Chapter 4
Gravity Concentration

Introduction

Gravity concentration is a process to concentrate the mineral of interest (in this case gold) using the difference of specific gravity of gold and gangue minerals. The specific gravity of gold is 19.5 and the specific gravity of quartz (the common gangue mineral associated with gold) is 2.65 (i.e., gravity concentration works because gold is heavy, and quartz is light). Often gravity separation methods are confused with size classification because large particles of light minerals can behave like a small particle of a heavy mineral. The most effective gravity separation processes occur when applied to ore particles of about the same size. The most important factor for a successful gravity separation is liberation of the gold particles from the gangue minerals. It is not easy to establish the degree of liberation of low-grade minerals such as gold. Classical microscopy of screened fractions to establish mineral liberation is unreliable with gold ores. The most recommended method to establish the optimum gold liberation size is grinding for different times (or grain size distributions) and applying gravity concentration to the ground products. This is a classical and important procedure to recommend any type of gravity concentration process. Because most artisanal miners do not classify (screen) the crushed/ground material (i.e. they work in open circuit), their chances to improve gold recovery are very limited.

The main advantages of gravity concentrators over gold cyanidation are:

- relatively simple pieces of equipment (low capital and operating costs)
- little or no reagent required
- works equally well with relatively coarse particles and fine grained materials

Sluices

Sluices are inclined, flat-bottomed troughs that are lined on the bottom with a trapping mechanism that can capture particles of gold and other heavy minerals. They can be used either for alluvial or for primary ore (sluices are sometimes called "strakes" or "blanket tables"). Ore is mixed with water and the pulp poured down the trough. Sluice designs have utilized readily available materials for thousands of years, such as animal furs as trapping mechanisms--in the ancient Greek myths, the Argonaut hero Jason recovered the "golden fleece", a sheepskin sluice lining, by killing the dragon that guarded it.

Sluices work on the principal that heavy particles tend to sink to the bottom of a stream of flowing water while the lighter particles tend to be carried downstream and discharged off the end of the sluice. Sluices are used in various sizes, from small hand-fed sluices to large sluices found on dredges or fed by trucks, front-end loaders or bulldozers, which can process as much as 150m^3 of alluvial ore per hour. Much like in the past, today's hand-fed sluices are usually 1 to 2 meters long, 30 to 50 cm wide, with walls 10 to 30 cm high. Sluices are usually inclined at a 5 to 15 degree angle. Many miners working alluvial deposits today use large sluices when sufficient water and operating capital is available. In monitor-gravel pump systems, slurry is pumped through 7.5-15 cm hoses onto 1-1.5 m wide by roughly 5 meter long sluices, such as those used in Guyana, Indonesia and Brazil.

Used correctly, sluices are efficient devices to separate gold from gangue. While sluices are not necessarily more efficient than panning, they do allow miners to increase the amount of ore they process, thus boosting their income considerably. Unfortunately, the resulting increase in the volume of ore processed can put large amounts of silt into streams, damaging regional water supplies and thus harming people, animals and aquatic life. Sluices can cause other environmental problems as well--those lined with mercury coated copper plates are especially destructive because the slurry solids scratch the mercury from the copper plate and carry it downstream, poisoning fish and people.

Fig. 4.1 - Hand fed sluice in South Africa

Fig. 4.2 - Monitor pump fed sluice in Indonesia. Note the turbulent flow which limits recovery of fine gold

Good sluice design

Even though sluices have been used throughout the world for thousands of years, they are often not designed or operated correctly. Limited knowledge of the basic operating principles, lack of capital and access to more efficient modern lining carpets greatly reduces gold recovery, especially recovery of fine gold.

Particles suspended in a slurry stream settle when the intensity of the turbulence cannot support them. A well-designed sluice insures that the maximum amount gold can settle near the bottom of the slurry stream where it can be caught by trapping mechanisms such as carpets or riffles. Trapping mechanisms shelter gold particles from being lifted back into the current by turbulent forces, holding the gold from being washed off the end of the sluice.

Gravity causes gold to settle in water faster than silica and other gangue minerals. The rate of settling depends on particle density, size and shape: Large, dense, spherical grains settle quickly, whereas small, less dense and flatter particles settle much more slowly. Coarser grained low-density particles can settle at the same rates as finer high-density particles. In sluices where turbulence is low, the difference in settling rate between heavy and light particles tends to separate the slurry into loosely stratified zones. As the slurry stream flows down a sluice, the densest and largest particles accumulate in a zone close to the bottom where they can become trapped within the lining carpet's pile or weave and sheltered from the current, while the smaller, lighter particles tend to stay in suspension near the top of the stream and be carried off the end of the sluice.

The rate of flow influences how gold and gangue particles in the feed stream settle to the bottom of the sluice, and how they become re-suspended. Flow velocities are controlled by the amount of feed pulp, and by the sluice box's inclination, width, and length. At low flow velocities, the densest and largest particles settle to the bottom, while the less dense and smaller particles remain suspended in the feed stream. On the bottom of the sluice, sediments in the surface layer move slowly down the sluice by rolling and sliding. Increased flow velocities can cause these sediments to be lifted and suspended or bounced downstream: High flow velocities cause turbulent currents that, if strong enough, can fully re-suspend the bottom bed load and carry it all downstream.

For efficient operation, the slurry flow velocity must be adjusted fit both the range of gold particle sizes in the feed, as well as the trapping mechanism used. Flow should be fast enough to insure that the trapping spaces created by the riffles or carpet liner are not filled and blocked with gangue (i.e., the carpet must be kept from "sanding up"), yet slow enough to allow as much fine gold as possible to settle to the bottom where it can be trapped.

Increasing the angle of the sluice causes the flow velocity to increase; increasing the slurry depth by narrowing the width (or by increasing the input) also causes the flow velocity to increase; lengthening the sluice also increases the flow velocity as the slurry moves down the sluice because the fluid accelerates with distance. For a given feed rate and sluice width, the optimum flow velocity is empirically determined by incrementally increasing the angle of inclination until the trapping mechanism is clear of silica and other light gangue minerals (or the other way round, reducing the angle of inclination until the sluice starts sanding out, and increasing it again slightly).

Fig. 4.3 - Stream contaminated with silt in Mozambique

The flow rate should be constant. The highly variable, discontinuous feed rates in hand-fed sluices are not efficient because the bottom carpet quickly becomes clogged with gangue, blocking the trapping spaces. In hand-fed sluices, water is poured onto the sluice one bucket at a time, but even at the peak-flow of each bucket pour, the velocity is usually too low to lift much of the gangue and keep the trapping mechanism open. Even though some gold particles can become entrained within the surface sediments as they roll and slide down the sluice, the trapping efficiency of these surface sediments is much lower than that of a carpet with exposed fibers. Continuous gravity flow from a diesel barrel filled with water is better than pouring one bucket of water at a time into hand-fed sluices.

Gold ores typically contain a mixture of coarse and fine-grained gold particles. Because fine gold settles much more slowly than course gold, it is often best to use multiple stage sluices—capture the coarse gold using riffles, coarse expanded metal or/and vinyl loop carpets in a relatively steeply inclined first stage (faster flow velocity); then screen the coarse material off by using an inclined grizzly screen at the end of the first sluice, and feed the passing fine material (plus the water) onto a more shallow angled, perhaps wider sluice, where the remaining fine gold is recovered on a more tightly woven or pile carpet. This second sluice

Fig. 4.4 - Feed box for hand fed sluice: mixing ore with water

can be oriented either perpendicular to, or underneath the first sluice in a zigzag configuration. Differently angled zigzag sluices allow variable flow velocities, while reducing acceleration of the slurry stream by shortening the length of the bed. The feed box for zigzag sluices usually has to be higher than straight sluices, so they work best when the feed can be pumped to the sluice, and when the discharge can be in the opposite direction as the feed. Zigzag sluices are used often in large alluvial mining operations.

The American company Keene Engineering offers a large variety of riffled sluice boxes made of aluminum with rubber ribbed matting and vinyl carpets. The A52 Keene 10"x 51" (25 x 129 cm) may be an interesting alternative to demonstrate to ASM. The cost in the USA of this sluice is around US$ 100. This small portable sluice (weighing 5kg) has the capacity of processing up to 5 tonnes/h of ore. Keene sluices were very popular in Africa some years ago. A copy of the Keene sluice was widely promoted in Zimbabwe as the Bambazonke. The company also provides pumps (8 to 20 centimeters) and a large variety of accessories.

Fig. 4.6 – Ground ore from a Chilean pan feeding alternating sluice boxes with carpet (Ecuador)

Fig. 4.5 - Clogged trapping mechanism (blanket) of hand-fed sluice

Feed preparation

The ore should first be screened so that the particle size is as uniform as possible and the coarse barren material is eliminated. Under ideal conditions, the feed should not be coarser than the largest possible gold particle. Large rocks on the sluice create eddies and turbulence that keeps the fine gold in suspension; the high flow velocities required to move rocks off the sluice also leads to loss of gold. In alluvial sluices, a “grizzly” (inclined parallel bars spaced about 1-2.5 cm apart) can be used to screen the feed and make sure larger rocks are kept out of the sluice. Grizzlies also remove clumps of clay that can roll down the sluice bed, sticking to gold particles and carrying them into the tailings.

Do not over-grind primary ore. Grinding too much can make smaller and flatter gold grains that tend to stay in suspension and ultimately be washed off the end of the sluice. Gold particles are very difficult to be concentrated when the material is a slurry of fine-grinding minerals. The same happens when the ore is rich in clayminerals. This forms a muddy-viscous pulp that must be adequately dispersed with caustic soda or dispersants to create conditions for gold to be concentrated by gravity processes. The more fine particles in the ore, the less % of solids must be used in the concentration process.

The ideal feed contains between 5 to 15% solids. A high percentage of solids makes the slurry too viscous - dense particles are buoyed upwards by less dense particles, limiting the ability to the slurry to stratify according to density. If very little water is available, and the gold is not too fine, coarse gangue particles can carefully be raked out of the sluice.

Fig. 4.7 - Pump-fed zigzag sluice in Suriname

Fig. 4.8 - Cleaning up Hessian carpets using a series of buckets

Sluice design and construction

Miners should design sluices to accommodate the anticipated feed rate by adjusting the width (increasing width decreases depth and flow velocity). Note that adjusting the width strongly influences the flow velocity - width is considered by some researchers to be the best control of flow velocity. Flow rates can be fine-tuned by adjusting the slope. When possible, miners should design sluice features (e.g., angle, width, etc.) so that they can be changed to insure optimum recovery. Wide sluices need to have carefully designed feed boxes to insure even slurry distribution over the whole width of the sluice.

Flow accelerates with distance, making it harder for the trapping mechanism to capture small gold particles. Research has shown that 90% of gold is recovered in the first 1/3rd of the sluice, 9% in the 2nd 1/3rd, and only 1% in the last 1/3rd. Most gold is caught in the first 0.5 meter of the sluice, so keep the sluice length short (less than 2 m for hand-fed sluices). Zigzag configurations break flow velocity and help to increase recovery; three 2m zigzag sluices are usually better than one single 6m sluice.

The optimal slope is usually between 10 and 15 degrees, but can be as low as 5% for fine grained primary feed.

Use multiple stage sluices to capture coarse and fine gold in different passes. Capture the coarse gold first, then the fine gold. The turbulence from faster flows needed to capture coarse gold in riffles can be calmed by placing a short smooth section (a “slick plate”) before the next stage.

Clean-up time is a critical activity. Trapping mechanisms should be easily removable and cleaned. Complex assemblies reduce the likelihood of cleaning. Trapping efficiency can be monitored by checking sluice tailings constantly by panning. Clean-up time can be as often as once an hour to prevent blocking of the carpet, especially for primary ore with high sulfide content. To enable continuous operation, parallel sluices should be installed (one sluice in operation, one in cleanup and preparation). To improve recovery and prevent theft, the top sections of alluvial sluices should be washed at least once per day.

Secondary sluices can be used to re-concentrate the concentrate recovered by the primary sluice, therefore reducing the mass of material to be amalgamated. Secondary sluice tailings should be recycled to the primary sluice.

Trapping mechanisms

Bed linings should be firmly fixed to the bottom of the sluice, especially when not backed, to prevent captured gold from migrating down the sluice underneath the lining and being lost off the end of the sluice.

Riffles

a) Cross riffles made from railroad rails, angle iron, wood or split bamboo are often used to trap gold particles >1mm. The simplest riffles are stones, but these can cause turbulence likely to cause gold loss. Carpet and/or expanded metal should be used underneath the riffles.

b) Rudimentary riffles do not necessarily improve recovery--turbulence can break up stratification, and cause the loss of fine gold. While catching some of the coarse gold, riffles often only leave the impression that recoveries have improved.

c) Riffles protect the carpet lining from wear and keep it firmly on the bed of the sluice.

d) Ore with a range of coarse particle sizes may need to utilize several kinds of riffles (e.g., large and small expanded metal riffles).

e) Select riffle size and spacing, then select the flow rate that keeps the sheltering spaces behind the riffles clear of sand.

f) 25 mm angle iron riffles are commonly used with 4.0-6.5 cm gaps, canted uphill at about 15 degrees. There should be very little sand between the riffles. If there is too much sand, the flow is either too slow, or the riffles are too high.

g) Expanded metal grating (see picture, below) forms shallow riffles which cause a local turbulence that keeps the sand moving downstream while providing effective shelter for gold grains less than 0.1 mm. Wider sluices need a heaver gauge metal to hold the liner flat.

Fig. 4.9 – Expanded metal and cross riffles in a Keene sluice

h) When the ore contains some magnetite, Cleangold® (see below) sluices can form a magnetite bed that can trap fine gold.

Carpets

a) Type of carpet lining is usually determined by what is available.
b) Fibrous or hairy fabrics like sacking, sisal, blankets, or old carpets have hairs that can trap fine gold particles and prevent them from being lifted back up into the current by turbulence. Animal hides are usually not a good option, because they tend to fowl.
c) In general, the best carpets have open fibrous structures that let gold particles settle deeply in the lining.
d) If rubber backed carpets are not available, use a tighter weave cloth backing underneath the carpet to prevent loss of gold.
e) Wash carpets in a series of buckets, in barrels cut lengthwise into troughs, or in tubs.

It is important to demonstrate different types of sisal fabrics and carpets. The best carpet used in ASM operations is the 3M Nomad Dirt Scraper Matting, especially the type 6050 (medium traffic with backing) which consists of a coiled vinyl structure; type 8100 (an un-backed version) can also be used. Nomad is usually recommended for relatively coarse gold, but can also trap fine gold efficiently. The price of Nomad carpets in ASM sites can reach up to US$ 150/m²; alternately, a Nomad type vinyl loop carpet is available from manufacturers in China for a fraction of this price. The Brazilian company Sommer (subsidiary of the German company Tarkett Sommer) sells 2 types of carpets widely used by Brazilian ASM: “Multiouro Tariscado” (which is good for gold of medium sized rice grains) and “Multiouro Liso” (which is good for -0.15 mm gold). These carpets can cost around US$ 10 to 15/m². None of these carpets are easily accessible to ASM in Africa. Sisal fabrics however, can cost as little as US$ 3/m², and are available in most African countries; depending on the type, they can be used for coarse, medium and fine gold recovery. It is a matter of trying different types. Raffia mats have been used in Zimbabwe for fine gold concentration. This definitely must be further investigated and collaborative tests can be done with the miners to establish the ideal type of sisal cloth.

Another interesting sluice liner is the one manufactured by **Cleangold®**, a company based in Lincoln City, Oregon. The Cleangold® sluice uses polymeric magnetic sheets similar to the material used to make magnetic advertisements, with the magnetic poles aligned perpendicular to the direction of the slurry flow, glued to the bottom of a simple aluminum sluice box.

Magnetite, a mineral commonly found in gold-ore deposits, is held by the magnetic sheeting, and forms a fine-grained corduroy-like trapping mechanism on the sluice floor. These inserts can be available in any size, but they are relatively expensive. For example, Cleangold® can manufacture a 60 x 50 cm insert for around US$ 165 (in USA). The main advantage of this sluice is the high concentration ratio. Gold becomes trapped in a magnetite layer which can be easily scrapped and washed into a pan. Using a magnet, the magnetite is removed and a high grade of gold concentrate is obtained. In many cases the use of mercury to amalgamate the concentrate is not necessary. However, as the magnetic separation isn't always 100% efficient, and the concentrate tailings can carry some gold, so amalgamation or even leaching of the concentrates is recommended. In one test comparing the Cleangold® sluice with a centrifugal concentrator, the sluice obtained slightly better gold recoveries than the centrifuge. In a recent field test in Venezuela conducted by UNIDO, tailings from hammer mills and Cu-amalgamating plates were passed without regrinding through a 60 cm long Cleangold® sluice box. About 11% of gold in the tailings was recovered and the concentrate analyzed 2850 ppm Au. The Cleangold sluice can also take advantage of the fine pieces of steel released from hammer and ball mills. They are also concentrated on the magnetic sluice and play the role of magnetite.

Fig. 4.10 – Cleangold magnetic sluice

MINTEK (South Africa) has devised interesting sluice boxes (strakes) with rubber mat glued to it. Black ribbed vinyl mats are also useful to recover gold; they are easy to clean and cost in USA about US $15/m².

Optimal slurry flow velocity

Different trapping mechanisms require different flow velocities. Adjust the width and/or slope to control flow velocity to optimize the performance of the various riffles and carpets used. Coarse gold recovery needs faster flow velocity (narrower and/or steeper sections); finer gold recovery requires slower speeds (broader and/or less steep sections).

Keep feed rate and pulp density constant. Increasing the flow can increase turbulence and make it more difficult for gold particles, especially the fine gold grains which tend to stay in suspension, to contact and be trapped at the bottom of the sluice. Slowing or stopping the flow fills the trapping mechanism with gangue. Avoid turbulent flow, especially when trying to capture fine gold. Higher flow velocities can be necessary to keep the gangue from clogging riffles and carpets, but high speed tends to push fine gold off the end of the sluice. Lower flow velocities can yield higher recovery (fine gold is recovered in addition to the coarse gold), but if too slow, can lead to clogging of the trapping mechanism.

Distribute the flow evenly over the sluice bottom by making sure the sluice bottom is flat—avoid twisting and sagging.

When water supply is short, use narrower sluices to insure adequate flow velocity to keep trapping mechanism clear.

Assess the efficiency of recovery by panning the tailings, or by passing them over a short test-sluice.

Centrifugal concentrators

Centrifugal concentrators were originally developed to improve gold recovery from alluvial sands. Since about 1990, they have been used increasingly for hard rock mines, which is now the largest area of application. Centrifugal concentrators consist of a vertical rotation bowl with a series of concentric rings that trap the gold. A centrifugal force is applied on the ore particles, in such a way that this force is 60 (in the case of Knelson) to 300 (in the case of Falcon) times higher than the gravitational force. The rotor is accelerated and feed slurry is introduced to the concentrating cone through a stationary feed tube. Upon reaching the deflector pad at the bottom of the cone, the slurry is driven outward to the cone wall by the centrifugal acceleration. As slurry flows up the cone wall, the solids fill each ring to capacity creating the concentrating bed. The tailings product overflows the bowl and the gold becomes trapped in the rings. Some centrifuges have a smooth wall at the bottom of the bowl where stratification takes place. The high density gold is concentrated at the wall forcing and displacing lower density particles away from the wall. Compaction of the bed in the rings can be prevented by introducing pressurized fluidization water from behind the rings. This helps the high-density gold particles displace the lower density gangue particles causing the gold grade to increase in the concentrating rings with time. After a period of time, the feed is stopped and the rotor is shut off. The concentrate is flushed from the cone into the concentrate launder and can be upgraded further by panning.

The two main manufacturers of centrifugal concentrators are: Knelson and Falcon, both from British Columbia, Canada. Both concentrators have a ribbed rotating cone into which the pulp of 20 to 40% solids is fed and the concentrate is accumulated in the riffles. Compaction of the concentrate layer is avoided by injection of water in counter flow. This water fluidizes the concentrate bed and allows fine gold particles to penetrate into the concentrate layer. The main problems of these centrifuges in ASM operations are:

- high cost
- lack of skilled operators
- lack of clean water and controlled pressure for counter flow

For hard rock deposits, the ore must be ground before feeding to the centrifuge. The feed should also be screened to below about 1 mm to remove coarse material, which can be ground further and fed back to the separator. These centrifuges recover between 15% and 60% of the gold, depending on the mineralogy of the ore. In large scale mines the tailings are usually processed by cyanide leaching.

Fig. 4.11 – Centrifuges operating in Brazil

There are many models of centrifugal concentrators with capacity up to 100 tonnes of ore/h. For a small-scale production, a centrifuge with 1-2 tonnes/h capacity is more than enough. This uses a motor with 1.5 hp and 80-140 liters/min of water.

Many other types of centrifuge are available in artisanal mining sites. In Brazil there are at least 4 manufacturers of cheap centrifuges. The bowls of these machines are not made of polyethylene like the ones of Knelson concentrator but of carbon steel. In Poconé, Brazil, these cheap centrifuges work for 8 hours with nominal capacity of 24 tonnes/h resulting in a concentration ratio of 1000 to 1 or higher. It is common to observe concentrates with more than 1000 g/t of gold. The volume of concentrates is fixed, limited by the volume of the riffles so the weight of the concentrate recovered each cycle is almost constant.

The "ABJ Bowl," in effect is a copy of the Knudsen concentrator out of California, is extensively used in Zimbabwe. The conic centrifuge does not have counter-flow water. The centrifuge has 3 vertical pieces of steel that promotes turbulence of the slurry flowing up the riffles on the bowl, facilitating the ability of the gold to replace other less dense minerals trapped in the riffles. When the concentrate bed in the riffles is thus "scratched," sites on the bed are opened for gold concentration. About 30 to 33 kg of concentrate are obtained during a given run. The main specifications of the ABJ centrifuge used by artisanal miners in Zimbabwe are:

- Diameter of the bowl: ∅0.78 m
- Operation: unfluidized centrifuge, ribbed cone
- Cone Material: butyl rubber
- Operating Speed: 102 rpm
- Feed Capacity: up to 3 tonnes/h in slurry at 30% solids
- Feed Size: -4mm max
- Shipping Weight: 130kg
- Extent of Mechanization: partially mechanized; batch discharge of concentrates
- Mode of Operation: batch
- Discharge: from bottom
- Drive Bevel gear and V-Belt
- Installed Power: 0.7 kW
- Price: about US$ 2000

Fig. 4.12 – ABJ centrifuge operating in Zimbabwe

Fig. 4.13 – Rubber cone with ribs (ABJ centrifuge)

The company Small Mining Supplies from Zimbabwe recently introduced a new centrifuge called GoldKacha Concentrator. The specifications of this centrifuge are:

- High capacity – 3-4 tonnes/hour

- Feed size -3mm
- No fluidization water
- No drive belts
- Replaceable polyurethane cone
- Slurry distributor
- Low power requirement: 0.5 kW
- Weight 108 kg
- Cost approximately $US 2200, but variable depending on currency fluctuations

Fig. 4.14 -- Small Mining Supplies (Harare) new centrifuge, the "GoldKacha

One of the main problems observed in Zimbabwe ASM operations is the use of mercury in the ABJ concentrators. Mercury flours in the process, and it is lost to the tailings together with fine gold. Very little has been done to change this bad practice.

Panning

Panning is the most ancient form of gravity concentration. Pictures of gold pans appear on Egyptian monuments as old as 2900 BC. The circular or back-and-forth shaking of ore and water in a pan causes the ore to stratify--the heavy minerals settle to the bottom of the pan while the lighter gangue can be washed off the top.

Panning is the basic means of recovering gold from alluvial and high-grade primary ore. In Zimbabwe, for example, miners rarely use the stamp milling plants for their high-grade reef ores. They rely on pounding this ore with mortar and pestle and use pans for concentration. They later wash these panning concentrates through a clay/sand sluice lined with blanket or rubber matting. Assays of these tailings are always high, suggesting that either gold liberation is poor, or panning efficiency is low. Primary crushing uses a 4-pound hammer to produce affordable sizes for grinding in a mortar using a steel bar pestle. The ground up material is then classified through a sieve to collect the fine undersize material. In most cases in Zimbabwe, the coarser oversize is thrown away and not reground for better liberation. All the undersize is then panned and the gold recovered. A magnet can be used to remove the black magnetite. The magnet is applied to the bottom side of the pan and moved in a circular motion with the pan slightly tilted. Thos rich gold concentrate does not need amalgamation, as it can be smelted directly.

Different kinds of gold pans

While artisanal miners are usually expert panners and are able to achieve incredible results, even with the most rudimentary pans, they are sometimes unaware of the advantages of the range of shapes used by their fellow miners around the world.

Panners commonly use gourds, kitchen bowls or cooking pans to pan for gold. They also use specially designed gold pans made of wood, metal and plastic. Gold pans are usually round, but can sometimes be rectangular, as in Vietnam. Wooden pans have the advantage of having a slightly rough surface than can hold the gold a bit, but steel pans can be roughened by rusting with acid (or lemon juice), and new plastic pans can be given a “tooth” by rubbing with sand. Wooden pans also have the advantage of buoyancy, making it easier to support a pan full of ore in water. Pans can be cut from steel sheeting and riveted, or pounded into shape from steel oil or cyanide drum tops using auto-body repair techniques. Steel and aluminum pans are sometimes mass-produced by metal “spinning” processes. Cast aluminum pans are also available in some places.

In North America, flat bottom pans have been used for over 150 years to capture coarse gold. Typically these types of pans are made of steel, with sides about 35 degrees from horizontal. Today these pans are also formed of plastic and have 2 or 3 small riffle-like ridges circling the sides.

Fig. 4.15 - Miners can capture fine gold even in a very worn out pans (Tanzania).

Fig. 4.16 - Aluminum kitchen bowl used as a gold pan (Sudan)

Fig. 4.17 - Using a gourd ("calabace") as a gold pan (Guinea)

Fig. 4.18 - Wooden bateas in Lao PDR

Fig. 4.19 - Riveted shallow batea made of sheet metal (Brazil).

Fig. 4.20 - North American plastic pan with riffles in the side (Mozambique).

Fig. 4.21 - Using a steel batea (Brazil)

Fig. 4.22 - Small rubber coated cone-shaped batea for testing ore (Peru).

Fig. 4.23 - Steep-walled plastic kitchen bowl (Mozambique).

Fig. 4.24 - Hand carved wooden bowl and gourds (Sudan).

Fig. 4.25 – Child in Lao PDR panning gold with a wooden batea

In Brazil, Indonesia and elsewhere, 150 to 155° conical "bateas" capture coarse gold relatively quickly, and are also good to capture fine gold. In Peru, miners use small 15 cm diameter bateas coated with rubber to evaluate recovery by testing sluice tailings. In Africa, miners often use steep-walled plastic pans, but these are less efficient than bateas. Sudanese panners use hand-carve ellipsoidal wooden bowls and gourds.

Basic knowledge for miners

- Gold pans, sluices and centrifuges are all methods of "gravity concentration"
- Gravity concentration works because gold settles faster than other minerals (e.g., sand) in water
- Gravity concentration works best when the particles in the feed are close to the same size—screen the ore before concentrating, and re-grind the oversize
- Using mercury in sluices and centrifuges does not improve recovery—indeed, gold is often lost along with the mercury. These practices release much mercury to the environment and should be banned in all countries.
- Panning
    - Panning is an efficient and very low cost method of gravity concentration—unfortunately, miners can only process small amounts of ore in a day.
    - There are many shapes and sizes of gold pans that are used by miners in the world
- Sluices
    - Sluices are as efficient as panning, but a miner can process much more ore per day with a sluice
    - Sluices work best when the water/slurry is fed at a constant rate
        - Use an old diesel drum to feed the water at a constant rate
    - Miners should experiment with different kinds of carpets and riffles
    - Control the slurry flow velocity by adjusting the slope angle to be just steeper than the angle where the sand clogs the carpet
        - Keep the sand out of the spaces in the carpet fibers in order to trap the gold
    - Adjust the sluice width and slurry depth to fit the feed rate, kind of ore and grain size, the slurry density and trapping

mechanism (e.g., about 1 cm depth is good for one meter wide Nomad carpet sluices at stamp mills grinding quartz ore in Zimbabwe)

  - Most gold is captured in the first 1/3rd of the sluice
  - Use short sections of sluice (consider using a zigzag configuration if possible) to limit acceleration of slurry
    - If the slurry flowing over a sluice is deep, the pulp can speed up too much and lead to loss of gold; shallow slurry (e.g., 1 cm deep on a Nomad carpet) does not accelerate as much as deep slurry
  - Use different trapping mechanisms and/or slope angles to capture coarse and fine gold
  - Copper amalgamation plates are a form of sluice that should be banned in all countries
- Centrifuges
  - Centrifuges (e.g. Knudsen type-ABJ, GoldKacha) can be simple and relatively inexpensive; these centrifuges recover about the same amount of gold as a copper amalgamating plate
  - More sophisticated centrifuges (Knelson and Falcon) are more expensive and require a clean constant water supply to operate, however these centrifuges can recover more gold than other forms of gravity concentration equipment
  - Putting mercury in centrifuges leads to the loss of fine gold with the floured mercury