

Basic considerations regarding the mineability of oil shale deposits in relation to Mineral Reserve Estimation



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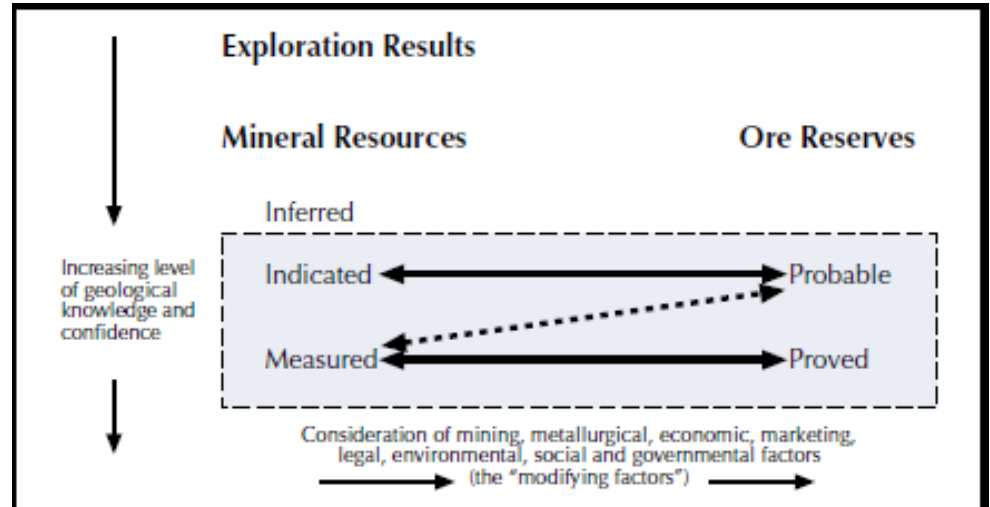
SRK Oil Shale Experience

- Estonia- Resource and Reserves
- Jordan – Exploration and assistance with project development
- Brazil - Benchmarking the Mining Operation
- Belorussia –Mineral Expert Report
- USA, Utah- Resource Estimation



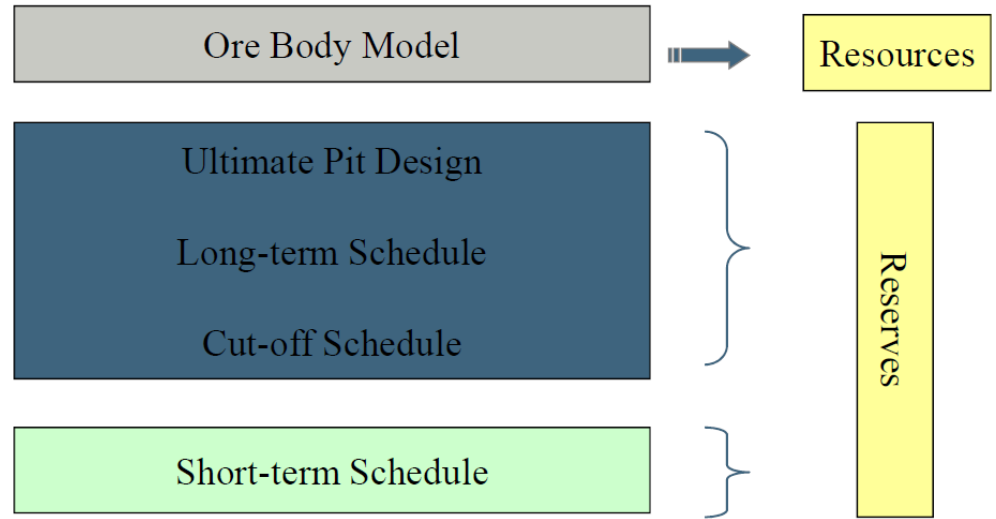
How does a “Resource” become a “Reserve”?

- Reserves can be taken only from Measured or Indicated Resources
- Company strategic plan and Life of Mine Plans (LoMP) form the basis for Reserves Estimate
- To be demonstrated as economically viable after the application of “modifying factors” (i.e. Discounted cashflow model)
- Need to define the basis of the Reserve estimate:
 - ✓ Run-of-mine
 - ✓ Saleable product



Modifying Factors

- Resources are representative of the in-situ oil shale
- In-situ oil shale is converted to a saleable product by the mining and beneficiation process
- The considerations that are applied to the design and operational planning are called “Modifying Factors”
- These include:
 - ✓ Mining
 - ✓ Beneficiation/Processing
 - ✓ Economic
 - ✓ Marketing
 - ✓ Legal
 - ✓ Environmental
 - ✓ Social and Governmental



Oil Shale Reserve Estimation

- **Marketing factors:**
 - ✓ What is the saleable product
 - ✓ Availability of market for the product
 - ✓ Does market capacity affect production rate?
- **Legal factors:**
 - ✓ Mining legislation
 - ✓ Other land users (native title, etc.)
- **Social and Environmental factors:**
 - ✓ May restrict mine or infrastructure footprint
 - ✓ Stakeholder engagement/ESIA
- **Governmental factors:**
 - ✓ Licensing and permitting
 - ✓ Government energy policy



Oil Shale Reserve Estimation

- **Mining factors:**
 - ✓ Dilution, mining losses and extraction ratios
 - ✓ Grade adjustment factors
 - ✓ Geotechnical and hydrogeological
 - ✓ Minimum mining width, interbedded waste, mineralised thickness, stripping ratio
 - ✓ Grade/stratigraphic continuity
- **Cut-off grade:**
 - ✓ What is being sold and for how much?
 - ✓ How does the selling price relate to the oil content/calorific value of the in-situ Resources?
 - ✓ Cut-off grade application must consider minimum mining thickness and diluted grade
 - ✓ Complicated by Internal Transfer Pricing on a 'cost plus' basis

Layers Index	Oil Shale&waste rock	Thickness, m	Oil content, %
G	Oil Shale	1.9	22.0
W	Waste rock	1.3	0.0
F	Oil Shale	0.9	14.0
W	Waste rock	3.1	0.0
D	Oil Shale	1.0	11.4
W	Waste rock	0.8	2.8
C	Oil Shale	2.3	17.4
W	Waste rock	1.2	0.0
B	Oil Shale	1.8	16.0
W	Waste rock	0.7	0.0
A	Oil Shale	0.5	18.0

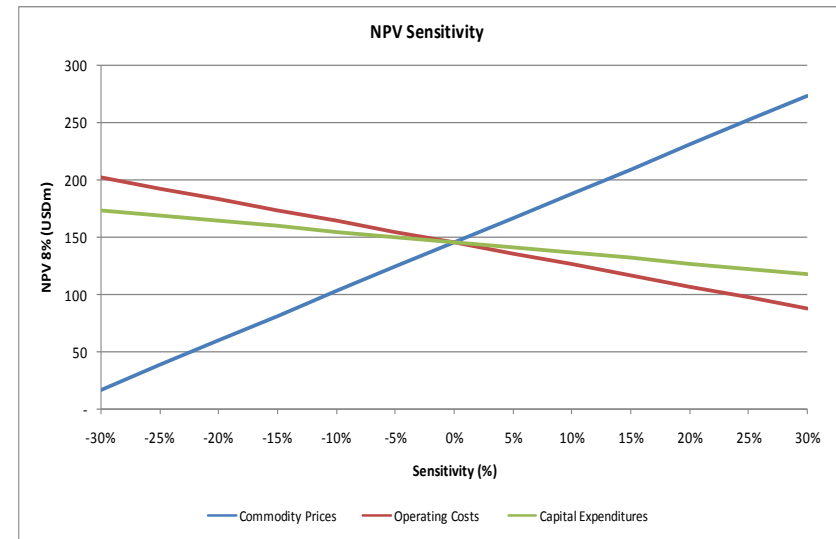
Oil Shale Reserve Estimation

- **Beneficiation/processing factors:**
 - ✓ Bulk sample and sizing selection for plant design:
 - representative of planned plant feed, grade variability
 - ✓ Product recoveries
 - ✓ Material hardness (Bond work index)
 - ✓ Bulk density
 - ✓ Presence and distribution of deleterious elements (sulphur, etc.)
 - ✓ Sales specifications
 - ✓ Plant capacity versus production rate
 - ✓ Stockpiling requirements/capacity



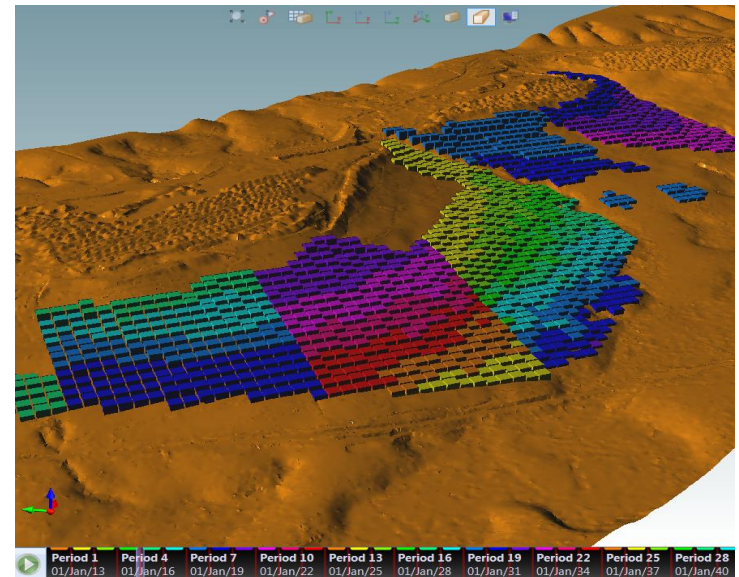
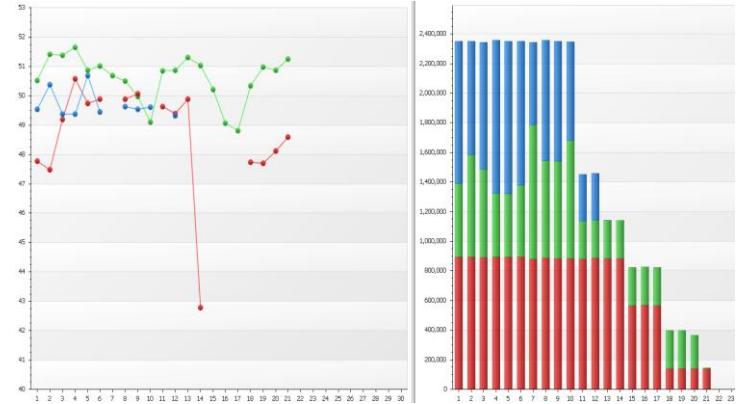
Oil Shale Reserve Estimation

- **Economic factors:**
 - ✓ Cut-off grade
 - ✓ Variation in selling price over time
 - ✓ Operating costs
 - ✓ Capital costs
 - ✓ Production rate
- **Technical-economic model**
 - ✓ Links production schedule to costs and revenues
 - ✓ Should use realistic, long-term price
 - ✓ Used to demonstrate economic viability
 - ✓ Traditionally uses discounted cash flow methods (NPV, IRR, etc.)
 - ✓ Sensitivity analysis on inputs should be understood



Oil Shale Project Reserve Estimation Sequence

- Exploration, data collection and geological interpretation
- Construction of Resource model (estimation and classification)
- Project planning
 - ✓ Mining method selection
 - ✓ Optimisation
 - ✓ Mine/beneficiation plant design
 - ✓ Production scheduling
 - ✓ Estimation of operating and capital costs
 - ✓ Integration of modifying factors
- Economic modelling and sensitivity
- Reporting



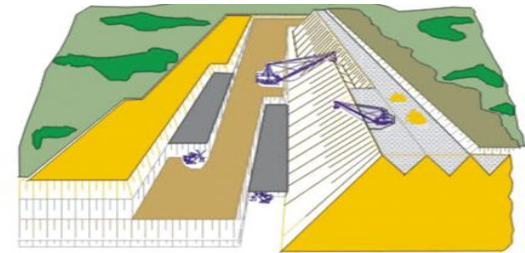
Mining Method Selection

- Physical Characteristics:
 - ✓ Deposit depth and geometry
 - ✓ Grade (or quality) distribution
 - ✓ Geotechnical characteristics
 - ✓ Hydrogeology
- Production Characteristics:
 - ✓ Production rate requirements
 - ✓ Grade/quality of feed
 - ✓ Maximising Resource recovery
- Environmental Factors:
 - ✓ Surface subsidence
 - ✓ Waste production
 - ✓ Skills of existing workforce
- Economic Factors:
 - ✓ Operating costs
 - ✓ Capital costs for establishment



Open Pit Mining

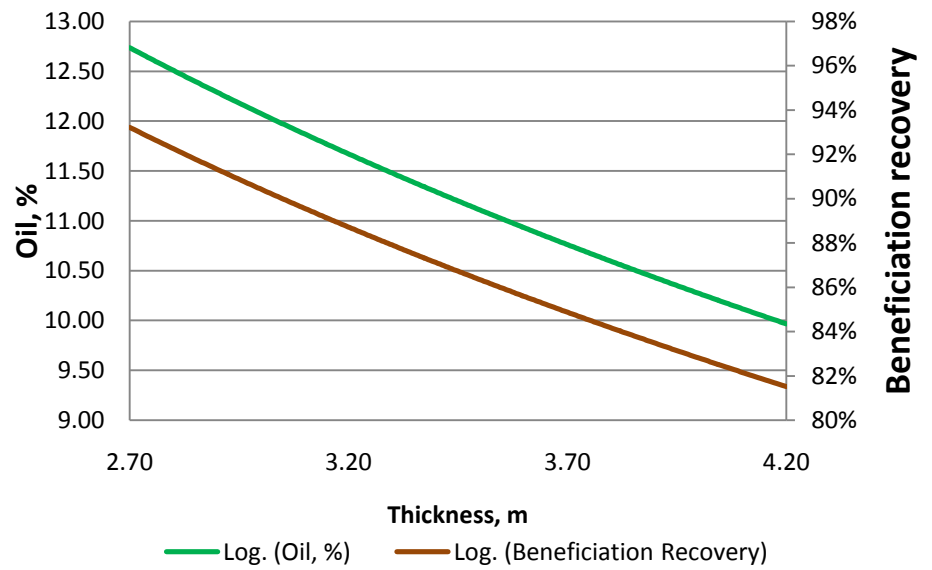
1. Optimisation of mining depth and footprint
 2. Optimal depth for open cast, pit, cut, trench
 3. Losses-Environmental pillars, Karstic zones
- Overburden
 - ✓ Drill&Blast
 - ✓ Stripping
 - Oil Shale
 - ✓ Bulk mining
 - ✓ Selective mining
 - ✓ Strip mining



Oil shale mining methods choice

Underground mining

- Room&Pillar mining
 - ✓ Losses in pillars
 - ✓ Losses in karst



Oil shale mining methods choice

Underground mining

- Longwall (Plow, Shearer) mining
 - ✓ Looses resulting from deceleration
 - ✓ Looses connected to lower cutting depth



Oil shale mining methods choice

Unconventional mining

1. In-Situ

- ✓ Minimum depth $\geq 100\text{m}$
- ✓ Minimum thickness $\sim 30\text{m}$

2. Ex-situ

- ✓ Material size
- ✓ Operation dimensions



Shell's experimental in-situ oil shale facility, Piceance Basin, Colorado

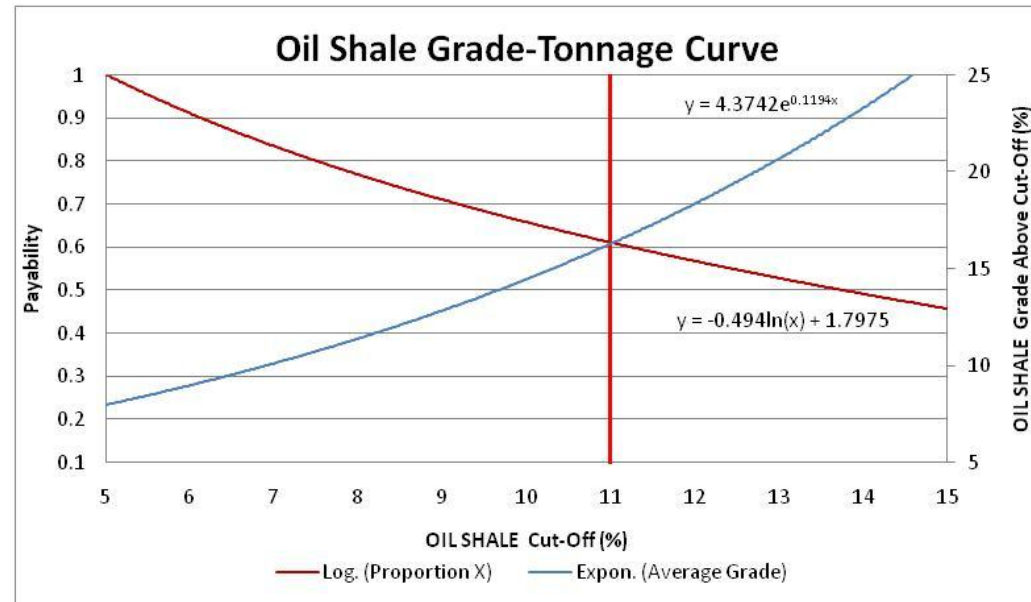


Red Leaf EcoShale™ In-Capsule Process plant, Utah

Oil Shale Grade-Tonnage Curve

Optimal cut-off grades can be determined at each stage of the mining operation when capacity related factors are incorporated in to the calculation

- Payability = Oil shale sent to processing/ Total rock mined
- Average grade above cut-off = Total oil yield/Total tonnes processed



NB! This graph is just an example on the specific case of underground mine. Please do not use it in your estimations!

Conclusion

These considerations facilitate the appropriate decisions for the development of methods suitable for oil shale Reserve Estimation and can aid the development of un-conventional mining methods



Thank You for Your Attention!

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