Risk Assessment in the Quality Control of Oil Shale in Estonian Deposit

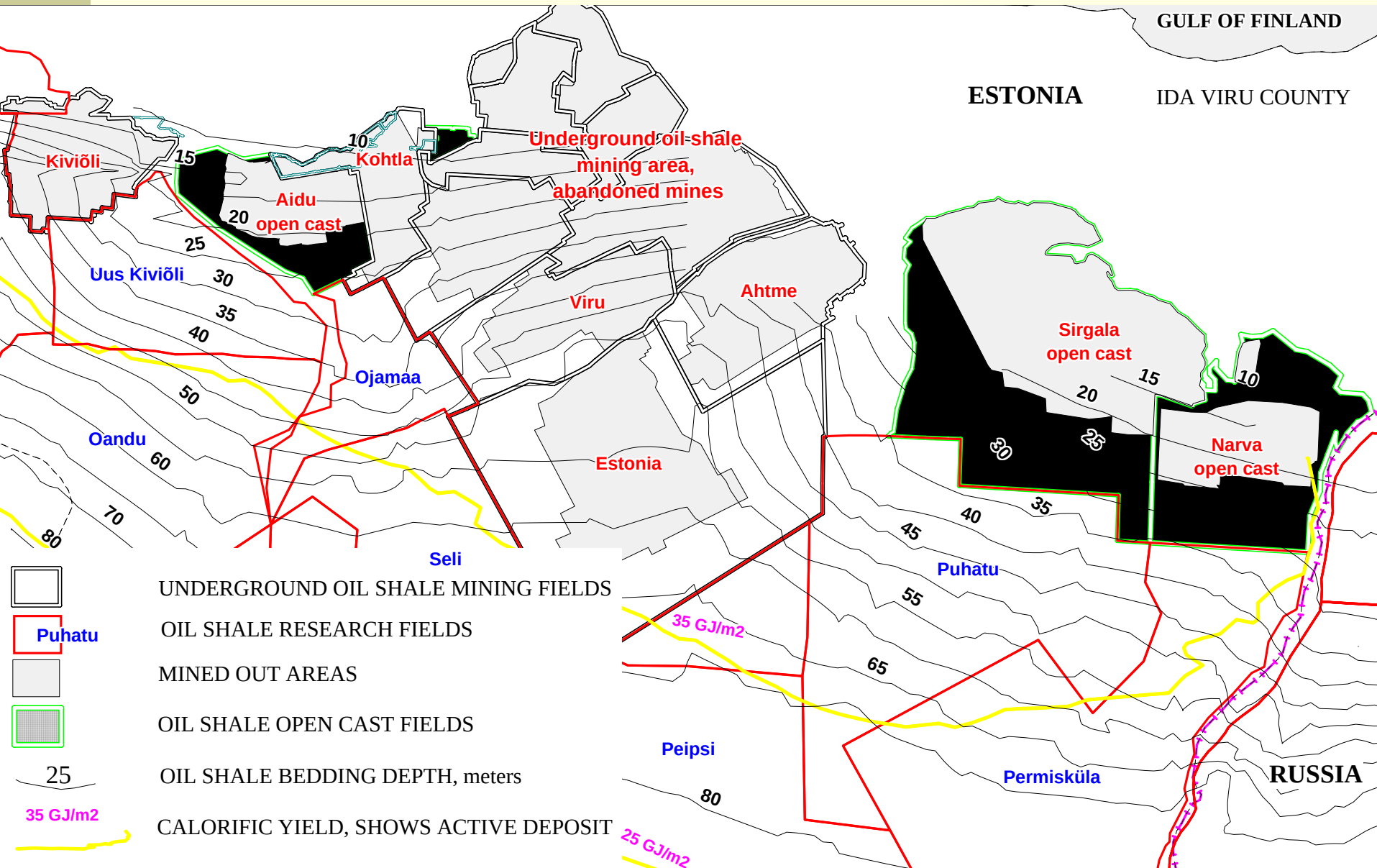
Sergei Sabanov

28th Oil Shale Symposium
October 13-17, 2008

Presentation outline

- Introduction
- Mining technology overview
- Risk assessment in mining
- Main factors determination of oil shale quality
- Oil shale enrichment
- Selective mining
- Conclusion

Oil shale in Estonia



Annual production of oil shale

	Million tones
Viru mine	2
Estonia mine	5
Narva open cast	5
Aidu open cast	2
Põhja kiviõli open cast	1
Ubja open cast	0.3
Average	15 -16

Characteristics of the oil shale and limestone seams

1 kWh ~ 1.4 kg of oil shale
Shale oil ~16 %

Layers index	Lithology	Thickness, m	Calorific value GJ/t	Kerogen %	Compressive strenght, MPa	Volume weight t/m3
F_2		0.17	6.7	19	24	1.72
F1/F2		0.18	2.9	8	65	2.10
F1		0.20	11.5	31	19	1.51
F		0.42	11.5	33	18	1.51
E		0.58	17.5	50	18	1.28
D/E		0.07	2.9	8	67	2.10
D		0.06	9.4	27	29	1.59
C/D		0.29	0.6	2	82	2.45
C		0.41	14.2	40	26	1.38
B/C		0.12	2.9	8	75	2.10
B		0.38	19.2	54	40	1.22
A1/B		0.18	1.3	4	65	2.25
A1		0.09	7.5	21	26	1.42
A/A1		0.06	2.9	8	32	2.10
A		0.12	15.1	43	32	1.37

Problems

- Raw material - extracted rock mass without enrichment does not meet requirements of customers for calorific values
- Decreasing calorific values in peripheral sides of the commercial oil shale deposit will demand additional enrichment of oil shale

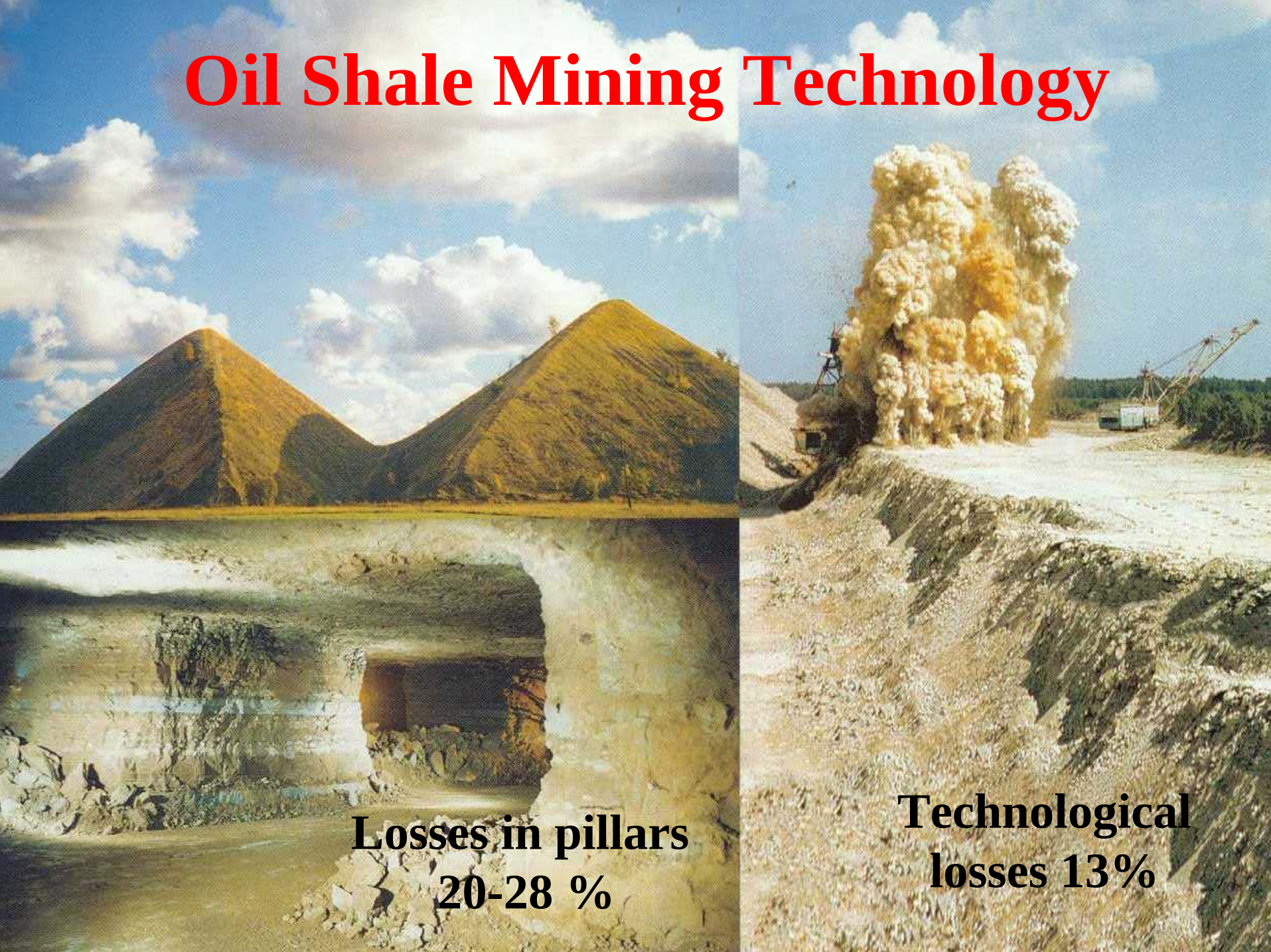
Aim

- Elaboration of the risk assessment methods for quality control of oil shale in according with technical opportunities of extraction and enrichment processes for various parts of Estonian deposit

Presentation outline

- Introduction
- **Mining technology overview**
- Risk assessment in mining
- Main factors determining quality of oil shale
- Oil shale enrichment
- Selective mining
- Conclusion

Oil Shale Mining Technology



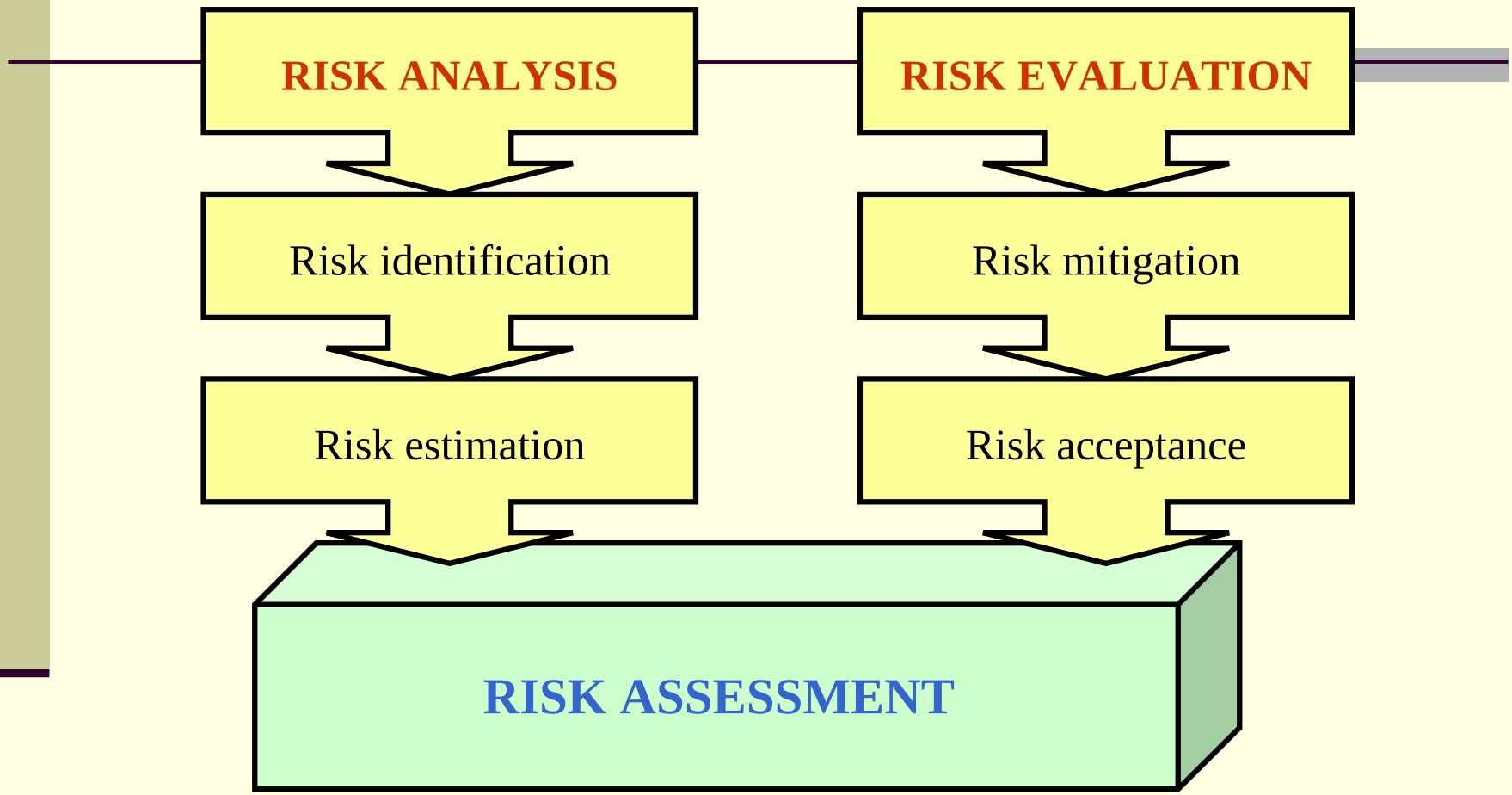
Open mining

Selective (surface) mining

Presentation outline

- Introduction
- Mining technology overview
- **Risk assessment in mining**
- Main factors determining quality of oil shale
- Oil shale enrichment
- Selective mining
- Conclusion

Why is Risk Assessment?



- Risk assessment is the process of deciding whether existing risks are tolerable and risk control measures are adequate

Risk Analysis

Risk analysis is used for performing safety assessment for many different mining systems. Risk analysis includes: scope and risk analysis plan definition, risk identification, risk estimation

Risk identification is the process of determining potential risks and starts with the source of problems, or with the problem itself. Failure can be described on many different levels. Conceptualization of the different possible failure modes for mining systems is an important part of risk identification.

Risk estimation entails the assignment of probabilities to the events and responses identified under risk identification. Probability estimation can be grouped into three general approaches depending on the type and quality of the available data: analytical approach uses logical models for calculating probabilities; empirical approach uses existing databases to generate probability; judgmental approach uses experience of practicing engineers in guiding the estimation of probabilities

Risk Evaluation

The principal role of risk evaluation in risk assessment is the generation of decision guidance against which the results of risk analysis can be assessed

Risk mitigation is a selective application of appropriate techniques and management principles to reduce either likelihood of an occurrence or its consequences, or both

Risk acceptance is an informed decision to accept the likelihood and the consequences of a particular risk

Presentation outline

- Introduction
- Mining technology overview
- **Risk assessment in mining**
- **Main factors determining quality of oil shale**
- Oil shale enrichment
- Selective mining
- Conclusion

Main factors determining oil shale quality

Environmental

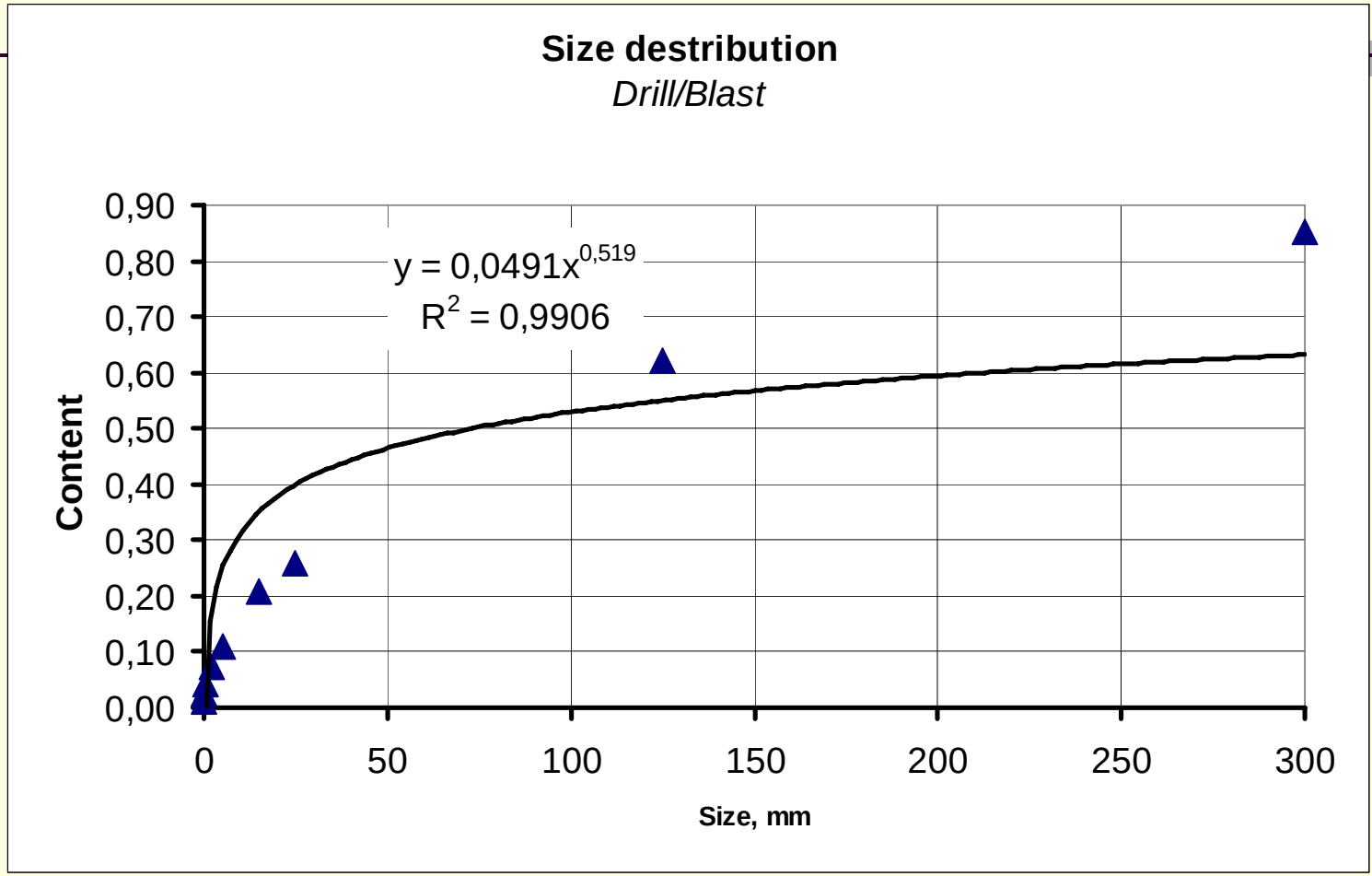
- Oil shale seam quality deterioration is controlled by two factors - increasing fraction of limestone and decreasing calorific value.
- Calorific value and layer thickness vary from place to place within a deposit.
- These parameters decrease from the center to the border of a deposit. The variation in the value of the calorific value comes to 0.07 MJ/kg per km.

Main factors determination of oil shale quality

Technological

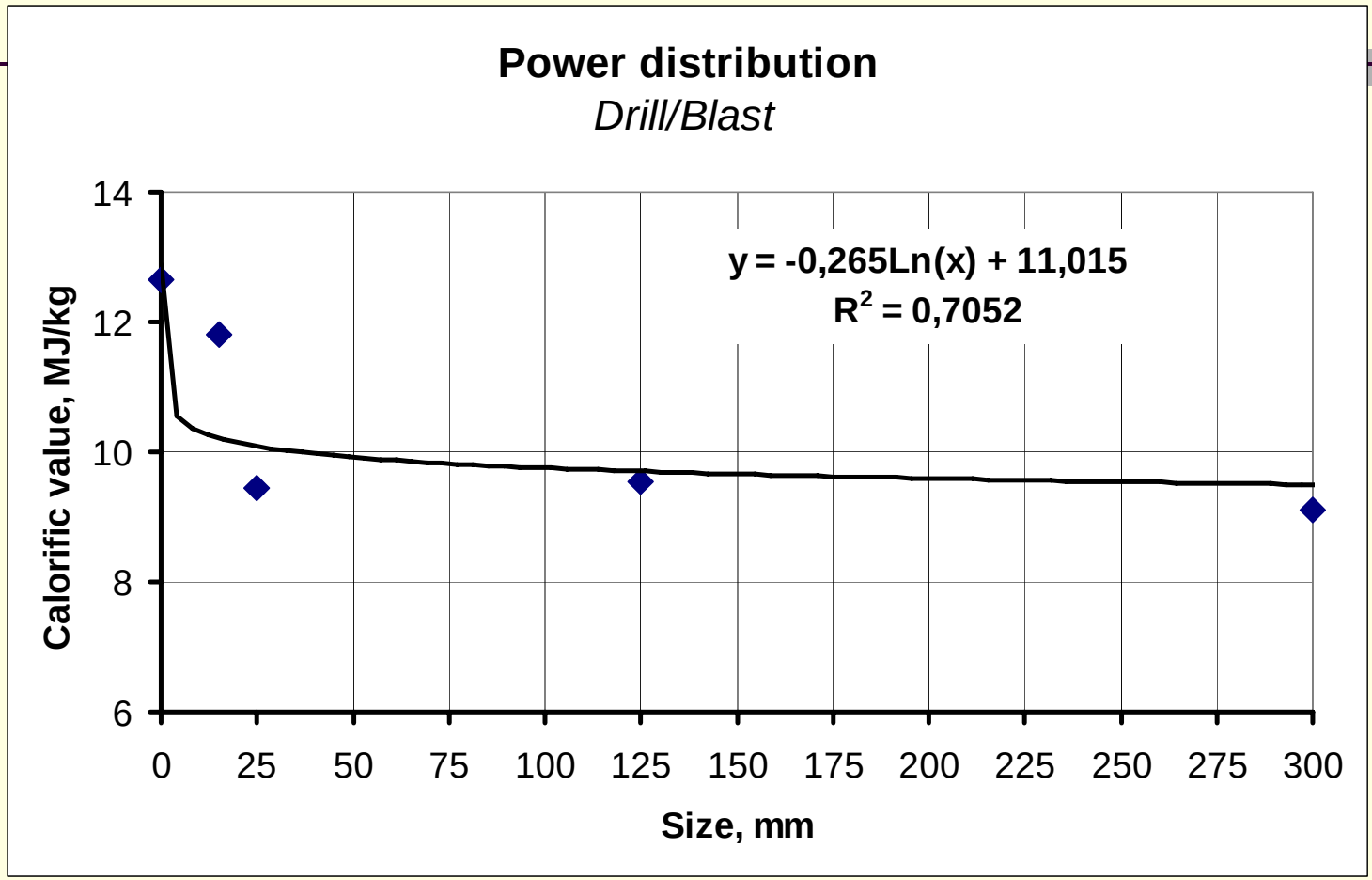
- Oil shale quality depends on the enrichment process
- Oil shale enrichment process depends on the grain-size, the calorific value, the size category distribution and the availability of karst clay
- Distribution of size and calorific value directly depend on excavation technology: **drilling-and-blasting and mechanical cutting**

Drilling-and-blasting



The share of fine grain-size material (0-30 mm) comprises 30-40% and calorific value is 2.5-3.0 MJ/kg higher than calorific value of raw material (rock mass)

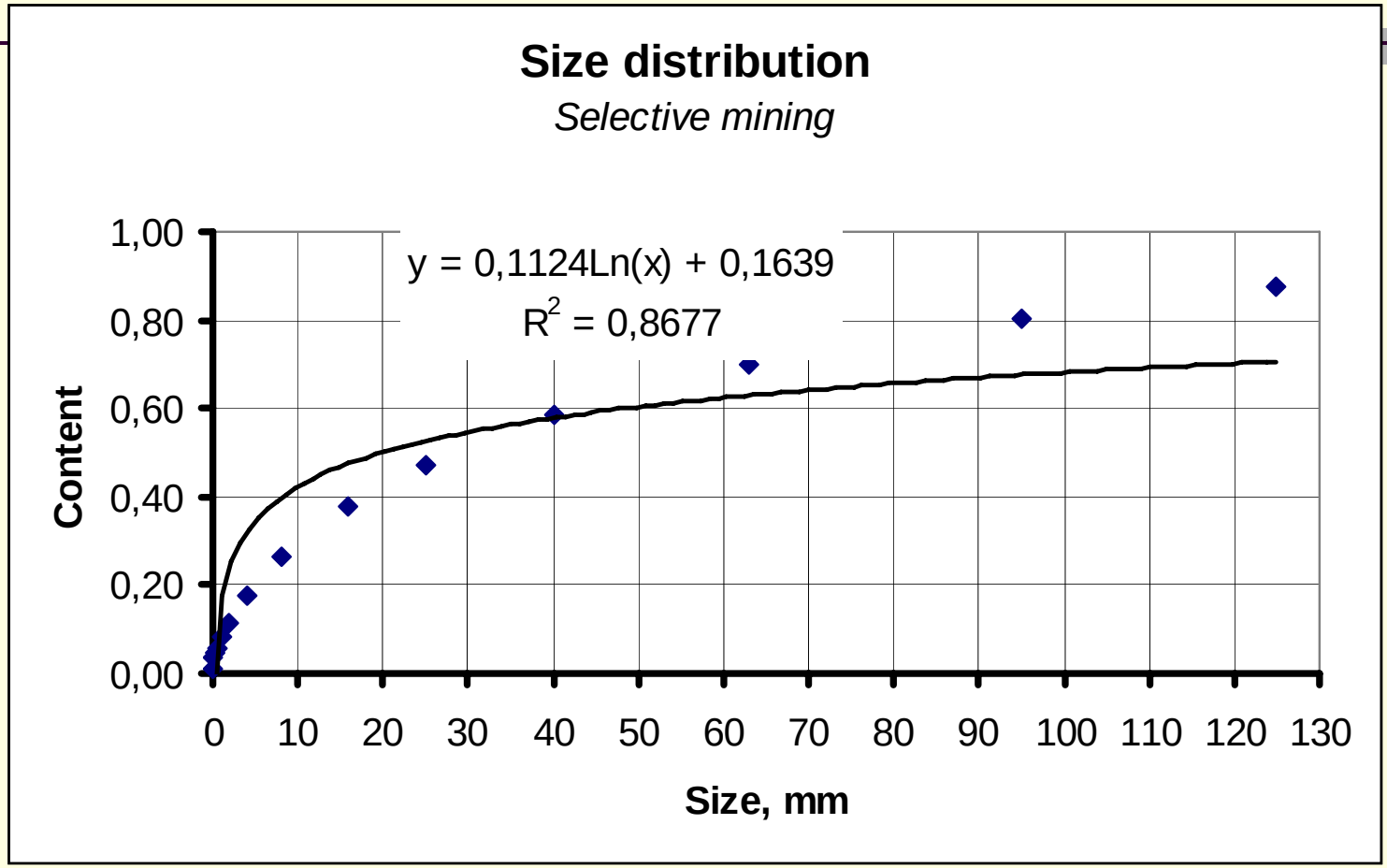
Drilling-and-blasting



The fine grained fraction (3.0-10.0 mm) has calorific value of 11.6-12.4 MJ/kg, but about 5 % of the fine grain > 1 mm which includes clay material will complicate the enrichment process.

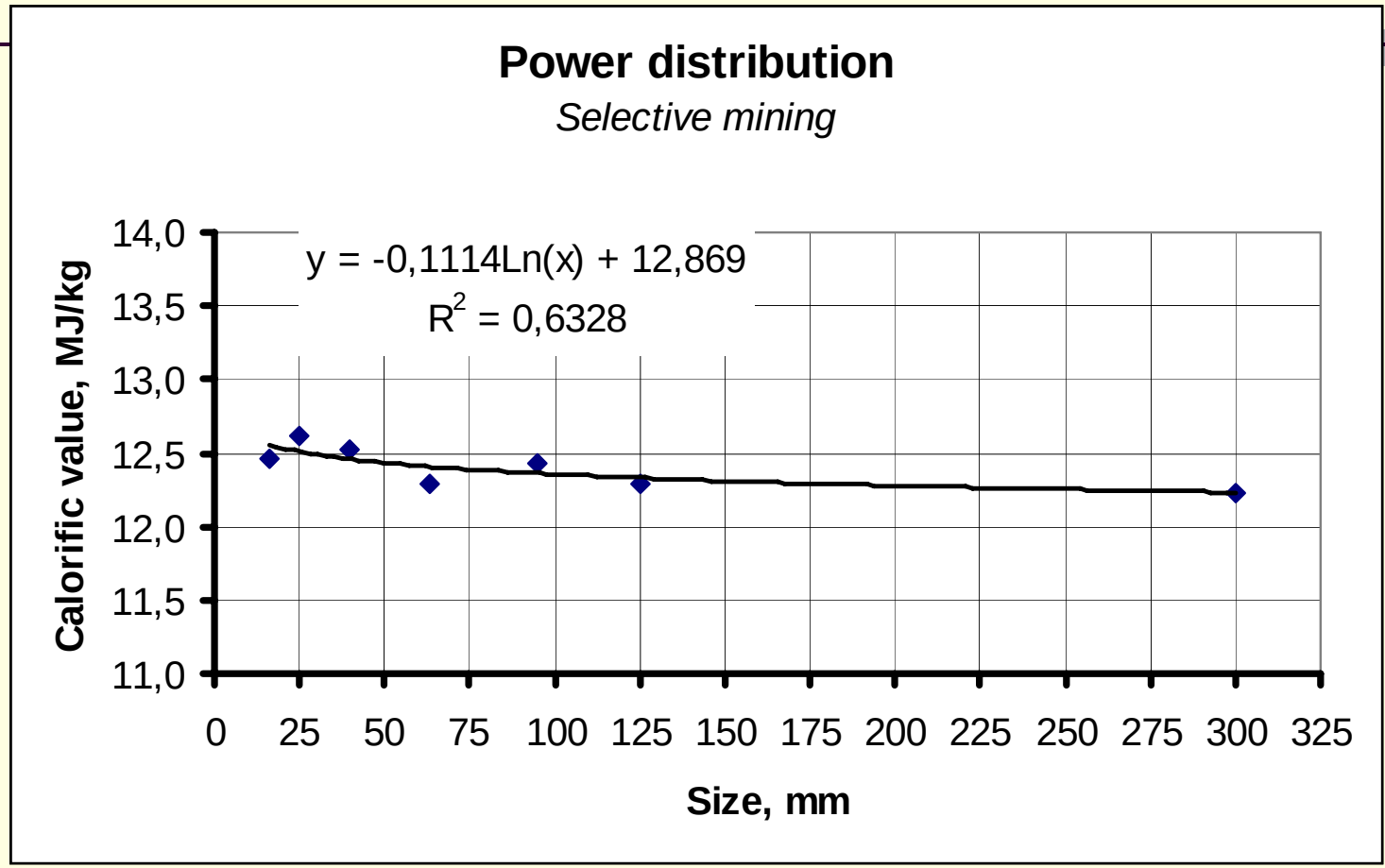
Selective mining

(Mechanical cutting)



Selective mining

(Mechanical cutting)



To achieve oil shale with calorific value 11.8-12.5 MJ/kg it is necessary to realize selective cutting not only of limestone and oil shale layers, but separately oil shale layers with concretions

Presentation outline

- Introduction
- Mining technology overview
- Risk assessment in mining
- Main factors determining quality of oil shale
- **Oil shale enrichment**
- Selective mining
- Conclusion

Oil shale enrichment

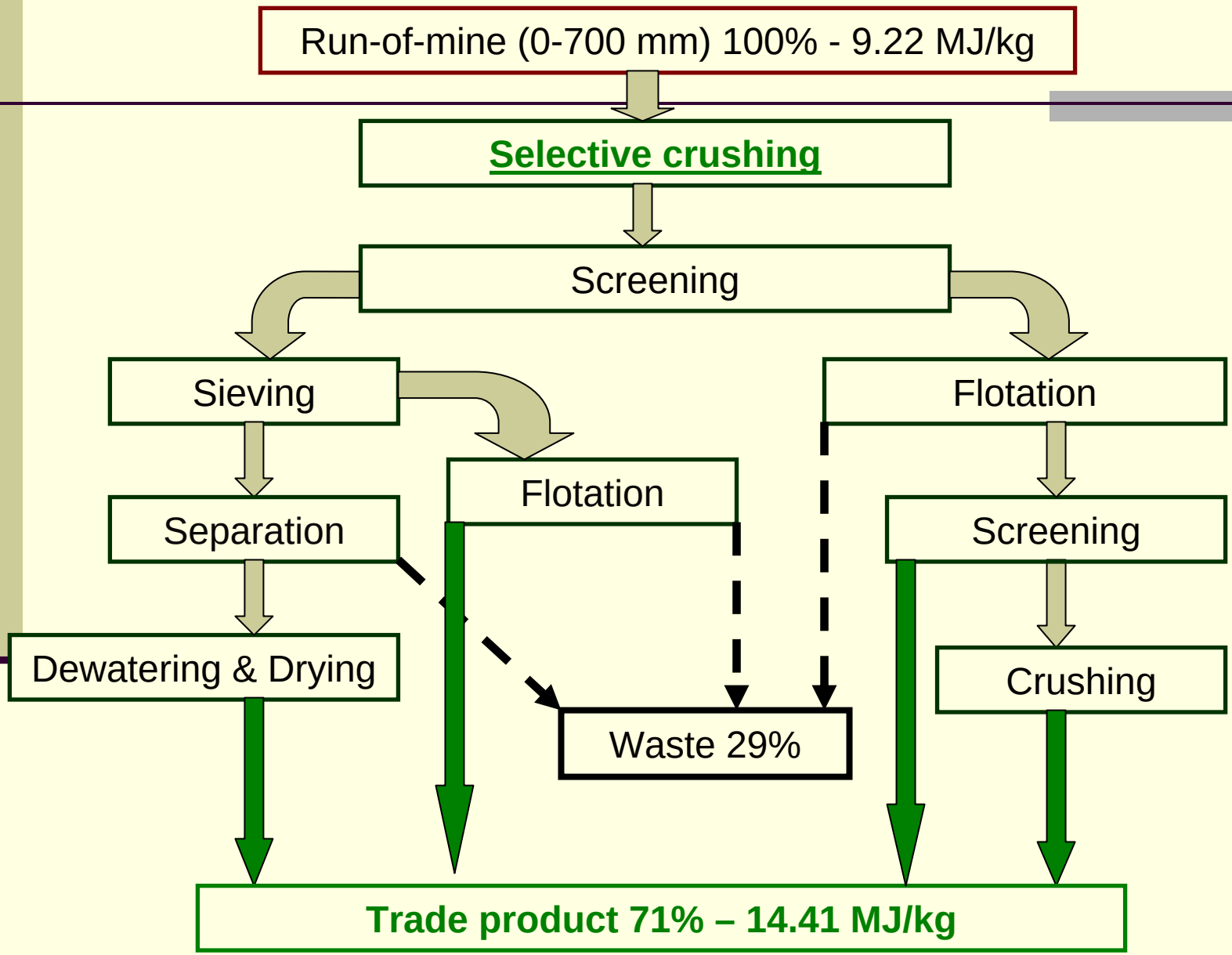
- **Advantage**

  Structure of oil shale and accompanying breed (limestone) has differences in properties. It gives possibility to easily enrich by gravitational methods.

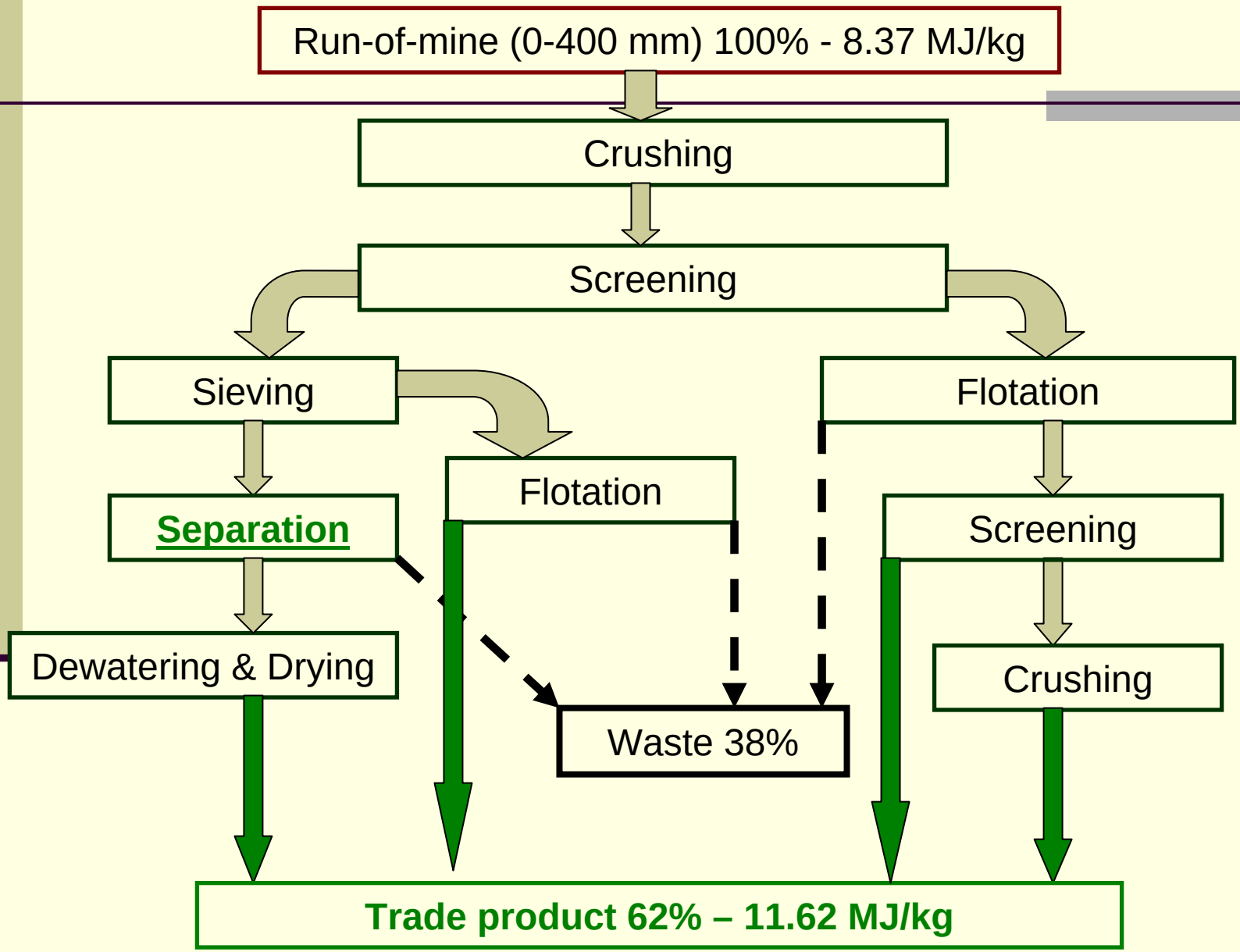
- **Disadvantage**

  As a result of the deterioration of oil shale quality in peripheral areas of the deposit, there arise problems in enrichment of the fine grain (0-25mm) fraction.

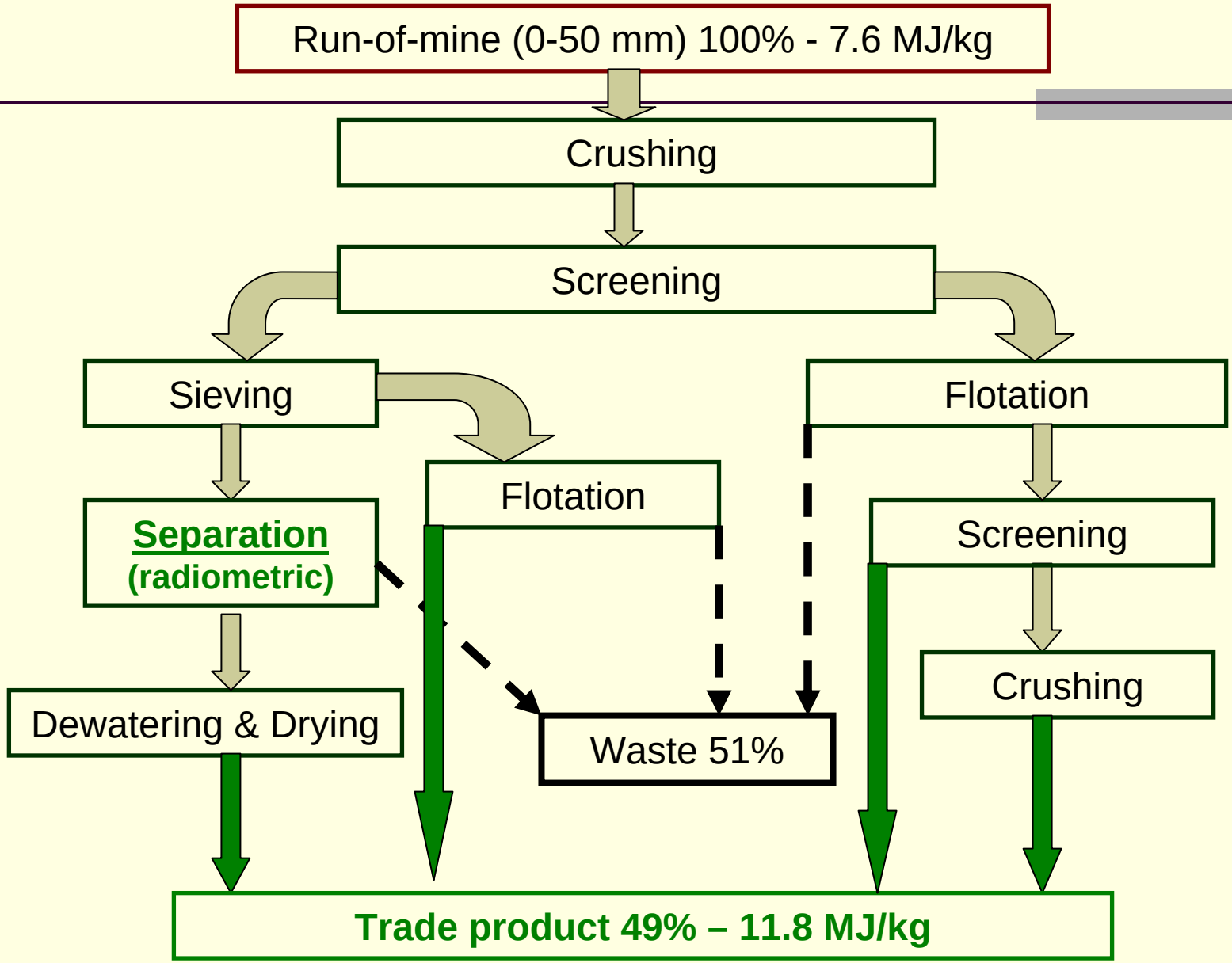
Oil shale enrichment



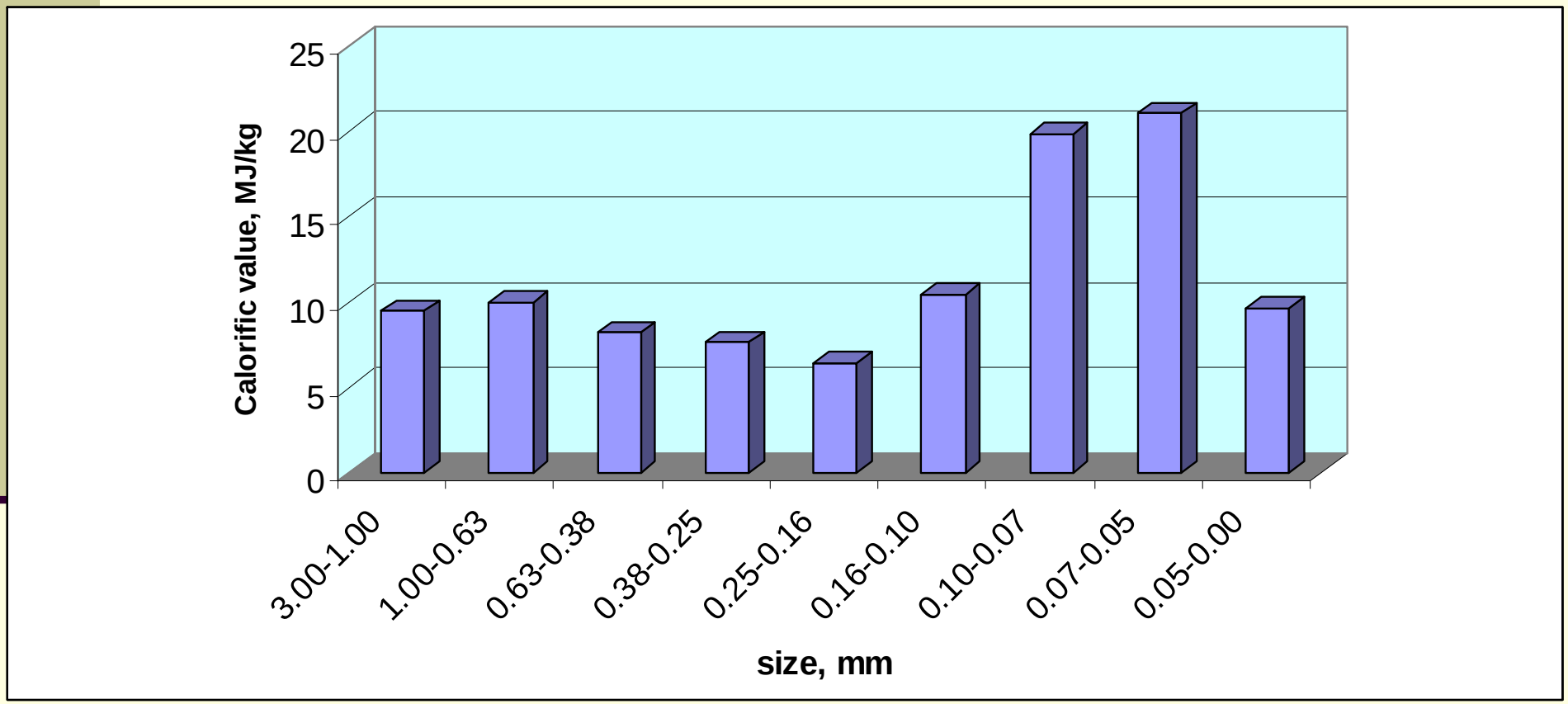
Oil shale enrichment



Oil shale enrichment



Quality-quantitive characteristic of slimes output in “Estonia” mine



Oil shale enrichment

- Dewatering of slime under using centrifuge is possible to exclude about 60 % of slime having sizes 0.7-1.0 mm. At the same time, slime with dampness 25-30 % will be transported together with non enriched riddling. The solids represent 50 % of size 0.01 mm

- Usage of the hydrocyclones, filter-press, pneumatic separators and centrifuges for enrichment of fine grained fraction of oil shale showed the possibility of increasing the calorific value

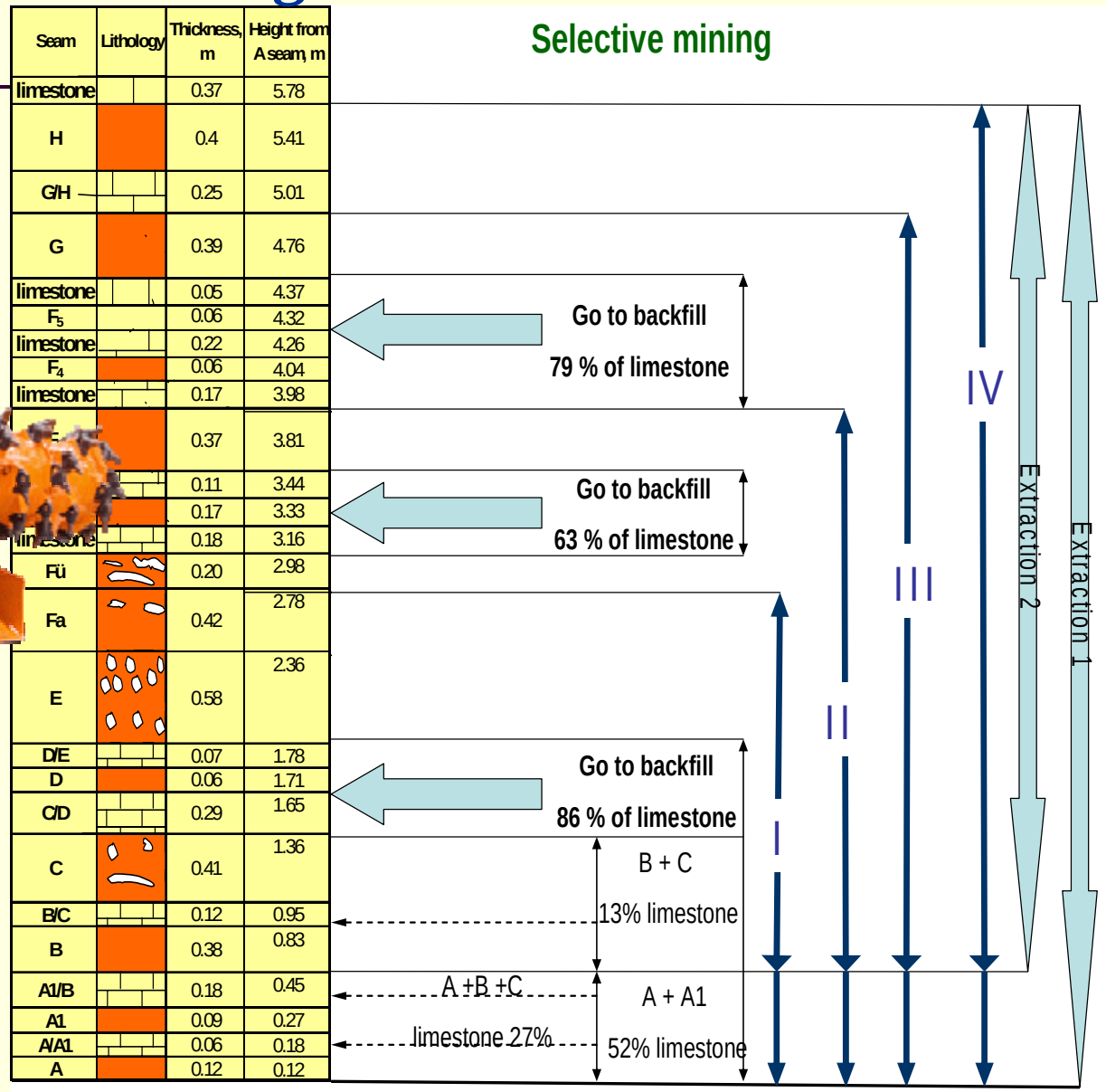
Presentation outline

- Introduction
- **Mining technology overview**
- Risk assessment in mining
- Main factors determining quality of oil shale
- Oil shale enrichment
- **Selective mining**
- Conclusion

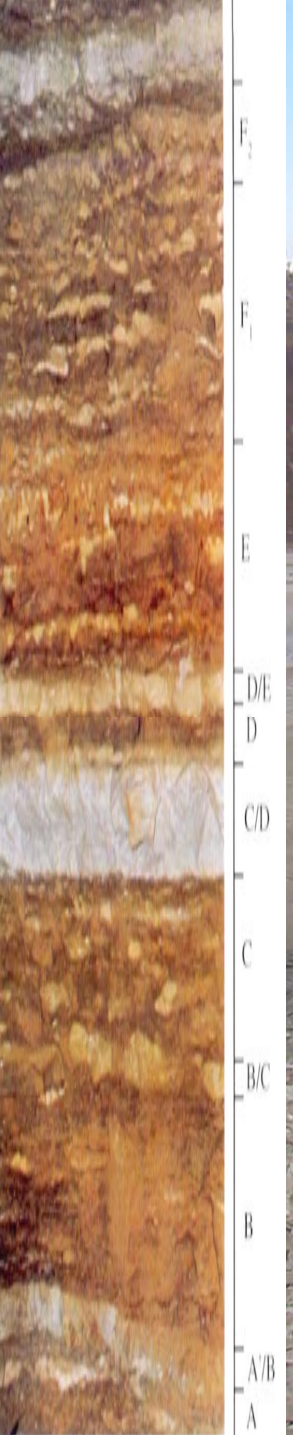
Selective mining

Underground

Seam	Lithology	Thickness, m	Height from A seam, m
limestone		0.37	5.78
H		0.4	5.41
G/H		0.25	5.01
G		0.39	4.76
limestone		0.05	4.37
F_5		0.06	4.32
limestone		0.22	4.26
F_4		0.06	4.04
limestone		0.17	3.98
F-		0.37	3.81
		0.11	3.44
		0.17	3.33
limestone		0.18	3.16
Fü		0.20	2.98
Fa		0.42	2.78
E		0.58	2.36
D/E		0.07	1.78
D		0.06	1.71
C/D		0.29	1.65
C		0.41	1.36
B/C		0.12	0.95
B		0.38	0.83
A1/B		0.18	0.45
A1		0.09	0.27
A/A1		0.06	0.18
A		0.12	0.12



Selective (surface) mining

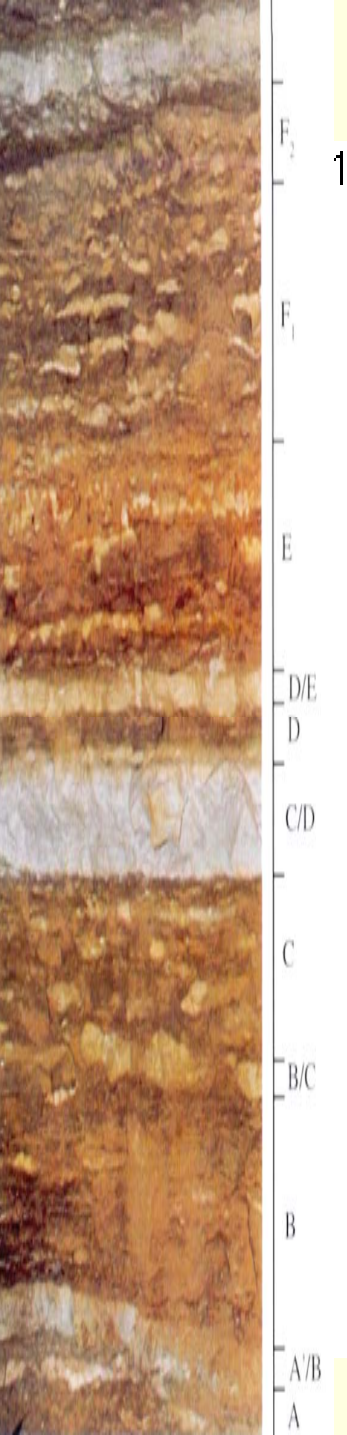


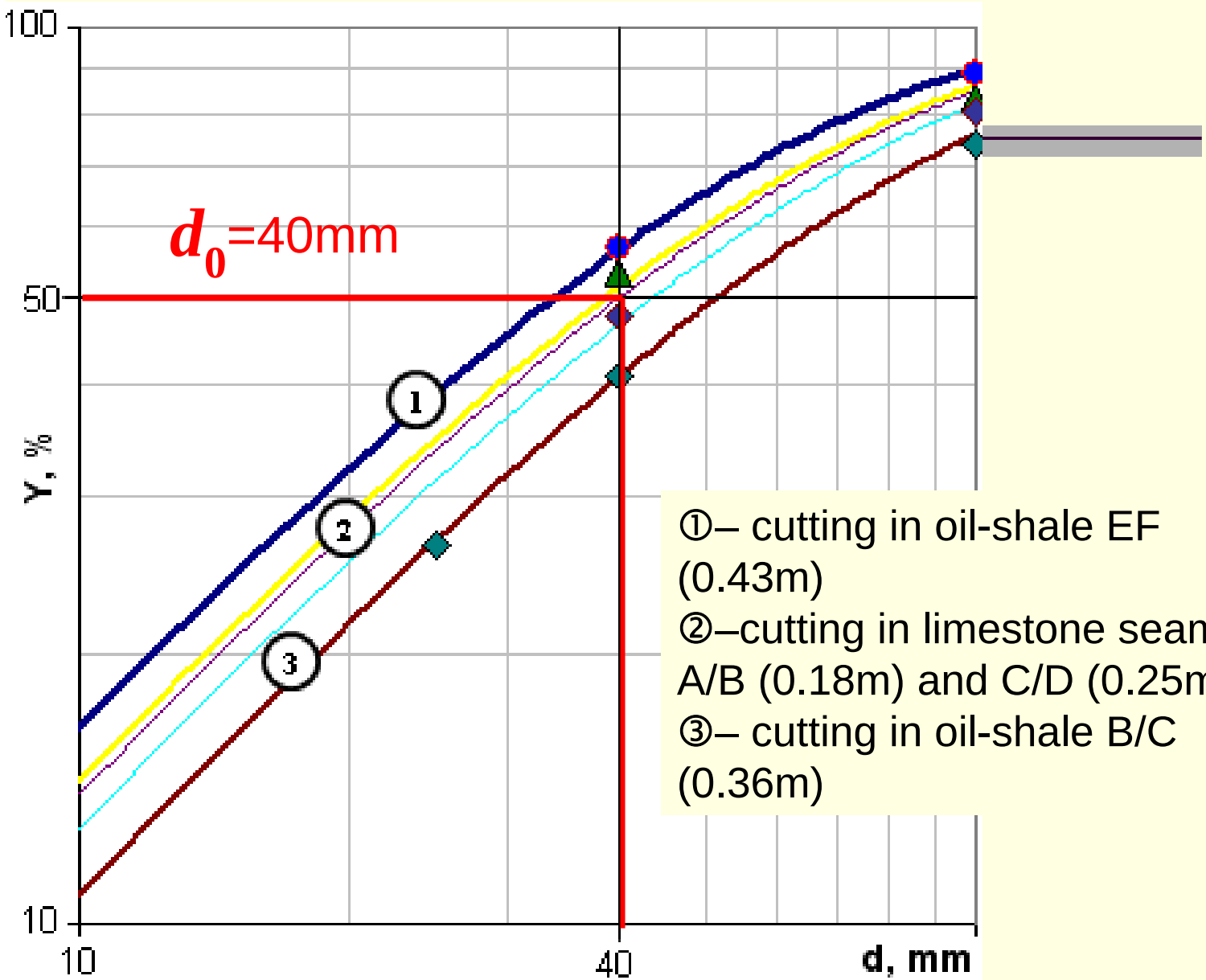
Surface Miner

Cutting depth up to 0.6 m

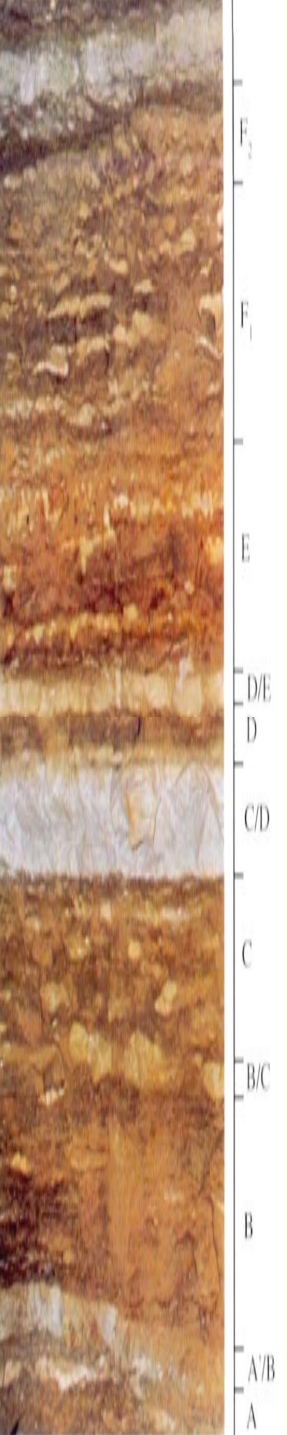
Cutting width - 2.5 m

Selective (surface) mining



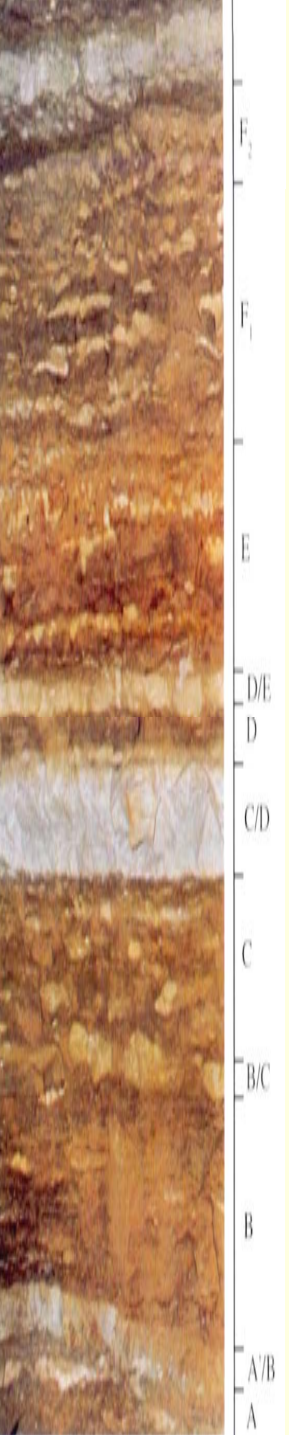


①– cutting in oil-shale EF (0.43m)
②–cutting in limestone seams A/B (0.18m) and C/D (0.25m)
③– cutting in oil-shale B/C (0.36m)



Selective (surface) mining

- Surface Miner can cut limestone and oil shale seams separately and more exactly than rippers (2-7 cm) with deviations about one centimeter
- Primary crushing and fragmentation of mineral rock
- Separately extracted limestone (C/D and A'/B) can be left directly in mine, which reduces haul costs and increase run-out oil shale heating value without additional processing
- Less stress and strain on trucks due to minimum impact of the excavated material
- Reduce capacity requirements for preparation plants



Selective (surface) mining

- Improve mineral recovery especially in areas sensitive to blasting
- Due to precise cutting increase the output of oil shale up to one tonne per square meter
- The oil yield increase by 30%, up to 1 barrel per tone during the oil shale retorting, on account of the better quality
- Decrease mineral losses from 13% to 6% and dilution
- Reduce oil shale cost price by 20% due to less mineral losses

Summary

- Risk assessment allows selecting suitable means for enhancing the quality of oil shale using different mining technology in various parts of Estonian deposits and has the ability to solve problems of quality control of oil shale in accordance with technical opportunities for extraction and enrichment processes

Conclusions

- Risk assessment methods assist in the selection of correct technological aspects for prospective development of mining under various mine-geological conditions

Thank You for Your attention!

Estonian Science foundation (Grand No. 6558, 2006-2009) supported the research

Contact information:

Sergei Sabanov

Ph.D., Senior Researcher

Department of Mining

Tallinn University of Technology, Estonia

E- mail: sergei.sabanov@mail.ru

sergei.sabanov@ttu.ee