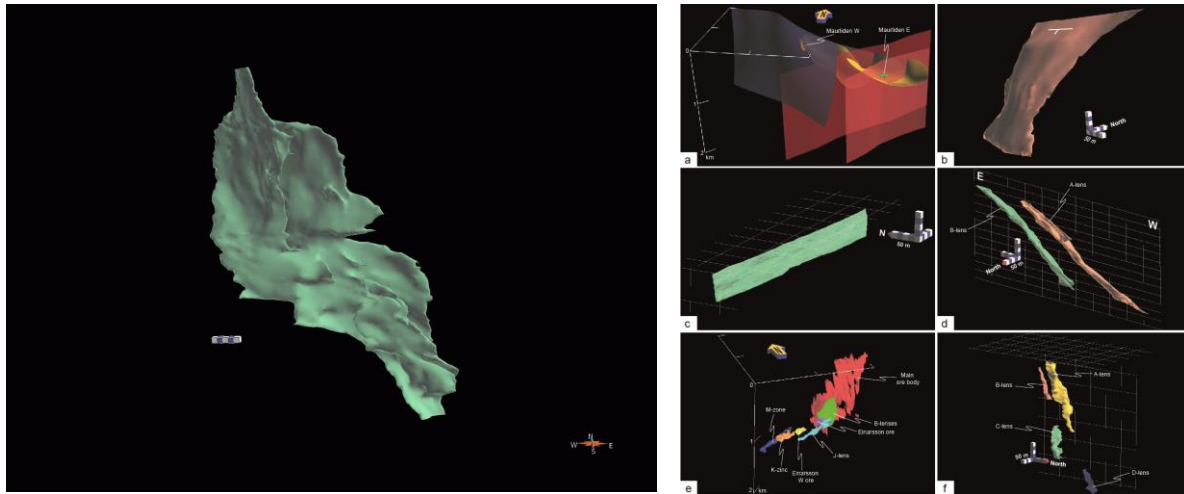


# Resource efficiency in mining

Pär Weihed, Luleå University of Technology, Sweden



WORLD  
MATERIALS  
FORUM

23 & 24 June 2015 - Nancy, France

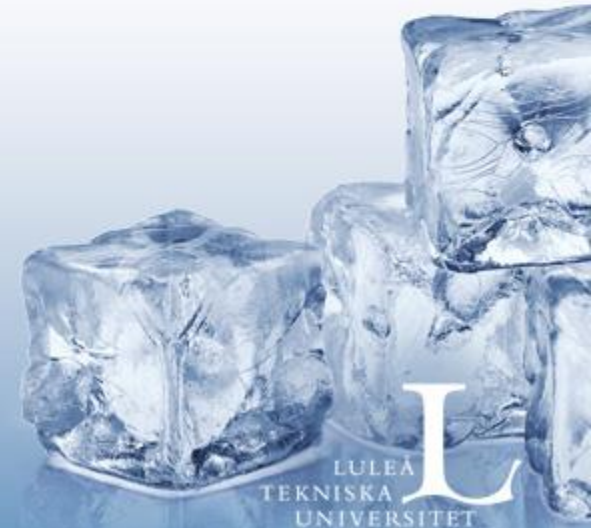
# Resource efficiency in mining

## Lean mining

- cash cost
- opex

## Increased recovery of by-products

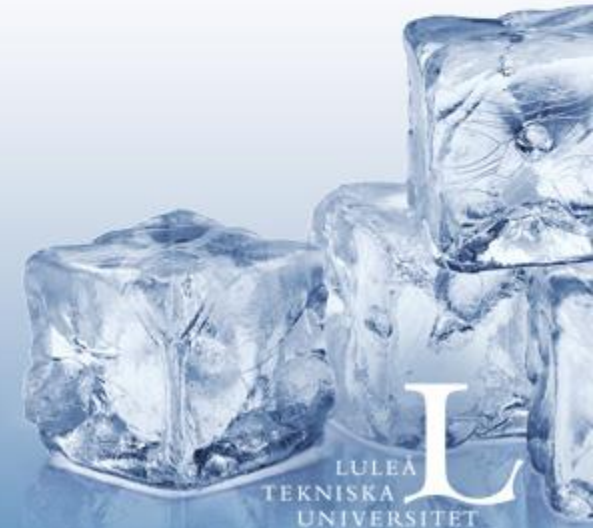
- resource characterization
- technological breakthroughs



# Resource efficiency in mining

## Case studies

- *Aitik* – low grade open pit Cu-mine north of arctic circle
- *Kankberg* – complex base metal massive sulphide underground mine
- *Kiirunavaara* – large scale underground Fe-mine north of arctic circle



# Aitik 45

45 (38) Mt annually, +20%

Reserve grade 0.22 (0.24)

- Reserves 1 085 (633) Mt
- Life of mine 2040 (2030) years
- Copper life of mine 2 348 (1 471) kt

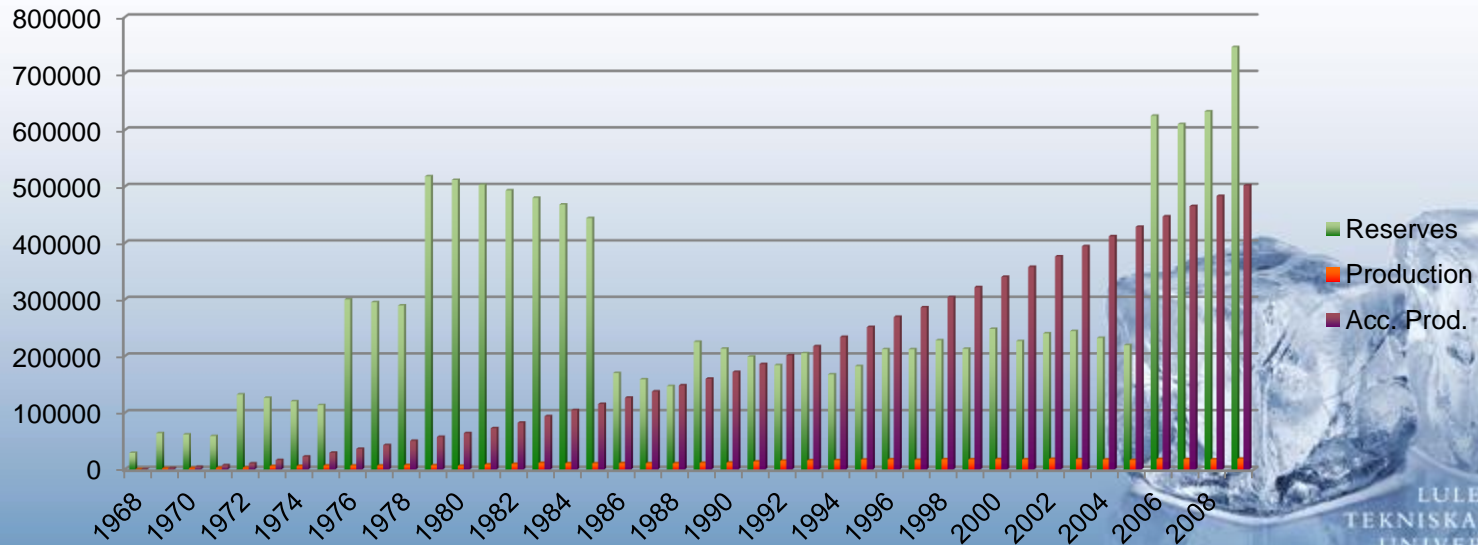
## Capex

- New crushers with improved reliability
- Lower stripping, approx. 0.5
- TMF

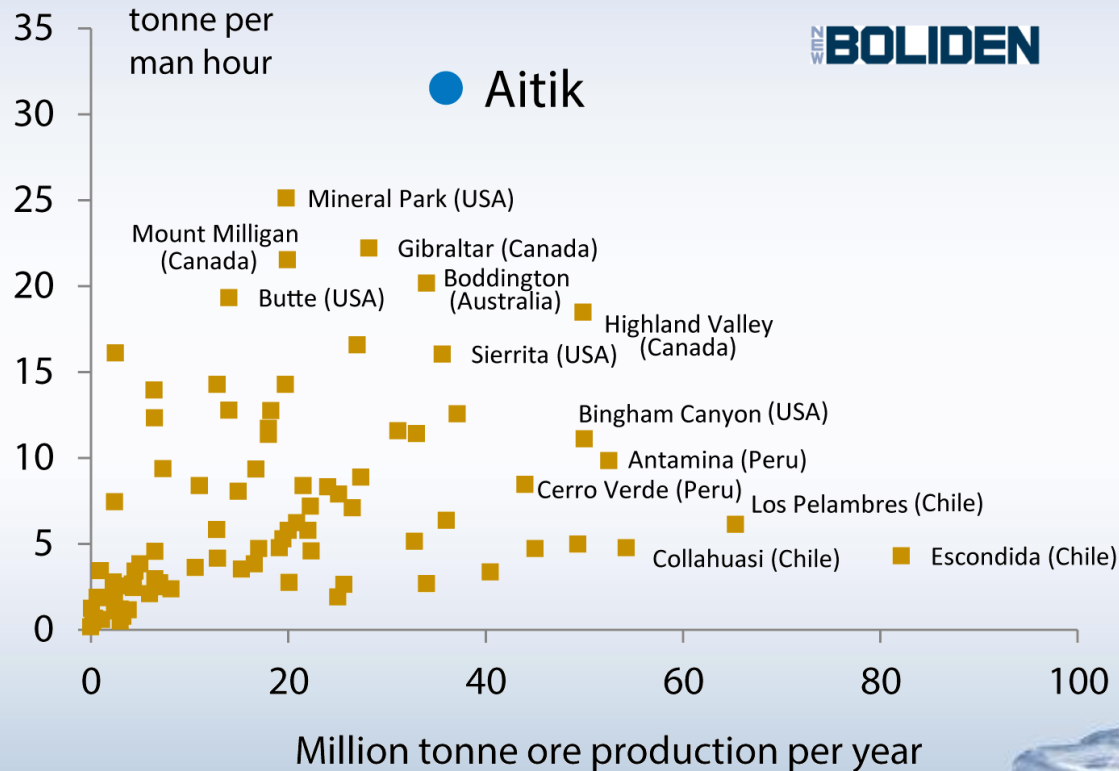
<10% costs per ton of ore

- Economies of scales

Source: Boliden AB webpages



## Copper- open pit with mill 2014



Source: Moström 2015

# Key productivity drivers at mine

Minimizing lead time between work processes faces, stopes and benches

## Aitik - productivity



Open pit Cu mines		Percentile **
Head grade	% Cu	99
<i>Mine</i>	<i>t ore/hour</i>	<b>1</b>
<i>Mill</i>	<i>t ore/hour</i>	<b>0</b>
<i>G&amp;A</i>	<i>t ore/hour</i>	<b>0</b>
<i>Overall</i>	<i>t ore/hour</i>	<b>0</b>
Wage rate	\$/hour	87
Labour cost	\$/t	12
<b>Cash cost, Normal C1* - <u>All mines</u></b>	<b>c/lb Cu</b>	<b>42</b>

\* Cash cost Normal C1, Wood Mackenzie Q3 2014 estimate for 2014

\*\* All mines in Woodmackenzie model, Q2 2014 estimates for 2014

Source: Moström 2015



# Integrated control system drives efficiency

Integrated control system for mine and mill

- Increased efficiency
- Lower costs

Mobile control room

- Enables operators to monitor and adjust in real time

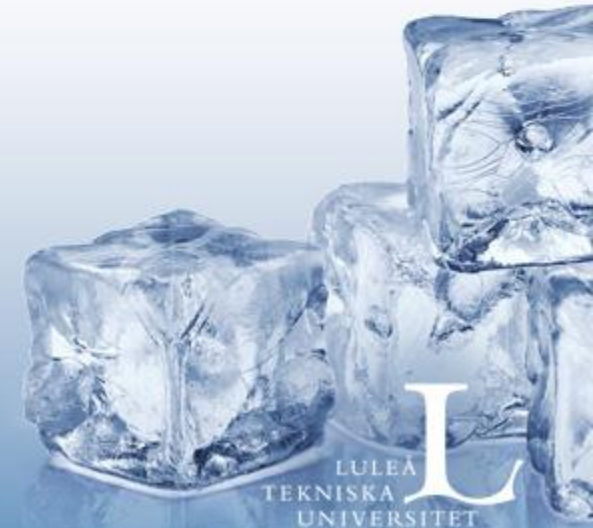
Control system integrated with maintenance system

- Only one original document
- All share same info
- Improved surveillance
- Easier to spot errors
- Diary improves visibility over time

WLAN

- Enable status control and operational guidance

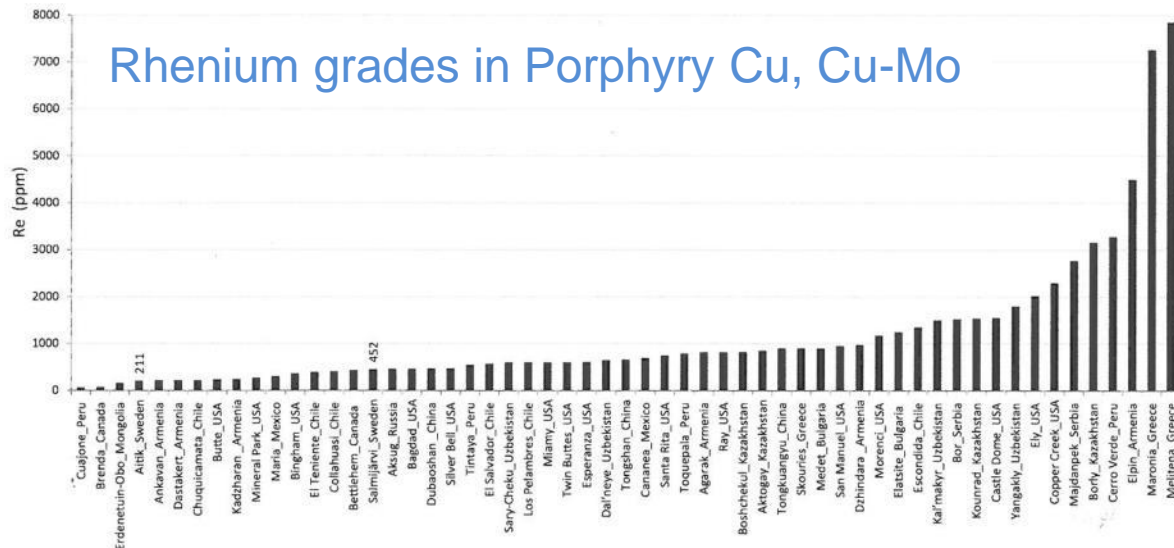
Source: Moström 2015



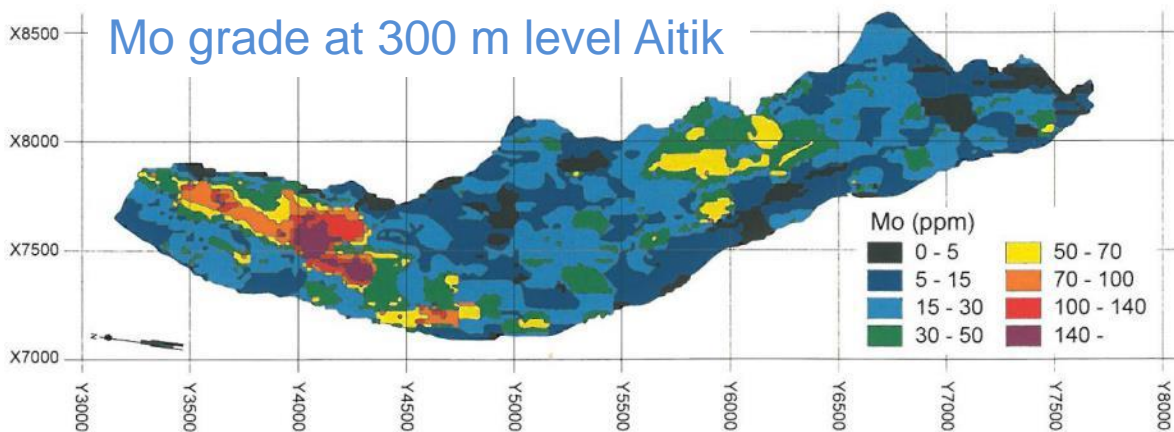
# AITIK

- Mo as by-product content 0.0025%
- Recovery 85% to copper conc.
- Annual prod 36 Mt
- Annual prod 544 tonnes Mo/year (9 MUSD/year)
- Additional resources Co in pyrite (reports to tailings)

## Rhenium grades in Porphyry Cu, Cu-Mo



## Mo grade at 300 m level Aitik



## MB for Mo production at Aitik

Product	Weight ktonne	Grade Cu	[%] Mo	Distribution Cu	[%] Mo
Ore feed	36,000	0.25	0.0025	100	100
Cu conc.	324	25	0.2479	90	85
Mo conc.	0.849	1.6	53	0.02	50
Cu final conc.	323	25.06	0.1093	89.98	35
Final tailing	35,676	0.025	0.00027	10	15

Source: Wanhainen et al. 2014

## By-products



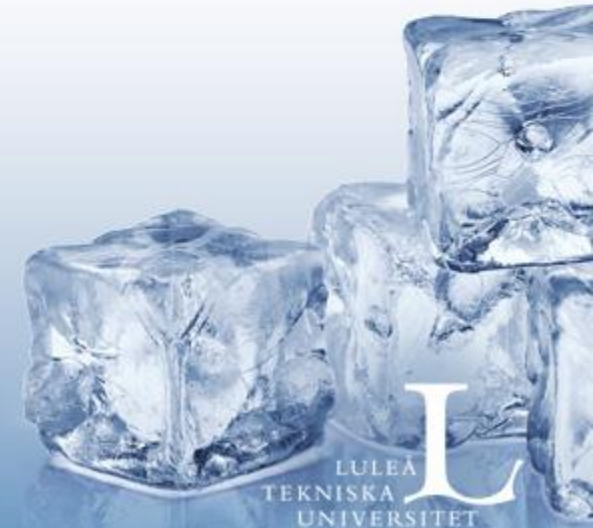
# Kankberg - a "New" Gold Mine

Operated 1966 -1969, 1987-1997 Zn+Cu± Au.  
In renewed production since 2012

- Ore reserve 2.9 Mton
- Average Grades
  - ✓ Gold 4.1 g/ton
  - ✓ Tellurium 186 g/ton
- Average production 320 kton/a
- Gold 1 150 kg
- Tellurium 41 ton

Source: Boliden AB webpages

**By-products**



# Kankberg – Technology breakthrough

leaching of gold and tellurium from gold tellurides, turning a non profit “VMS” into a profitable mine

## Conceptual study initiated 2008

A hot leaching process developed

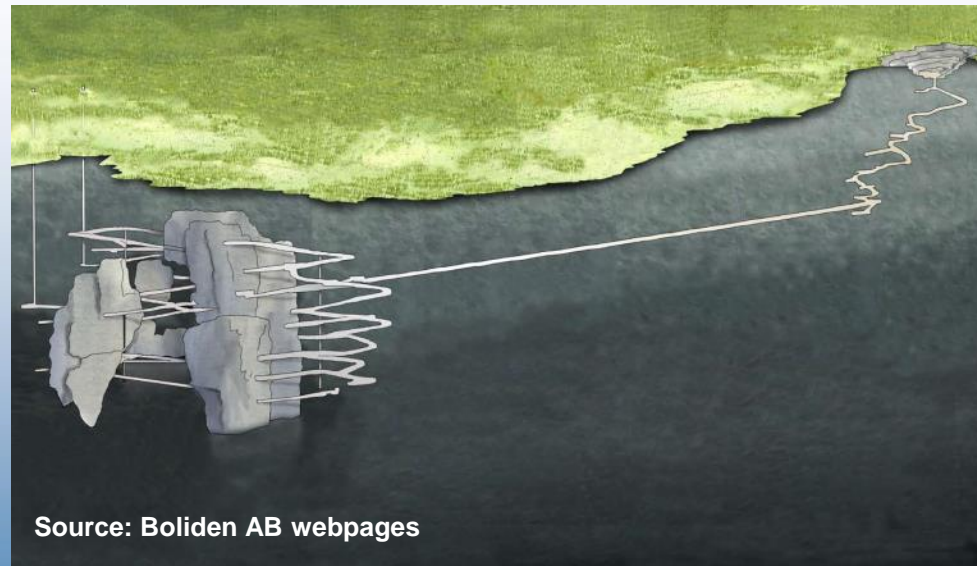
- Boliden patent
- Gold recovery 85% (without 45%)

Tellurium leaching process developed

- Tellurium recovery 65%

Source: Boliden AB webpages

By-products

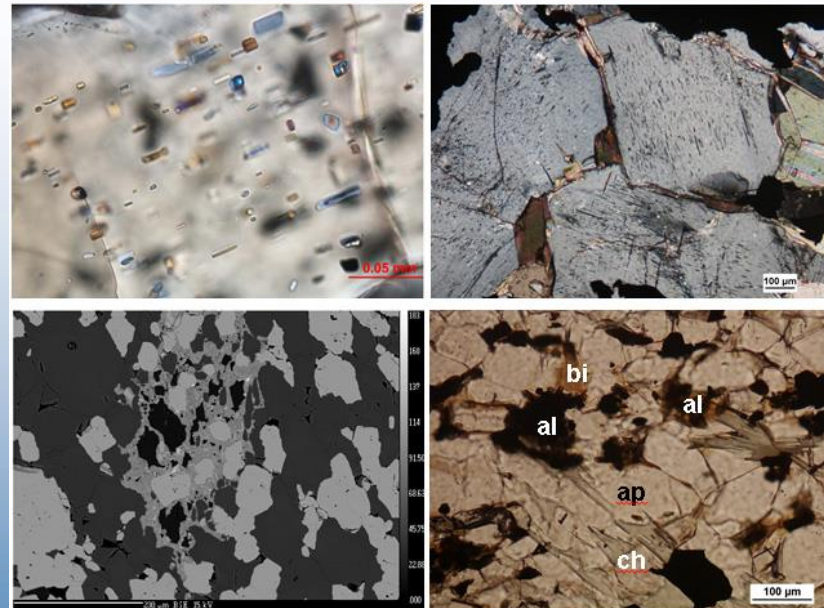


# Kiirunavaara Iron ore

## Potential of P and REE in Iron ores

- Apatite Iron ore, mined underground in northern Sweden, >100 km north of the arctic circle
- Production from two large underground mines and one open pit 25.5 Mt 2013
- Iron ores contain 1-5% P in apatite
- P produced as a byproduct during WW I and II, 1952-1953 and 1985-1988
- REE in apatite (av. 0.25%), monazite (c. 70%), allanite (c. 22%) a.o.
- Approx. 30 000 tonnes TREE in tailings
- Approx. 2 000 t/a goes to tailings
- Global annual production c. 110 000 tonnes

Source: Pålsson et al. 2014



# L

## Summary

- Cash cost control and lean production leads to economic and sustainable mining of low grade deposits in extreme environments
- Automation, systemic integration, resource characterization key factors
- Technological breakthroughs in especially mineral processing and metallurgy leads to economic extraction of by-products
- Economic extraction of by-products leads to resource efficiency
- Resources efficiency leads to increased economically viable primary extraction

