Global Mercury Project

Removal of Barriers to the Introduction of Cleaner Artisanal Gold Mining and Extraction Technologies

Improved Technologies for Small Scale Miners - Ulaanbaatar, Mongolia, 2007

Dr. Bern Klein – Expert Gold Extraction Technologies
Professor of Mineral Processing
University of British Columbia
Department of Mining Engineering

Outline

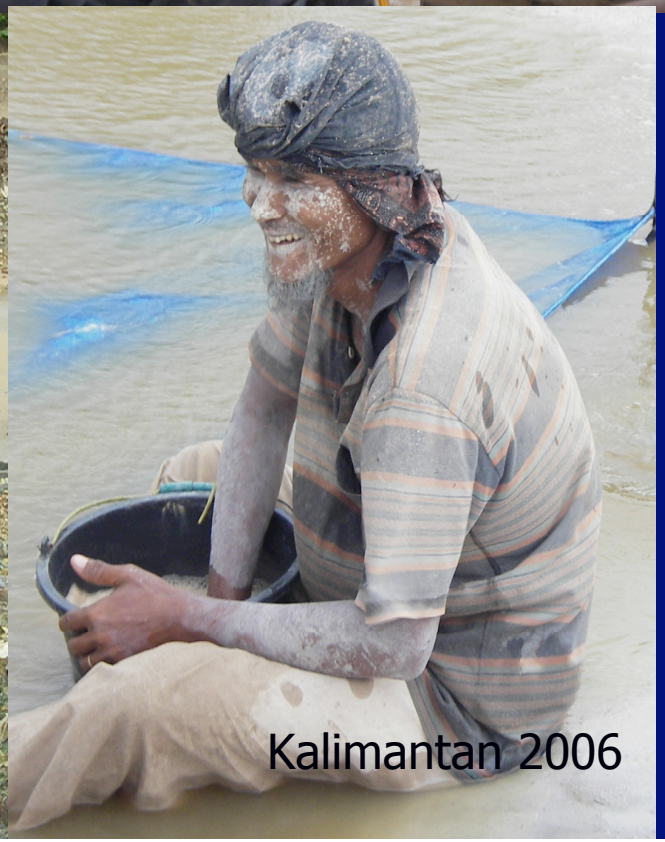
- Introduction
- ASM Best Practices / Technologies
- What Can Be Learned from Large Scale Miners?
- Improved Technologies for ASMs
  - Bad, Good and New
  - Cyanide Leaching
- Summary

GMP Alternative Technologies

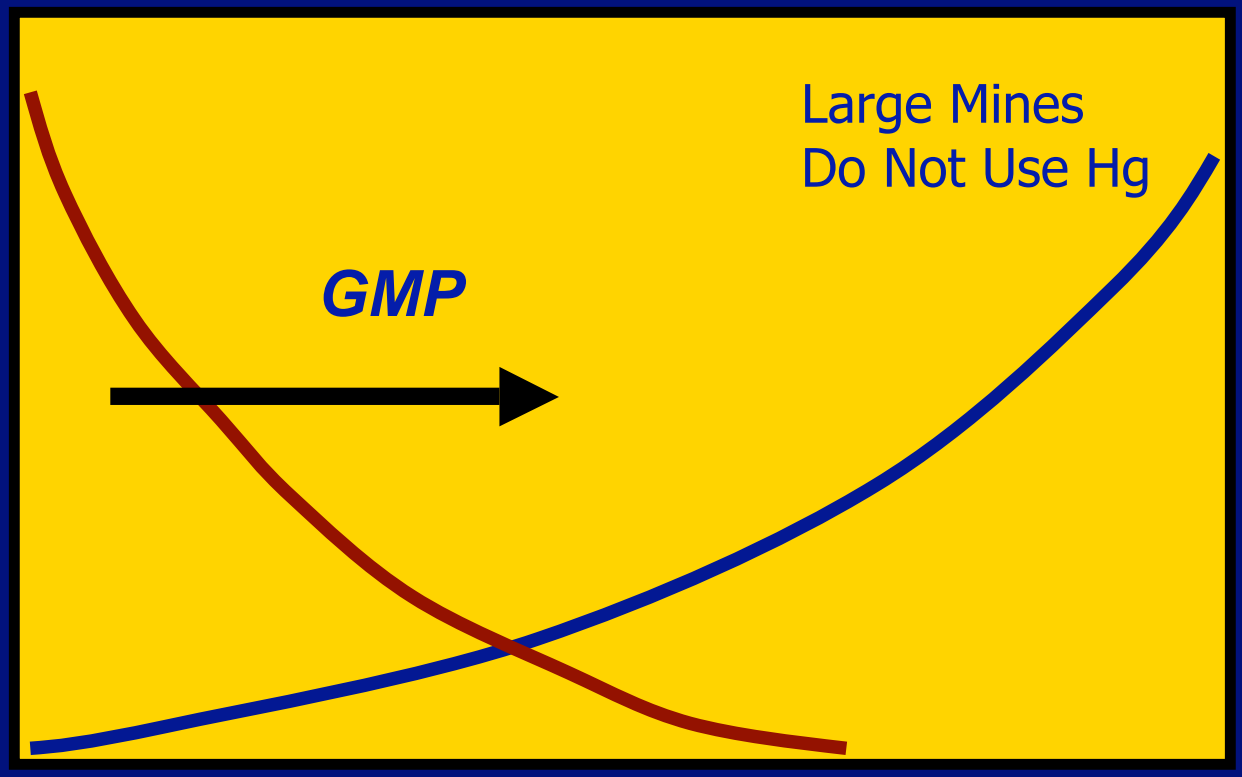

Sulawesi 2006

- **GMP Goals**
  - **reduce mercury pollution caused by artisanal miners on international waters and**
  - **introduce cleaner technologies for gold extraction and train miners**
- **Motivation for change - Increase gold recovery and thereby wealth, health, environment**

Zimbabwe 2005


Kalimantan 2006

Technology, Profit and Mercury Exposure



$ Profit

Hg Exposure

Technology

Mining Activities

- Mining*
- Processing - Focus of GMP 1
- Waste Management*

Considering incidents of underground fatalities and practices such as dumping mining wastes directly into rivers, these areas need more attention

Zimbabwe 2005

Alternative Technologies

- ASM Best Practices / Technologies
- What can be learned from large scale gold mines?
- Improved Technologies for ASMs

- Technology transfer was achieved by:
  - Transportable Demonstration Units (TDU)
  - Workshops to train trainers and miners
  - Demonstrations of technologies in the field at ASM operations.

University of British Columbia
Norman B. Keevil Institute of Mining Engineering
Center for Mineral Processing

- **Efforts to introduce improved technologies/practices was supported by the Center for Mineral Processing:**
  - **Lab tests to determine the processing characteristics of ores**
  - **Build and test technology prototypes**
  - **Develop technologies adapted from large scale mines to ASMs**

ASM Technologies

- Innovative technologies have been developed by ASMs in different parts of the world
- GMP has compiled information on these technologies and promoted the best technologies to other parts of the world.

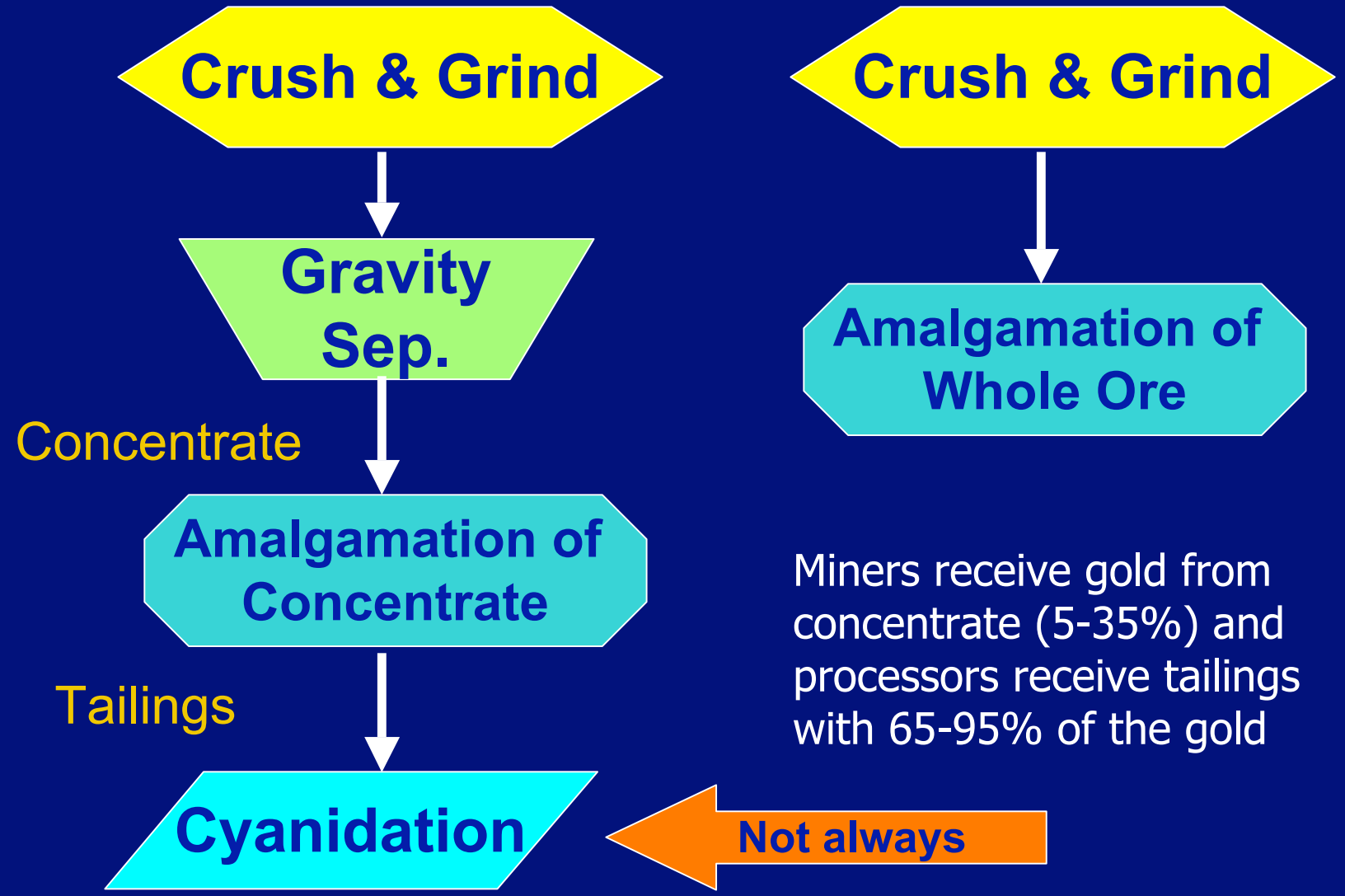
- Many technologies described in the ***Manual for Training Artisanal and Small Scale Gold Miners, 2006***

ASM Best Practices/Technologies

- Is the right equipment used?
- Is the equipment operating efficiently?
- What are proper operating conditions?
- Can more gold be recovered?

- Steps to effectively promote change
  - Assess local capacity of miners as well as manufacturers/fabricators
  - Understand how the gold occurs and test processes
  - Evaluate the existing process
  - Recommend improvements
  - Implement changes and evaluate process

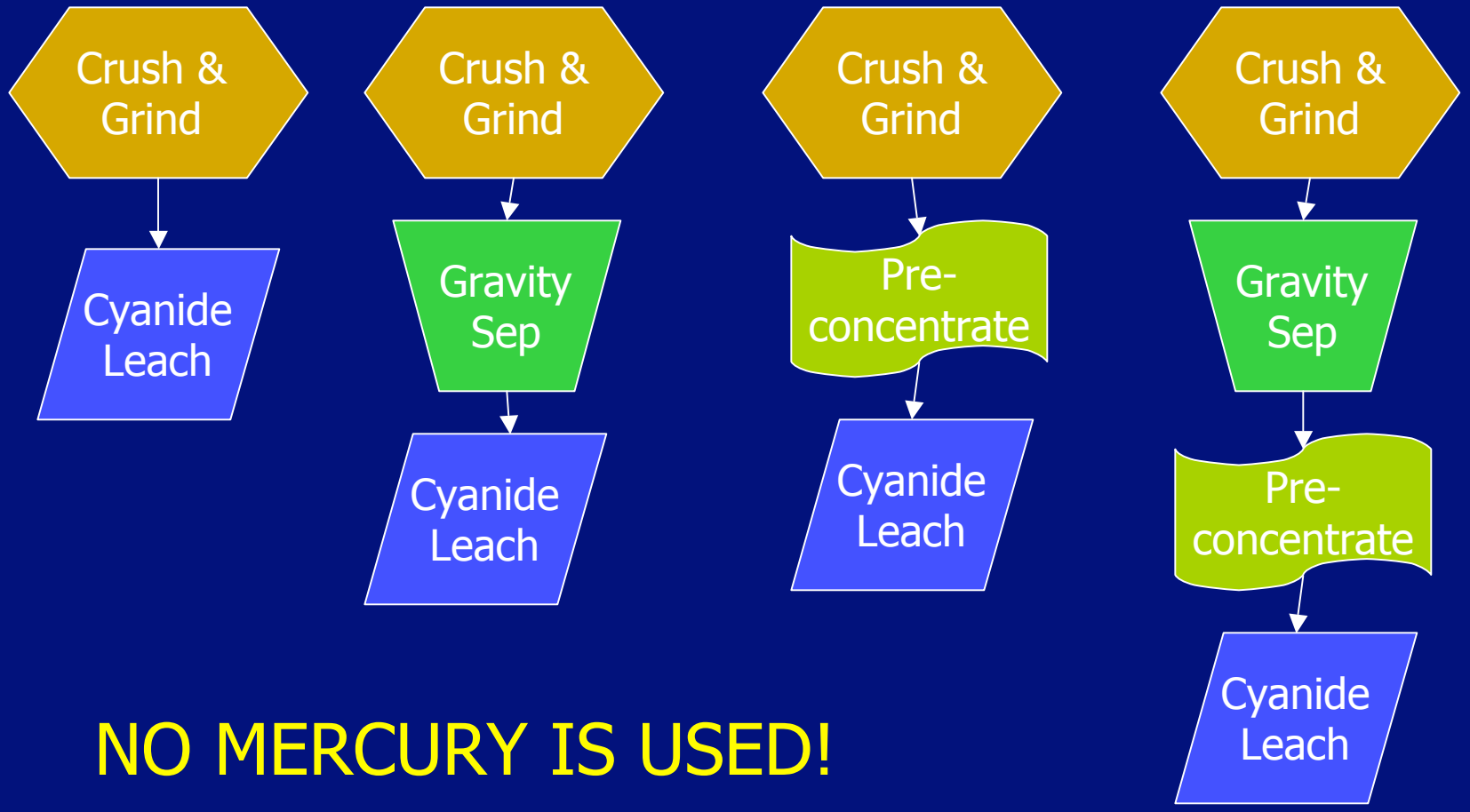
How the Artisanal Miners Work



Miners receive gold from concentrate (5-35%) and processors receive tailings with 65-95% of the gold

What can be learned from large scale industrial miners that can be applied to small scale mining?

- Simple process with minimum number of steps
- Pre-concentration reduces size/cost of downstream process
- Monitoring and control ensure efficiency and high gold recovery

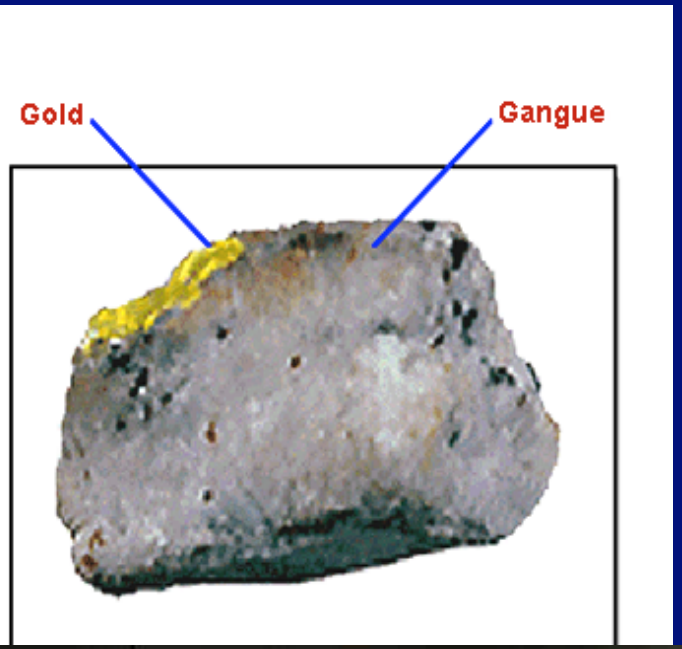


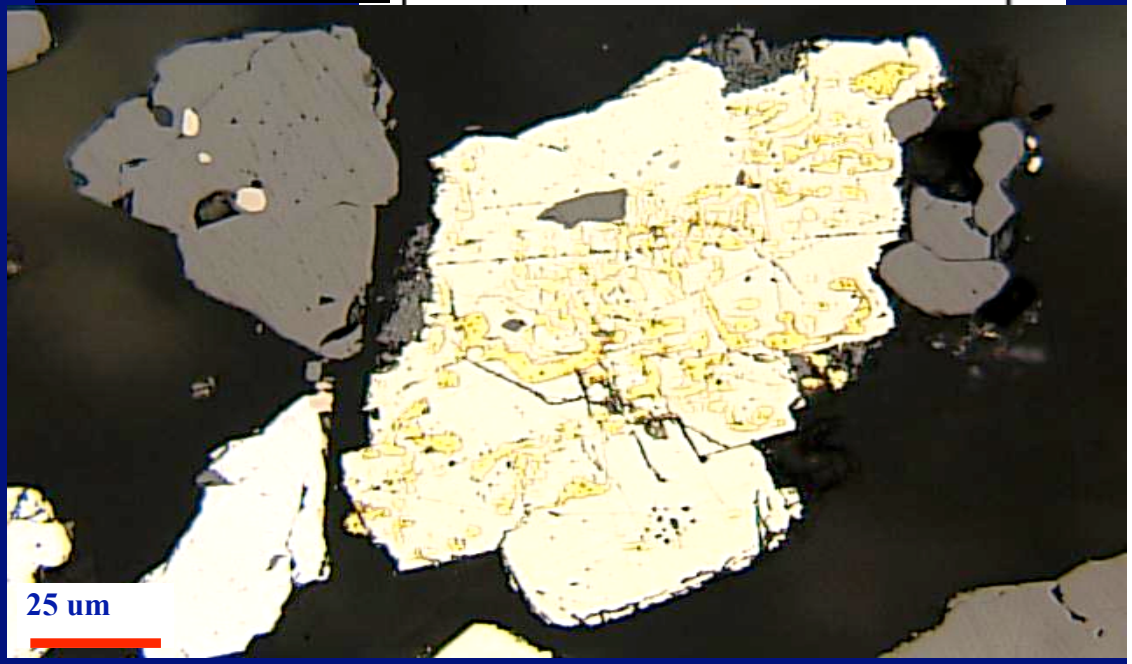
NO MERCURY IS USED!

Process Selection

- Determined by gold properties
  - Large grains
  - Fine grains
  - Free gold
  - Attached to minerals
  - Included in minerals
  - Refractory

- Ore testing is used to design and select process





Comparison of Large & Small Scale Mines

Typical Large Scale Mine

- Crushing and grinding
  - finer than 0.1 mm
- Gravity separation recovery
  - ranges from 10-60%
- Overall gold recovery >90%
- ***No Hg is Used!***

Typical Small Scale Mine

- Crushing and grinding
  - finer than 1 mm
- Gravity separation recovery
  - from 5-35%
- Gravity separation plus cyanide leaching recovery 45-75%

Estimates based on personal observations

Bad ASM Practices

- Practices that cause health risks, lead to contamination of the environment or lower the potential gold recovery include:
  - Burning mercury amalgam in the open
  - Amalgamation of whole ore
  - Grinding with mercury
  - Cyanide leaching of mercury contaminated ore
  - Carbon burning
  - Discharging waste and contaminated water into environment (streams, lakes, rivers)

Grinding with Mercury

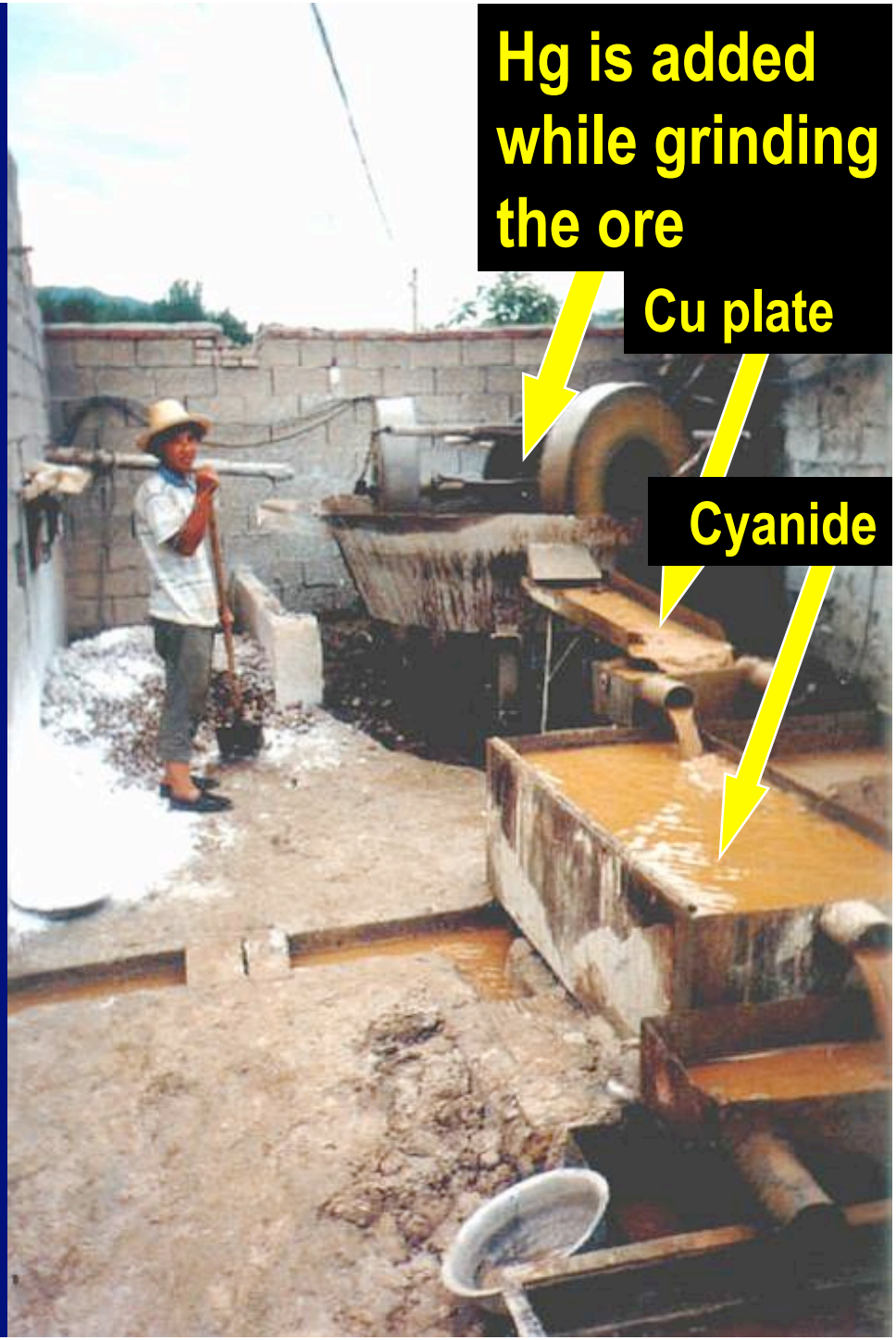
- Grinding with mercury results in mercury losses
  - Very fine mercury becomes trapped in rock - typically 300-500 ppm
  - Mercury becomes floured and is difficult to recover
  - Contaminates all of the ore
  - Amalgamation of ground pre-concentrated product limits Hg pollution and exposure
- Mercury losses equal gold losses !
- Don't add mercury to grinding

Indonesia 2006

Amalgamation and Cyanide Leaching

- Amalgamation followed by cyanidation
- Hg becomes more soluble spreading the pollution over larger area
- Methylation of residual Hg is favoured
- Situation occurring in many countries
- China: 250 tonnes Hg/a released

Photo AJ Gunson
China, 2002



Misuse of Cyanidation with Amalgamation

Occurring in

- Brazil
- China
- Ecuador
- Indonesia
- Peru
- Philippines
- Zimbabwe
- Others?

Sulawesi, Indonesia, 2004

Zinc Precipitation and Smelting

Atmospheric Zn ppt is inefficient resulting in gold loss. Ecuador 2007

Gold Recovery

- Carbon recovery
- Burning
- Smelt
- Amalgamation

- Hg Exposure
- $ Carbon

Improved practice - strip gold from carbon and recycle carbon

Recommended Technologies/Practices

- Ore testing
- Process monitoring to optimize and maintain high gold recovery
- Efficient crushing and grinding technologies
- Pre-concentration.
- Zig Zag sluice
- Retorts
- Tailings ponds and water recycling

Crushing

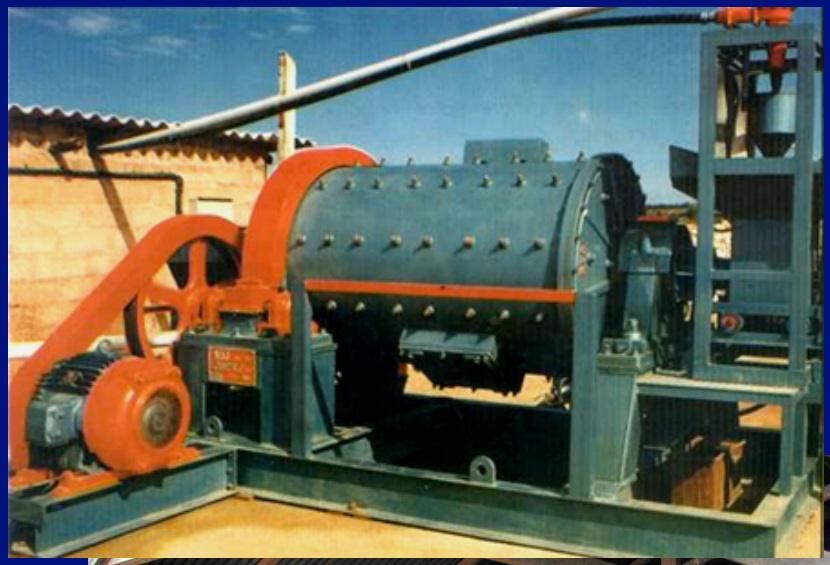
Stamp Mill
Zimbabwe

Hammer Mill
Brazil

Jaw Crusher
Brazil

Grinding

Rod/Ball/Pebble Mills



Zimbabwe

Ecuador

Indonesia

Sluice

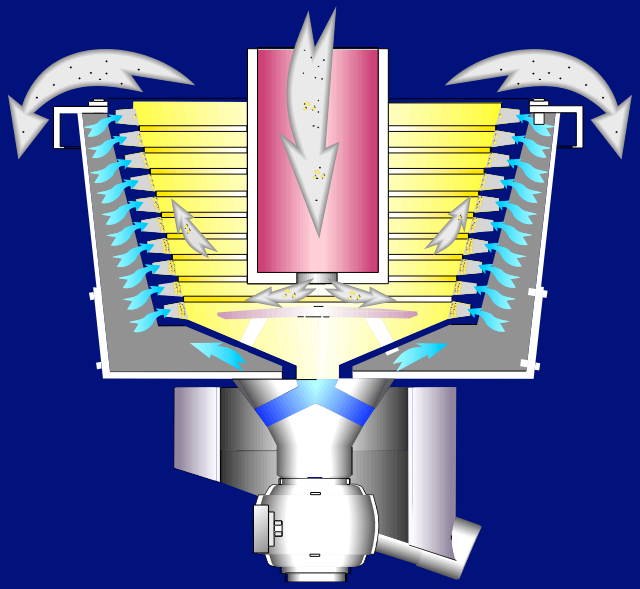
Pre-Concentration

Kalimantan 2006

Zig Zag Sluice

Centrifuge

- Recover coarse and fine gold (0.05 mm)
- Used by large scale mines
- Concerns
  - High cost
  - Maintenance/parts



Companies working to develop more affordable centrifuges

Gold Panning

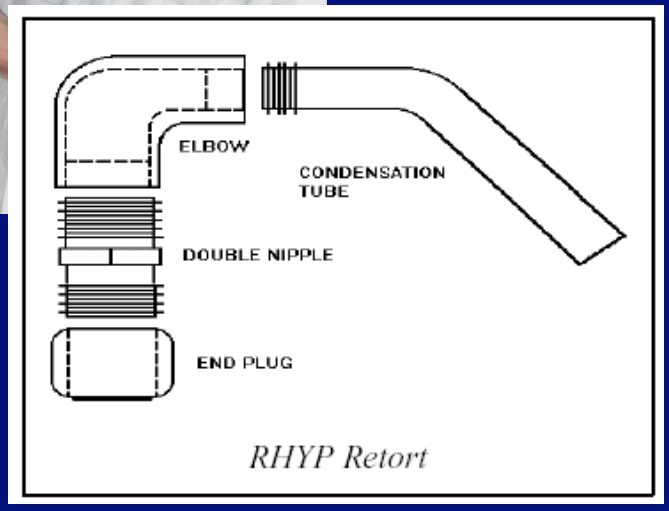
- Prospecting
- Gold Recovery
- Upgrade Sluice Concentrate
- Process Evaluation

North American gold pan

Batea - Brazil

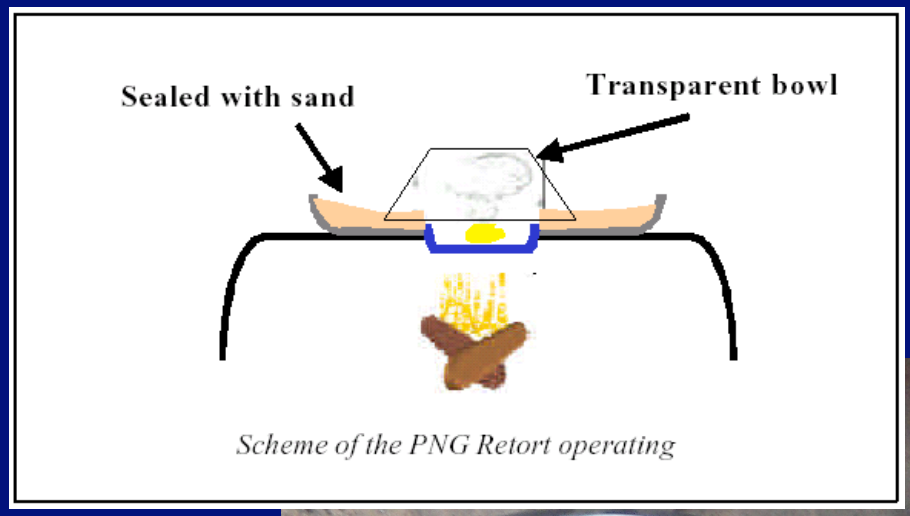
Mercury Retorts

Kalimantan
2006

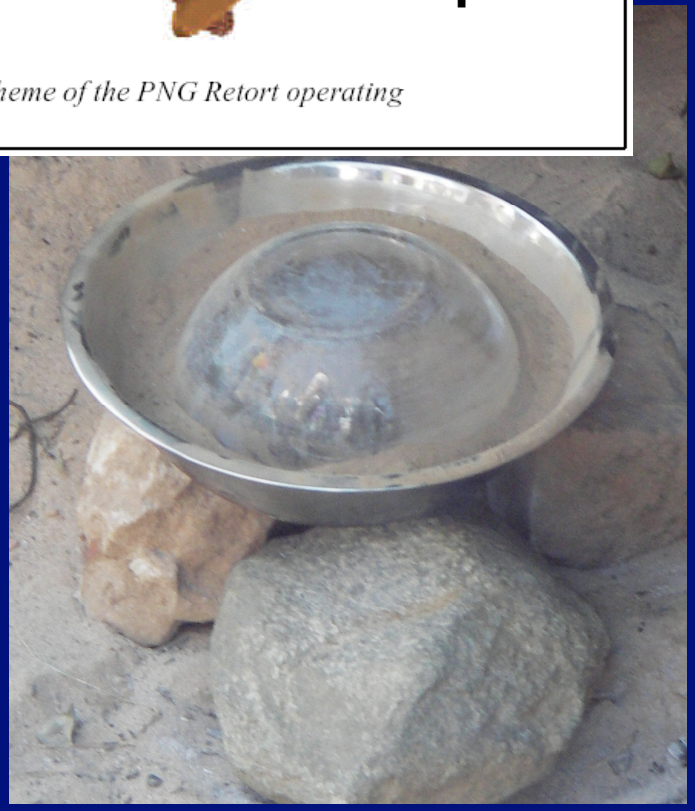


RHYP Retort

Salad Bowl Retort



Scheme of the PNG Retort operating



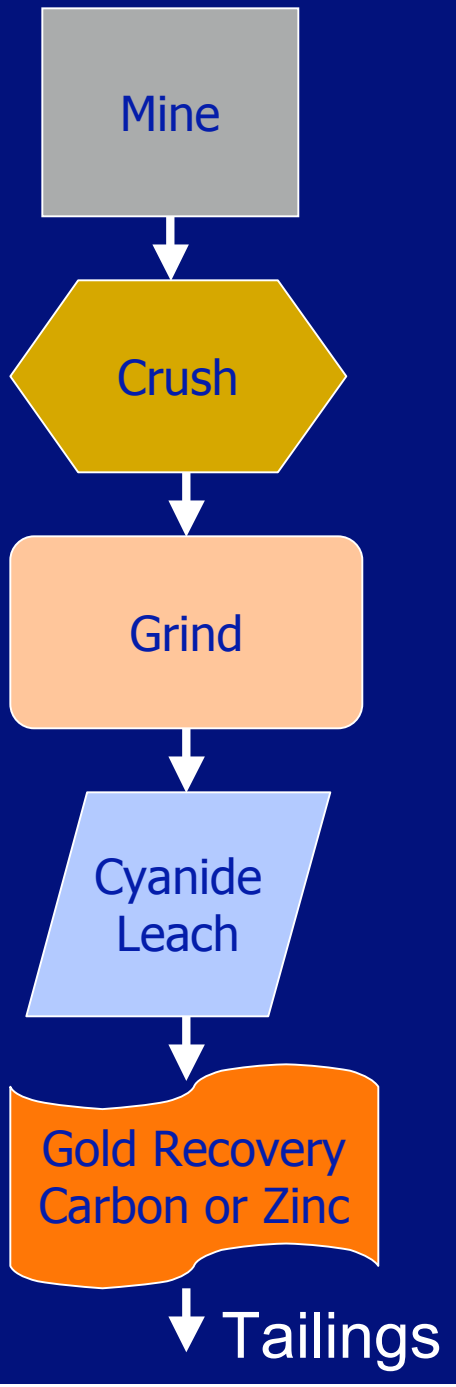
China and Papua New Guinea

Cyanide Leaching

Adapting Technologies from Large Scale Miners

Tank Leach Sulawesi 2006

Vat and Pachuca Leach Zimbabwe 2005



Cyanide Leach

Cyanide Leaching

-Health and safety risk
-Requires skills and tools for safe & efficient operation
-Not understood by many ASMs

- We need to know:
  - Grind size?
  - Leach time?
  - Cyanide concentration?
  - pH?
  - How much carbon is added?
  - What is gold loading onto carbon?
  - What is gold grade ore/tailings?
  - What is gold recovery?
  - Is mercury in ore?
  - Is cyanide stored safely?
  - Is tailings pond shallow (to destroy cyanide), fenced and far away from streams and wells

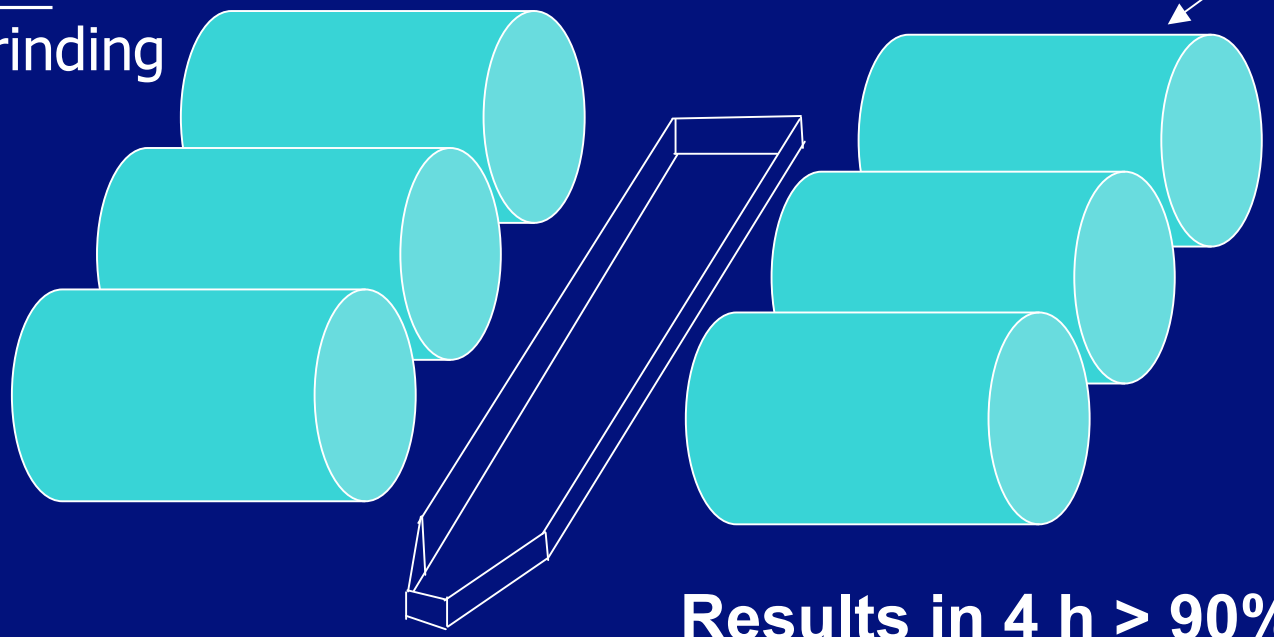
Using Cyanide in the Grinding Circuit (replacing Hg)

200 kg of gold ore in ball mills with 0.5 g/L NaCN

Carpet or centrifuge to trap coarse gold after cyanidation

Indonesia, 2006

Using Cyanide in the Grinding Circuit (replacing Hg)



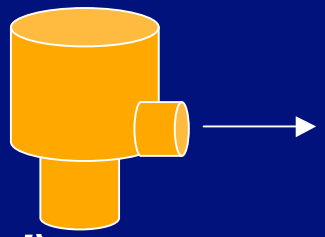
Ball mills (200 kg)

2 hr
Grinding

pH 10.5
$Ca(OH)_2$
NaCN (1g/L)
Balls

4 hr
Activated
charcoal

Results in 4 h > 90% Au extraction



Centrifuge or sluice (unleached gold)

Tailings Pond (recycle water)

Grinding with Cyanide

	Weight, kg	Au grade, ppm	Au distribution
Sand	80	1,4	5%
Water	85	3,1	12%
AC	0,38	4826	83%
Head grade		**27,6**	100%

Testing of Cyanide Leaching in Ball Mill Ecuador 2007

Grind & Leach Extraction 95%

Carbon Stripping and Recycling

- Process tested in labs at UBC and then in field in Ecuador 2007

- Stripping Conditions
  - NaCN 2g/L
  - NaOH 10g/L
  - Alcohol 20%
  - Temperature: 90^{o} C
- Gold Recovey Zn Ppt

- Initial AC gold grade: 941ppm
- Final AC gold grade: 25ppm
- Gold Recovery: 97%

- Whole ore amalgamation gold recovery 30%

3 Times More Gold Recovered from Ore!

Summary

- Sources for Alternative Technologies
  - Technology transfer from ASMs in other parts of the world
  - Apply what can be learned from large scale mines
- For successful technology transfer
  - Need to asses local capacity
  - Need to understand the properties of the ore through testing
- The use of Hg with CN has the potential to become a very serious environmental and health issue ha needs more attention
- New ASM technologies can be developed and applied to change ASM practices such as Grinding with Cyanide, Carbon Stripping and Recycling
- Total replacement of mercury while increasing wealth is possible
- Other technological challenges for ASMs relate to Mine Safety and Waste Management