Oil Shale

Characteristics and Utilization

Rock of Oil Shale

Oil shale is a type of rock that can be burned for energy or fuel.

Oil shale

Introduction

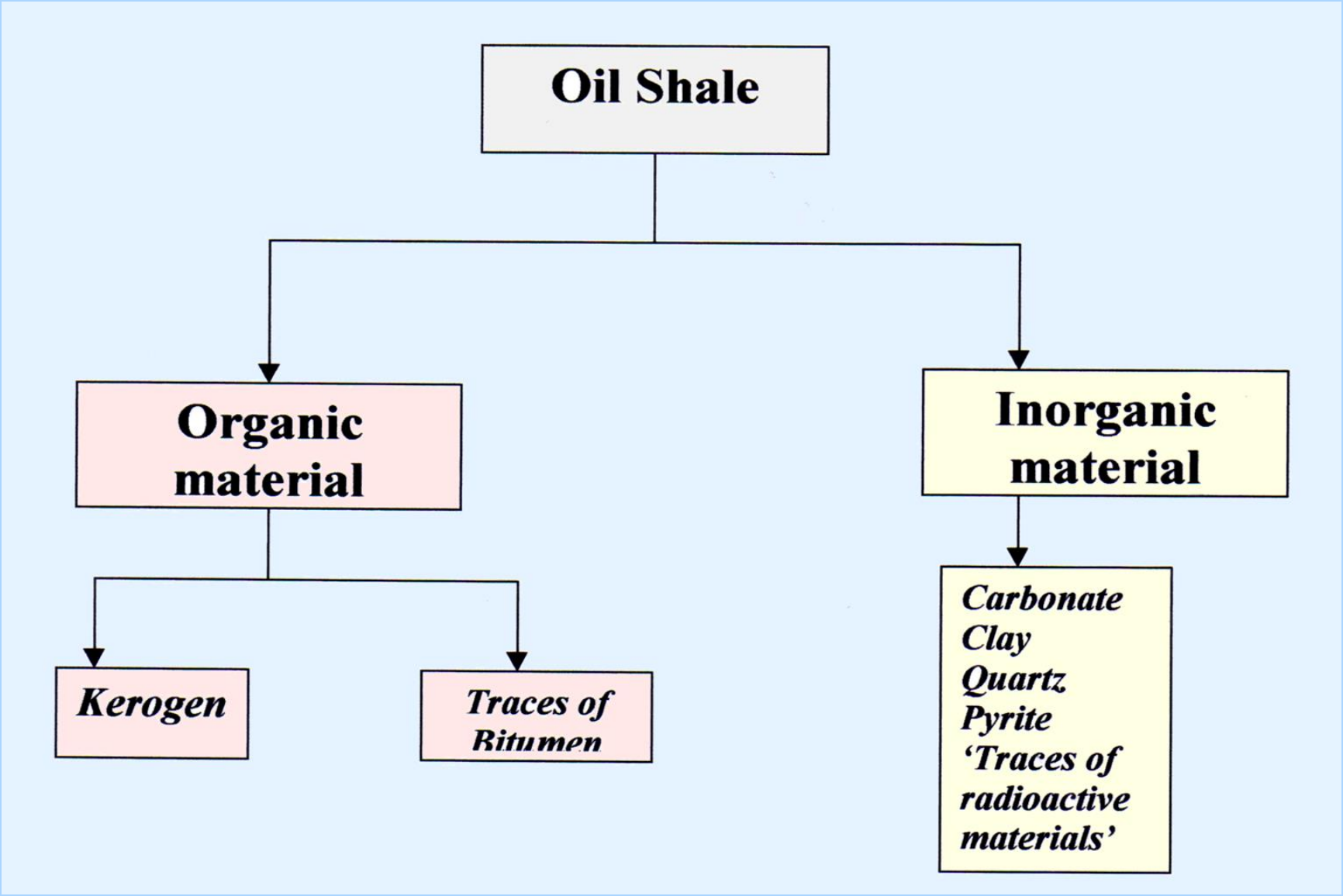
- 40-50 million-year-old sedimentary rock.
- This rock contains solid hydrocarbon materials called 'Kerogen'.
- Kerogen is basically "fossilized algae".
- Kerogen is a complex hydrocarbon molecule.

Oil shale

Introduction

- Under the effects of time, pressure, and temperature, these sediments have transformed into a hydrocarbon-bearing rock, known as oil shale.
- Global oil shale resources exceed 3.4 trillion barrels.
- Kerogen is almost insoluble in all common organic solvents.

Composition of oil shale



Oil shale and Heat

- If the oil shale is heated, kerogen will decomposed according to the following eq.

$$\text{Kerogen} \xrightarrow{480\text{–}500^{\circ}\text{C}} \text{oil} + \text{gas} + \text{Char}$$

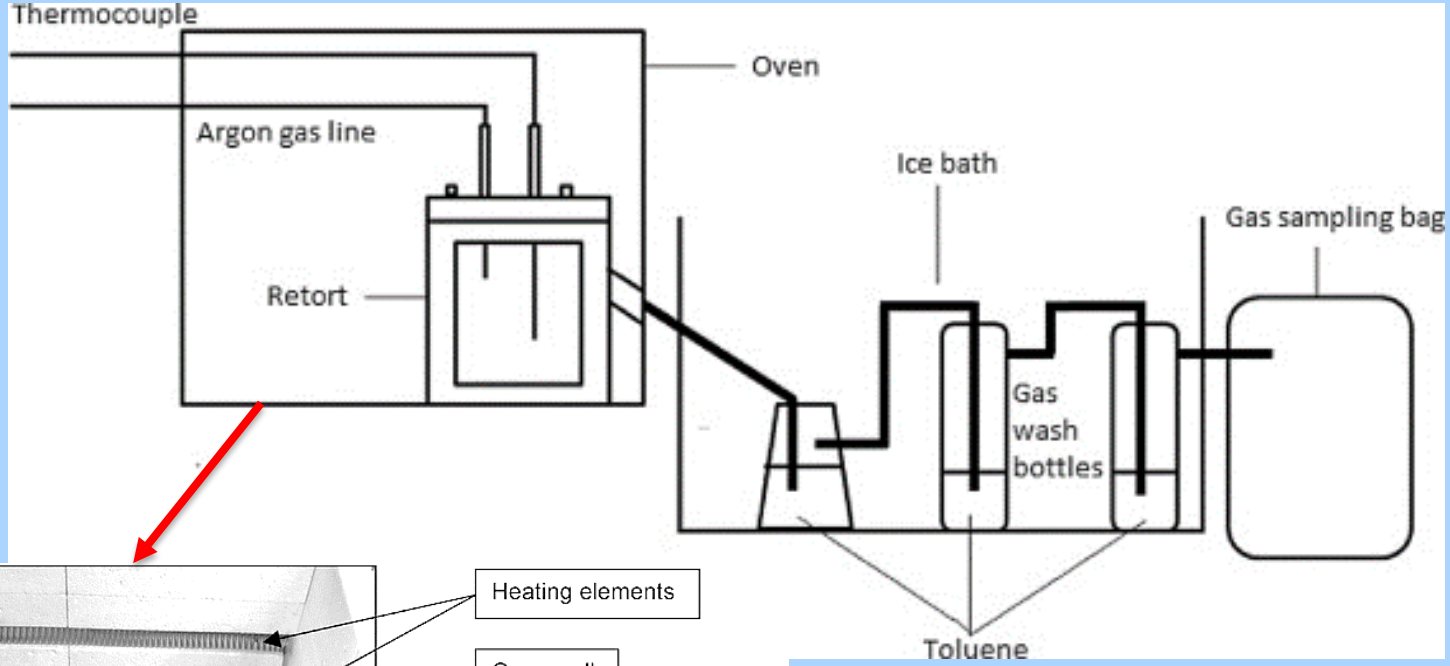
- Experimentally, 'Modified fisher assay' is used to evaluate the oil yield.

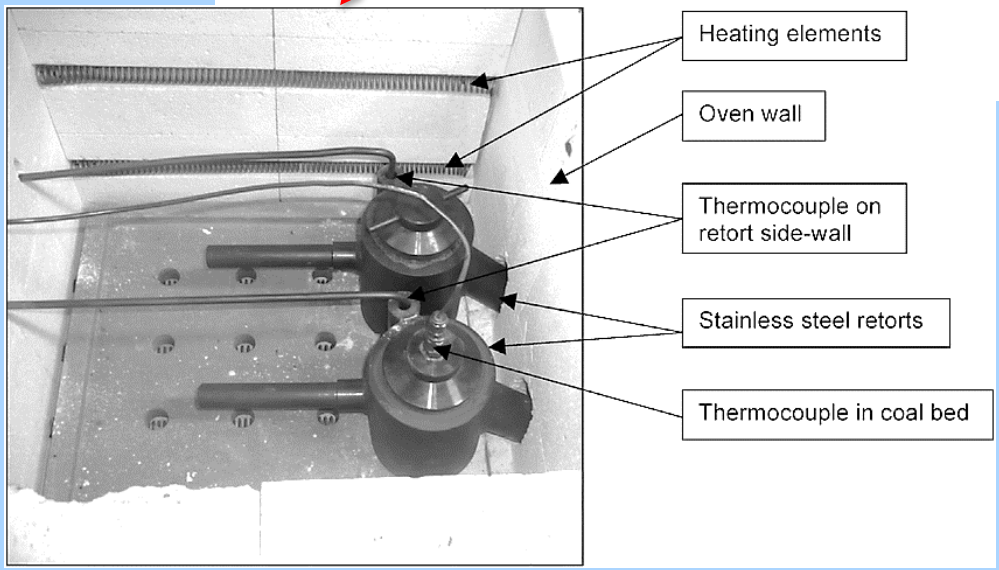
Fischer assay

- The **Fischer assay** is a standardized laboratory test for determining the oil yield from oil shale
- Procedure (summary): A 100 gram oil shale sample crushed to -2.38 mm is heated in a small aluminum retort (with air excluded) to 500 °C (at a rate of 12°C/min) and held at that temperature, usually 20 minutes, but up to 40 minute for richer shales.

- The distilled vapors of oil, gas, and water are passed through a condenser and cooled with ice water into a graduated centrifuge tube.
- Fischer Assay method is not necessarily optimum, where another pyrolysis procedure could give a different value.

Fischer Assay - Schematic diagram





Empirical formula

- The following formula may be used to predict the yield (L/t) of oil, based on Green river oil shale and modified Fischer oil yield in L/t

$$\text{Yield (L/t)} = 8.22 \times \text{organic matter (mass\%)} - 10.8$$

- note

38% organic matter	300L/t	Rich shale
13.5% organic matter	100L/t	Poor shale

Important Properties

1. Calorific value
2. Sp. Gravity
3. Sp. Heat
4. Permeability of rock
5. Color
6. Hardness
7. Melting point ~ 1260 °C
8. Proximate and Ultimate analysis

Top 10 Countries of Global Oil Shale Reserves

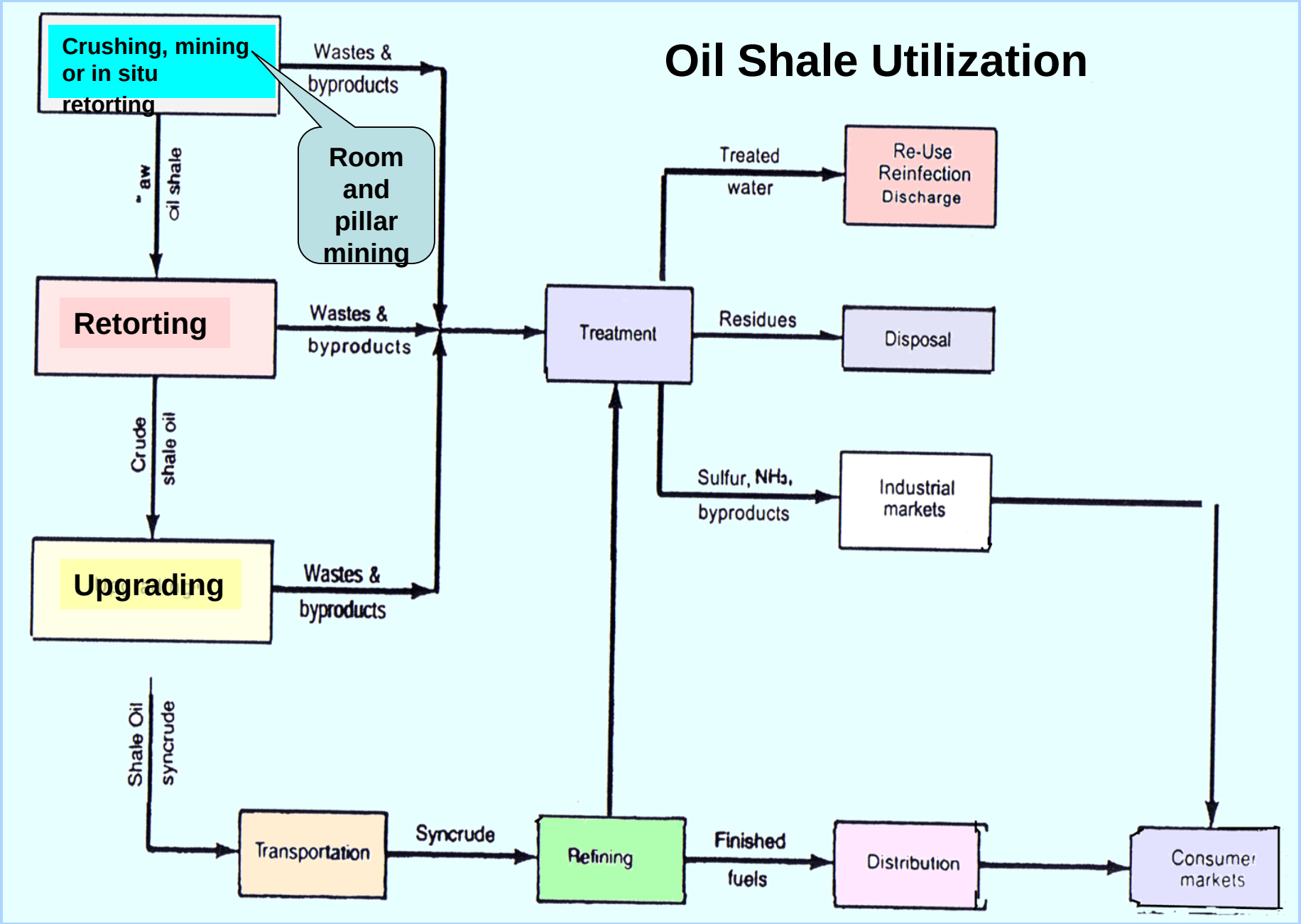
Rank	*Country*	*Reserves (Million MT of Oil Equivalent)*
1	USA	303.56
2	Russia	39.00
3	Congo	14.31
4	Brazil	12.00
5	Jordan	5.20
6	Morocco	5.02
7	Australia	4.54
8	China	2.74
9	Estonia	2.49
10	Italy	1.43

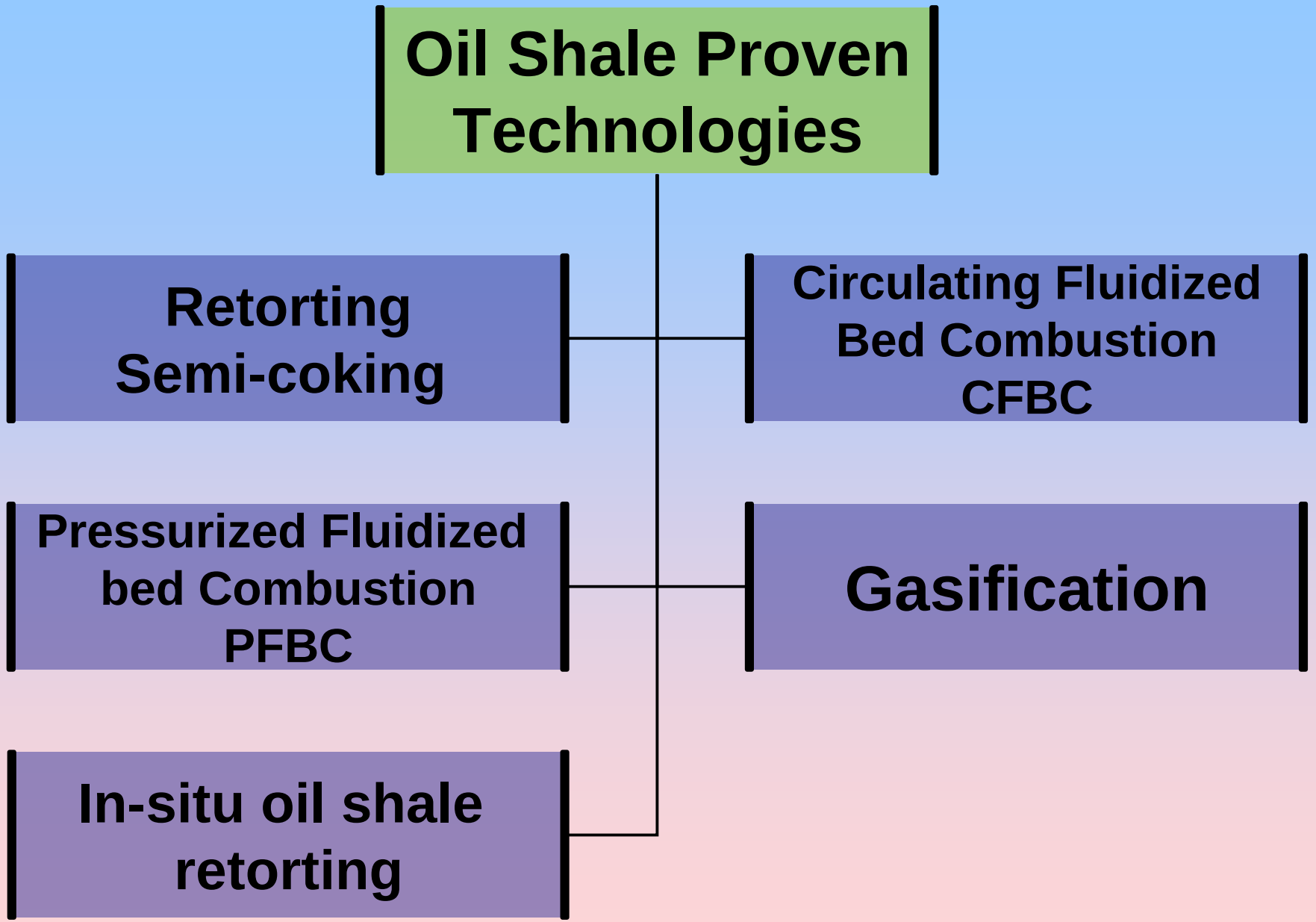
Top 10 countries with technically recoverable shale resources

Shale oil

rank	country	billion barrels
1	Russia	75
2	United States	58
3	China	32
4	Argentina	27
5	Libya	26
6	Venezuela	13
7	Mexico	13
8	Pakistan	9
9	Canada	9
10	Indonesia	8
	World total	**345**

Oil Shale Utilization



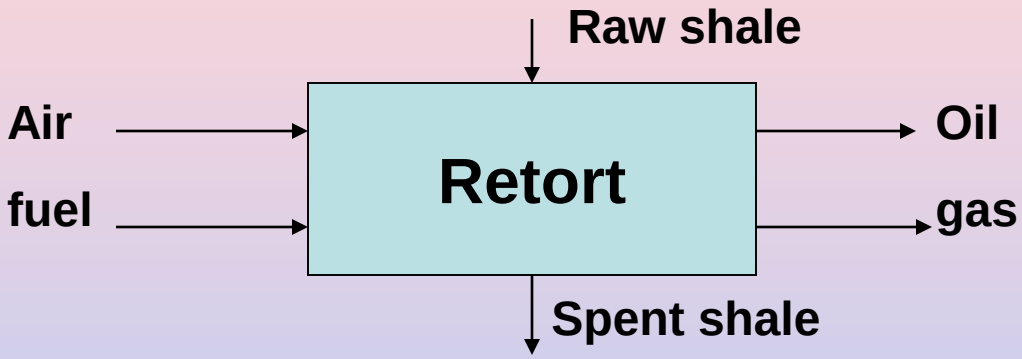

Oil Shale Proven Technologies
Retorting Semi-coking
Circulating Fluidized Bed Combustion CFBC
Pressurized Fluidized bed Combustion PFBC
Gasification
In-situ oil shale retorting

Retorting Process

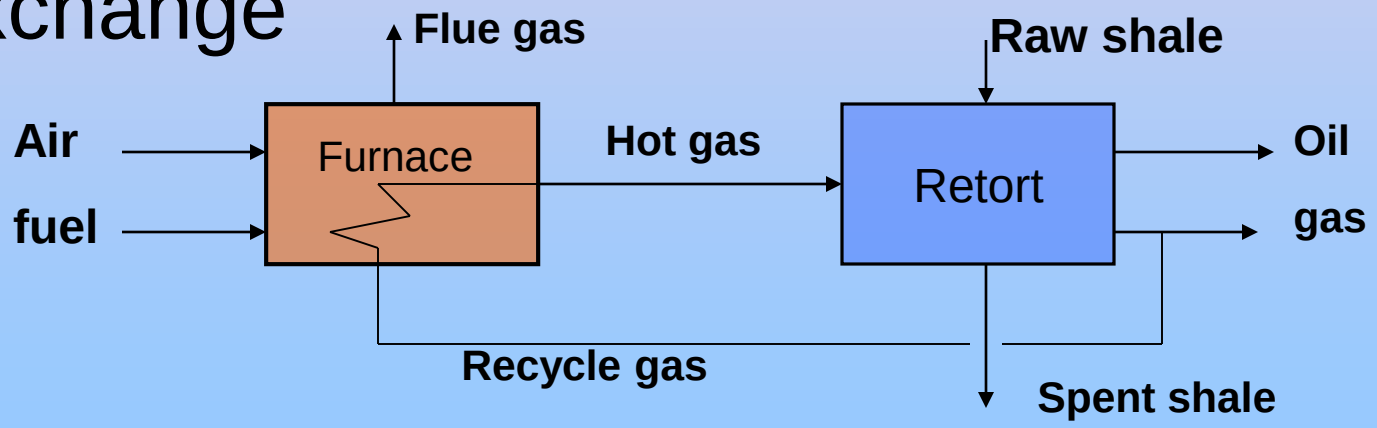
- Retorting means pyrolysis of shale in a vessel . This vessel is called retort and the process is known retorting.
- There are two types of retorting:
    1) surface retorting
    2) in situ, or in place, retorting
- The main objective of retorting is to obtain oil.

Methods of heating

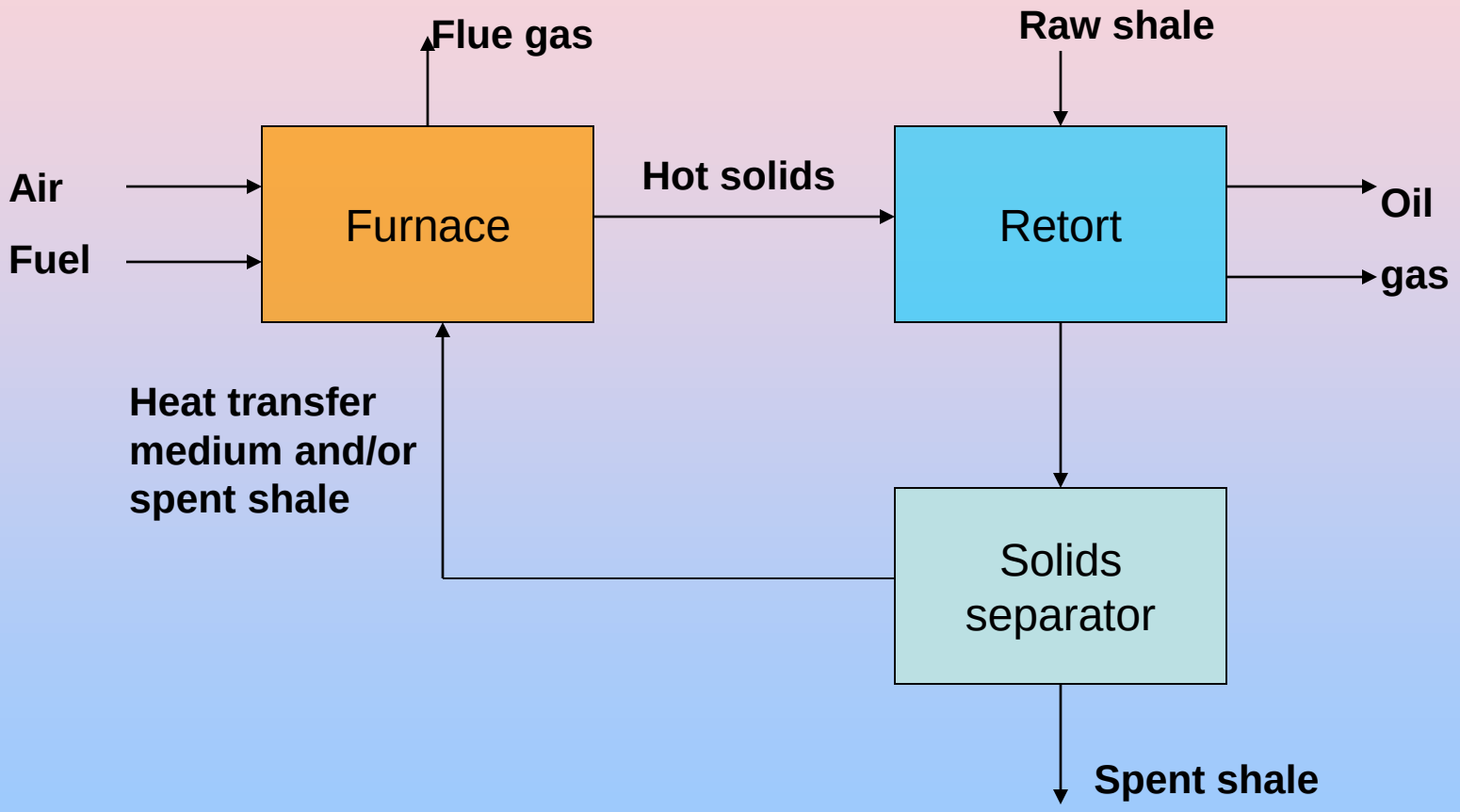
1. Directly heated retort



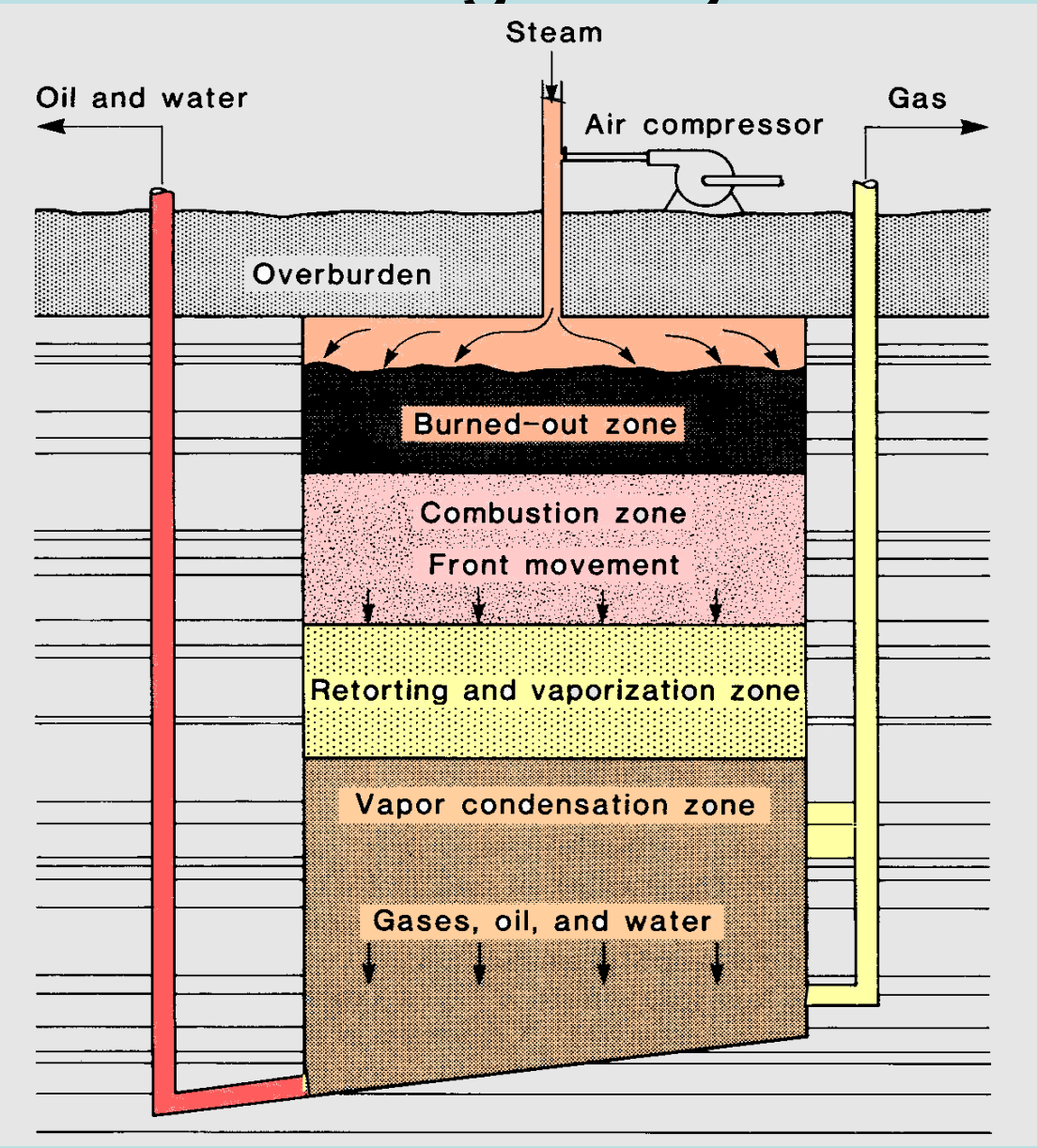
2. Indirectly heated retort, gas-to-solid heat exchange



3. Indirectly heated retort, solid-to-solid heat exchange

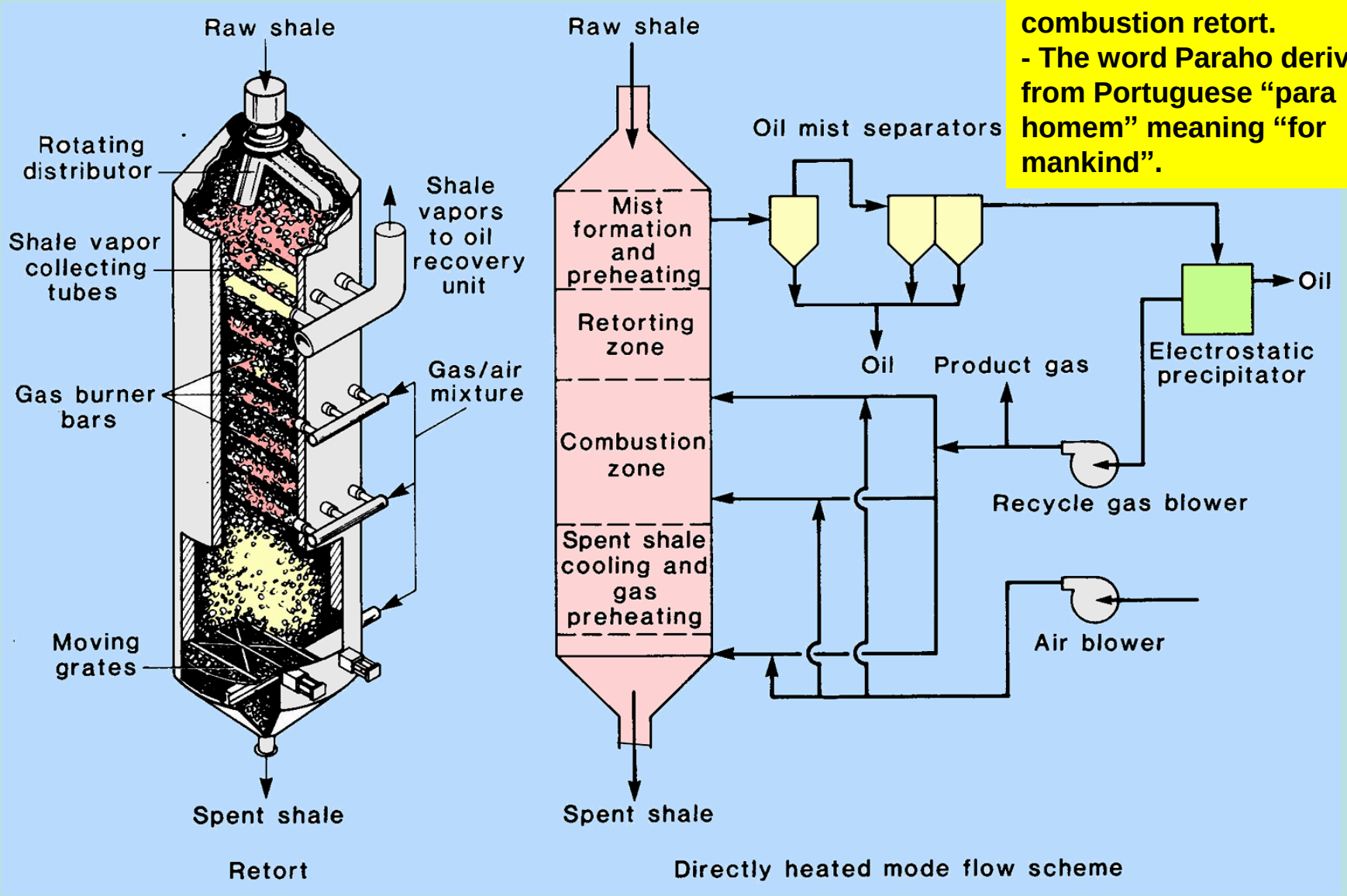


In-Situ Retorting ‘Oxy MIS retort’

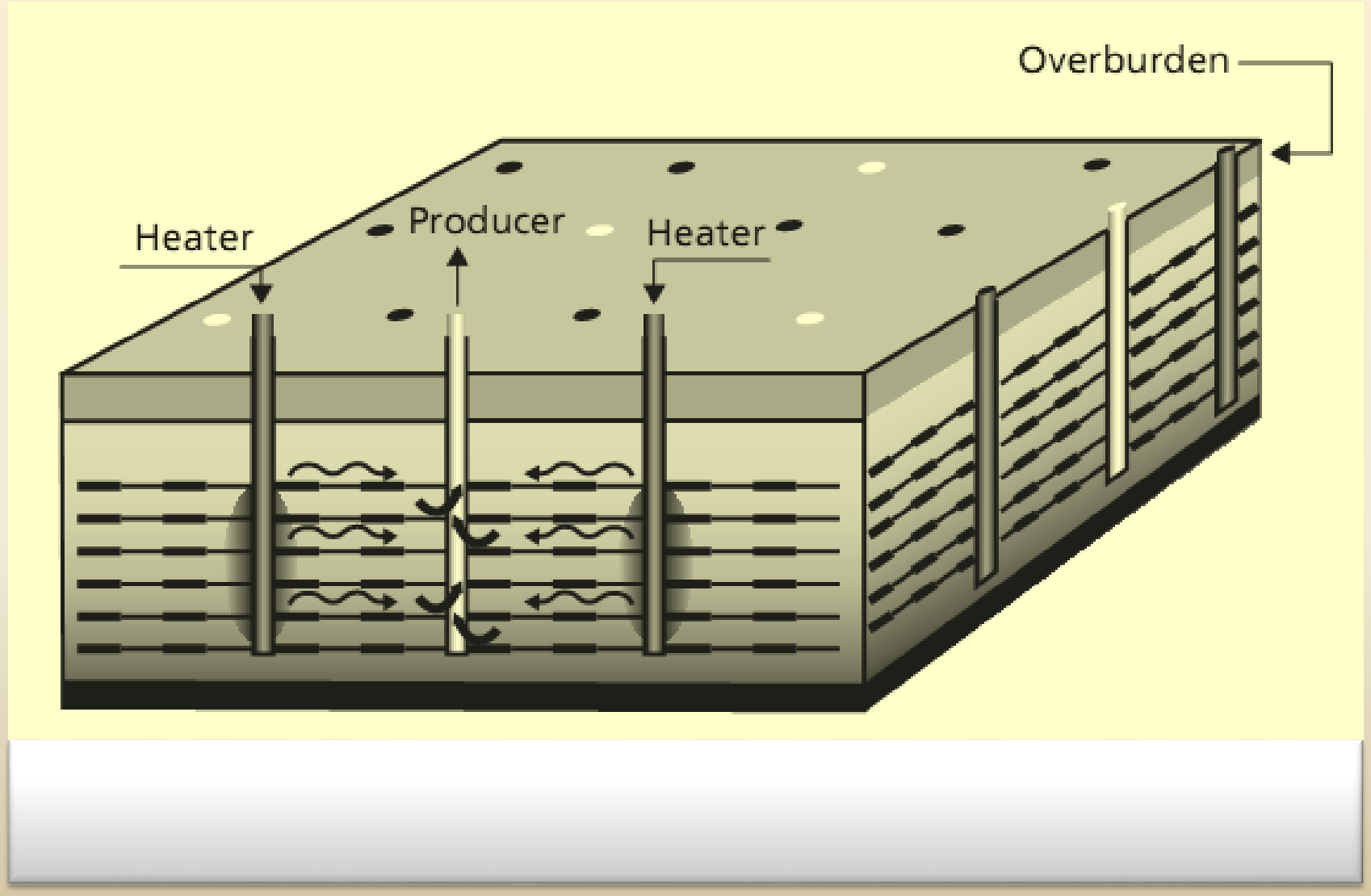


Paraho Retorting Process

- Developed from The US Bureau of Mines 'Gas combustion retort.
- The word Paraho derived from Portuguese "para homem" meaning "for mankind".



In-Situ Conversion Process (ICP)

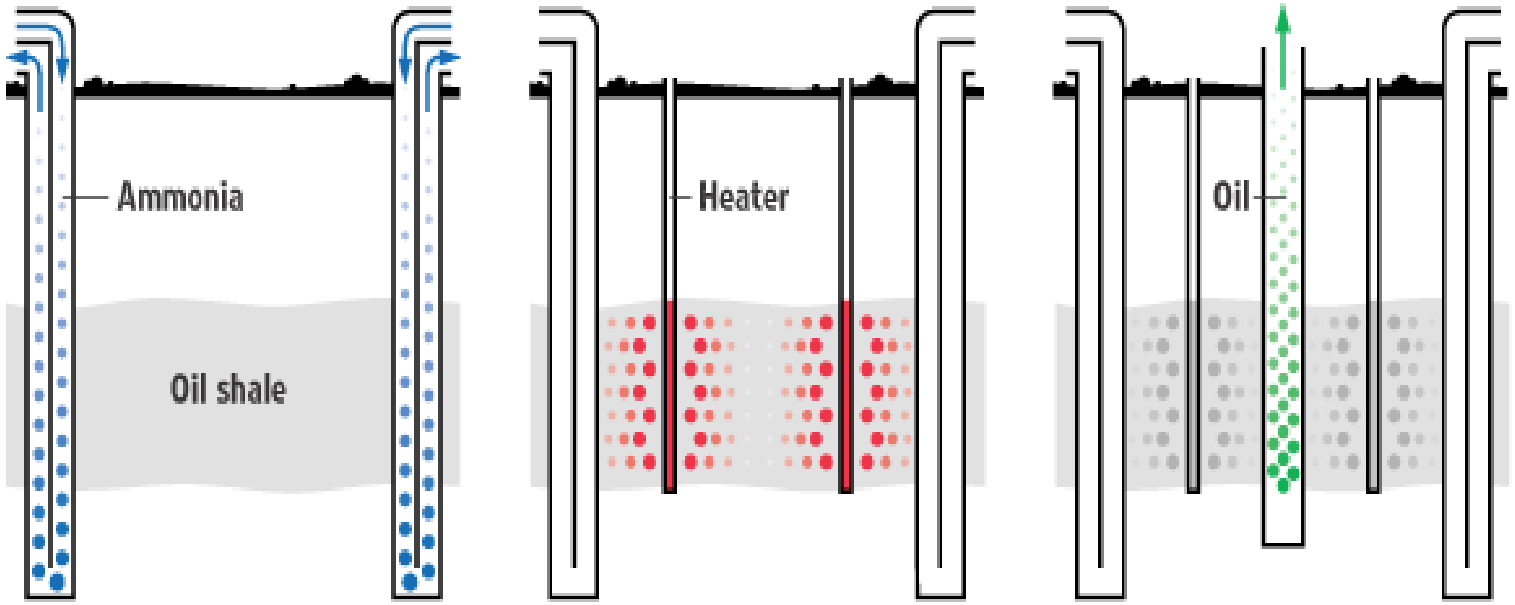


Shell’s in-situ conversion process

- Electric or gas heaters, placed in closely spaced vertical wells.
- The slow heating creates micro-fractures in the rock that improve natural permeability.
- Resulting shale oil and gases are moved to the surface by conventional wells and vapor recovery technology.
- Slow heating improves product quality; subsequent product treating is less complex, than for surface retorts or other in-situ approaches.
- Much more oil and gas may be recovered from a given area as shale oil and combustible gas products can be produced
- The ICP process involves no subsurface combustion of the resource, reducing environmental impacts.
- Close spacing, adjustable heat sources, and modern downhole monitoring technologies vastly improves temperature control.
- Innovative “freeze wall” technology is being tested to isolate production areas from intrusion of groundwater.

Crude Boil

A look at Shell's process for extracting crude oil from oil shale formations



Ammonia circulates through pipes in the ground, creating a frozen wall that protects groundwater from contamination.

Electric heaters warm the rock, converting organic matter within the shale into oil. This process takes over two years.

The oil is pumped to the surface using convention methods.

Source: the company

ICP Technology

- Jordan oil shale Company (JOSCO) will develop oil shale using a novel technology that is called In-Situ Conversion Process (ICP). With ICP, oil is produced through heating the oil shale in place. Neither excavation nor mining is required. The heating process pyrolyzes the organic matter of the oil shale, thereby converting it to oil and gas underground. These products then are produced using conventional oil field extraction technology.

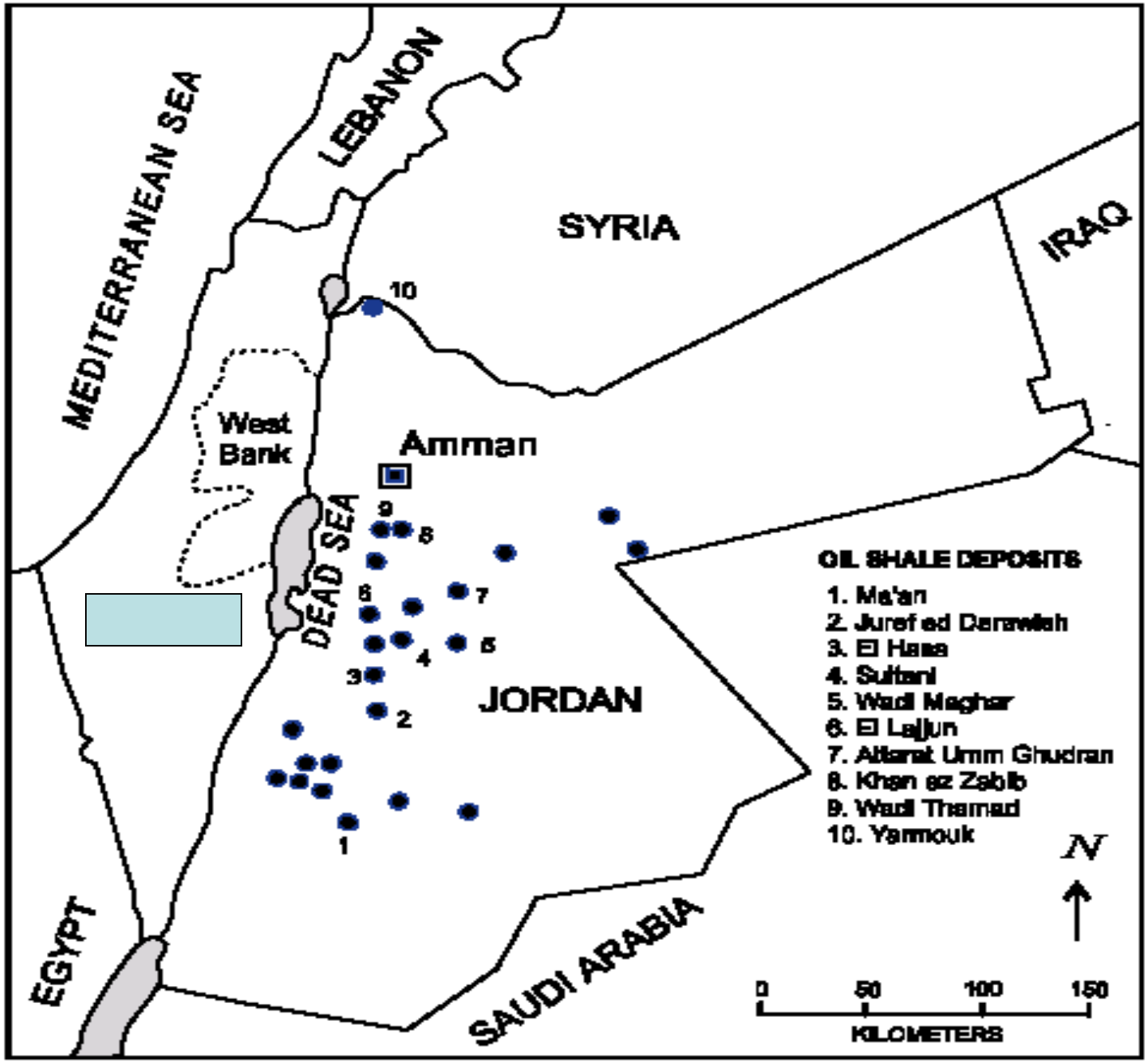
- With ICP, JOSCO can develop oil shale where it is richest and thickest. Unlike surface retorting operations that are limited to utilizing near surface exposures of oil shale beds, ICP can develop oil shale at depths of up to 1000 meters. This means that JOSCO can explore for the most favorable occurrences of oil shale.

- ICP also produces light crude oil that requires less refining to produce high quality transportation fuels (e.g. gasoline, jet and diesel fuels).
- It can also produce a larger volume of oil and gas from a relatively smaller surface area compared to surface retort technology.
- Traditional surface retorting involves strip-mining the oil shale and transporting it to a retort facility for pyrolysis. The fact that oil shale is brought to the surface presents the subsequent problem of disposal of the spent shale ash after pyrolysis. With ICP technology, the pyrolysed shale remains in place underground.

Average composition of Kerogen in Colorado Green River Shale

Element	%
C	76.1
H_2	10.5
N_2	2.6
S	1.3
O_2	9.5
Total	100.0

C/H ratio: 7.2, avg. sp.gr. :1.05


MEDITERRANEAN SEA
LEBANON
SYRIA
IRAQ
West Bank
Amman
DEAD SEA
JORDAN
EGYPT
SAUDI ARABIA
OIL SHALE DEPOSITS
1. Ma'an
2. Juref ed Darawish
3. El Hasa
4. Sultani
5. Wadi Maghar
6. El Lajjun
7. Attarat Umm Ghudran
8. Khan ez Zabib
9. Wadi Thamad
10. Yarmouk
N
0
50
100
150
KILOMETERS

Main Characteristics of the Studied Oil Shale Deposits in Jordan

Indices	El-Lajjun	Sultani	Juref Ed-Darawish	Attaraat Um-Ghudran	Wadi Maghar	El-Thamad	Khan Ezzabib
Geologic reserves, billion tons	1.3	0.99	8.6	11.3	32	11.4	n.a.
Surface area, sq. km	20	24	150	226	29	150	n.a.
Overburden, thickness, m	31	69	47	47	40	142–400	66
Oil shale thickness, m	29	32	68	36	40	72–200	39–45
Number of drilled wells	135	57	50	41	21	12	–
Organic matter, %	28	25	18	29	20	25	n.a.
Average oil content, %	10.5	9.7	5.7	11.0	6.8	10.5	6.9
Moisture content, %	2.1	5.5	4.5	3.25	2.9	2.5	n.a.
Ash content, %	54.7	55.5	58.4	53.2	57.5	54.7	n.a.
Sulfur content, %	3.1	2.4	2.4	2.6	2.6	3.2	n.a.
Density, g/cm^3	1.81	1.96	2.1	1.8	2.03	1.8	n.a.
Calorific value:							
Kcal/kg	1650	1526	1100	1730	1090	1800	n.a.
KJ/kg	6906	6380	4603	7235	4773	6903	n.a.

Oil Shale outcrop in El-Lajjun deposit

The average physical and chemical characteristics of El-Lajjun deposit

Thick (m)	SiO_2	P_2O_5	Al_2O_3	$CaCO_3$	Cal.Value KgJ/kg	C-org	S	Moisture	Oil%
7	5.6	0.5	2.5	73.9	2580	3.6	1.9	3.6	4.3
17	6.7	1.3	3.1	71.1	2050	5.6	1.7	2.3	3.4
4-23	12.4	1.73	4.8-6.7	56.0	4180	8.6	2.6	2.8	5.7
2-11	13.3	3.35	5.0-6.7	45.0	6850	12.8	3.3	3.4	11.1
5-6	11.5	3.3	4.2-4.8	53.0	4700	9.8	2.3	2.2	7.8
8-11	26.1	3.6	2.6-2.9	33.0	8100	14	3.2	3.1	12.3
1-2	22.0	3.0	20.1-6.6	60.0	4090	6.2	1.7	2.3	5.2
12-18	14.6	2.7	3.4-3.5	46.0	8170	14.5	3.5	1.9	12.6
2-6	9.1	9.7	1.1-1.4	45.0	4200	8.3	1.9	1.8	6.1