

COPYRIGHT AND DISCLAIMER

Copyright (and any other applicable intellectual property rights) in this document and any accompanying data or models is reserved by SRK Consulting (UK) Limited ("SRK") and is protected by international copyright and other laws.

This document may not be utilised or relied upon for any purpose other than that for which it is stated within and SRK shall not be liable for any loss or damage caused by such use or reliance. In the event that the recipient of this document wishes to use the content of this document in support of any purpose beyond or outside that which it is expressly stated or for the raising of any finance from a third party where the document is not being utilised in its full form for this purpose, the recipient shall, prior to such use, present a draft of any report or document produced by it that may incorporate any of the content of this document to SRK for review so that SRK may ensure that this is presented in a manner which accurately and reasonably reflects any results or conclusions produced by SRK.

The use of this document is strictly subject to terms licensed by SRK to its client as the recipient of this document and unless otherwise agreed by SRK, this does not grant rights to any third party. This document shall only be distributed to any third party in full as provided by SRK and may not be reproduced or circulated in the public domain (in whole or in part) or in any edited, abridged or otherwise amended form unless expressly agreed in writing by SRK. In the event that this document is disclosed or distributed to any third party, no such third party shall be entitled to place reliance upon any information, warranties or representations which may be contained within this document and the recipient of this document shall indemnify SRK against all and any claims, losses and costs which may be incurred by SRK relating to such third parties.

© SRK Consulting (UK) Limited 2012

Oil Shale Beneficiation Considerations



Sergei Sabanov, *PhD*

16.10.2012

32 Oil Shale Symposium, Colorado 2012

Contents

1. Introduction

2. SRK oil shale projects

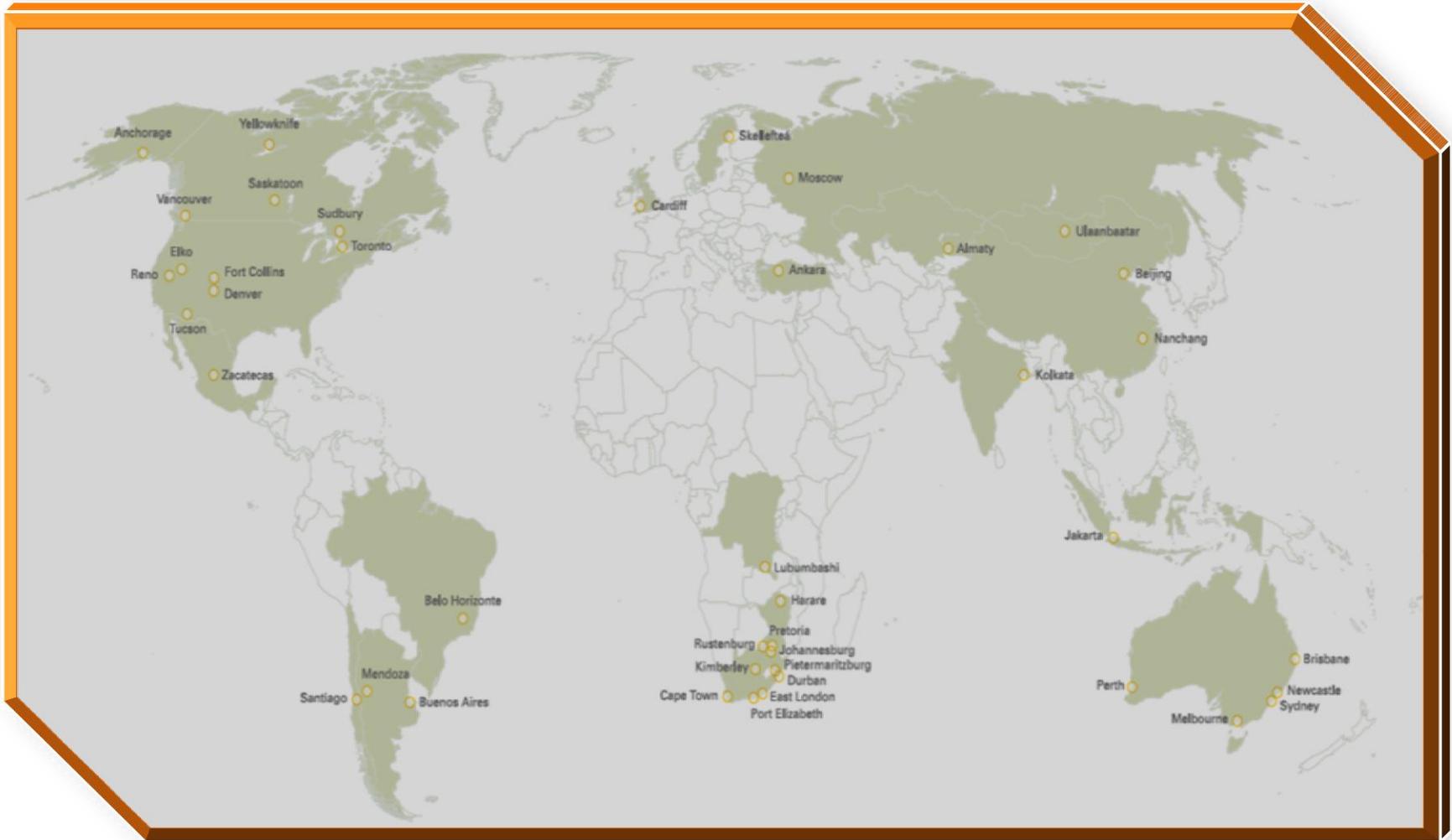
3. Oil shale deposits

4. Beneficiation process

5. Reserves estimate

6. Conclusion

Key facts about SRK Consulting



SRK Services

- ❖ Multi Disciplinary Services Exploration
- ❖ Mining Geology & Resources Estimation
- ❖ Mineral Reserves & Ore Reserves Reporting
- ❖ Mining Engineering
- ❖ Geotechnical Engineering
- ❖ Mineral & Metallurgy Processing
- ❖ Tailings & Waste Management
- ❖ Geochemistry
- ❖ Environmental & Social
- ❖ Mining Economic



SRK Oil Shale projects

- Estonia- Resource and Reserves
- Jordan – Managing of Prefeasibility Study
- Brazil - Benchmarking the Mining Operation
- Byelorussia –Mineral Expert Report



SRK Exploration Services

SRK ES is currently involved in directing and designing Oil Shale exploration in North America and the Middle East and has qualified professionals with extensive experience in working with Oil Shale and other stratiform deposits.

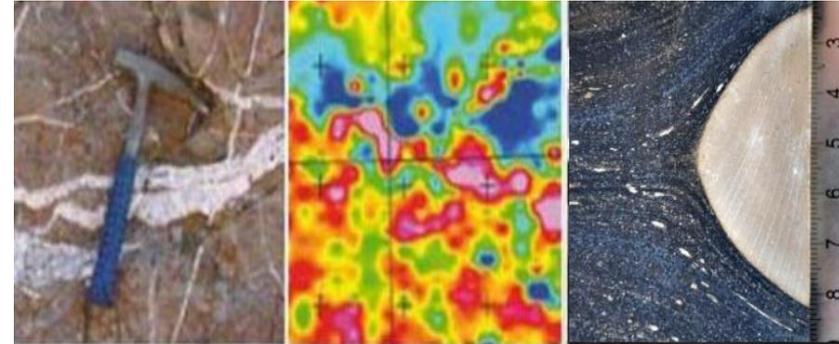
Specific oil shale experience:

- Independent project reviews and fatal flaw analyses
- Exploration design and scheduling
- Exploration field and logistics management
- Exploration programme implementation and geological supervision
- Oil shale assay analysis and quality review
- Design and implementation of international best practices
- Technical drilling quality reviews and advice
- Oil shale exploration project management
- Data collection, compilation and database construction

SRK ES has the added advantage of being able to draw on the wider SRK Group's experience and therefore take projects beyond the exploration phases through to resource modelling and ultimately towards feasibility and production studies.

SRK Exploration Services in Jordan

- Reviewed, amended and redesigned exploration programmes
- Designed sampling procedures and flow paths along with parallel quality control protocols
- Designed, processed and interpreted geophysical data
- Acted as the JORC Qualified Person during exploration programmes
- Undertaken targeted structural mapping exercises
- Reviewed sequence stratigraphy studies along with oil shale weathering studies
- Reviewed annual and programme end reporting
- Complied and audited exploration data/databases

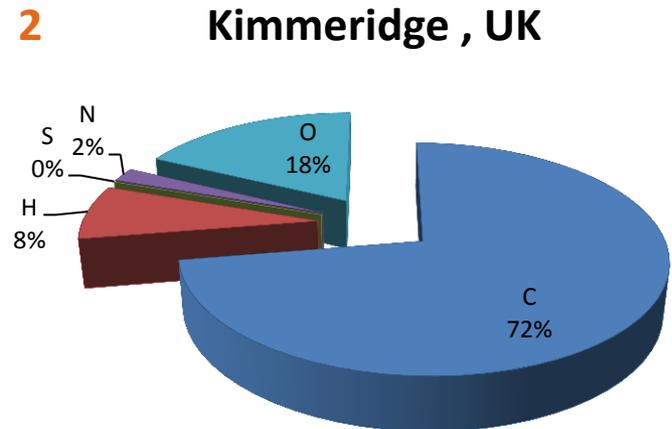
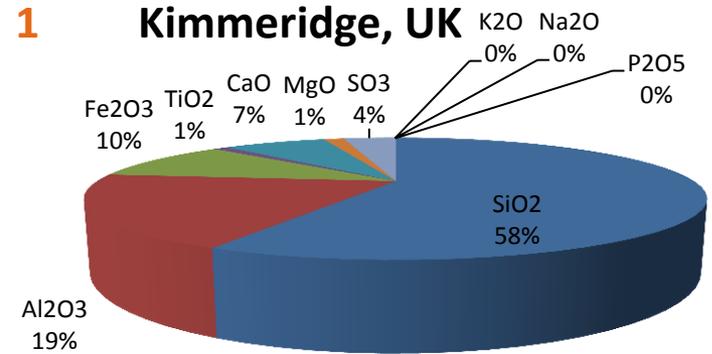


Oil shale deposits

1. Chemical composition of the mineral part
2. Elemental composition of kerogen

Oil shale products:

- oil – 25.5%
- Semicoke- 60.2%
- Gases- 10.7%
- Pyrolitic water – 3.6%



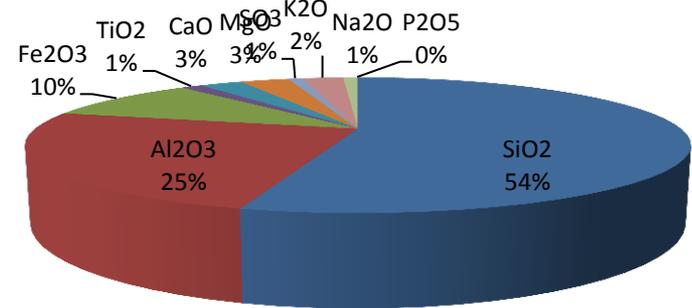
Oil shale deposits

1. Chemical composition of the mineral part
2. Elemental composition of kerogen

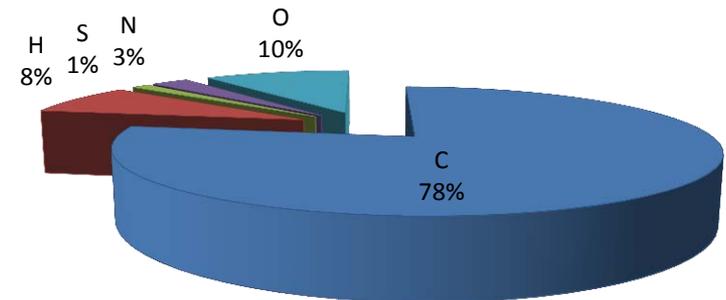
Oil shale products:

- oil – 8.2%
- Semicoke- 86.6%;
- Gases- 3%
- Pyrolitic water – 2.2%

1 Westwood, Scotland (UK)



2 Westwood, Scotland (UK)



Oil shale deposits

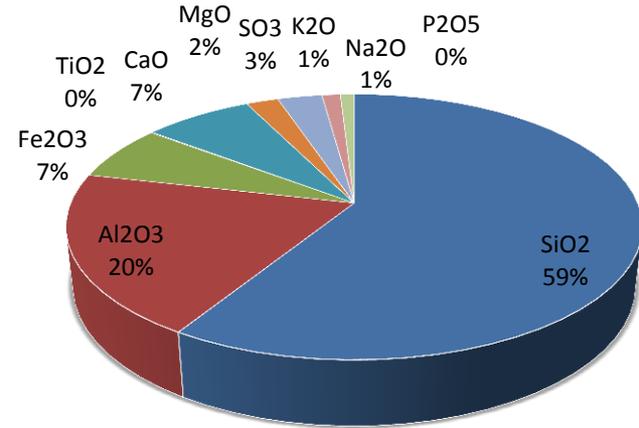
1. Chemical composition of the mineral part of boltyscheski oil shale deposit
2. Elemental composition of kerogen

Oil shale products:

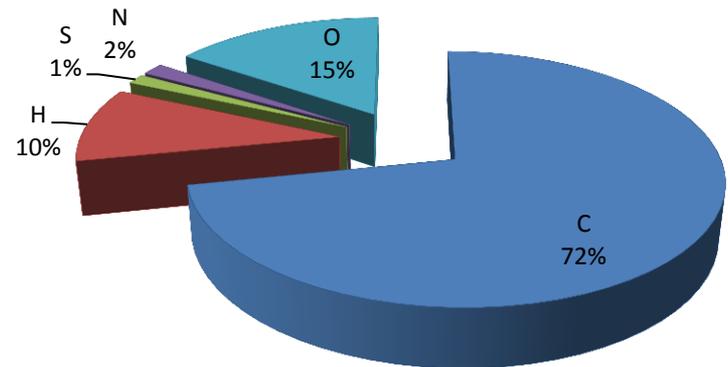
- oil – 17%
- Semicoke- 73%;
- Gases- 6%;
- Pyrolitic water – 4%

Organic compound is typical sapropelite, which in some cases contains humus.

1 Boltys (Ukraine)



2 Boltys (Ukraine)



in oil shale	%	in ash	%
Ni	0.030	Ni	0.01-0.03
Co	0.003	Co	0.001-0.004
Cr	0.030	Cr	0.003-0.03
Zr	0.030	Zr	0.01-0.03
Cu	0.030	Pb	0.003
Ge	0.030	Sr	0.03-0.1
V	0.030	V	0.001-0.03
		Ba	0.03-0.3

Oil shale beneficiation

Grade distribution by blast breakage:

$$G_x = \Delta G \exp(-kx) + G_{ROM}$$

➤ G_x – grade of the size 0–x (mm)

➤ ΔG_x – effect of selective crushing

➤ k – parameter of distribution

➤ x – grain size

➤ G_{ROM} – grade from ROM.

$$y = A * n + \delta$$

y – screen underflow;

x – grain size, mm;

A – part of fine grains less 1 mm,

n – granularity range;

δ – pieces splitting at transportation

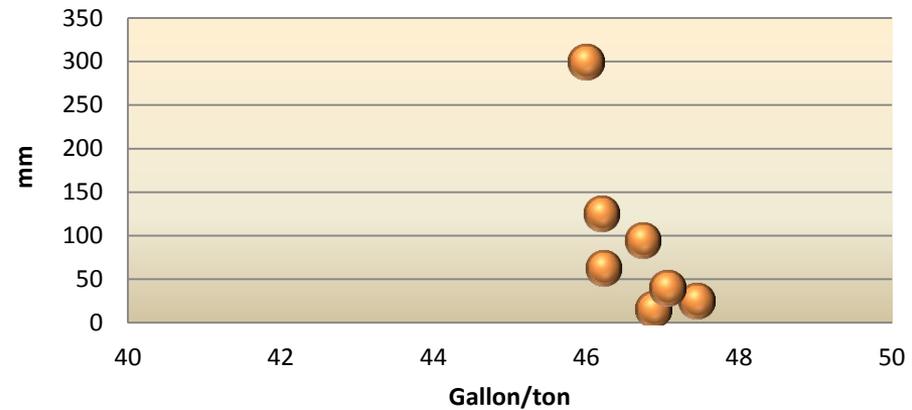
Parameters	Symbol	Mining method		
		Drill&Blast	Mechanical cutting	Ripping
Granularity	n	0.5-0.6	0.3-0.5	0.4
Splitting factor	A	0.03-0.06	0.06-0.02	0.1-0.2
Fines factor	δ	0.05-0.15		
Distribution factor	k	0.006-0.05	0	-
Selective crushing factor	ΔQ	3.0-5.8	0	-

Oil shale grade distribution

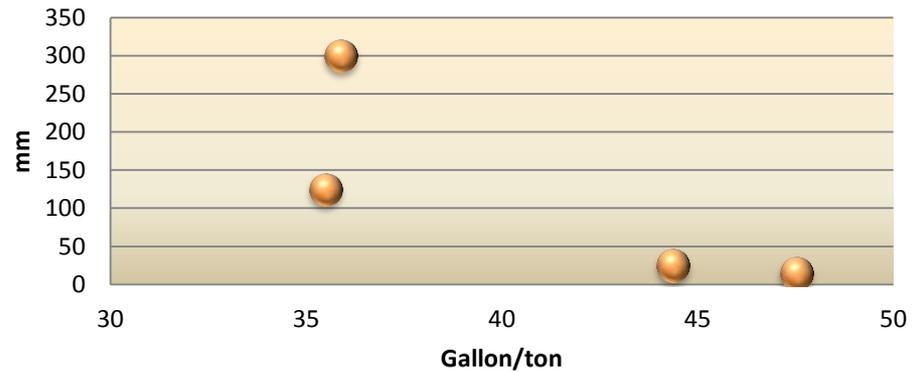
Average grade in oil shale layer with concretion:

$$G_{AV} = (G_{os} * m_{os} + G_c * m_c) / m_{AV}$$

Mechanical crushing



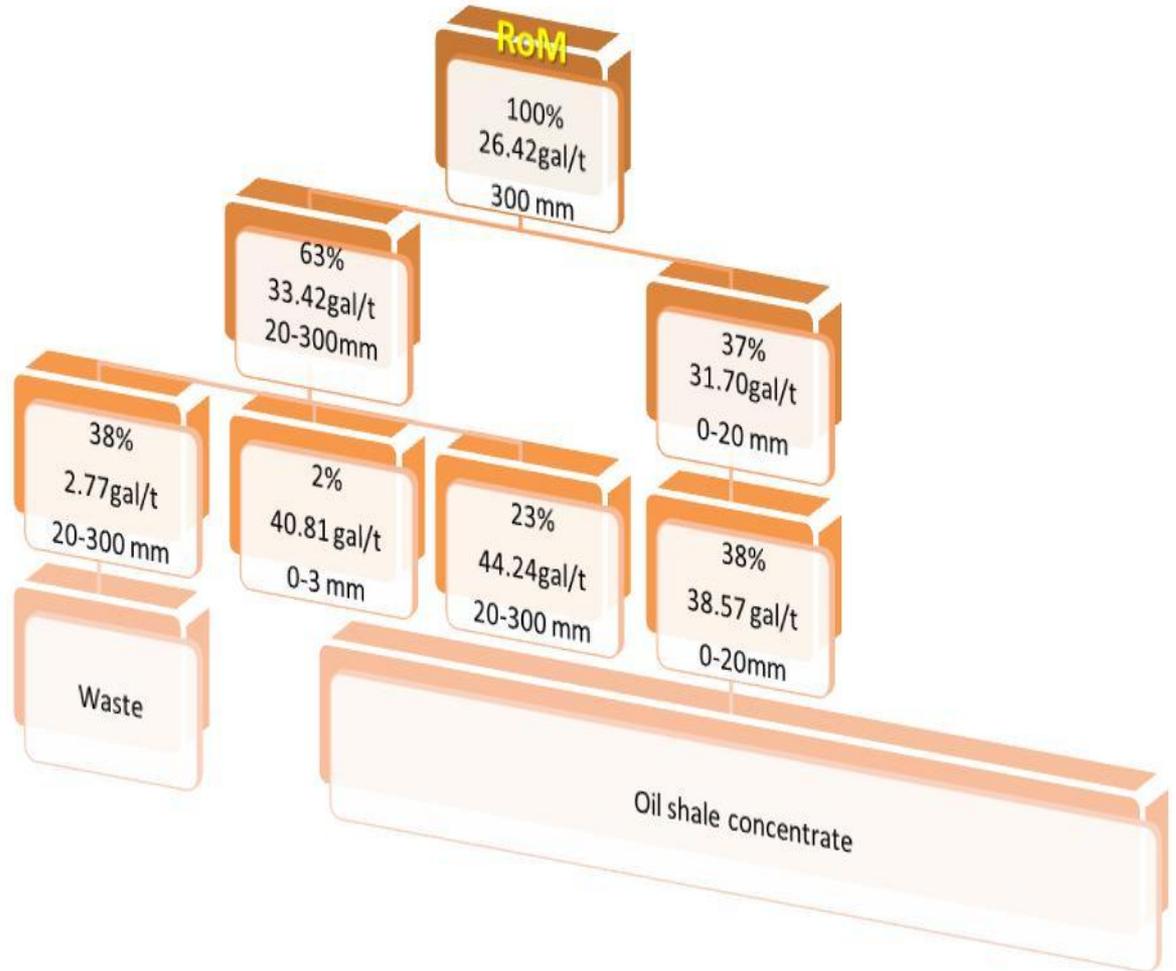
Drill&Blast



Oil Shale beneficiation flow sheet diagram

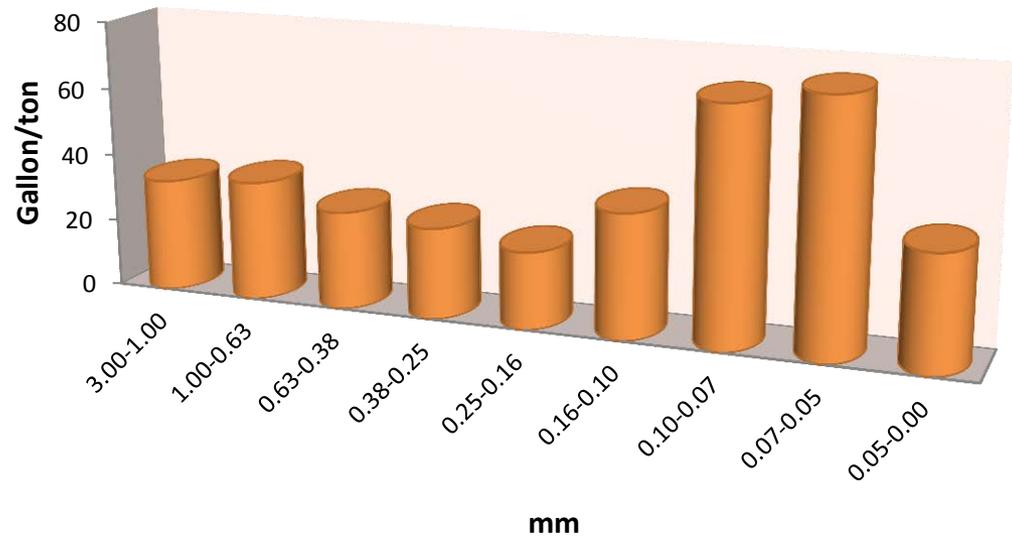
Flow diagram processes:

1. Dry screening
2. Coarse concentration
3. Wet screening
4. Fine concentration
5. Dewatering
6. Final product blending



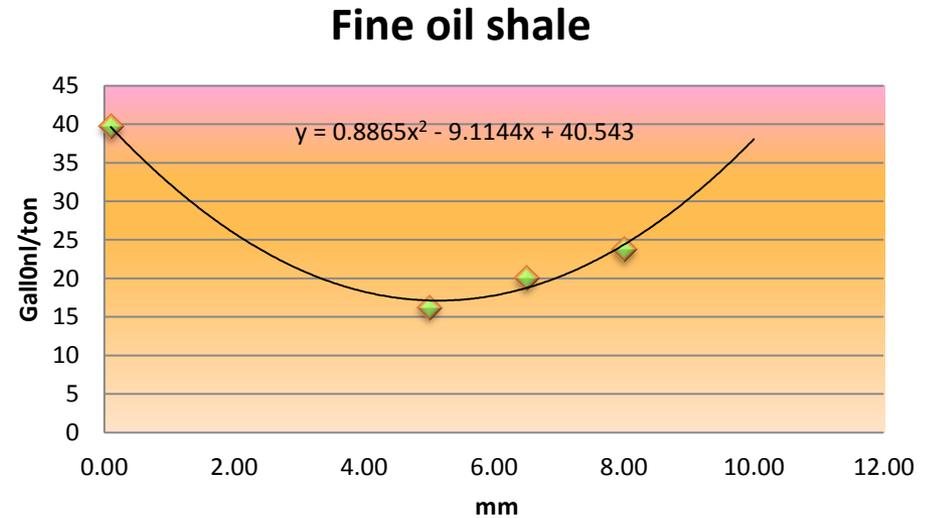
Fines oil shale grade distribution

- Fine particles of oil shale 0.1-0.05 mm have higher grade and don not contain sand and clay inclusions



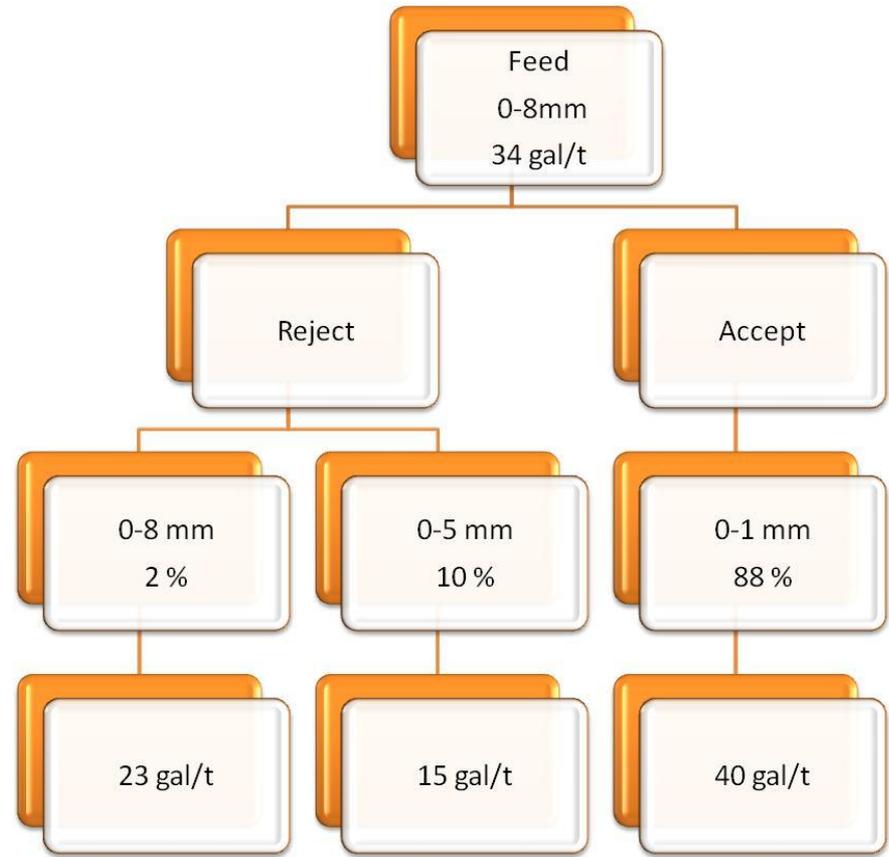
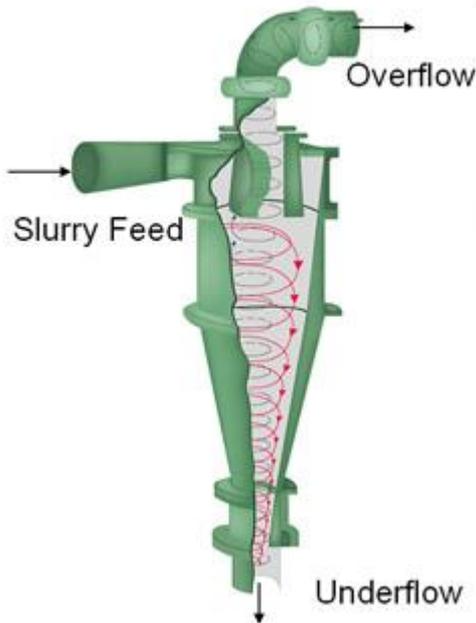
Wet screen separation

- Wet screen separation process includes water which then contain 2-3% of fine oil shale
- Fine oil shale 0-8mm can be separated by radial thickener or hydrocilones



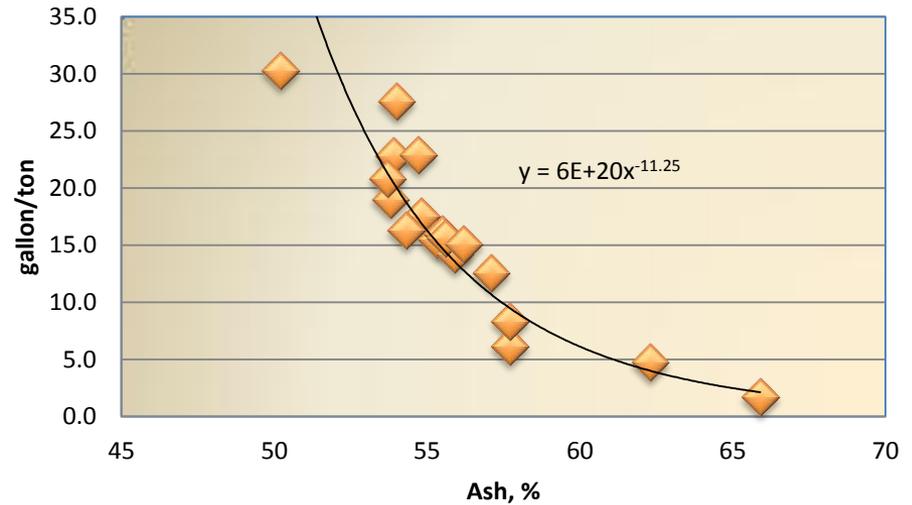
Hydrocyclone separation

- Hydrocyclones have low efficiency in separation of fine oil shale slurry substances from waste material and need additional dewatering installations to dry oil shale



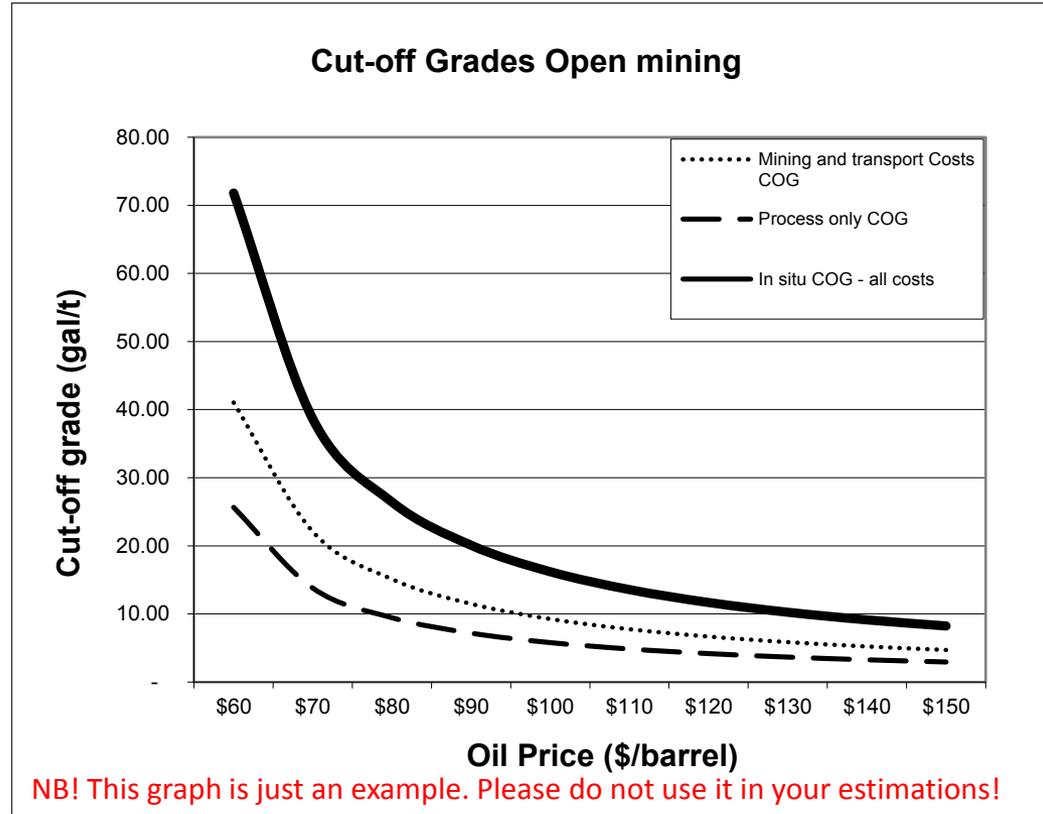
Fine oil shale grade and ash content distribution

- Fine particles of oil shale 0-8mm have ash content 50-67%
- Aluminosilicate-Carbonate (CaO+MgO >10%)



Cut-off Grades

- Stripping ratio – 4:1(tore/toil shale)
- Productive oil shale seam thickness 4-12m
- Stope recovery-95%
- Dilution-5%
- Must define material which has potential for eventual economic extraction:
 - optimistic revenue parameters
 - realistic technical parameters
 - benchmarked costs
- Must calculate and use an appropriate cut-off grade (COG) to the envisaged mining method
- Material above the COG must form spatially contiguous volumes that would/could form mining targets



Reserves estimate

- Information supporting mine design (geotechnics, water if relevant, design constraints, proximity of lease boundary to operation, waste dump capacity, etc.)
- Mining modifying factors
 - Mining losses & dilution – how measured, appropriateness of projections, what were the results of the reconciliation?
 - Resource utilisation, minimum mining width, minimum width to exclude waste
- Economic factors:
 - Verification of cut-off grade: average, marginal, operational; strip ratio limits
 - What price is used? Is it a long term price?
- Marketing constraints:
 - Is there a market for the product?
 - Is the production rate constrained by market capacity?
- Social and Environmental constraints:
 - Is mining restricted on any portion of the deposit? Will the community support the project?
- Governmental constraints:
 - Is there any doubt that the government may not grant the necessary permits?

Conclusions

The results of the analysis can be used in estimation of a material balance and technological schemes, and at technological considerations for choosing suitable flowsheets for beneficiation process and selection of mining methods.

These technological considerations are facilitate the appropriate decisions for further oil shale processing and can be useful for oil shale reserves estimation.



Thank You for Your Attention!