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

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srk consulting

Contents

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- Mining Geology & Resources Estimation
- Mineral Reserves & Ore Reserves Reporting
- Geotechnical Engineering
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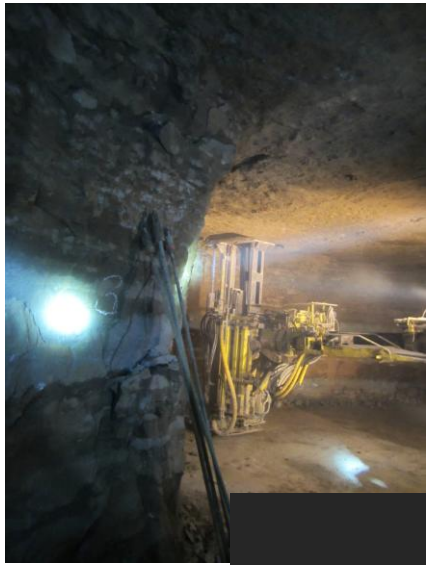
SRK Oil Shale Experience

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



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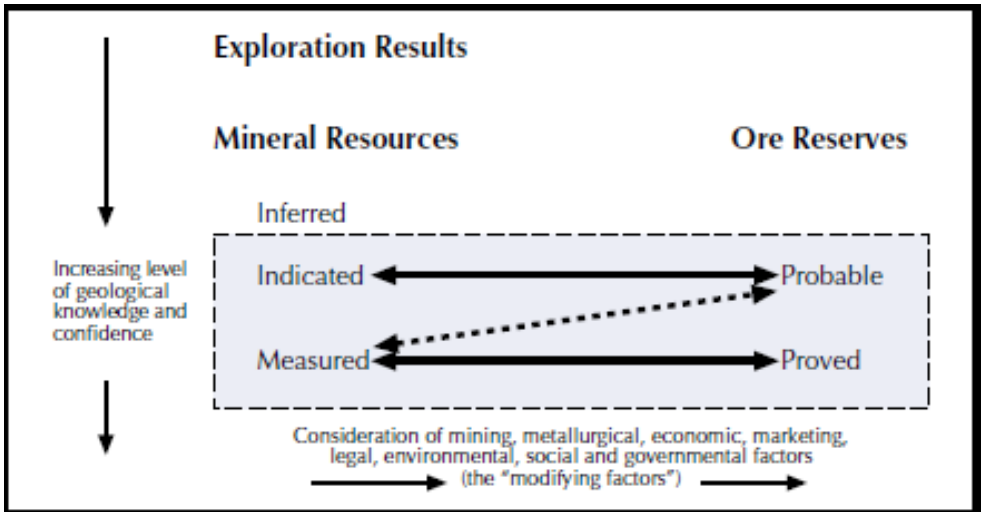
How does a “Resource” become a “Reserve”?

- 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



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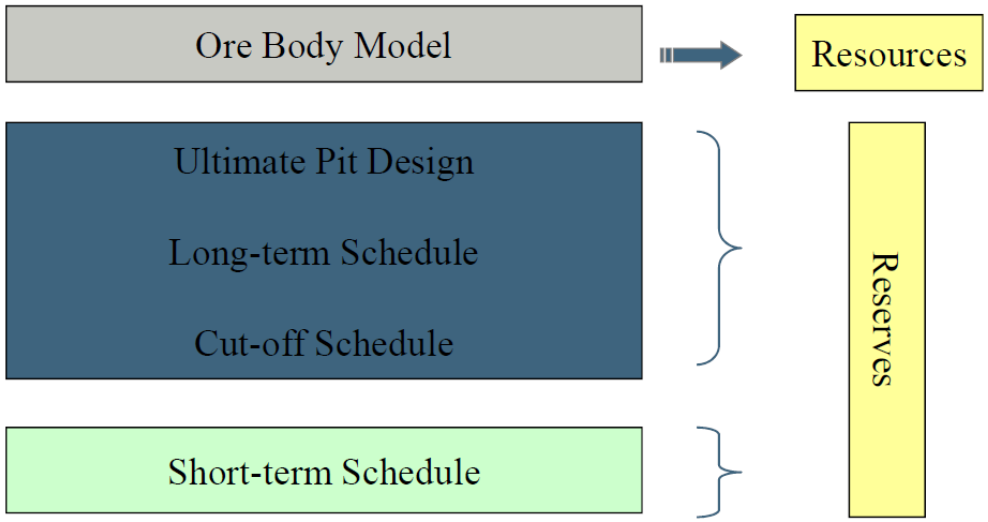
Modifying Factors

- 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



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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

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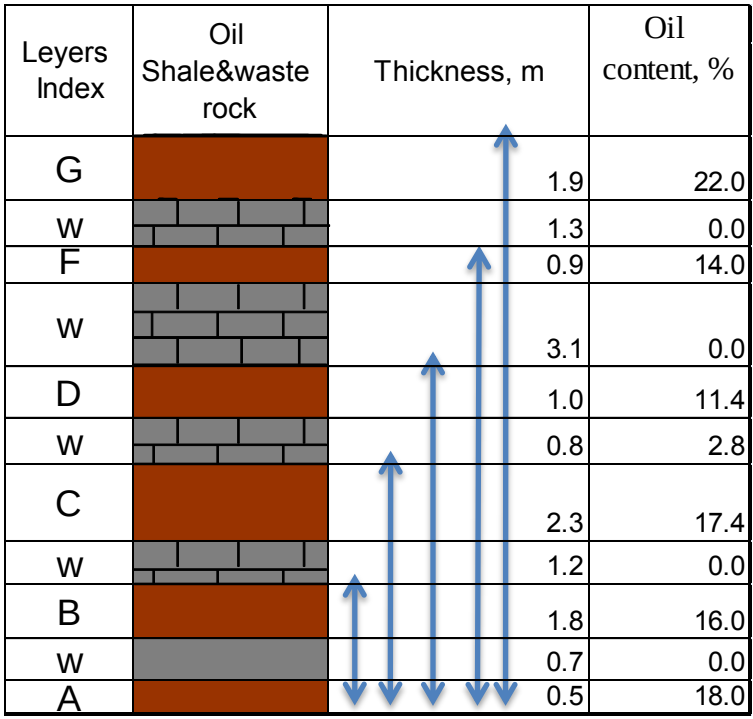
Oil Shale Reserve Estimation

- **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



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

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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

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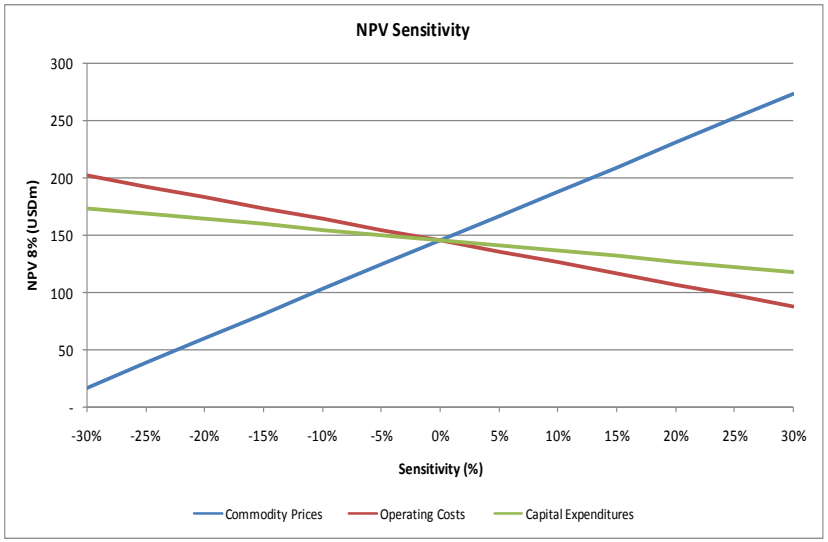
Oil Shale Reserve Estimation

- **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



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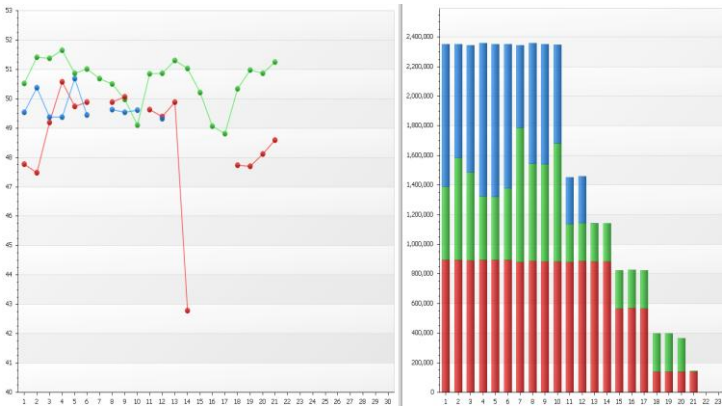
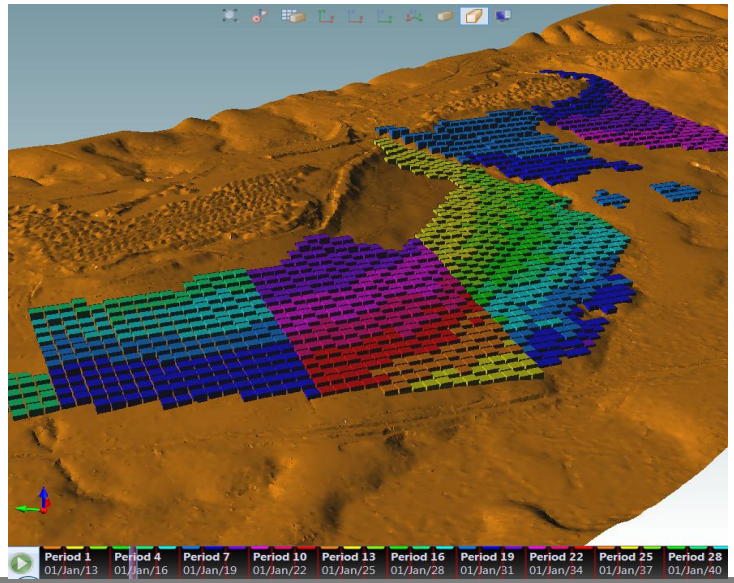
Oil Shale Project Reserve Estimation Sequence

- 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





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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

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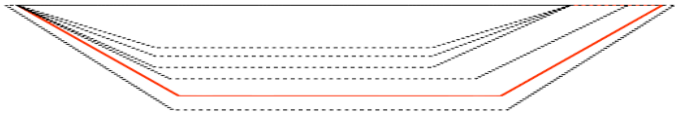
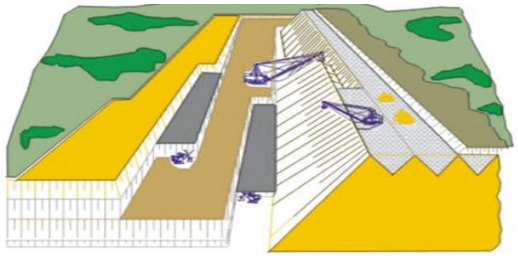
Open Pit Mining

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





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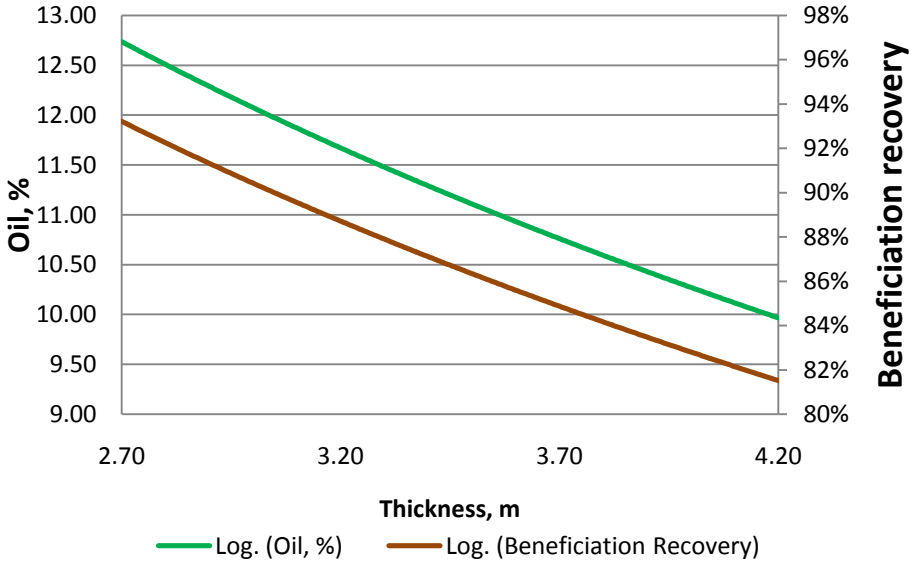
Oil shale mining methods choice

Underground mining

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



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Oil shale mining methods choice

Underground mining

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

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Oil shale mining methods choice

Unconventional mining

1. In-Situ
   - ✓ Minimum depth ≥ 100m
   - ✓ Minimum thickness ~ 30m
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

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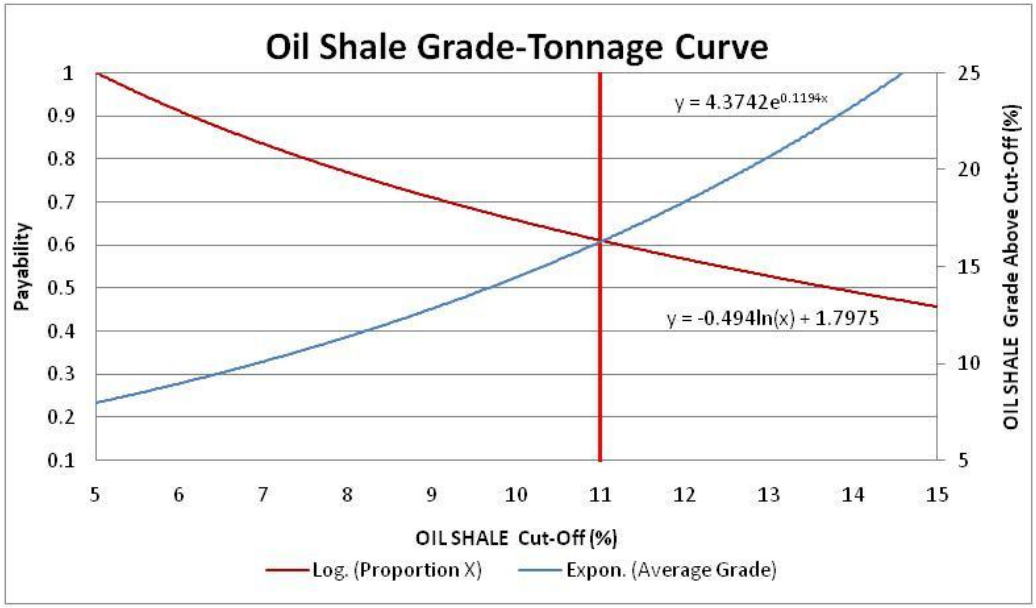
Oil Shale Grade-Tonnage Curve

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!

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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

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Thank You for Your Attention!

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