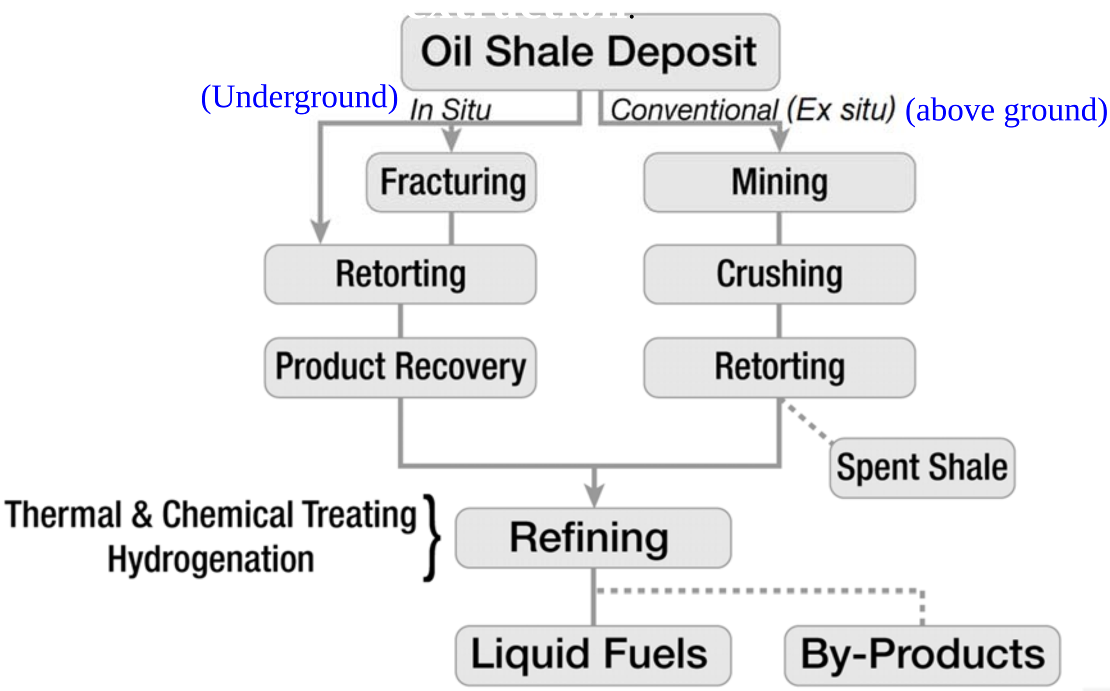
Origin of Oil Shale

- Oil shales result from the contemporaneous deposition of fine-grained mineral debris and organic degradation products derived from the breakdown of biota.
- Conditions required for the formation of oil shales, therefore, include abundant organic productivity, early development of anaerobic conditions, and a lack of destructive organisms
- Continued sedimentation provided overburden pressure necessary for the compaction and diagenesis of organically-rich strata.
- Chemical activity at low temperature *(as* 150°C) results in the loss of volatile fractions, which ultimately produces a sedimentary rock having a high content of refractory organic residues.
- Kerogen and bitumen are of biological origin and are largely derived from the lipid fraction of algae

Types of Oil Shales

- **Torbanites**
  - Constitute the richest type of oil shales, characterized by the low ratio of mineral to organic material content
  - Occur **as** lenticular bodies, often associated with coal deposits.
- **Tasmanites**
  - Marine deposits, formed in very shallow seas adjacent to the coastline and are often laterally related to the terrestrial spore-containing coals.
  - Their organic matter is composed of spherical disseminules believed to be algal spores.
- **Green River oil shale,**
  - Are of lacustrine origin, intermixed with varying amounts of tuff, siltstone, halite, trona, and nahcolite.

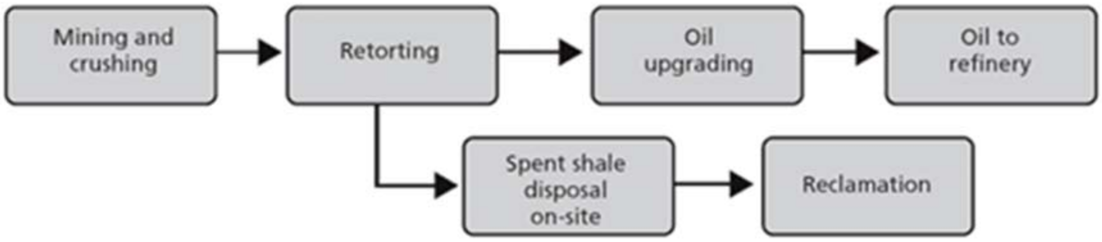
Recovery Methods



Recovery Methods

i. Surface Retorting

Major Process Steps in Mining and Surface Retorting



- Oil shale is mined (surface or underground), crushed, and then conveyed to a retorter, where it is subjected to temperatures ranging from 500 to 550°C.
- The chemical bonds linking the organic compounds to the remainder of the rock matrix are broken.
- The liberated compounds, in the gaseous state, are collected, condensed, and upgraded into a liquid product that is the rough equivalent of a crude oil

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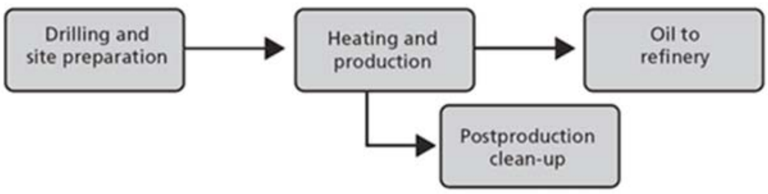
Recovery Methods

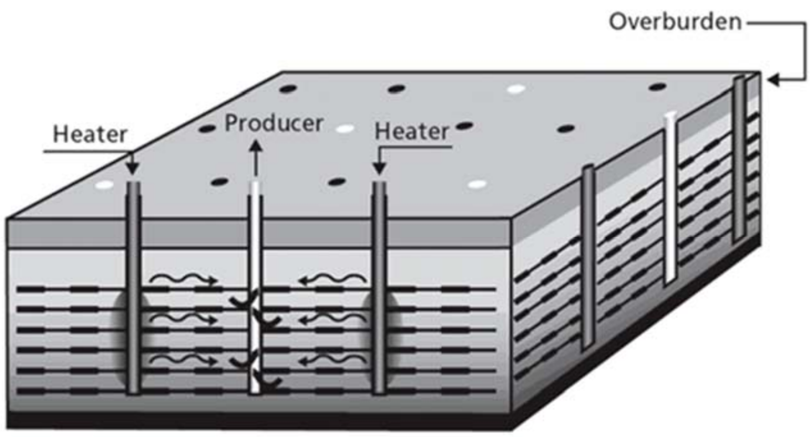
ii. On-site or In Situ Retorting

- The process includes: fracturing, injection to achieve communication, and fluid migration, take place at the underground location of the shale bed

Major Process Steps in Thermally Conductive In-Situ Conversion



The Shell In-Situ Conversion Process



SOURCE: Adapted from material provided by Shell Exploration and Production Company.
RAND MG414-3.2

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Recovery Methods

Fracturing

- Through the use of explosives, both conventional and nuclear.
- The process involves heating underground oil shale, using electric heaters placed in deep vertical holes drilled through a section of oil shale to fracture the rock

- The volume of oil shale is heated over a period of two to three years, until it reaches 650–700 °F, at which point oil is released from the shale.
- The released product is gathered in collection wells positioned within the heated zone.

Injection *of fluids to achieve intercommunication.*

- Hot gases, water, and other fluids can be injected into the wells and forced through the fractures.
- These fluids are able to expand the width of the fractures and push the fractures deeper into the shale bed, i.e., extend the fracture.
- If the wells are very close to each other, then it is feasible to have continuous fractures to extend from one well to another

Recovery Methods

Fluid migration

- If hot gases are passed through the rock bed, liberation of organic compounds may occur.
- The organic compounds, then, flow along with the gases to a producing well where they can be brought to the surface

limitations and disadvantages

- Shale for surface retorting must be mined and transported to the processing plant, which may cause environmental damage in addition to transport expense
- Present retorting methods all require an expenditure of thermal energy, which may be supplied by electrical arc, gas combustion, or other energy sources. This diminishes the net energy production
- Retorting is not an efficient method for the liberation of organic material locked in oil shales (kerogen removal)

Recovery Methods

- Present retorting techniques require high temperatures (about 550°C), which, in the presence of minerals in the rock, cause the formation of organic chemicals that are difficult to refine into fuel. In addition, these high temperatures burn off a great deal of otherwise useful organic material
- Retorting produces large volumes of waste rock, which undergoes a volume increase (about 10%) during processing. These large volumes of spent shale present **an** important disposal problem
- Retorting results in the formation of large amounts of the carcinogenic compounds, i.e. , 3,4-benzopyrene.
- At high temperatures, dehydrogenation of hydrocarbons precedes aromatization. As a consequence, large amounts of hydrogen have to be used during subsequent refining processes.

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Recovery Methods

iii. Biochemical recovery method

- Bioleaching is the interaction of biological agents with the oil-shale matrix, regardless of whether the reaction is biochemical, chemical, or physical.
  - Biodegradation and biodisintegration of the inorganic components in the oil-shale matrix.
  - The organic-inorganic linkages can be disrupted by microorganisms to cause the organic components to separate
- The main drawback of bioleaching is the large amount of water required by this process.

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Oil Shale in Jordan

- Jordan has huge reserves of oil shale, currently the 8th largest in the world with more than 40 billion tons of oil shale
- El-lajun surface outcrop. El-lajun is located about 20 km east of Karak city, in Jordan, covering an area of about 50 km^2
- Oil shale, by far the largest indigenous energy resource, did not contributed any power since its development is still at the planning stage.
- The Oil shale is not of high quality.
- Its exploration, development and utilization is rather difficult and currently not economically feasible.
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