Technologies for Small Scale Mining

Examples of traditional and alternative mining and processing methods

Part 1

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Mining Techniques in Small Scale Mining

(Examples, mainly gold mining)

Mining techniques in Small Scale (Gold) Mining

Alluvial deposits:

Alluvial mining:

- manually (pics and shovels, wheelbarrows)
- ground sluicing
- monitors/gravel pumps
- dredges (gravel pump/jet pump)
- heavy equipment
  (bulldozers, front end loaders, backhoes, trucks)

Ground sluicing

Monitor/gravel pump

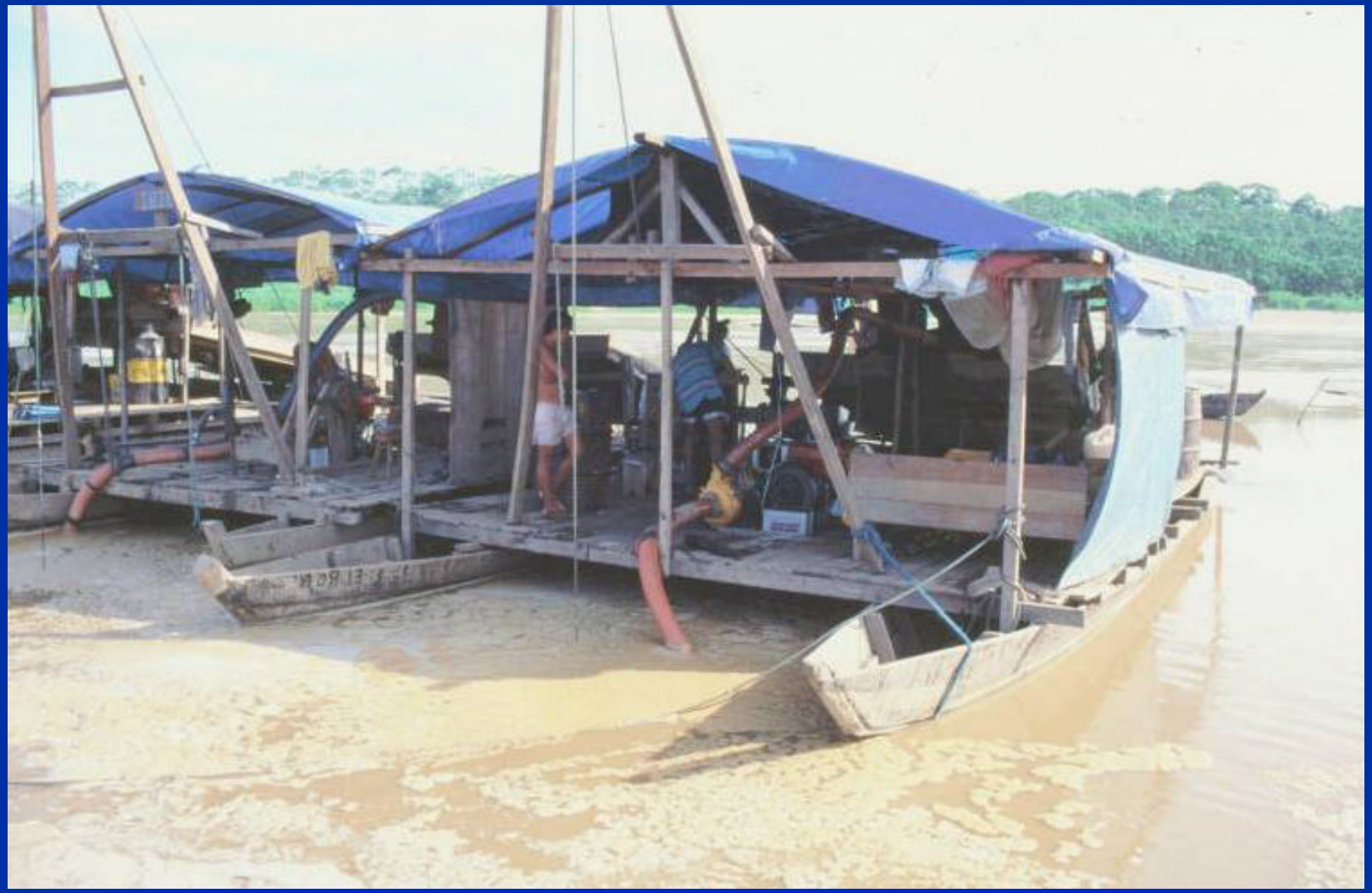
Monitor/gravel pump

maximum capacities of monitor/gravel pump operations:

pump inlet diameter	m^3/d (16h)	m^3/h
4“	150	9,4
5“	200	12,5
6“	280	17,5

Monitor/gravel pump

Dredges (gravel pump)



Dredges (gravel pump)

Heavy equipment (bulldozers, front end loaders, backhoes, trucks)

Primary deposits

Primary mining

- manually (hammers and chisels, crow bars)
- manual or mechanized drilling
- use of explosives
- open pit mining
- underground mining

Electrical drilling machine and small generator

Processing Techniques in Small Scale Mining

(Examples, mainly gold mining)

Processing techniques in small scale mining

great variety of individual methods

- depending on knowledge and financial situation of the small miners
- gap in technology reaches from
  - "**primitive methods"** (gold pans, stone mills) to
  - **"Agricola methods"** (sluice boxes, strakes, stamp mills) to
  - **"modern methods"** (shaking tables, spirals, centrifugal concentrators)

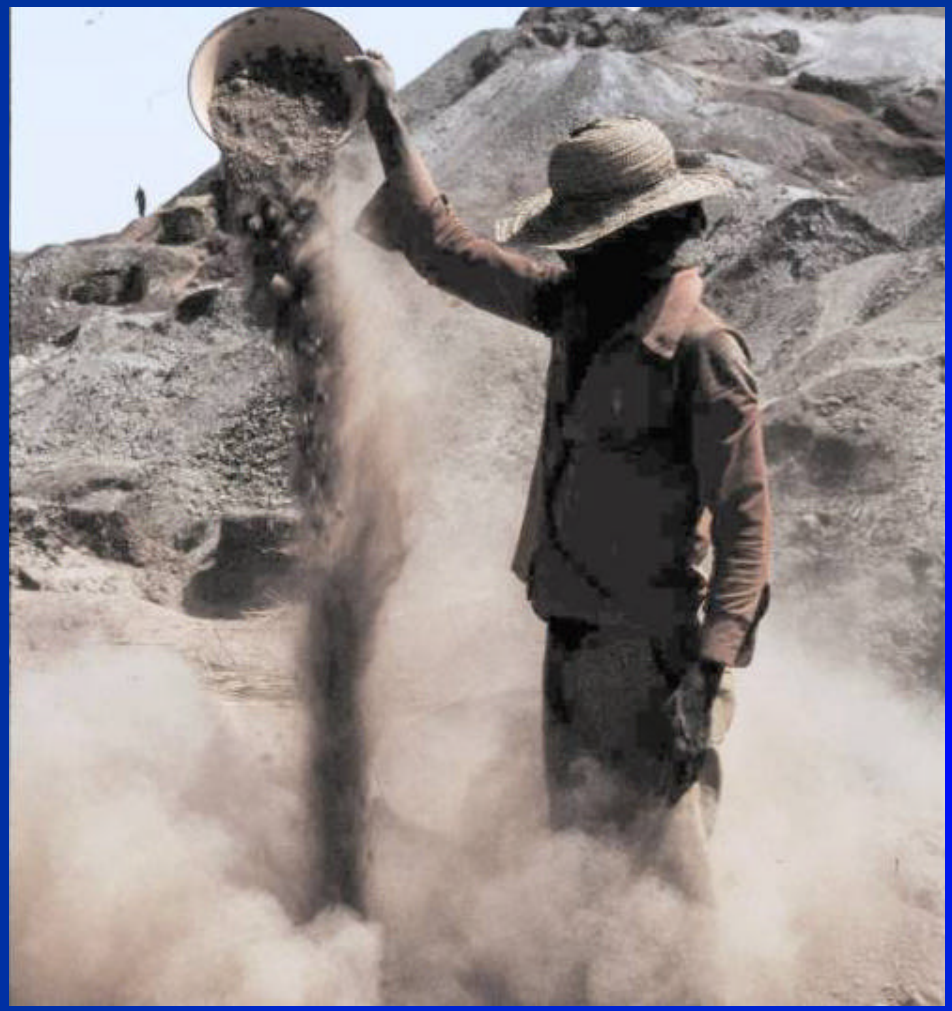
Alluvial ore processing

- manually (pan, hand jigging for diamonds or cassiterite)
- sluice boxes and strakes
- mechanical jigs (for gold, diamonds, tantalite and cassiterite)
- direct amalgamation of gold bearing ore (in situ, in sluices)
- amalgamation of free gold concentrates
  (manually, in barrels, cones, mixers)
- „burning“ of amalgam
- dry panning and windsorting (for gold, tantalite)

Primary ore processing:

- manually (gold pans, stone mills, rocking crushers, sluices, hand jigs)
- mechanized
    - jaw crusher
    - mills (ball mill, hammer mills, chilean mills, stamp mills)
    - sluices and strakes
    - jigs
    - amalgamating plates
    - centrifuges (home-made, industrial)
    - direct amalgamation of gold bearing ore
    - amalgamation of gold bearing concentrates (manually, in barrels
    - „burning“ of amalgam
- cyanide leaching
- flotation (rare)

Pans (for gold, tantalite, cassiterite)

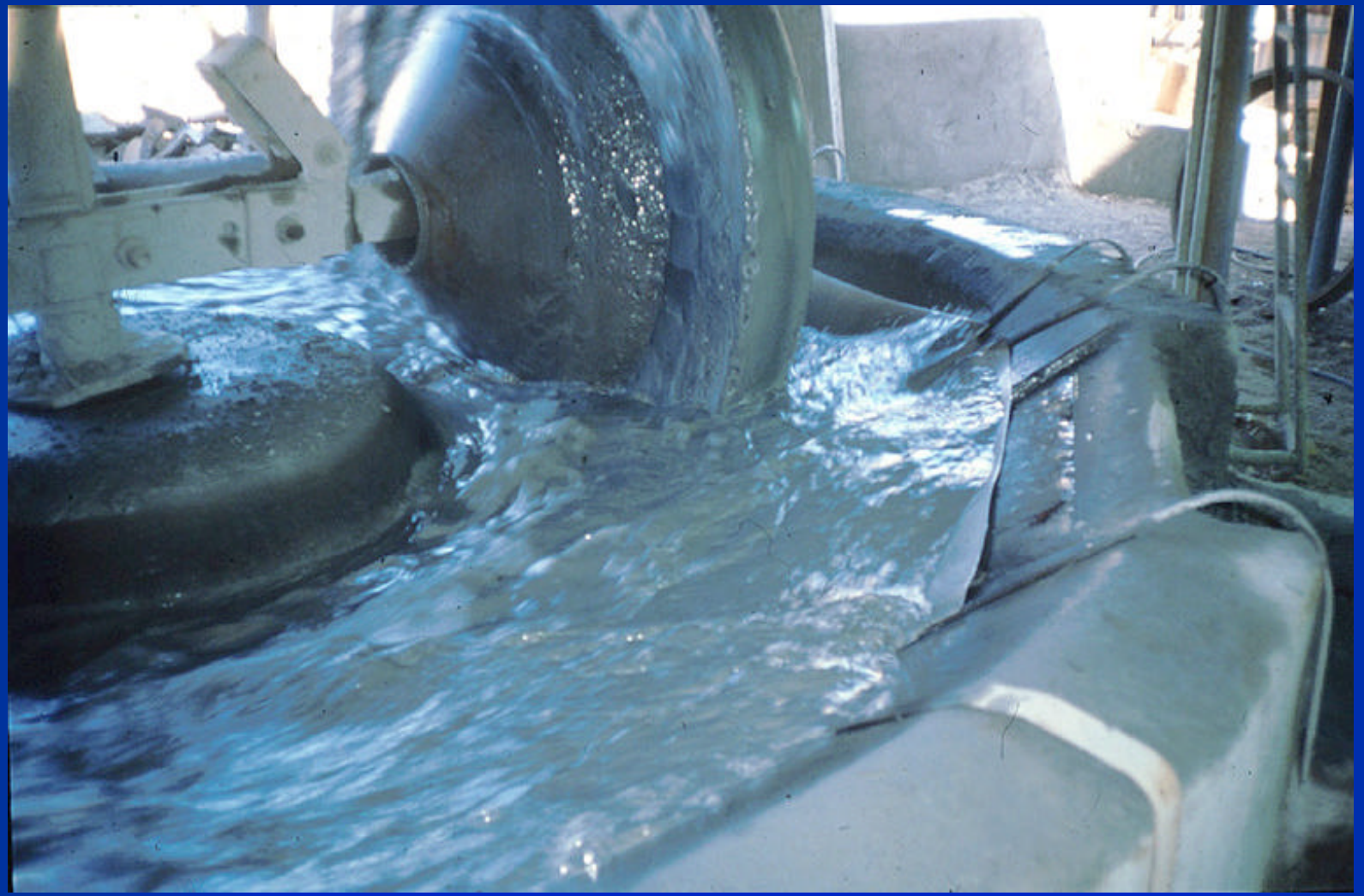


Windsorting

Manual milling

Sluice box (manual)

Stone mill (quimbalete, toloca)



Chilean mill

Amalgamation plate
(primary gold mining)

Sluice box (alluvial gold mining)

Sluice box (alluvial gold mining)

Sluice box /strake after hammer mill (primary gold mining)

Sluice „Palong“ (cassiterite and tantalite mining)

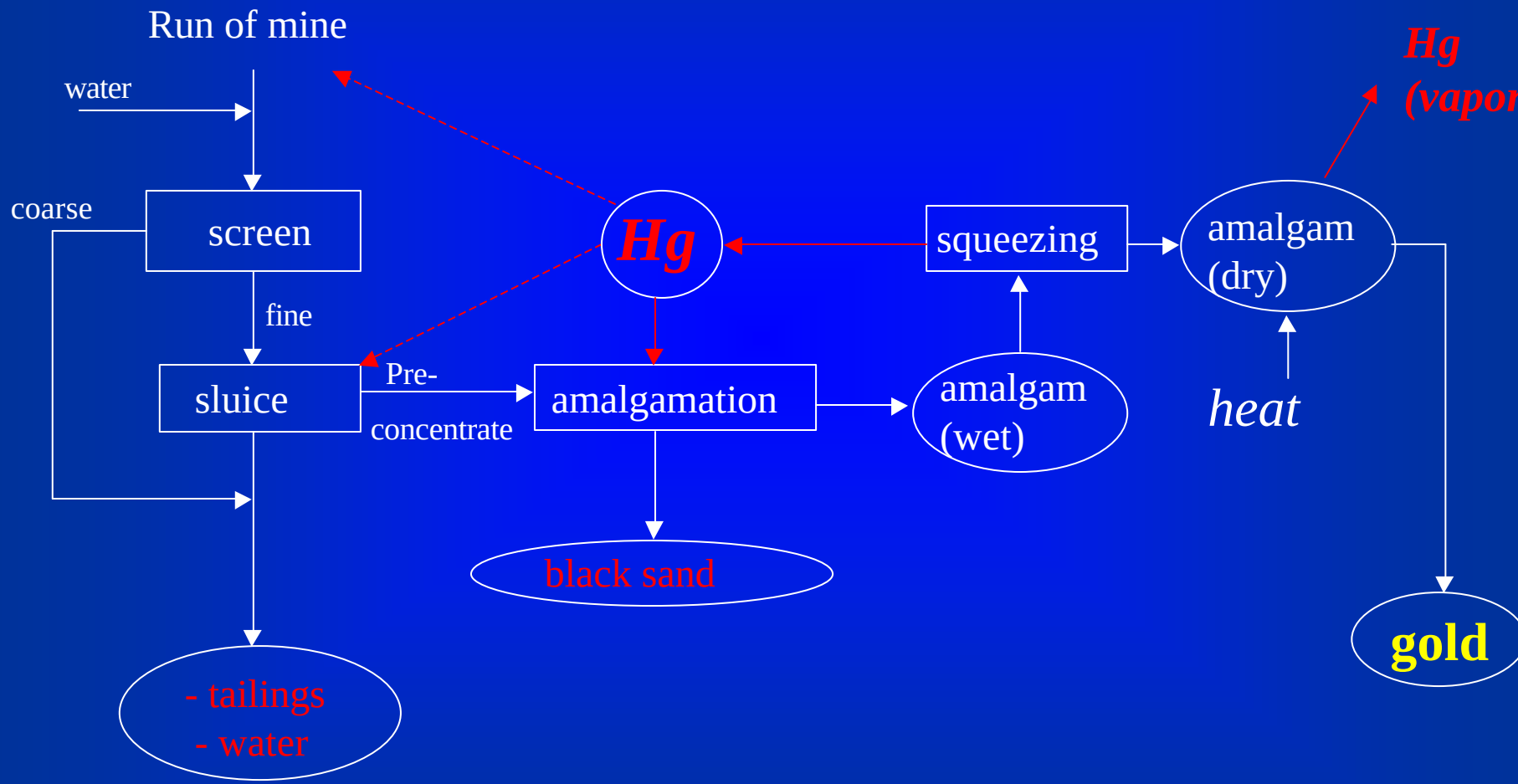
Amalgamation of gold concentrates (manually)

Manual amalgamation of gold bearing concentrates

- in buckets

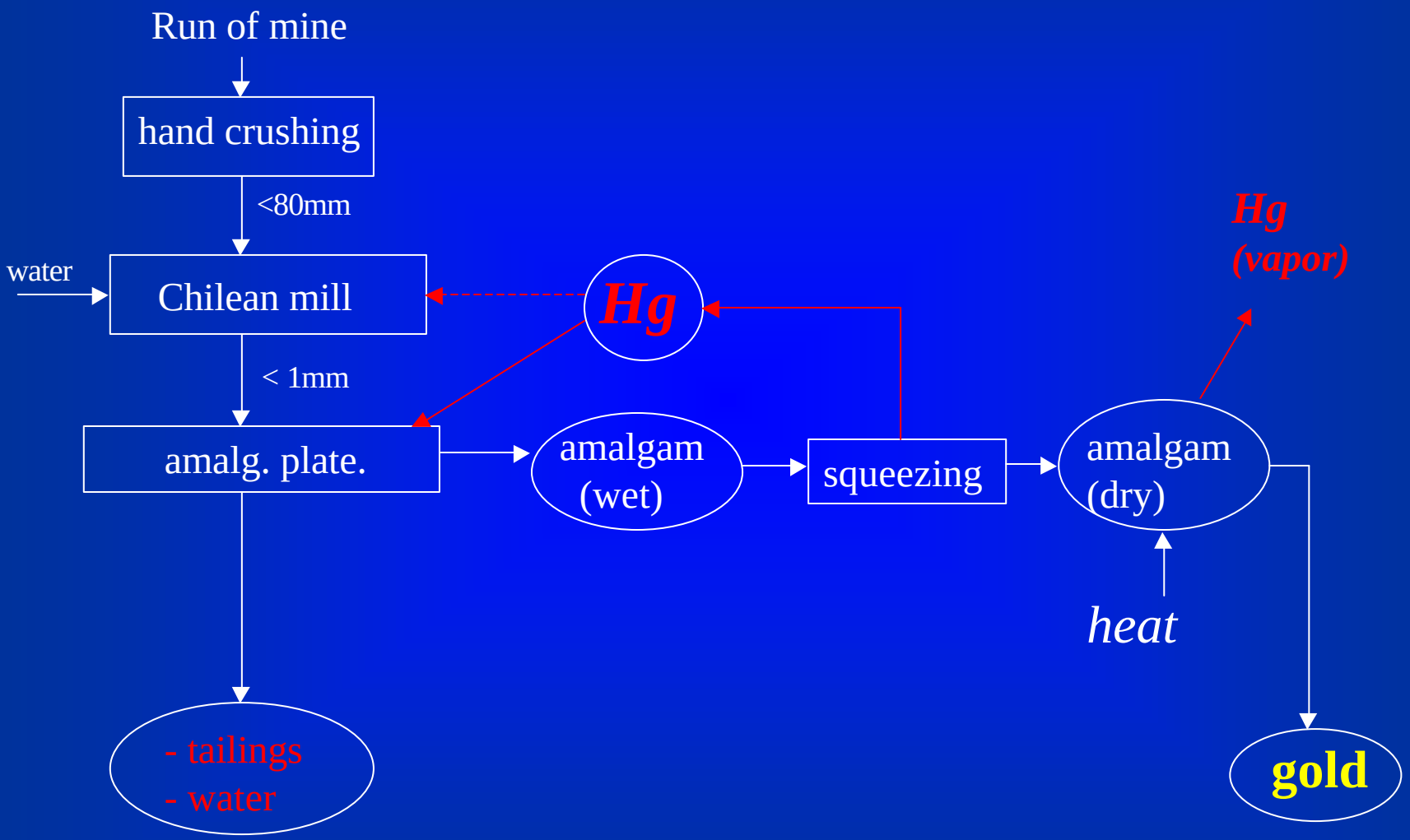
in the sluice box

Flow-sheet traditional alluvial gold processing (example)



Cleaning and squeezing of amalgam

Flow-sheet traditional primary gold processing (example)



"Burning" of amalgam

Mercury emission in the traditional processing (1)

- pre-concentration and concentration in open circuits

- use of mercury in the open cut (in situ) (alluvial mining)
- use of mercury in sluice-boxes (alluvial and primary mining)
- use of mercury in mills (ball mills, Chilean mills, stone mills)
- use of amalgam plates
- use of mercury in centrifugal concentrators

mercury is lost as:

floured mercury, amalgam flocs, fine amalgam, partially amalgamated gold

Mercury emission in the traditional gold ore processing (2)

- in amalgamation tailings

(floured mercury, amalgam flocs, fine amalgam, partially amalgamated gold)

- burning of amalgam

(vapor)

- losses through spilling

(liquid mercury)

Mercury emissions in traditional gold ore processing (typical average values)

emissions through (pre-)concentration in open circuits	1- 40kg Hg/kg recovered Au
emissions in amalgamation tailings	0,01-1kg Hg/kg recovered Au
emissions through separation Au-Hg (generally burning of amalgam)	0,5 – 2 kg Hg/kg recovered Au

(values are depending on the used method, the type of ore, the experience of the operators, etc.)

Amalgamation of raw ore means that all tailings are contaminated with mercury. It has to be strictly avoided!

Alternatives for the amalgamation of raw ore/in open circuits

- gravity concentration with direct smelting and amalgamation **or** leaching of the concentrates (not both!)

- flotation

- cyanide leaching of raw ore or concentrates

Deficiencies of traditional methods

- limited capacity (manual mining and processing)
- low recovery (in some cases)
- negative environmental impacts (mostly)
- industrial safety not existent (mostly)
- high demand and costs for mercury and other reagents like cyanide (gold mining)
- hard manual work (mostly)
- limitation to high grade ores (in many cases)
- no recovery of valuable by-products (often))
- processes not really made for the particular deposit but copied from the neighbour

Advantages of traditional methods

- known and accepted processes (sometimes since centuries)

- simple processes (handling and maintenance)

- low-cost, self made or locally produced equipment and machines

- processes are adapted to the local working structure, to the cultural and social environment

- processes are adapted to the existing marketing system

- little mechanization gives work to many uneducated people

It is often better, to improve the traditional methods in a mining area than to introduce new, unknown processes

Critics against small scale mining concentrate generally on the following main factors

- informal activity

- deficient industrial safety

- environmental impacts

Main environmental impacts of small scale mining

- mercury emissions
- sulfide emissions
- heavy metals emissions
- emissions of solids (coarse, fine to rivers)
- cyanide emissions
- deficient tailings management
- devastation of land, riverbanks; erosion
- deforestation

Requirements for a clean technology in small scale gold mining (1)

Technical-economical criteria:

- the technology must be technically efficient (more than the traditional methods)
- low in investment and operating costs
- the equipment, if possible, needs to be manufactured locally
- simple and safe handling and maintenance (also by less qualified personnel)
- durable and long life span
- can be integrated into the existing processes
- compatible to existing machines/equipment

Requirements for a clean technology in small scale gold mining (2)

Environmental criteria:

- low actual environmental impact
- no environmental "time bomb”
- better use of non renewable resources
- if possible, win-win-option (environmental improvement + economic advantage
- use of new process helps to meet environmental standards/regulations
- use of new process helps to reduce conflicts with neighbors (e.g. farmers)
- if possible, integrated solution, no ”end-of-pipe”

Requirements for a clean technology in small scale gold mining (3)

Social and cultural criteria

- the new technique approved by and proved together with the miners
- the new method is used elsewhere in the country (helps finding experienced personal)
- appropriate personal is available (quality and quantity)
- the new process does not interfere with religion, habits, superstitions
- the new process does not need substantial changes in the organization of the miners, it fits into existing work schedules and forms
- the new process does not create problems in the marketing of the products
- the new process does not cause problems between miners and other actors (concession owners, gold buyers, equipment and consumable suppliers, etc.)

Examples for processes and equipment appropriate for Small Scale Mining

- Crushing and grinding
- Screening and classifying
- Gravity concentration
    - Sluice boxes and strakes
    - Jigs
    - Shaking tables
    - Spirals
    - Centrifugal Concentrators
- Amalgamation of concentrates
- Flotation
- Cyanide leaching
- Tailings and water management

Crushing and Grinding

Jaw Crusher

capacity: 0-1000t/h

Sizes appropriate for SSM: 8´x 12´ (20cm x 30cm) or larger

- can be produced locally
- simple operation and maintenance
- is necessary before a ball mill
- improves capacity for other mills

Jaw crusher

Mills (mechanized)

- stamp mill
- Chilean mill
- ball mill
- hammer mill

Stamp Mill

capacity: 50-90kg per hour and stamp (e.g. with 4 stamps ca. 5-9 t / 24h)
(depending on product size, hardness of feed, stamp weight, etc.)

Advantages:

- good for local production (can be made mainly of wood)
- can be driven by water wheel
- feed size up to 100mm (depends on the weight of the stamps)
- can work with hard feed
- good for „batch“ processing

Disadvantages:

- low capacity (especially for fine grinding)
- makes a lot of noise and vibrations
- often used for simultaneous amalgamation

Stamp mill (wooden, driven by water wheel)

Stamp mill (iron, driven by electrical motor)

(both mills with amalgamation plate)

Chilean Mill

capacity: 3 to 25 t / 24h

Advantages:

- can be produced locally (simple forms)
- can be driven by a water wheel
- feed size until 10mm (depends on diameter and weight of the wheels)
- works with hard material
- good for batch processing

Disadvantages:

- for larger mills relatively high investment costs
- often used for simultaneous amalgamation

Chilean mill

(above: in combination with strakes)

Ball mill

capacity: 0-500t/h

Sizes used in SSM: 2“ x 3“ (60cm x 90cm), ca. 5t/24h
3“ x 4“ (90cm x 120cm), ca. 15t/24h
(capacity depends on hardness of feed, feed size, product size)

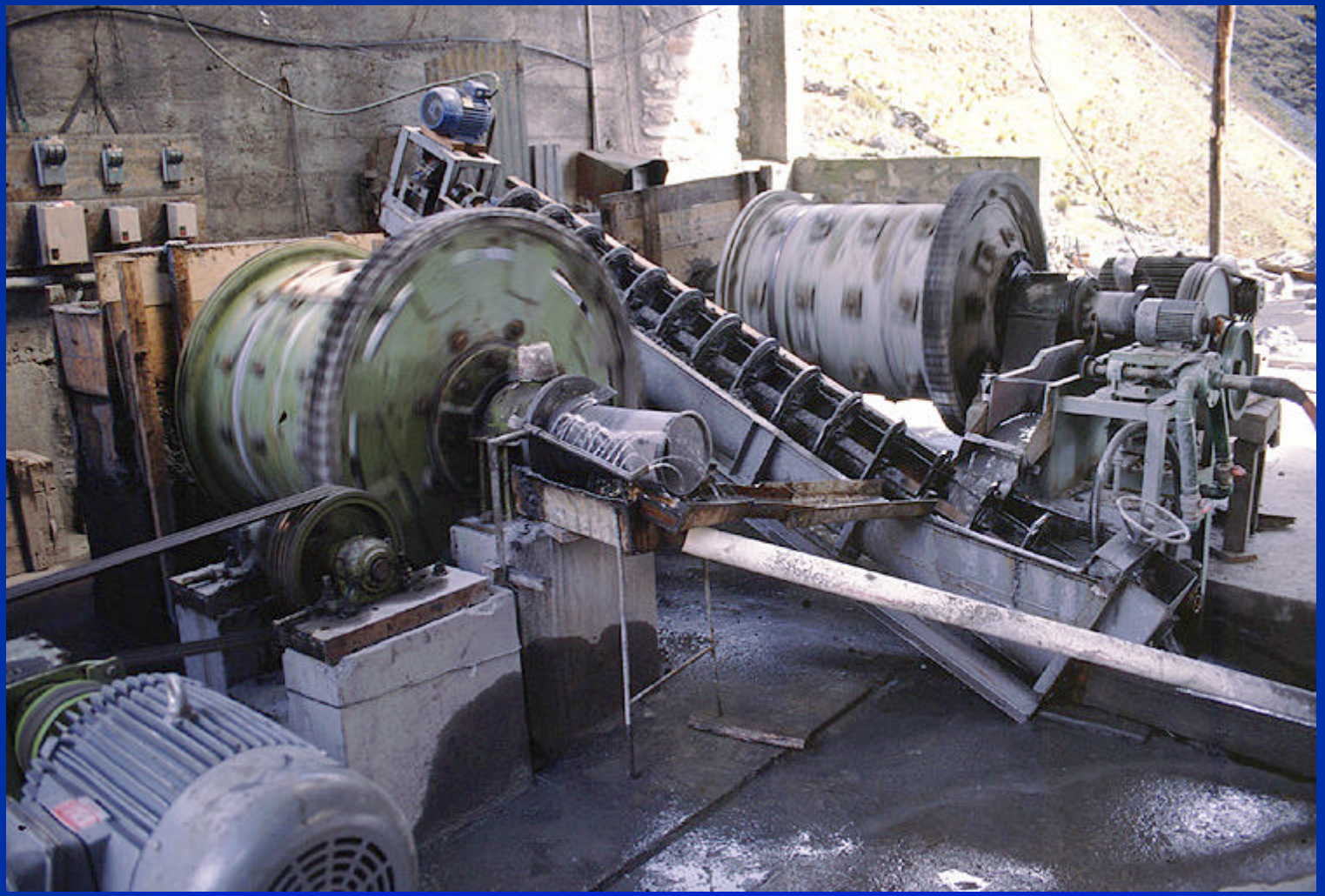
Advantages:

- product size can be very fine (e.g. for flotation, < 150µm)
- works with very hard material
- can be built locally (in experienced workshops)
- saves coarse gold inside

Disadvantages

- feed size <20mm (needs crusher)
- danger of overmilling
- mills gold to very thin flakes, stains the gold with iron
- not good for batch processing
- in non-mining countries, balls difficult to find
- high investment costs compared to capacity

Ball mill (dry batch operated, Peru)



Ball mills (primary and secondary, with spiral classifyer and jig)

Hammer mill

capacity (used with water) in SSM: 0,3 to 2,5t/h
normal sizes in South America: „H 33“ , ca. 17 t / 24h or 700kg/h
„H 48“ , ca. 60 t/ 24h or 2,5 t/h

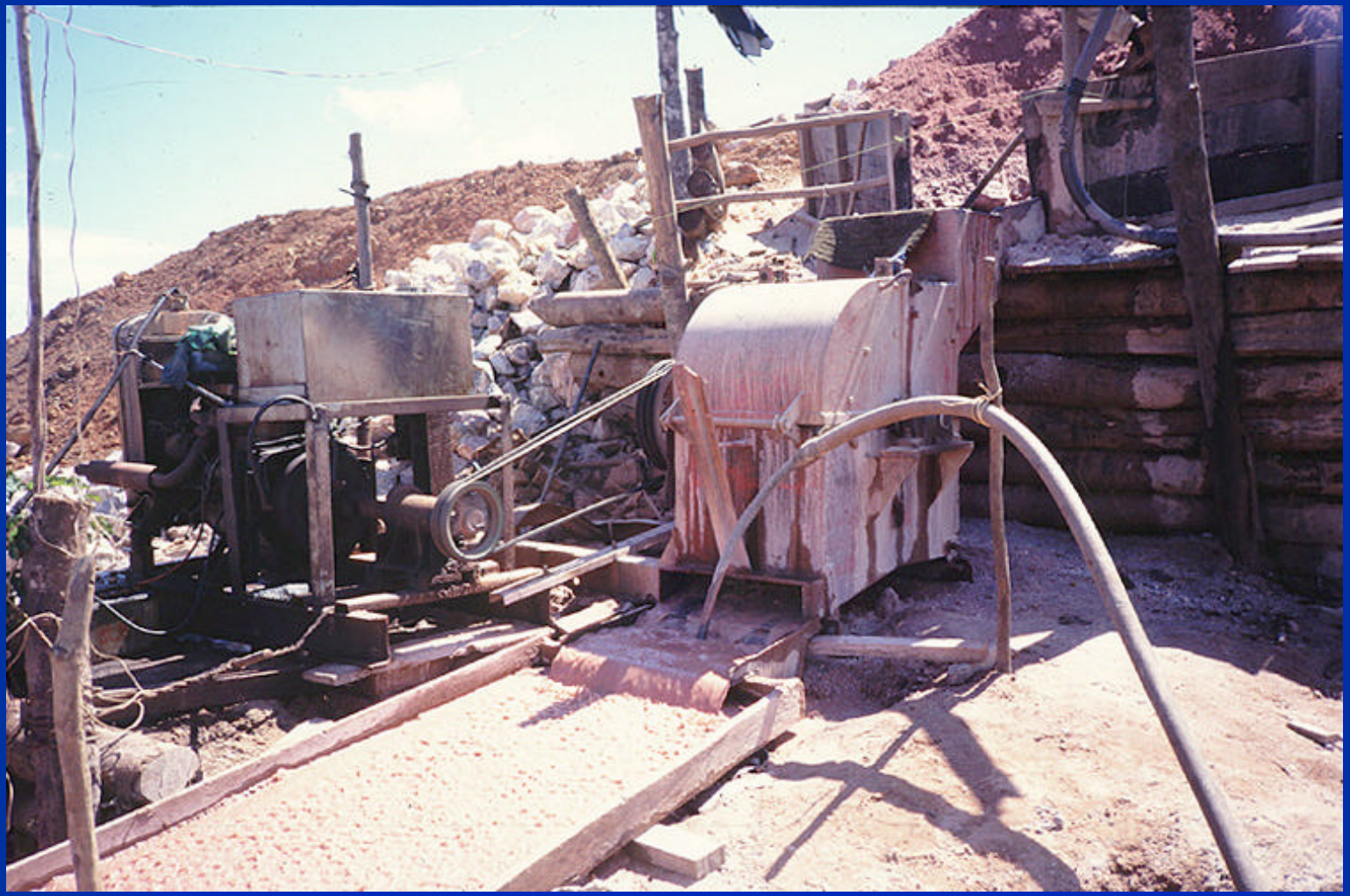
Advantages:

- can be produced locally
- feed size up to 60mm
- good for batch processing
- light weight
- simple operation and maintenance
- low cost compared to capacity

Disadvantages:

- not for very fine product size (usually until p_{80} of about 300µm)
- not for very hard material (chalcedonic quartz veins)
- not good for brittle valuable minerals (tantalite, cassiterite)
- relatively high operation costs (hammers)

Small hammer mill (700kg/h)



Large hammer mill (2,5t/h)

Screening and Classifying

Grizzlies, non moved screens

examples for use:

-removes fine material before a crusher

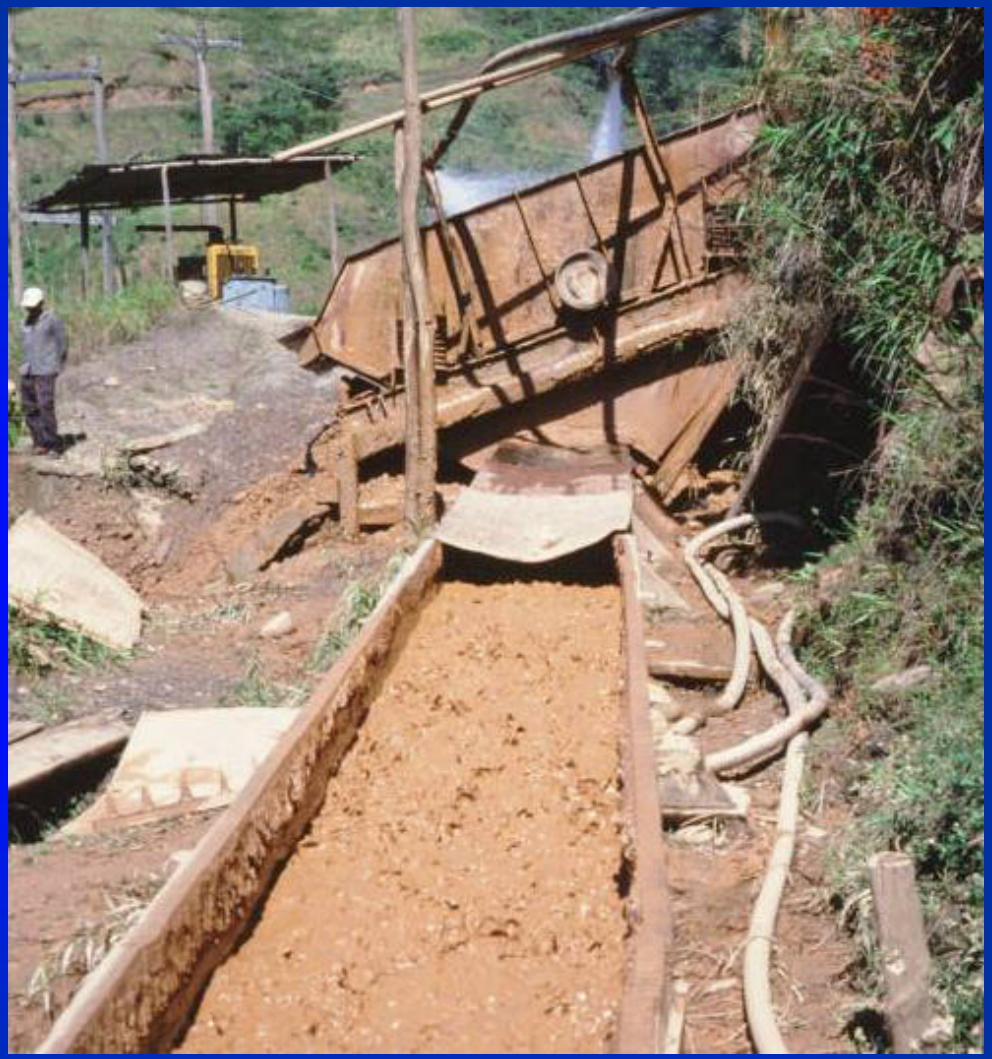
-removes coarse barren oversize before a sluice (alluvial mining)

Screen

Vibrating screens

examples for use:

-removes coarse barren oversize before a sluice (alluvial mining)



Trommel screens, revolving screens

examples for use:

-scrubbs and screens
alluvial material

- at ball mill discharges

manual trommel screen

Scrubber/trommel screen

Spiral classifyer

examples for use:

-in milling circuits, in combination with ball mills

-to dewater sand tailings (for dry depositing)

Spitzkasten (or Cone)

examples for use:

- classify mill discharge in different sizes as gravity concentration feed
- for desliming, e.g. gravity concentration feed or vat leaching feed
- to classify leaching feed (fine to agitation leaching, coarse to vat leaching

Hydrocyclon

Examples for use

- for desliming, e.g. gravity concentration feed or vat leaching feed
- to classify leaching feed (fine to agitation leaching, coarse to vat leaching
- in milling circuits (usually in larger plants)

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