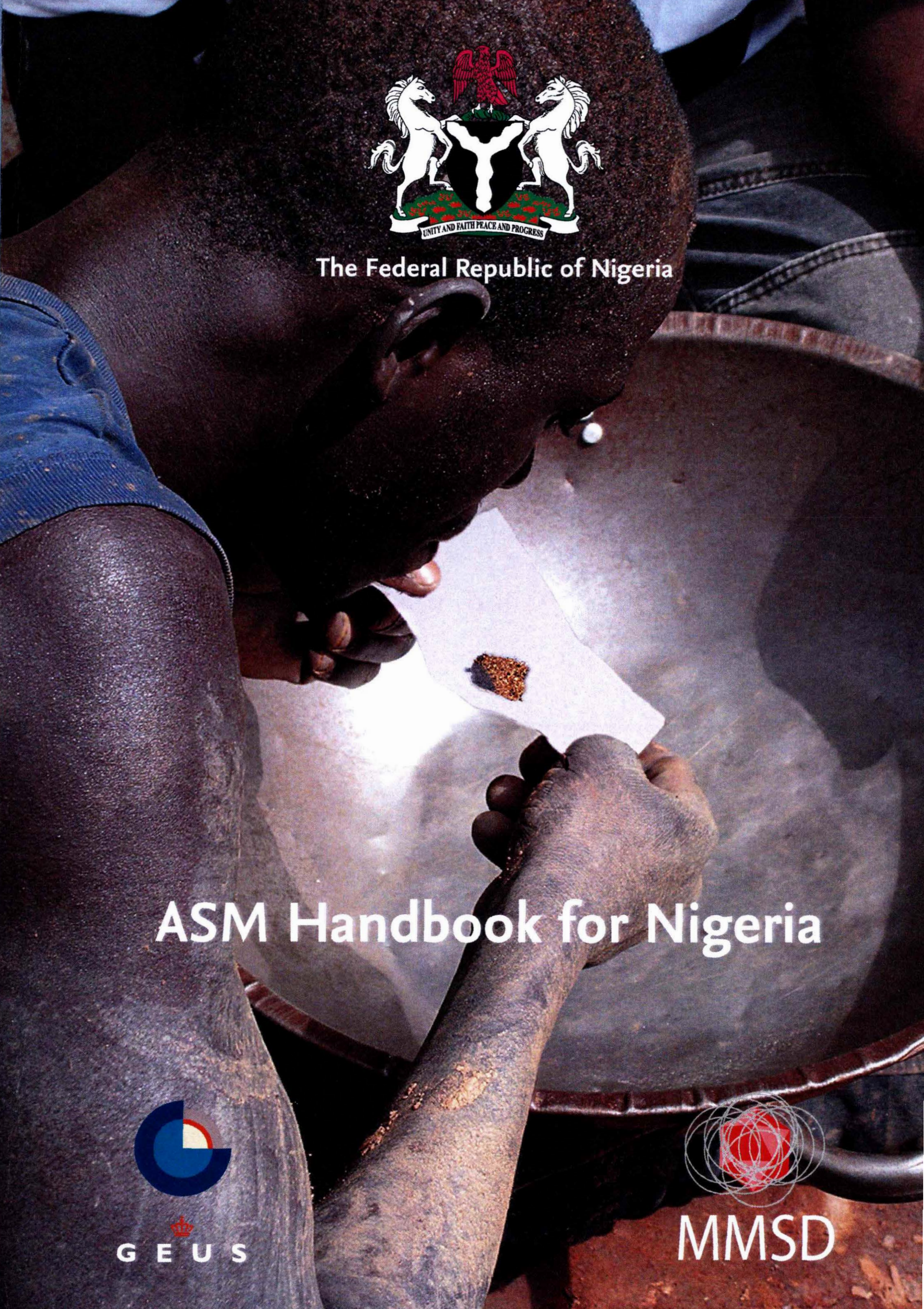

The Federal Republic of Nigeria

ASM Handbook for Nigeria

GEUS

MMSD

FEDERAL REPUBLIC OF NIGERIA

MINISTRY OF MINES AND STEEL DEVELOPMENT
Sustainable Management of Mineral Resource Projects

ASM Handbook for Nigeria

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MMSD

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"Now a miner, before he begins to mine the veins, must consider seven things, namely: the situation, the conditions, the water, the roads, the climate, the right to ownership and the neighbours".

From the book De Re Metallica by Georgius Agricola, 1556 –
Even today the thoughts of Georgius Agricola,
a German scholar and scientist, are appropriate when starting a mining operation.

Contents

Abbreviations

ASM:	Artisanal and Small-scale Mining
CBO:	Community Based Organisations
CDA:	Community Development Agreement
EIA:	Environment Impact Assessment
EL:	Exploration License
FEPA:	Federal Environmental Protection Agency
FMoE:	Federal Ministry of Environment
GEUS:	Geological Survey of Denmark and Greenland
LSM:	Large Scale Mining
MMSD:	Ministry of Mines and Steel Development
MCO:	Mining Cadastre Office
MECD:	Mines Environmental Compliance Department
MID:	Mines Inspectorate Department
MMSD:	Ministry of Mines and Steel Development
NESREA:	National Environmental Standards and Regulation Enforcement Agency
NGO:	Non Governmental Organisations
PMU:	Project Management Unit
QL:	Quarry Lease
RP:	Reconnaissance Permit
SME:	Small and Medium Enterprises
SMMRP:	Sustainable Management of Mineral Resources Project
SMO:	State Mines Officers
SSML:	Small Scale Mining Lease
UNIDO:	United Nations Industrial Development Organization
WPU:	Water Use Permit

Women sorting stones in tailing from ASM operations, Azara, Nasarawa state

1. Introduction

1.1. Why this Handbook?

This ASM Handbook has been written to help improve the performance of ASM operators in Nigeria. Every chapter responds to needs and issues that Nigerian female and male miners have said are important to them.

ASM operators throughout Nigeria face many challenges, the most important being lack of training and information in:

- Geology
- Mining methods
- Mineral processing methods
- Business skills to improve mining operations
- Safety and health practices
- Environmental management.

Communities in ASM areas are affected by the mining operations in many positive and negative ways; therefore this Handbook also provides guidance on how to address issues that are critical to community health, environment and development. This will hopefully lead to:

- Legalisation of ASM operations
- Improvement of safety
- Healthier working conditions and environment
- Access to financing improving operations
- Increased profits

1.2. Who is the Handbook for?

This Handbook was *mainly* written for:

- *Government Officers in MMSD*, who want to fulfil their mandate to support the national poverty reduction objectives by improving the performance of ASM nationally, in their state, county or village

- *ASM operators.* They can use very basic, manual methods or be more organised and somewhat mechanised

- *Community-Based and Non-Governmental Organisations* (CBOs/NGOs) who are trying to develop Nigeria.

The ASM Handbook is a reference guide, training manual and source of information for any individual or organisation who wants to see ASM operators benefit their communities and their country.

1.3. How to use the Handbook

It is our hope that the answer to most questions related to ASM activities in Nigeria are contained within this book - from clay and sand, over gold and coltan to stone aggregate and marble, from ASM close to towns and cities to the ASM in the most remote parts of the country.

You can read the Handbook cover-to-cover to increase your knowledge about all the topics or you can select the chapter or section that seems useful to you and start from there.

Use the handbook as a reference book. Go through the table of contents and find the sections that help you deal with different issues as they come up.

1.4. What is mining?

Mining is the activity of extracting and processing economically valuable minerals. The mining industry also includes finding (prospecting and exploring for) mineral resources to make mining possible.

Some examples of economically valuable minerals are:

- Metals and metal-bearing minerals: gold, copper, zinc, lead, niobium and tantalum (coltan), tungsten (wolfram), tin (cassiterite), aluminium (bauxite) and iron (magnetite)

- Dimension stone: limestone, stone aggregate, granite, marble, kaolin, clay and sand

- Gemstones: diamonds, rubies, emeralds, tourmaline, garnet, beryl and amethyst

- Other useful minerals, such as salt, phosphates and diatomite.

1.5. What is Artisanal and Small-scale Mining (ASM)?

ASM is one of those terms that do not lend itself to a universally acceptable definition. The term can be used to cover a broad spectrum of activities:

- Individuals panning for gold in remote regions of the Brazilian Amazon
- Simple rural folks digging for rock phosphate in Danji/Shini in Sokoto state to the ones digging for barite and tourmaline in Azara, Nasarawa State and Iseyin, Oyo State, respectively.

ASM is a livelihood strategy adopted primarily in rural areas. Minerals extracted by artisanal and small-scale mining by people working with simple tools and equipment, usually in the informal sector, outside the legal and regulatory framework. When not formalised and organised, ASM can be viewed negatively by governments, environmentalists, etc; because of its potential for environmental damage, social disruption and conflicts.

However, The Federal Government of Nigeria and donor agencies like the World Bank believe that ASM can contribute to socioeconomic development in poor and rural areas when properly formalised.

Currently, artisanal and small-scale mining ranges from artisanal miners to small-scale mechanised outfits and within this range are various levels depending on their financial capacity.

Artisanal Mining according to Minerals and Mining Act, 2007 means:

- Mining operations limited to the utilisation of non-mechanised methods of reconnaissance, exploration, extraction and processing of mineral resources within a small-scale mining lease area.

Small-scale Mining according to Minerals and Mining Act, 2007 means:

- Artisanal, alluvial and other forms of mining operations involving the use of low-level technology or application of methods not requiring substantial expenditure for the Conduct of Mining Operations within Small-Scale Lease Areas.

The ASM Department in the Ministry of Mines and Steel Development points out the following charateristics of ASM operation in Nigeria:

- ASMs exploit marginal or small mineral deposits

- Application of very basic and rudimentary mineral extraction techniques
- Lack or low level of mechanisation
- Unskilled personnel are involved at all levels of operation: technical and managerial
- Inefficient mining and processing techniques are most often adopted
- Low level of production
- Poor access to markets and support services
- Chronic lack of investment capital
- Low level of consideration to health and safety
- Have significant negative impact on the environment
- Low level of income amongst operators
- Operating without legal mining titles
- Gender issues and child labour
- Conflicts.

1.6. History of mining in Nigeria

For over 2,400 years, the mineral resources of Nigeria have been exploited using artisanal methods – from basic clays to base metals and gold.

Between 400 BC and 200 AD vibrant societies and kingdoms such as the Nok culture exploited iron and clay deposits and produced the famous terracotta figurines. Between the 11th and 12th century, the Ife and Oyo Kingdoms mined and used a variety of minerals. From 1903 to 1940, ASM operation dominated mining in Nigeria, particularly for tin. From 1970 till date, ASM has continued to dominate mining in Nigeria.

ASM accounts for over 90% of solid minerals mining in the country. Minerals produced include, but are not limited to, gold, barite, limestone, gemstones and gypsum. More than 107 ASM sites are identified in the country and more than 200,000 people are directly involved (Wardell Armstrong, 2008).

Mining gypsum i Alamgafe, Yobe State

Mining operation in Kaduma State

2. The obligations of the Department of Artisanal and Small-Scale (ASM) Mining to the Artisanal and Small-Scale Miners

The obligations of the Ministry of Mines and Steel development (MMSD) through the Artisanal and Small-Scale Mining Department are in accordance with the Nigerian Minerals and Mining Act, 2007, to provide Extension Services to mining communities in the following areas:

- *Prospecting and exploration services shall be provided for registered mining co-operatives to determine the geological setting, structure and nature of occurrence, quantity and quality of minerals being mined*
- *Provide mineral testing standards and the determination of mineral grades*
- *Provide proven mineral reserve evaluation including feasibility reports*
- *Assist small scale miners on mine design and planning suitable for the deposit*
- *Teach adequate skills in mining to small scale and artisanal miners and regularly introduce them to new mining technology*
- *Provision of teaching equipment and plant for hire on an arrangement with manufacturers of leasing companies and proper linkage and guarantees provided*
- *Introduce appropriate mineral processing technology skills in order to meet market demands and optimise profit*
- *Provision of environmental impact assessment report and detailed guidelines on waste and tailing disposal*
- *Introduction of health and safety procedures in the mines, provision of water and health facilities to large mining camps*
- *Holding regular workshops to update miners' knowledge about legal, marketing, business skills and infrastructural support, facilitate mineral testing and the determination of mineral grades*
- *Facilitate mineral testing and the determination of mineral grades.*

3. Basic geology as guide on how to discover mineral deposits

Commodities mined by ASM operators occur at or near the Earth's surface. Some of them, however, were formed deep in the Earth's crust. The description below aims at giving, in brief, the ASM operators an understanding of the geological processes and the environment in which the commodities in question were formed. This may help the miners to discover further deposits.

The continents consist of rocks of different origin (Fig. 3-1). Some of the rocks are remnants of volcanic eruptions such as lava and volcanic ash others are sediments such as clay, sand and gravel all deposited on the Earth's surface. Others are what we call metamorphic rocks. Metamorphic rocks formed deep in the crust of the Earth where sediments and volcanic rocks were heated to temperatures between 300 and 1100°C and were deformed due to pressure.

How did the sedimentary and volcanic rocks end up deep in the crust of the Earth? This happens when more and more sediments and material from volcanic eruptions are piled on top of each other. Another way is the formation of mountains, where the Earth's surface is compressed and rock units are thrust on top of each other. The rock pile will gradually sink into the crust where high pressure and temperature prevail. Layers of sand will be consolidated and metamorphosed into sandstones and quartzites, and clay into shales and schists. Well-developed foliation and folds due to rock deformation are characteristics of metamorphic rocks.

Hydrothermal deposits

There are basically two types of hydrothermal deposits; (1) magmatic-hydrothermal, and (2) hydrothermal without a relationship to magmatism.

At high temperatures some of the rocks start to melt and eventually form magmas, which are large bodies of molten rocks called igneous rocks. These magmas are gradually squeezed further up in the crust, where they start to cool and crystallise. Many elements such as gold, tantalum and boron cannot be accommodated in the minerals which crystallise in the magma, but are concentrated at the top of the magma chambers. When pressure builds up, the rocks above start to crack and fluids from the top of the magma chamber flow up into the cracks. These hot fluids are called hydrothermal fluids. The cracks are gradually filled with quartz and with the elements, which could not be accommodated in the magma such as gold, tantalum-forming tantalite and boron-forming tourmaline (rube-

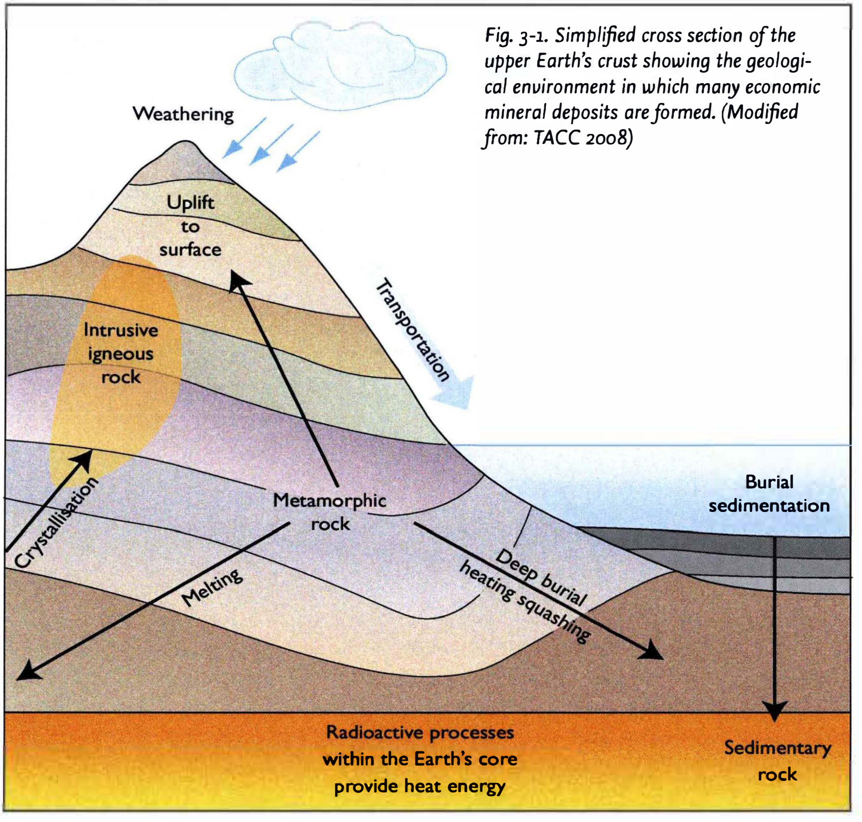


Fig. 3-1. Simplified cross section of the upper Earth's crust showing the geological environment in which many economic mineral deposits are formed. (Modified from: TACC 2008)

lite) found in quartz veins. These types of deposits are collectively called magmatic-hydrothermal deposits and are found close to the igneous rocks, commonly granite.

The second type is found in the form of quartz-carbonate veins or as impregnations in sediments and volcanic rocks. These rocks are often strongly overprinted and do not look like their original counterparts. Such unusually looking sediments or volcanic rocks can be used as a tracer to find hydrothermal deposits. These deposits also form from hot fluids that migrated through the rock, but have not been formed from crystallising melt. They could be old rain water that percolated through the rocks for some time picking up the elements of interest that can be gold, barium, copper, lead and zinc. Barium forms barite that is very often associated with a massive sulphide accumulation hosting a copper-lead-zinc mineralisation. Gold mineralisation is often hard to distinguish from the first type of hydrothermal deposits, because it is also hosted within quartz veins.

Magmatic deposits

There are again two types of magmatic deposits; (1) light-coloured, coarse-grained rocks as dykes, and (2) dark to black, medium-grained rocks.

Sometimes, part of the magma is squeezed into the cracks where it cools and crystallises to a coarse-grained rock type, namely pegmatite, which occurs in dyke-shaped bodies. Pegmatites often contain rare minerals such as tantalite, emeralds and rubelite.

During crystallisation of magmas, economic minerals such as chromite, magnetite, nickel and platinum will appear as bands in the magmatic rocks. These deposits can be recognised by checking for magnetite and for massive and semi-massive sulphide occurrences, because it is those that host nickel and platinum. These types of mineral deposits called magmatic deposits are a target for small-scale miners.

Surficial deposits

This type of deposit was formed at or near the surface. Some were later brought into the crust but at very low levels and were thus not subject to high temperature and pressure. Nigerian examples comprise gypsum, bentonite and diatomite deposits.

Gypsum was formed in restricted basins, i.e. salt lakes, where sediments such as clay were brought in by rivers. During prolonged dry conditions the basins dried out, and the components dissolved in the water, such as calcium and sulphate, were precipitated on the floor together with the clay minerals. During low temperature and low-pressure conditions, gypsum deposits were formed consisting of impure layers of shale and gypsum and, locally, very pure gypsum layers may have formed.

Bentonite is a clay mineral formed by surface weathering of ancient very fine-grained volcanic rocks. These deposits are found close to active and old inactive volcanoes.

Diatomite represents accumulations of algae (diatoms) which lived in lakes, in the tidal zones and in oceans. When the diatoms died they accumulated on the bottom. Later compaction resulted in a very light white stone.

When continental rocks are eroded, the material is flushed down the rivers. Also

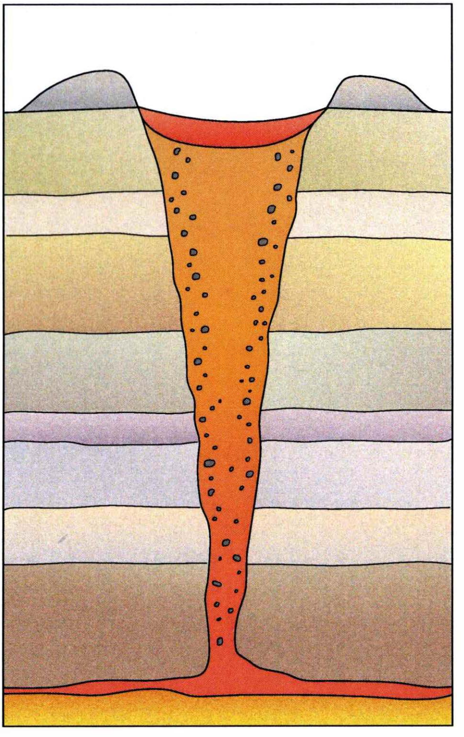


Fig. 3-2. Simplified cross section of a kimberlite pipe showing parts of the crust from which boulders were carried with the kimberlite magma towards the surface of the Earth. The dark red-coloured upper part of the kimberlite shows the weathered soft blue and yellow ground kimberlite. (Modified from: TACC 2008)

primary mineral deposits can be eroded. On their way down-stream, the minerals are separated according to density whereby so-called placer gold deposits can be formed. These deposits can be found in dry river beds as well as in rivers and streams, mainly where the flow-velocity of the water changes rapidly.

Kimberlite

Kimberlite is the host rock of diamonds. Diamonds have recently been found in Nigeria. It is thus appropriate to give a short description of the geological setting of diamonds.

Diamond is a high-pressure form of the element carbon. Amongst the low-pressure forms graphite and coal can be mentioned. Diamonds occur deep down in the Earth. They are brought up to the surface by volcanic eruptions, which are not the type that produces the volcanoes commonly seen on the surface of our planet, such as Kilimanjaro. These volcanic rocks originate much farther up in the crust. Kimberlitic volcanism originates from depths at or below 150 km. Kimberlitic magmas pick up diamonds on their way up. When the volcanic eruption approaches the surface of the Earth a funnel-shaped body filled with kimberlite is formed. This is called a kimberlite pipe (Fig. 3-2). Dykes of kimberlite are abundant below and around the funnel-shaped kimberlite pipe.

In kimberlite small and large blocks of country rocks are abundant. Those blocks were torn off from the surrounding rocks in the crust and brought towards the surface, when the kimberlitic magma rose. In exposed kimberlite pipes, the kimberlite has been altered and now appears as a very soft rock with colours ranging from yellow to blue (called yellow ground and blue ground). These soft rocks can be dug with shovels and diamonds are easily separated out of the soft rock merely by passing the soft rock with water through a sieve. They are thus easy targets for ASM.

The concentration of diamonds in kimberlite is very low, but if the diamonds are of good quality the yield is very high. The weight of diamonds is in carats and five carats equals one gram. The largest diamond ever found is the Cullinan diamond found on 26 January, 1905, in Premier Mine in South Africa weighed 3106,75 carats (621,35 g).

3.1. How to discover a mineral deposit

This description focuses on how to find the minerals and mineral occurrences frequently exploited by small-scale miners in Nigeria. The mineral deposits are divided into three classes: 1. Metalliferous minerals; 2. Industrial minerals and 3. Gemstones.

Mineral deposits are discovered in two ways:

- **Luck.** This is how the majority of mineral deposits are discovered. Observant people walk the fields and notice strange looking stones lying on the ground. They pick them up, crack them open and wonder whether the stones have any value. Rusty rocks and stones, black coating and bluish-greenish colours often betray metalliferous deposits such as copper, lead and zinc.

- **Hard work.** In areas where mining is or has been carried out, there is often a good chance of finding more mineable mineral deposits. This requires mostly tedious work involving extensive sampling either by digging pits and trenches, sampling river and stream sand and gravel or expensive geophysical investigations.

3.1.1. *Exploration methods for ASM*

Most ASM operators have limited financial means to embark on sophisticated exploration methods. The most common way for ASM operators to find new deposits is to trace the geological unit, which is known to host economic deposits and then search the surface soil for possible indications of the deposit. If they find such indications they must dig trenches in order to see fresh rock. If the ASM operators have access to aerial photographs and are focussed on mining gold-quartz veins then they may be able to see a regional structural pattern, which may host more gold-bearing quartz veins.

3.2. How to identify interesting minerals

A minimum knowledge of what the mineral looks like is required when exploring for a mineral deposit. Minerals are the building blocks of rocks. A rock consists of one or more minerals. Minerals can be indentified by a number of characteristics of which the following represent the first steps in the identification of the mineral:

- Colour
- Transparency/translucency
- Hardness
- Magnetic or not

Minerals that may interest ASM vary in colour from pitch black to white. They may also vary in hardness or have particular physical properties such as being attracted by a magnet or not.

Mineral	Mohs hardness	Absolute hardness	Chemical formula
Diamond	10	1600	C
Corundum	9	400	Al_2O_3
Topaz	8	200	$Al_2SiO_4(OH^-,F^-)_2$
Quartz	7	100	SiO_2
Orthoclase Feldspar	6	72	$KAlSi_3O_8$
Apatite	5	48	$Ca_5(PO_4)_3(OH^-,Cl^-,F)$
Fluorite	4	21	CaF_2
Calcite	3	9	$CaCO_3$
Gypsum	2	3	$CaSO_4 \cdot 2H_2O$
Talc	1	1	$Mg_3Si_4O_{10}(OH)_2$

Fig. 3-3. Mohs Hardness Scale.

Fig. 3-4. White quartz richly mineralised with gold. Centimetre-scale for estimating size. Sample from Lasa, Borno State.

The hardness of minerals helps identifying them. The scale on Fig. 3-3 shows ten minerals representative of each hardness group, from Mohs Hardness scale. In general, a mineral from one group can scratch the minerals in the lower groups. Quartz can scratch all minerals in groups 1 to 6. Diamonds being the hardest mineral and can scratch all minerals. A fingernail has the hardness just above 2, so it can scratch minerals from group 1 and 2. A pocket knife has hardness of 5 and can scratch minerals in groups 1 to 4. Quartz has hardness just above glass and can thus scratch a bottle.

Characteristics of the most common minerals extracted by ASM in Nigeria are listed below:

3.2.1. *Metalliferous minerals*

Gold mostly occurs as very fine grains in quartz (Fig. 3-4). Hardness 2,5 to 3. However, the grains are mostly too small to be seen. Gold often has a rich yellow colour but may also occur in light yellow grains. The colour depends on how much silver is included in the gold. The more silver the more light yellow the gold looks. Gold is a soft mineral which can be easily scratched with a knife.

Fig- 3-5. Galena (lead mineral) with characteristic metallic grey lustre and cubic shapes. The yellow mineral is pyrite consisting of iron and sulphur. Sample is 13 cm long, and is from Gwana, Bauchi State.

Fig. 3-6. Sphalerite (zinc mineral) with dark-brownish colour. Small amounts of galena can be seen. The yellow mineral is pyrite consisting of iron and sulphur. Sample is 15 cm long, and is from Zumo, Adamawa State.

Fig. 3-7. Chalcopyrite (copper mineral) with characteristic yellowish colour. Sample is 10 cm long, and is from Gwana, Bauchi State.

Galena is the main source of lead but also of silver. Hardness 2.5. It is very easy to identify. It is very heavy, it looks metallic. It has a grey colour and is often cubic in shape (Fig. 3-5). It can easily be scratched with a knife. It is not attracted by a magnet. Galena is often found together with zinc and copper minerals such as sphalerite and chalcopyrite.

Sphalerite is the main source of zinc. Hardness 3.5 to 4. It is dark brown to light honey-coloured and can easily be scratched by a knife (Fig. 3-6). It is not attracted by a magnet. It is often rather fine-grained and can thus be difficult to identify. The mineral is often found together with galena and chalcopyrite.

Fig. 3-8. Tantalum-rich columbite (tantalite) as veinlets in quartz and as loose crystals. Samples are about 2 cm long, and are from Andaha, Nasarawa State.

Chalcopyrite is the main source of copper. Hardness 3.5 to 4.5. It can be scratched by a knife and it is not attracted by a magnet. The colour is yellow, but not the same yellow as gold (Fig. 3-7). The chalcopyrite is yellow with a faint greenish hue. Chalcopyrite is often betrayed by a bluish-green mineral called malachite, which occurs in cracks and on surfaces of rocks containing chalcopyrite. Malachite is very soft.

Tantalite/columbite is a black, very heavy mineral, which is not attracted by a magnet, but has the same dull black colour as the strongly magnetic mineral magnetite (Fig. 3-8). Hardness 6. The mineral has several names. The trade name is coltan. It is called columbite or tantalite depending on which metals are dominant, niobium or tantalum. It cannot be scratched by a knife. The mineral is the source of a number of metals of which the most prominent is tantalum which is a key metal in every mobile phone. The mineral is often found together with coarse, centimetre-scale quartz. Tantalite often contains high amounts of uranium. Uranium is highly radioactive and produces the radioactive gas radon. If the mineral is stored indoors the risk of people inhaling it is very high.

3.2.2. *Industrial minerals*

Gypsum is a soft grey to white mineral. It is the dihydrate form of calcium sulphate ($CaSO_4.2H_2O$) and is found in association with anhydrite ($CaSO_4$, the anhydrous form of calcium sulphate) and shale. It has a specific gravity of about 2.3 and a hardness of 2 with the anhydrite having a specific gravity of about 2.85 and a hardness of about 3. They can both be scratched by a finger nail and are sometimes transparent, but mostly not (Fig. 3-9). Gypsum often forms in platy crystals and is not attracted by a magnet.

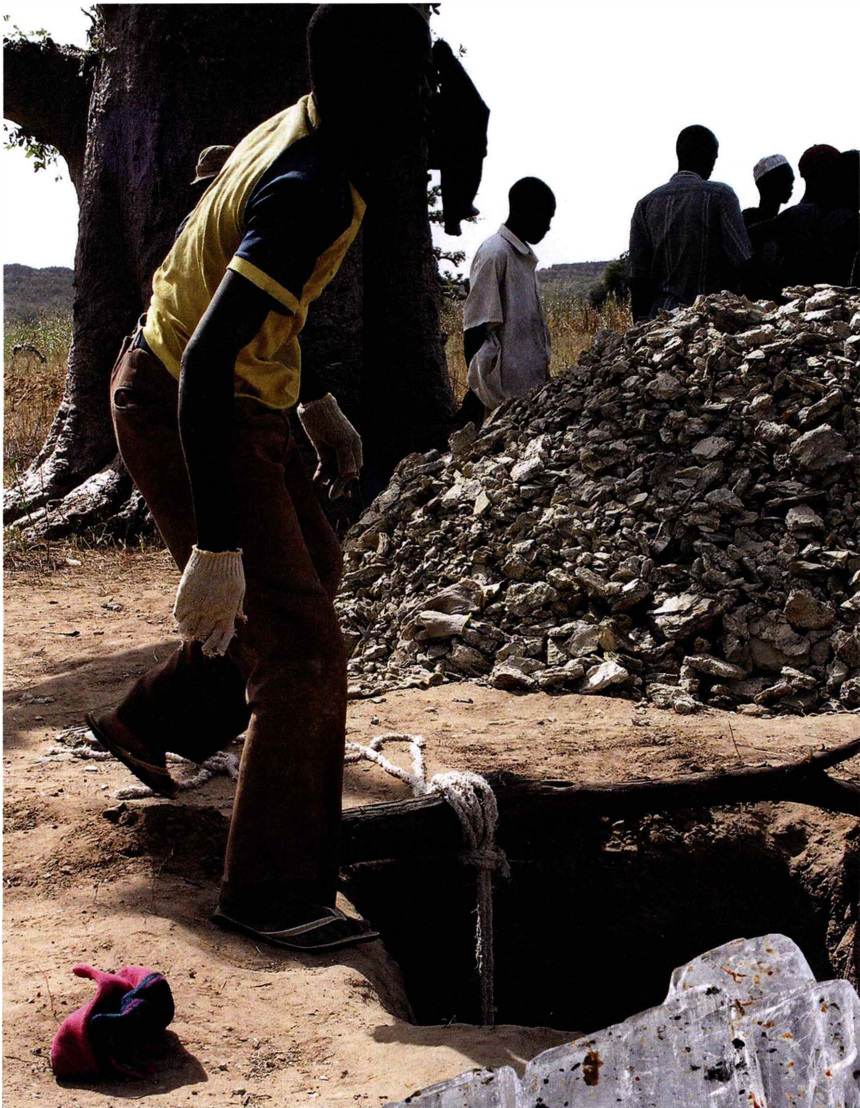


Fig. 3-9. Gypsum of the transparent type (4 cm long sample) and of the white, earthy non-transparent type next to the shaft from where it was dug out. Azara, Nasarawa State.

Fig. 3-10 Barite, white partly translucent. Sample is about 10 cm long, from Gabu, Cross River State.

Barite also called barite, cawk, tiff or heavy spar, is barium sulphate having a calculated specific gravity of 4.5, but inclusions of other minerals may reduce this figure considerably. It occurs in many colours, although shades of white to gray and black are most common (Fig. 3-10). Barite has a hardness of 2.5 to 3. It is non-magnetic as well as being insoluble in water and acid.

Bentonite is a hydrous aluminium silicate composed of essentially clay mineral and smectite (montmorillonite). It is commonly divided into the high-swelling or sodium, low-swelling or calcium, and moderate-swelling or intermediate types.

It ranges in colour from white over yellow, olive green and brown to blue and has a characteristic soapy texture and waxy appearance. Weathered sodium bentonite has a distinctive popcorn texture while that of calcium bentonite has an alligator skin texture (Carr, D. D., 1994).

Diatomite is not a mineral, but a white rock that consist of remnants of tiny small algae (diatoms). Diatomite is soft and can be cut with a knife. A characteristic feature with diatomite is that it is has a chalky appearance and is very light (Fig. 3-11) possessing a bulk density of about 0.3 to 0.5 g/cm3.

The colour may vary from snow white in a pure, well-bleached and dry deposit, to olive green or darker where substantial organic remains are still present and where the moisture content is high. It may exhibit stratification, caused by either, or both, sedimentation of particularly flat beds or a large number of discoid diatoms, or by seasonal rhythmic deposition of clay and other impurities.

Fig. 3-11. White, very light diatomite being dug out of the ground, Alamgafe, Yobe State.

Mineral	Chemical formula	Commercial use
Gold	Au	Jewelry and electronics
Galena	PbS	Source of lead and silver
Sphalerite	ZnS	Source of zinc and cadmium
Tantalite/columbite	$(Fe,Mn)(Nb,Ta)_2O_6$	Tantalum used in electronics
Gypsum	$CaSO_4.2H_2O$	Cement and Plaster of Paris
Barite	$BaSO_4$	Drilling mud for oil drilling
Bentonite	$(Al,Mg)(OH)_2Si_4O_{10}$	Drilling mud for oil drilling
Diatomite	Not a mineral	Dynamite, beer and wine
Rubelite		Gemstone
Ruby/sapphire	Al_2O_3	Gemstone and abrasive
Diamond	C	Gemstone and for drill rods

The chemical composition and some of the uses of the described minerals.

3.3. Types of mineral deposits

Exploitable mineral deposits can be divided into the following classifications:

1. Vein type deposits
2. Layered /banded deposits
3. Placer/regolith deposits

3.3.1. *Vein type deposits*

This is one of the most frequent types of mineral deposits exploited by small-scale miners. Veins are irregular bodies cutting through the wall rocks with a sharp contact. Veins range in width from a few millimetres to several metres. They can be hundreds of metres long and extend deep below the surface. Following a vein can be very difficult. Sometimes the vein is very wide sometimes it pinches out and sometimes it disappears. In the latter case, the vein may have died out or it has just been offset. The problem is to find in which direction it is offset. The vein may pinch out downwards or continue below the reach of small-scale miners. Typical examples of vein type deposits are gold quartz veins, lead-zinc-copper veins and barite-rich veins.

3.3.2. *Layered or banded deposits*

This type is characterised by the minerals occurring as bands or layers in their host rocks. The bands and layers are generally very extensive and can be followed for kilometres. They range in thickness from a few millimetres to many tens of metres.

Typical examples of this type are gypsum, bentonite and diatomite deposits.

3.3.3. *Placer/regolith deposits*

These deposits occur mainly in loose sediments or soils. Placer deposits are formed in river systems and consist of sand, gravel and boulders with minor amounts of economic minerals. Regoliths are soft deposits, mainly soil, which were formed by weathering of hard rocks. Placer and regolith deposits are surface deposits and thus easy to outline.

A typical example of placer deposit is gold. A typical example of a regolith deposit is tantalite/columbite mined near the village Jyelu.

3.4. How do minerals frequently exploited by ASM in Nigerian occur?

3.4.1. *Metalliferous deposits*

Gold-bearing quartz veins. This is the most common type of gold deposit exploited by ASM. The veins vary in width from a few millimetres to several metres. The veins can be single or appear as many narrow parallel veins. The quartz is often fairly coarse-grained. Bluish-grey to grey quartz is very often associated with the richest gold mineralisation. Milky-white quartz is often barren or contains less gold. The veins can be followed up to several hundred metres, but often they suddenly disappear and it is a major problem for the ASM to find the continuation of the vein if there is any. There is no preferred orientation of the veins. They can be flat-lying or steeply dipping, but usually, once defined, they don't change orientation along strike and down-dip.

There is no relation between gold content and width of the vein. Very narrow veins may have high gold contents and wide veins have low contents and vice versa. The gold is generally too fine-grained to be seen, but millimetre- to centimetre-sized nuggets are sometimes found.

Gold-bearing quartz veins often consist of gold and quartz only, and those are the easiest for ASM to exploit. However, other minerals are locally found in the gold quartz veins. Lead, zinc and copper minerals are locally abundant.

Placer gold. Placers are river sediments consisting of sand, gravel and boulders, which originate from the surrounding and upstream land. If there is gold along the path of the rivers then the gold will be washed out of the land and end in the river sediments. It is characteristic that the gold is found between boulders and in coarse-grained sand rather than in the fine-grained sand. Much of the gold in a placer deposit is fine-grained but locally nuggets are found. These can weigh more than 50 kg but are generally smaller. Nuggets are made of tiny gold particles which assembled to nuggets. Gold nuggets are collector's item and often fetch a higher price than the equivalent gold price.

Lead, zinc and copper occur in many types of rocks. However the ones which are of interest to ASM are veins. These veins are often steeply dipping and occur in a variety of host rocks such as sandstones. The veins can be metres wide and consist of coarse-grained galena (lead mineral) and fine- to medium-grained zinc and copper minerals. The veins can often be followed for hundreds of metres, and then they bifurcate or disappear. The minerals are often massive or occur as stringers together with quartz.

Fig. 3-12. Steeply dipping barite vein partly mined out by ASM operators, Azara, Nazarawa State.

Tantalite/columbite occurs in quartz veins or in a rock type called pegmatite. Pegmatite is a coarse-grained rock which occurs as irregular bodies with sharp contacts to wall rocks. Tantalite in pegmatite is generally not a target for ASM operators because pegmatite is very hard, which makes it difficult to extract the tantalite. Furthermore, the amount of tantalite grains in pegmatite is often low. ASM operators can therefore only exploit tantalite if the pegmatite has been weathered over time and has left the tantalite as up to centimetre-sized loose grains in the soil covering the pegmatite.

3.4.2. *Industrial minerals*

Gypsum occurs mainly as thin layers in fine-grained shales. The gypsum layers are from a few millimetres to several centimetres wide. They can be followed in the same level for tens to hundreds of metres. In the smaller layers, gypsum may have a fibrous texture. Some of the thin gypsum layers are very pure and transparent. They are well suited for producing Plaster of Paris. Most of the gypsum, however, is mixed with shale and is best suited for cement production.

The Nigerian gypsum is found in association with shale in sedimentary formations evidenced by, amongst others, the Nafada, Bajoga, Fika gypsum fields in the Gombe and Yobe states as well as those located in the Gboko and Wurno in

Benue and Sokoto States. Gypsum deposits can be discovered by scouting in salt formations for gypsum or anhydrite crystals along river banks or sides of gullies left behind by gully erosion followed by scout pitting around the area where gypsum or anhydrite crystals are found.

Barite occurs mainly in vein and cavity fillings, residual deposits and bedded formations. The veins can be up to several metres wide and be traced for up to hundreds of metres (Fig. 3-12). The veins can occur as single veins or bifurcating systems. Barite deposits often contain lead and zinc minerals as well as quartzite, calcite, iron minerals.

Nigerian barite deposits are found in vein and cavity filling as well as in residual deposits. These deposits are mostly discovered by scout searching for distinctively heavy but moderately soft white to gray coloured rocks (barite). The presence of these rocks can be confirmed by trenching and / or pitting if the deposit is of the residual type.

Bentonite is mainly found intermixed with other minerals like gypsum and occurs in layers which range from a few centimetres to metres in thickness. The layers can be traced for long distances.

Bentonite is mostly formed as a result of in situ weathering of volcanic ash or tuff. It is found in bedded formations that can be extensive or exist as small lens-shaped bodies with a limited lateral extent.
Bentonite deposits are generally characterised by the presence of high surface cracks especially in areas where the bentonite clay occurs near the surface.

Bentonite deposits are discovered by scout searching for the characteristics weathered features of alligator skin and popcorn textures as well as the massive cracked surfaces followed by pitting to confirm occurrence.

Diatomite occurs in centimetre to metre thick layers, interlayered with shale. The layers can be traced for hundreds of metres.

Diatomaceous silica is not pure silica but contains other intimately associated elements. Associated with the diatomaceous silica, and integrated as part of the diatomite, may be variable amounts of organic matter, soluble salts, and particles of rock-forming minerals that were co-deposited or precipitated with the diatom frustules. Sand, clay, carbonate, and volcanic ash are typical common contaminants.

Diatomite deposits are discovered by locating the occurrence of the distinctive very light and white diatomite masses followed by pitting or trenching to confirm its presence.

3.4.3. *Gemstones*

Gemstone deposits
Ruby and sapphire often occur in metre wide bands or lenses which can be a few hundred metres long.

Rubelite, which is a variety of the mineral tourmaline, is found in metre wide zones of pegmatites which can be traced for hundreds of metres and can be mined tens of metres down. The near surface deposits are altered and can be mined by digging, whereas deeper deposits are mined using blasting and hand sorting.

Amethyst is associated with quartz-rich pegmatites which can be metres wide and traceable for many tens of metres.

Diamonds occur in a rock called kimberlite which is of volcanic origin. The diamondiferous kimberlites are funnel shaped with diameters up to many tens of metres.

Gemstones are also often found in river gravel.

3.5. How to follow-up on a promising discovery

When a promising mineral occurrence has been found, the next step is to discover whether it is big enough to start a mining operation. This can be done in a number of ways depending completely on the type of commodity and the geometry of the deposit.

3.5.1. *Vein type deposits*

When the vein has been located, its width must be found as well as how far it can be traced. The concentration of the commodity must also be estimated.
In order to locate the vein, small pits or trenches have to be dug down to the bedrock. The number of trenches and pits to be dug depends on the size of the vein. Once the vein is located and the width and length have been determined, the grade of the vein has to be evaluated. This will require sampling and analysing a number of samples across the width of the vein and along the vein.

If the size and grade are satisfactory, the next step is to obtain a mining licence.

3.5.2. *Layered or banded deposits*

This type of deposit requires a different approach. Pits and shafts must be dug to determine the thickness of the mineralised layer or band and to determine how far below the surface the deposit is located. When this has been done, more pits must be sunk in an appropriate pattern to determine the extent of the deposit. Sampling through the thickness of the deposit and at several sites will determine whether the deposit has the potential to create a mine.
The next step is to obtain a mining licence.

3.5.3. *How to find the source of placer gold or tantalite showing*

Specks of gold or tantalite are sometimes found in rivers and streams. The number of specks or grains is so big that they may betray an unknown metalliferous deposit somewhere upstream from the point where the specks have been found.

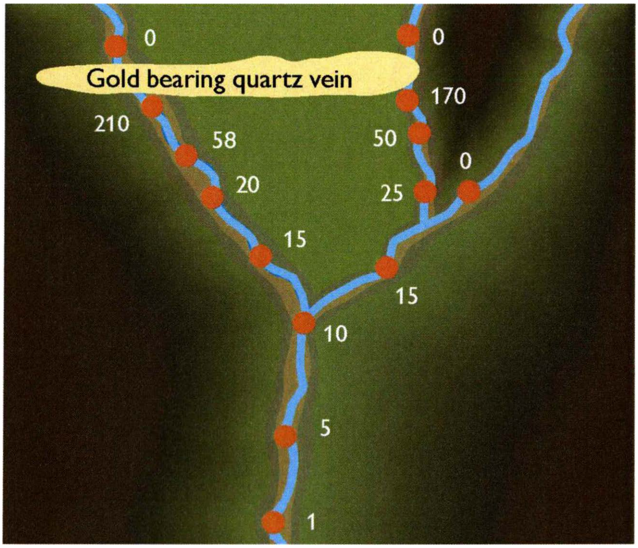
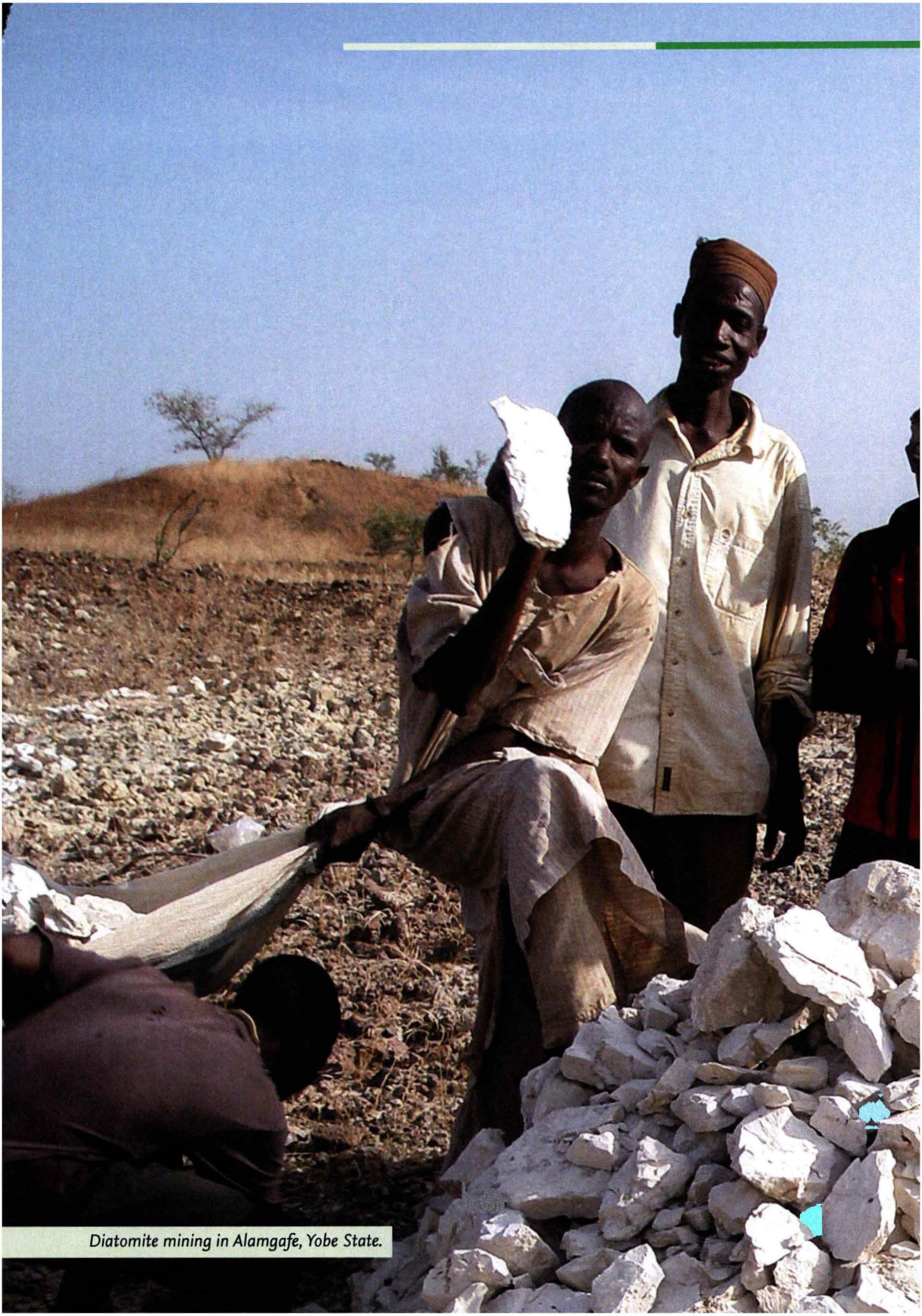


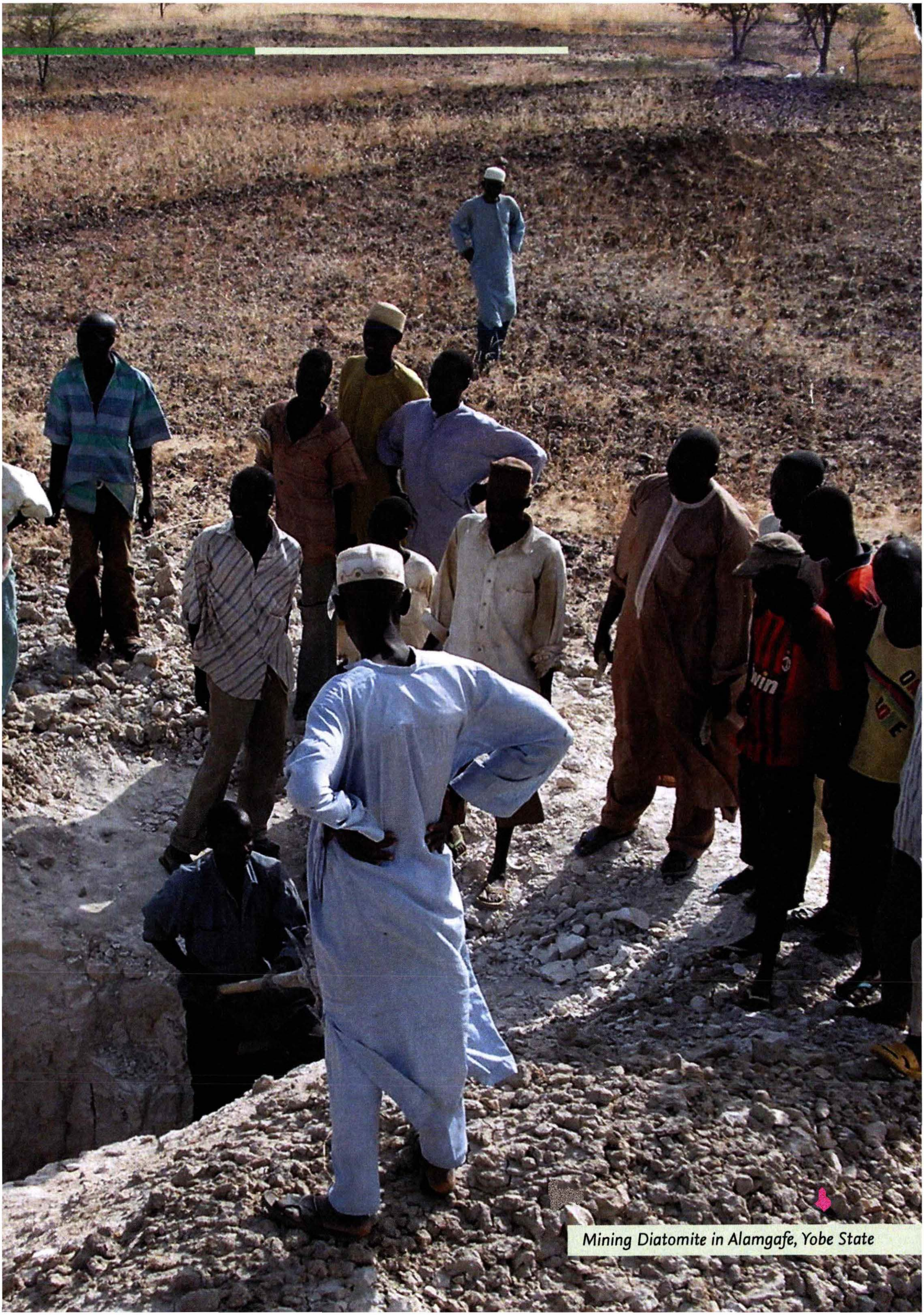
Fig. 3-13. Sketch map showing how to find a gold deposit by collecting samples of river sand and gravel. In the main river a few grains of gold is found. Upstream more gold grains are found. Farther upstream in both river branches, large number of gold grains are found until one branch is barren. The two other branches prove to contain a higher and higher number of gold grains going upstream until no more gold grains are found. Then the gold deposit must be situated below the sample sites with no gold grains. The numbers indicate how many gold grains are found at each sample site.

It is often possible to trace where the gold or tantalite came from. The trick is to collect samples of sand and gravel in the stream and use a gold digger's washing pan to concentrate the sample. Then the number of gold specks is counted. Next sample is collected upstream, concentrated and number of gold specks counted. The closer you get to the source of the gold the more gold specks occur in the pan. The procedure is to collect samples upstream until no more gold specks are found. Then the deposit must be below the spot with no specks and above the last sample with many gold specks (Fig. 3-13). The distance from the spot in the river where you found the first specks of gold up to where the gold came from may be up to many kilometres.

A similar procedure can be used for tracing the origin of tantalite. This does, however, require analyses of the mineral concentrates since it is not possible to distinguish small grains of tantalite from other black heavy mineral grains. The majority of the black grains are mostly a mineral called magnetite, which can be separated from the other black minerals with a simple magnet.



Diatomite mining in Alamgafe, Yobe State.



Mining Diatomite in Alamgafe, Yobe State

4. How to apply for ASM-related mining titles

As an ASM operator in Nigeria you need to get a licence to legally mine and there are many reasons for miners to get a licence. These include:

- *Training and support:* Miners are more likely to get the training and support they need from the government to help them make more money, mine more safely and protect the environment in their activities
- *Secure tenure:* Licensed miners cannot be kicked out of their mining area by other land developers, exploration companies or mining companies while their licence is valid
- *Access to financing:* Licensed miners can use their mine as collateral to get bank loans, helping them get the equipment and tools they need to improve their operations. Grant programmes for small enterprises usually need applicants to be licensed also
- *A voice with Government:* It is easier to approach local leaders, the DGSM and other Government officials to voice your issues and concerns when you are working legally, paying taxes and fees and the government recognises you as contributing to local and national development!

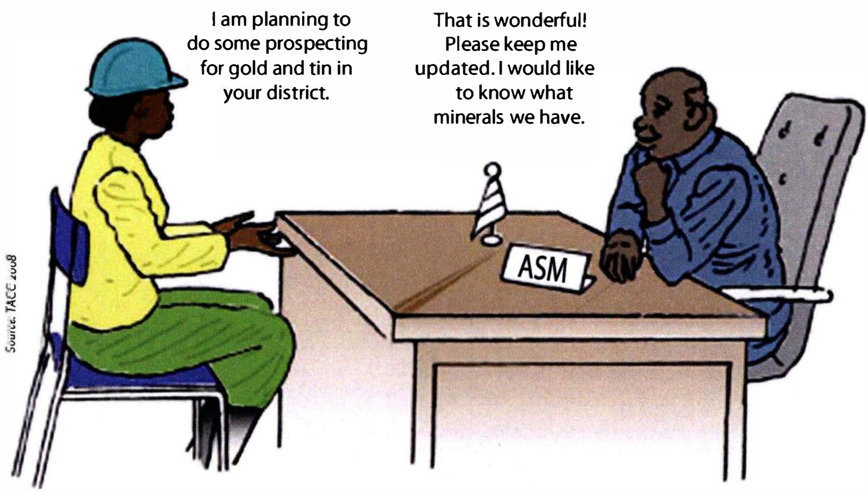


Fig. 4-1. If you intent to start an ASM operation you should see the ASM officer in your state and update him or her on you prospecting activities.

Having the piece of paper that says you are licensed is not enough! As a mining right holder, you have obligations to fulfil. This chapter deals with the steps to take to get your legal right to mine and the obligations required of licence holders. This is all contained in the Nigerian Minerals and Mining Act, 2007, National Minerals and Mining Policy, 2008 and Minerals and Mining Regulations, 2011 and parts of other legislations (related to environment, land, forests, national parks, labour and other sectors).

In many ways ASM operators are very different from large-scale miners (LSM) in terms of the resources they have and legislation they have to comply with. Because of power imbalances between the ASM and LSM, access to resources can be somewhat unequal and illegal miners can easily be displaced from where they are working!

ASM activities are a major challenge because they are mainly informal and disorganised, can have negative environmental impacts and usually work outside the reach of regulators and tax collectors. A policy that provides consistent and easy-to-access incentives to make the operation legal is believed to be the foundation for technical, socio-economic and environmental improvements of ASM.

4.1. Mining Legislation

Legislation (or statutory law) is a law which has been promulgated (enacted) by Parliament or other governing body. It can refer to a single law or the collected body of enacted law. The Mining Legislation of Nigeria makes up the rules and procedures needed to fulfil the goals and objectives of the Mineral Policy of Nigeria. These laws and regulations try to be investor friendly while recognising the limited technical possibilities and financial difficulties faced by ASM operators in Nigeria.

Mine Cadastre Office (MCO) is responsible for:

- Receiving and disposing of applications for the transfer, renewal, modification, relinquishment of mineral titles or extension of areas
- Maintaining a chronological record of all applications for mineral titles
- Addressing the issues of transparency in the grant/access to titles
- Dealing with matters of overlapping titles.

Five Mining titles are currently relevant to ASM operations in Nigeria. These are:

- Reconnaissance Permit
- Exploration Licence
- Small-Scale Mining Lease
- Quarry Lease
- Water Use Permit.

The first two apply mainly to the small-scale mining companies with the last three expected to cover the needs of the ASM operators.

Mine Inspectorate Department (MID) is responsible for:

- Supervision of all reconnaissance, exploration and mining operations
- Enforcement of all health and safety regulations as approved by law at mine sites
- Inspection and investigation necessary for ensuring compliance with applicable regulations.

As a general requirement, when applying:

- Individuals should not be under the age of 18 years, be undischarged bankrupt or otherwise declared bankrupt under any written law
- A company or cooperative, any of its directors holding controlling shares must not have been convicted of any criminal offence or committed an offence under the Nigerian Minerals and Mining Act, 2007 or Mineral Regulations. See Form AT-1 at the end of this chapter.

Application forms for these titles can be obtained from:

- Mining Cadastre Office (MCO), Wuse, Abuja
- ASM Department, Ministry of Mines and Steel Development, Abuja
- State ASM and Mines Offices.

ASM Operators are expected to register with Artisanal and Small Scale Department by completing Form 45 to qualify them for Extension Services Programmes and Incentives. See Form 45 at the end of this chapter.

All completed forms (in triplicates) are to be submitted to the MCO office, Abuja.

The breakdown of the relevant titles and their requirements are outlined below:

Reconnaissance Permit (RP)

Conditions / Requirements

- The permit is non-exclusive
- The permit has a duration of one (1) year and is renewable annually
- Duly completed RP application forms (in triplicates)
- Description of work area and the activities to be carried out
- Attestation of no conviction of criminal offences under the Nigerian minerals and mining act, 2007
- Receipt of payment of N10,000.00 application processing fee
- Evidence of technical competence
- Certified true copy of certificate of registration or incorporation
- Evidence of financial capability, see Form 42
- A valid RP application shall be granted and issued within 30 days of filing application.

Exploration Licence (EL)

Conditions / Requirements

- The licence is exclusive and has a maximum area of 200 km2
- The licence has a duration of three (3) years and is renewable twice for two (2) years each.
- Duly completed EL application forms (in triplicates)
- Detailed minimum work programme
- Evidence of financial capability, see Form 42
- Evidence of technical competence
- Consent from land owners/land occupiers
- Attestation of non conviction of criminal offences under the Nigerian minerals and mining act, 2007.

Small Scale Mining Lease (SSML), Mining Lease (ML) OR Quarry Lease (QL)

Conditions / Requirements

- The three leases are exclusive.
- The SSML, ML and QL respectively have maximum areas of 3 km^2, 50km^2 and 5 km^2.

- The SSML has a duration of five (5) years for alluvial deposit and ten (10) years for lode formation and is renewable for further periods of five (5) years for alluvial formation and ten (10) years for lode formation provided that the holder has complied with minimum work commitments and that all other legal and regulatory requirements have been met;
- The ML has a duration of twenty five (25) years and is renewable for further periods of twenty (20) years provided that the holder has complied with minimum work commitments and that all other legal and regulatory requirements have been met;
- The QL has a duration of ten (10) years and is renewable as often as required provided the minimum work obligation is met and renewal application is made three (3) before the lease expires.
- Duly completed SSML, ML or QL application forms (in triplicates)
- Pre-feasibility study report
- Evidence of financial capability, see Form 42
- Evidence of technical competence
- Consent from land owners/land occupiers
- Attestation of non conviction of criminal offences under the Nigerian Minerals and Mining Act, 2007
- Certified true copy of certificate of registration or incorporation
- Evidence of payment of N10,000.00 SSML application processing fee or N50,000.00 ML application fee or N20,000.00 QL application processing fee
- Area specified to be surveyed in accordance with provisions of survey Coordination Act
- A valid SSML, ML or QL application shall be granted and issued within 45 days of filing application.

Water Use Permit (WUP)

Conditions / Requirements

- Duly completed WUP form (in triplicates)
- A copy of the mining title granted
- Description of area and water use plan
- Agreement with all persons likely to be adversely affected by the grant of the permit
- Evidence of payment of N10,000.00 application processing fee
- It has the same duration with the mining title granted
- A valid Water Use permit application shall be granted and issued within 7 days from grant of lease approval.

4.2. Managing Natural Resource Conflicts

Fig 4-2. Be prepared to explain mineral rights versus land rights.

Conflicts often arise over the occupation, use, management and control of land. Finding minerals requires access to large areas of land, much of which is subject to different uses or conflicting claims of ownership.

Natural resource conflicts related to mineral rights usually arise because:

- Land occupants and users often confuse mineral rights and land rights, sometimes believing that mineral-rights holders are there to take the land – even when they are only doing prospecting or exploration

- Lawful occupiers and landowners sometimes do not understand the terms of compensation for any land disturbances (e.g. to crops) or re settlement

- Sometimes ownership (land title) and lawful occupancy are not clear.

FEDERAL REPUBLIC OF NIGERIA

MINING CADASTRE

MINERAL TITLE
APPLICATION FORM
Version 3.0 – February 2008

RECONNAISSANCE PERMIT

APPLICATION N° ⊖

I – APPLICANT'S IDENTIFICATION

☐ BODY CORPORATE ☐ CO-OPERATIVE ☐ INDIVIDUAL * | HAVE YOU APPLIED BEFORE ? * ☐ YES ☐ NO

Full name			Registration No *		
			ID card No * if any		
Address	Street / Road *		No *		P.O. Box
	City / Town *		Zip		
	State *				
	LGA *				
	Country of origin				
Communication	Telephone *				
	Fax				
	Mobile *				
	Email *				
	Web site				

II – REPRESENTATIVE

Full name			ID card No * if any		
Address	Street / Road *		No *		P.O. Box
	City / Town *		Zip		
	State *				
	LGA *				
Communication	Telephone *				
	Fax				
	Mobile *				
	Email *				
	Web site				

III – DOCUMENTS SUBMITTED

- ☐ Certified copy of the certificate of incorporation (Body corporate)
- ☐ Attestation of non conviction of criminal offence or an offence under the Minerals and Mining Act 2007
- ☐ Receipt of payment for application fees
- ☐ Other(s)

IV – RECORD DATA ⊖

Date	DD	MM	YYYY	**Office**	

V - SIGNATURES

Applicant or Representative	*Mining Cadastre Officer + Stamp*

⊖ To be filled in by the Mining Cadastre Officer - *Application submitted in 3 copies*
* Mandatory information *PLEASE USE CAPITAL LETTERS ONLY*

RECORDED *REGISTER* ☐
SIGTIM ☐

FEDERAL REPUBLIC OF NIGERIA

MINING CADASTRE

MINERAL TITLE
APPLICATION FORM
Version 3.0 – February 2008

EXPLORATION LICENCE

APPLICATION N°

I – LOCATION OF THE REQUESTED LICENSE

States	*	LGAs	*	Topo sheet(s)	*

II – APPLICANT'S IDENTIFICATION

☐ BODY CORPORATE ☐ CO-OPERATIVE *

HAVE YOU APPLIED BEFORE ? * ☐ YES ☐ NO

Full name			Registration No *		
Address	Street / Road *		No *		P.O. Box
	City / Town *		Zip		
	State *				
	LGA *				
	Country of origin				
Communication	Telephone *				
	Fax				
	Mobile *				
	Email *				
	Web site				

III – REPRESENTATIVE

Full name			ID card No * if any		
Address	Street / Road *		No *		P.O. Box
	City / Town *		Zip		
	State *				
	LGA *				
Communication	Telephone *				
	Fax *				
	Mobile *				
	Email *				
	Web site				

IV – DOCUMENTS SUBMITTED

- ☐ Description of the minimum work programme
- ☐ Certified copy of the certificate of incorporation (Body corporate)
- ☐ Attestation of non conviction of criminal offence or an offence under the Minerals and Mining Act 2007
- ☐ Receipt of payment for application fees
- ☐ Other(s)

⊖ To be filled in by the Mining Cadastre Officer - *Application submitted in 3 copies*
* Mandatory information

PLEASE USE CAPITAL LETTERS ONLY

MINERAL TITLE APPLICATION FORM

V – COORDINATES

Type *Corners of the perimeter* ☐ *Center of the cadastral units* ☐ *Number of CUs* ☐

#	Longitude X			Latitude Y		
	D	M	S	D	M	S
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23						
24						
25						

Additional Coordinates sheets

Yes ☐ *No* ☐

Quantity ☐

#	Longitude X			Latitude Y		
	D	M	S	D	M	S
26						
27						
28						
29						
30						
31						
32						
33						
34						
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45						
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48						
49						
50						

VI – RECORD DATA

Date	DD	MM	YYYY	Time	HH	MM	Office	

WARNING TO THE APPLICANT

If the title issued from the present application surrounds one or more other titles and/or pending application(s), the applicant agrees that if those latter come to expire or are simply abandoned by their owners or not granted by the Mining Cadastre, they will be fully integrated into their own title with all obligations, including payment of fees, related thereto

VII - SIGNATURES

Applicant or Representative	*Mining Cadastre Officer + Stamp*

⊖ To be filled in by the Mining Cadastre Officer - *Application submitted in 3 copies*

* Mandatory information

RECORDED *REGISTER* ☐ *SIGTIM* ☐

FEDERAL REPUBLIC OF NIGERIA MINING CADASTRE

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FEDERAL REPUBLIC OF NIGERIA

MINING CADASTRE

MINERAL TITLE
APPLICATION FORM
Version 3.0 – February 2008

LEASE

APPLICATION N°

I – TYPE OF LEASE

☐ SMALL SCALE MINING LEASE
☐ MINING LEASE
☐ QUARRY LEASE

Requested duration ☐ Year(s)
If less than the maximum time allowed

Licence Type ☐
Number ☐
Emerging from (if any)

I – LOCATION OF LEASE

States *	LGAs *	Topo sheet(s) *

II – APPLICANT'S IDENTIFICATION

☐ BODY CORPORATE ☐ CO-OPERATIVE ☐ INDIVIDUAL * | HAVE YOU APPLIED BEFORE ? * ☐ YES ☐ NO

Full name		Registration No *		
		ID card No * if any		
Address	Street / Road *	No *		P.O. Box
	City / Town *	Zip		
	State *			
	LGA *			
	Country of origin			
Communication	Telephone *			
	Fax			
	Mobile *			
	Email *			
	Web site			

III – REPRESENTATIVE

Full name		ID card No * if any		
Address	Street / Road *	No *		P.O. Box
	City / Town *	Zip		
	State *			
	LGA *			
Communication	Telephone *			
	Fax			
	Mobile *			
	Email *			
	Web site			

IV – DOCUMENTS SUBMITTED

☐ Pre feasibility study
☐ Certified copy of the certificate of incorporation (Body corporate)
☐ Attestation of non conviction of criminal offence or an offence under the Minerals and Mining Act 2007
☐ Receipt of payment for application fees
☐ Other(s)

⊖ To be filled in by the Mining Cadastre Officer - *Application submitted in 3 copies*
* Mandatory information

PLEASE USE CAPITAL LETTERS ONLY

MINERAL TITLE APPLICATION FORM

V - MINERAL(S) TO BE MINED

1		6	
2		7	
3		8	
4		9	
5		10	

VI - MINERAL(S) LOCATED IN THE AREA APPLIED

1		6	
2		7	
3		8	
4		9	
5		10	

VII – COORDINATES

Type *Corners of the perimeter* ☐ *Center of the cadastral units* ☐ *Number of CUs* ☐

#	Longitude X			Latitude Y		
	D	M	S	D	M	S
1						
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20						
21						
22						

Additional Coordinates sheets

Yes ☐ *No* ☐

Quantity ☐

#	Longitude X			Latitude Y		
	D	M	S	D	M	S
23						
24						
25						
26						
27						
28						
29						
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31						
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39						
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43						
44						

VIII – RECORD DATA

Date	DD	MM	YYYY	Time	HH	MM	Office	

WARNING TO THE APPLICANT

If the title issued from the present application surrounds one or more other titles and/or pending application(s), the applicant agrees that if those latter come to expire or are simply abandoned by their owners or not granted by the Mining Cadastre, they will be fully integrated into their own title with all obligations, including payment of fees related thereto

IX - SIGNATURES

Applicant or Representative	*Mining Cadastre Officer + Stamp*

⊖ To be filled in by the Mining Cadastre Officer - *Application submitted in 3 copies*

* Mandatory information

RECORDED *REGISTER* ☐ *SIGTIM* ☐

FEDERAL REPUBLIC OF NIGERIA MINING CADASTRE

FEDERAL REPUBLIC OF NIGERIA

MINING CADASTRE

MINERAL TITLE
APPLICATION FORM
Version 3.0 – February 2008

WATER USE PERMIT

APPLICATION N°

I – RELATED TITLE ON WHICH THE PERMIT IS REQUESTED

Number *

Remark

Type *

Number of cadastral unit(s) *

Period of the WUP requested
Only if different from the related title

From DD MM YYYY To DD MM YYYY

II – LOCATION OF WUP

States * **LGAs** * **Topo sheet(s)** *

III – APPLICANT'S IDENTIFICATION

☐ BODY CORPORATE ☐ CO-OPERATIVE ☐ INDIVIDUAL *

Full name			Registration No *		
			ID card No * if any		
Address	Street / Road *		No *		P.O. Box
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	Country of origin				
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	Fax *				
	Mobile *				
	Email *				
	Web site				

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	State *				
	LGA *				
Communication	Telephone *				
	Fax				
	Mobile *				
	Email *				
	Web site				

⊖ To be filled in by the Mining Cadastre Officer - *Application submitted in 3 copies*
* Mandatory information

PLEASE USE CAPITAL LETTERS ONLY

MINERAL TITLE APPLICATION FORM

V – DOCUMENTS SUBMITTED

- [ ] Copy of mining title granted
- [ ] Topographical map with the size and configuration of the water use permit area
- [ ] Preliminary water use plan
- [ ] List of names of all persons and parties likely to be affected by the grant of the permit
- [ ] Consent of any persons likely to be adversely affected by the grant of the permit
- [ ] Receipt of payment for application fees
- [ ] Other(s)

VI – IDENTIFICATION OF WATER RESOURCES IN THE AREA APPLIED if any

1	
2	
3	
4	
5	

VII – DESCRIPTION OF WATER USE OPERATIONS AND QUANTITY TO BE USED

Description

Quantity		m³ per		Day		Month		Year

VIII – COORDINATES

Type *Corners of the perimeter* [ ] *Center of the cadastral units* [ ] *Number of CUs* [ ]

#	Longitude X D	M	S	Latitude Y D	M	S
1						
2						
3						
4						
5						
6						
7						
8						

Additional Coordinates sheets

Yes [ ] *No* [ ]

Quantity [ ]

#	Longitude X D	M	S	Latitude Y D	M	S
9						
10						
11						
12						
13						
14						
15						
16						

IX – RECORD DATA

Date	DD	MM	YYYY	**Office**	

X - SIGNATURES

Applicant or Representative	*Mining Cadastre Officer + Stamp*

⊖ To be filled in by the Mining Cadastre Officer - *Application submitted in 3 copies*
* Mandatory information

RECORDED *REGISTER SIGTIM*

FEDERAL REPUBLIC OF NIGERIA MINING CADASTRE

FEDERAL REPUBLIC OF NIGERIA

FORM AT-1

Ministry of Mines and Steel Development
Abuja, Nigeria

MINING CADASTRE OFFICE

ATTESTATION OF NO CONVICTION OF CRIMINAL OFFENCE OR OFFENCE UNDER THE MINERAL AND MINING ACT, 2007

Name of the legal Practitioner or Legal Firm:..

....

Address:..

....

....

Telephone No. (Office/Mobile):..

Fax:.. *Email:*..

do hereby attest that

Messrs / Mr / Mrs / Miss..

....

is legally capable and has no criminal or felony conviction or conviction under the Minerals and Mining Act, 2007.

Dated..

Signature and Seal

Procedures for resolving or arbitrating these disputes for Location Licences are well laid out in the Nigerian Minerals and Mining Act, 2007 (Section 116, 117, 100-110 and 112-113).

FEDERAL REPUBLIC OF NIGERIA
MINISTRY OF MINES AND STEEL DEVELOPMENT
The Nigerian Mineral and Mining Act 2007
Regulation 117 (3) (d)
Form 42

BANKER'S GUARANTEE

WHEREAS (1) .... have/has applied to the for the grant of a ....

AND WHEREAS (2) .... of ....

Have undertaken to provide the said (3) ....

with sufficient money to ensure the payment to..

of ....or any other sum which may become due to them as a result of the exercise of the rights under a ....

NOW THEREFORE I HEREBY GUARANTEE that I will at any time on the request of the .... deposit with .... the money required to make such payments, provided always that the sum shall not exceed the sum of .... and provided further that this Guarantee shall be irrevocable by me except with the prior consent of the ....

Dated this .... day of .... 20 ....

Signed: ....

(4) ....

In the presence of ....

(5) ....

To the ....

Stamp duty: ____

1. *Name, address and occupation of person guaranteed*
2. *Name, address and occupation of guarantor*
3. *Name of person guaranteed*
4. *Signature of guarantor*
5. *Signature of witness*

FEDERAL REPUBLIC OF NIGERIA
MINISTRY OF MINES AND STEEL DEVELOPMENT
The Nigerian Minerals And Mining Act, 2007
Regulation 144 (3)
Form 45
REGISTRATION FORM FOR MINING COOPERATIVES, QUARRYING ASSOCIATION AND
SMALL-SCALE MINING OPERATORS

1. Name of cooperative/association/organisation: ....
2. Date registered: ....
3. Registration number: ....
4. Business Address...
5. Number of members: .... (Attach list of members)
6. Mineral (s) being mined/quarried: ....
7. Mining/quarrying site (s): ....
   (State location to the nearest village)
8. State years of operation at location: ....

....
(Signature of Chairman with Stamp)

DOCUMENTS TO BE ATTACHED

i. Certificate of Registration
ii. Copy of the bye-laws
iii. List of members stating position held
iv. Licence over area of operation (if any)
v. Proof of payment

(For official use only)

i. Date of receipt:..

ii. All attachments checked by:...

iii. Application form checked by:..

Woman resting at Azara barite operation Nazarawa State

Boy organising his game on mining site

5. How to organise and develop an ASM site

The organisation and development of an ASM site following the discovery of a mineral deposit and the acquisition of a small scale mining lease (SSML) entails satisfying all requirements of the Nigerian Minerals and Mining Act, 2007, before the commencement of development activities needed to exploit the mineral deposit.

5.1. Satisfying statutory requirements

The statutory requirements that need to be satisfied before the commencement of development works are:

i. Submission of application and securing approval of water-use permit needed to legalise the use of water for all mining operations during the life span of the SSML
ii. Submission of environmental impact assessment studies and mitigation plans needed to minimise the negative impact of the operations on the environment to the Mines Environmental Compliance Department (MECD) and securing approval of same. These mitigation plans shall spell out how the mined-out area shall be reclaimed / restored to its initial condition or better as well as how effluents and wastes would be treated before discharge to the environment
iii. Preparing and submitting a detailed work programme to be undertaken in the SSML area to Mines Inspectorate Department (MID) for approval. This programme shall contain the production schedules of the operations, stripping ratio, pit limit, mine plan and design, mining and processing methods to be used amongst others. Copies of this report shall also be submitted to the Mining Cadastre Office (MCO) and MECD
iv. Submission of Community Development Agreement to the MECD and securing approval of same.
v. Payment of compensation to the land owners for the revocation of their rights to use the land as well as notify them and other land occupiers as to the commencement date of mining operations.
vi. Submission of copies of this notification and record of compensation payments to the MID, MCO and MECD. Submission of the environmental impact assessment statement (EIAS) to the Federal Ministry of Environment in respect of mining operations to be conducted over the SSML and securing approval of same. An approved EIAS must be submitted to MECD
vii. Arrange that a mandatory periodical operations report is prepared for submission to the MID, MCO and MECD

viii. Organise an effective management system for tailings and other waste disposal by ensuring that all discharges to the environment are within the threshold limits as specified by Federal Environmental Protection Agency (FEPA) Act.

5.2. Mine planning and design

Mine planning refers to the process of establishing a mine and mining sequence that will result in the extraction of mineral values from the said mine in a safe and economic manner. The factors that are usually considered while planning a mine as provided by Atkinson (1983) and Hartman and Mutmansky (2002) include:

a. *Natural and geological factors:* These comprise geological conditions, ore types and grades, hydrological conditions, topography, metallurgical characteristics, climate and environmental variables of the site.
b. *Economic factors:* These comprise ore grade, ore tonnage, stripping ratio, cut-off grade, operating cost, investment cost, desired profit margin, production rate, processing and / or smelting costs, and market conditions.
c. *Technological factors:* These comprise equipment, pit slope, bench height, road grade, property lines, transportation options and pit limits.

The objective in mine planning is always to get the mineral to be produced as soon as possible without disrupting production or cash flow. In line with this thinking, Mathieson (1982) and Hartmann and Murmansky (2002) listed the following objectives:

a. Mine the best ore to generate income as early as possible
b. Maintain proper operating parameters (adequate bench width and haul roads)
c. Maintain sufficient exposure of ore to overcome miscalculations or delays in-drilling and blasting
d. Defer stripping as long as possible without constraining equipment, manpower, or the production schedule
e. Follow a logical and achievable start-up schedule (for training, equipment procurement and development etc.) that minimises the risk of delays in the initial cash flow
f. Maximise pit slopes, while maintaining reasonably low likelihood of slope failure
g. Examine the economic merits of various production rates and cut-off grades
h. Subject the favoured choice of method, equipment and pit sequence to exhaustive contingency planning before proceeding with development.

To accomplish these goals the overall economics of the deposit and its extraction are analysed using several different alternatives, namely long-range mine plan-

ning, short-range mine planning and production scheduling.
Long-range mine planning refers to the general extraction plan for a mine with emphasis on the entire life of the mine or a major portion thereof. To accomplish this task, the mine is normally evaluated by dividing the deposit into relatively large geometric blocks and assigning values to each block based on the estimated ore grade within it. The possible extraction sequences are then analysed to provide an estimate of the overall pit limits and the gross sequence of exploitation.

Some of the technological factors that are used in pit design / optimisation are:

5.2.1. *Bench height*

This is the vertical distance between each horizontal level of the pit as shown in Fig. 5-1 below. Unless geological conditions dictate otherwise, all bench height should be of the same height which will depend on the physical characteristics of the mineral deposit; the degree of selectivity required in separating the ore and the waste with the loading equipment; the rate of production; the size and type of equipments; and the climatic conditions.

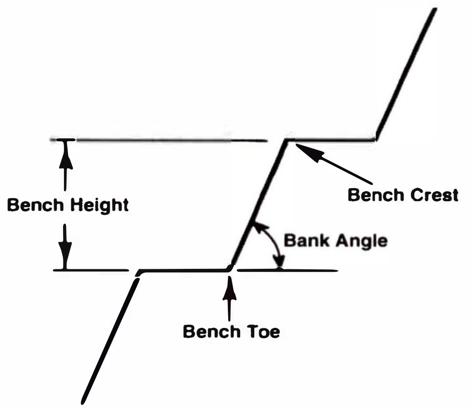


Fig. 5-1. Bench cross section (Source: Atkinson, SME, 1983)

The bench should not be too high as to present safety problems of towering banks of blasted or unblasted material. The bench height in open pit mines ranges from 1 m to as high as 15 m.

5.2.2. *Pit slopes*

The pit slope is expressed in degrees from the horizontal plane and helps in determining the amount of waste that must be moved to mine the ore. It is one of the factors that affects the size and shape of the mine pit. Rock strength, presence of water, faults, joints etc. are key factors used in evaluating the proper slope angle as they tend to change the pit slope as their conditions vary from one location to the other.

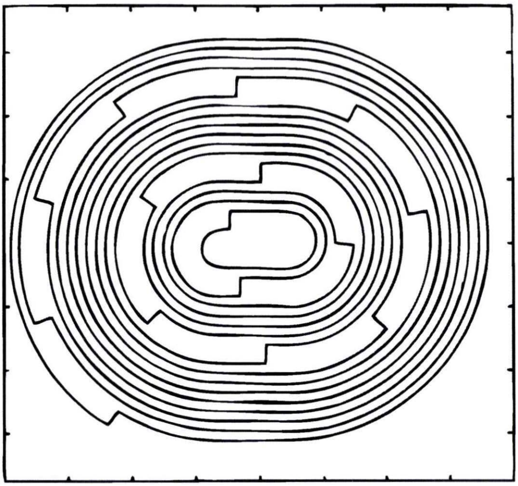


Fig. 5-2. Pit with 45 degree inter-ramp slope and a road system (Source: Atkinson, SME, 1983)

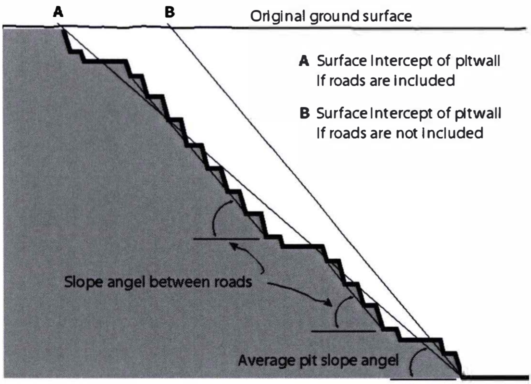


Fig. 5-3. Vertical section through a pit wall (Source: Atkinson, SME, 1983)

A pit wall needs to remain stable as long as mining activity is in that area which can only be obtained by proper slope evaluation. The pit slopes should be set as steep as possible to minimise the stripping ratio. The overall pit slope used for the construction must be flatter to allow for the road system in the ultimate pit. This will depend on the width, grade, and anticipated placement of the road.

Figure 5-2 shows a pit with 45° inter-ramp slope and a road system while Fig. 5-3 shows its vertical section. The inter-ramp angle is projected from the bottom of the pit upward to the original ground surface at point **B**. The overall pit slope angle is the angle from the toe of the bottom bench to the crest of the top bench. Point **A** shows the intercept of the overall pit slope angle with original ground surface.

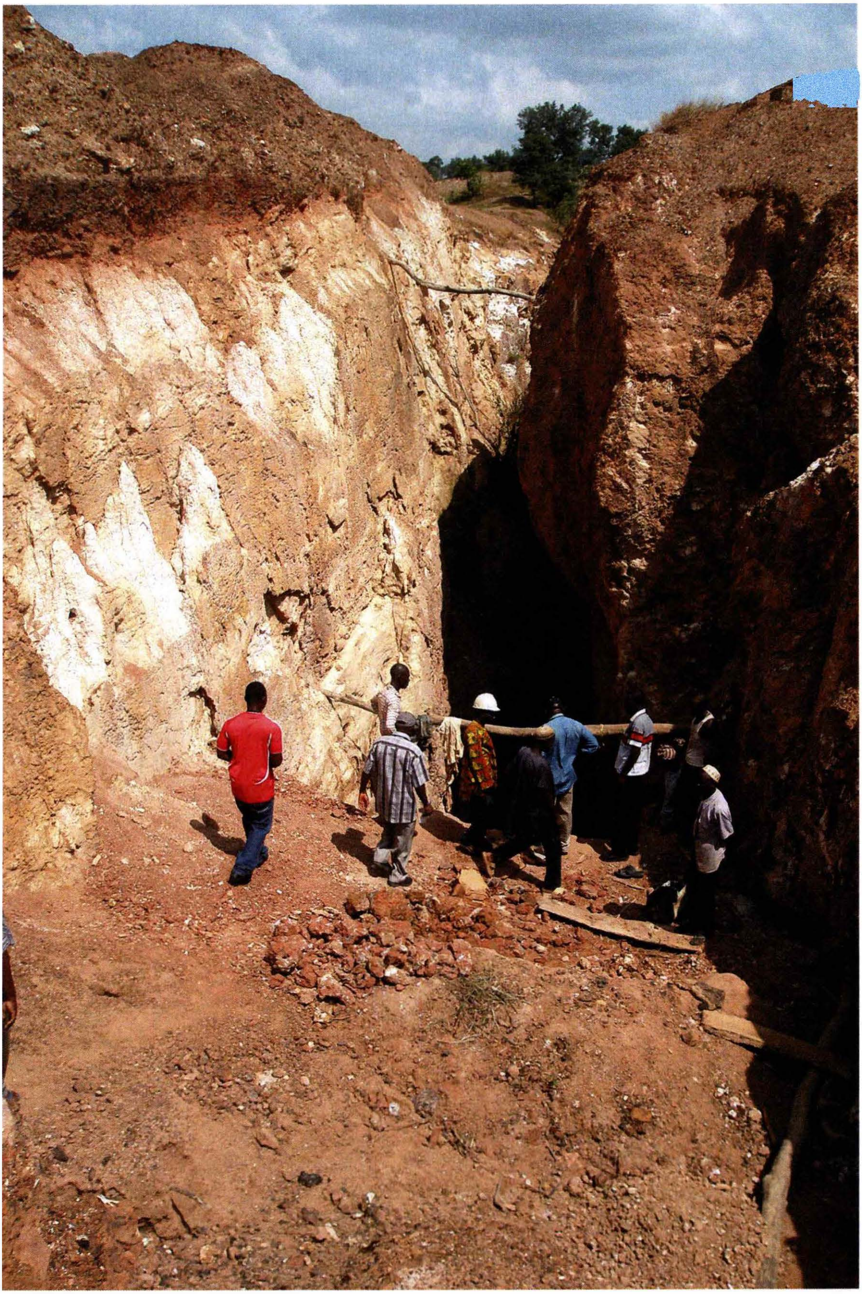


Fig. 5-4. Open pit barite mining in Azara, Nasarawa State.

5.2.3. Cut-off grade

Cut-off grade refers to the grade of mineral ore above which it can be exploited at a profit at the prevailing conditions and below which its exploitation is not viable. For any block to be mined, it must pay for the cost of mining, processing and marketing. The grade of ore that can pay for this but not for stripping is the break-even mining cut-off grade.

In the planning stage, all direct costs of mining, milling and marketing should be taken into account. In the mining stage, the drilling, blasting, loading and hauling cost should be used. In the processing stage costs should include crushing, conveying, grinding and concentration.

5.2.4. Strip ratio

This is the ratio of the number of tonnes of waste that must be removed for one tonne of ore to be mined. The pit design will determine the tonnage of waste and ore that the pit contains. The ratio of waste and ore will give the average strip ratio for the pit, which must be higher than the break-even strip ratio. The maximum allowable stripping ratio (SRmax) used in determining the pit limits is as follows:

$$SR_{max} = \frac{\text{value of ore} - \text{production cost}}{\text{stripping cost}}$$

5.2.5. Mine ventilation

Mine ventilation refers to the provision of air into the mine in order to:

a. Provide sufficient oxygen for workers to breath
b. Ensure that the working conditions allow for work to be carried out at maximum efficiency
c. To dilute and displace gases and dusts that would otherwise contaminate the mine atmosphere.

These objectives are achieved by passing a sufficient volume of clean, fresh air into the workings via the main shaft to displace foul air caused by the presence of carbon monoxide, carbon dioxide, nitrogen oxides, methane, hydrogen sulphide and dusts that are exhausted through the ventilation shaft. The fresh air also cools the working areas and provides adequate humidity.

To cause a flow, a pressure difference must be established to overcome the mine resistance to air flow. In small mines, such ASM underground mines, this is achieved by natural ventilation pressure due to the difference in the weight of the air columns in both shafts. Larger mines mostly require an exhaust fan installed over the collar of the ventilation shaft, reinforced by booster fans placed strategically in the main mine ventilation circuit to secure adequate pressure difference.

5.2.6. *Equipment selection*

Mine, process and auxiliary equipment are selected based on the following factors:

a. Scheduled production rate and type of method to be used in carrying out the activity
b. Depositional characteristics of drilling equipment and mineral processing equipment
c. Initial cost of equipment
d. Operational cost as well as availability of spare parts.

The equipment that will produce the required scheduled production rate at least cost is mostly selected.

5.3. Mine development

Mine development generally refers to the work needed to be carried out in order to bring a mine to full, scheduled production. It is carried out in order to provide access to the mineral deposit, permitting entry of miners, equipment, supplies, power, water, ventilation air, as well as exits for the mineral being mined and the waste produced.

Development for surface mines entails removal of overburden (stripping) to expose the mineral value. The overburden is then placed in disposal areas for later reclamation.

Development for underground mines is generally more demanding and expensive. The principal openings may be shafts or adits to allow for the passage of workers, machines, ore, waste, air, etc. Metal mines are mostly located along steeplydipping mineralisation resulting in the need to open up the mineral from shafts, with drifts, winzes, and raises serving as production areas.

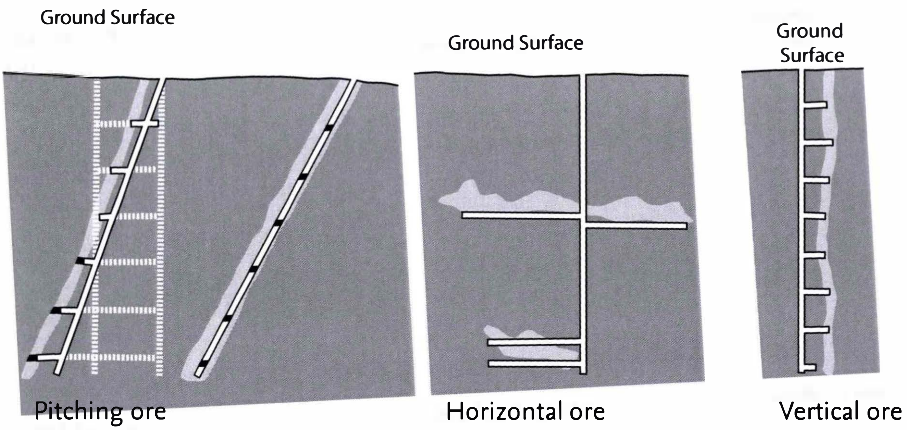


Fig. 5-5. Modes of entry (Source: Peele 1948).

Modes of entry for pitching veins, shown in Fig. 5-5, could be either a vertical shaft (**CD**) started in the hanging wall, a footwall vertical shaft (**AE**), a footwall inclined shaft (**AB**) or an inclined shaft (**GH**) in the vein. Except in the last case, crosscuts will be needed at intervals to reach the vein. A vertical shaft is the right entry for flat or vertical deposits.

Factors usually considered in mine development include the following:

a. *Locational factors*
Mineral deposits are rarely found in ideal locations resulting in geography affecting the mineral operations significantly. The following are some of the factors that are affected by location:

- Ease of transporting mineral products and supplies
- Availability of labour and support carriers
- Operational impacts of climate and weather.

b. *Natural and geological factors*
The natural setting of the mineral deposit and the geological environment govern many key aspects of mine development especially access openings and surface plant location. The most important factors in this category include:

- Topography
- Spatial relation of the mineral deposit (size, shape, depth, etc.)
- Geologic consideration (mineralogy, structure of ore, etc.
- Rock mechanics properties
- Chemical and metallurgical properties of the mineral deposit.

Fig. 5-6. ASM operators using a winch to raise material from a deep-shaft operation.

c. Social – economic – political – environmental factors

These factors exercise a disproportionate influence on both the development and operations of the mine. They mostly comprise:

- Demographic and occupational skills of the local population which will decide on whether to bring in workers from outside host community or not
- Means of financing or marketing which determine the scale and continuity of the operations
- Political situation and level of security in and around the mineral deposit area
- Environmental legislation.

5.3.1. Sequence of mine development

The steps usually carried out during mine development for both surface and underground mines after the acquisition of land and mineral rights are as follows:

- Adoption of the feasibility report as a planning document subject to modification as the project is developed and mined
- Confirmation of mining methods and general sequence of mining including

the initial choice of equipment types and size of workforce
- Arrangement of financing based on confirmation of ore reserves and cost estimates by independent assessors
- Erection of mineral processing plant, if required and mineral handling and shipment facilities as well as preparation of stockpiling and waste disposal facilities. These items should be located in areas that would not in any way disrupt mineral extraction activities
- Acquisition of mining equipment for development and exploitation
- Construction of main opening to the mineral body in underground mining or advanced stripping in surface mining to provide direct access to the ore zone.

5.3.2. *Mine exploitation*

Mine exploitation is a stage of mining that is associated with the actual recovery of mineral ores from their natural habitat. The methods used in mineral extraction fall into two broad categories, namely surface and underground mining methods. Surface mining includes mechanical excavation methods such as open pit and open cast (strip mining), and aqueous methods such as placer and solution mining. Underground mining is the type of excavation that is carried out underground and is usually classified into three categories: unsupported, supported and caving. A detailed breakdown of the various types of mining methods is given below.

Classification of mining methods used by ASM

CATEGORY	CLASS	SUBCLASS	METHOD	COMMODITY
Surface	Mechanical	-	1. Open pit mining*	Metallic
			2. Quarrying	Non-metallic
			3. Open cast (strip) mining*	Coal, non-metallic
			4. Auger mining	Coal
	Aqueous	Placer	Hydraulicking	Metallic, non-metallic
			Dredging	Metallic, non-metallic
		Solution	Borehole mining	Non-metallic
			Leaching*	Metallic
Underground	Unsupported	-	Room and pillar mining*	Metallic, non-metallic

*Asterisks indicate the most important and commonly used methods

5.3.3. Guidelines and procedure for selecting mining methods

Factors that are used or considered in reviewing the mining methods for suitability in ASM exploitation of a given ore deposit are listed below:

- Spatial characteristic of the deposit such as depth from the surface, size, shape, dip, etc.
- Geological and hydrological conditions such as mineralogy, petrography and chemical composition
- Geotechnical properties such as ore and surrounding rock strength, etc.
- Health and safety aspects associated with the mining methods.

The procedure of selecting a suitable mining method involves eliminating methods that are not suitable for the deposit at hand using the factors listed above.

Findings by Nilsson (1992) arising from works carried out are also used as guides in selecting suitable mining methods. The said findings are:

- That in a buried horizontal deposit, mining of the deposit will be optimised by using either surface method or underground method but not using both
- That for a steeply dipping vein or massive deposit that outcrops on the surface and extends to depth, the optimum strategy would be to mine first using surface methods, then switch to underground method
- The point at which surface mining should be switched to the underground mining method is normally reached when the surface mining cost reaches the underground mining cost, if ore production rates do not change at that point.

The decision to use either the surface method or the underground method for buried horizontal deposit will normally be made by a simple cost comparison between the surface method and the underground method. However, for steeply dipping deposit that extend to depth, the analysis of the strategy would involve both surface and underground mining costs as well as a thorough analysis of the optimum point of switching from surface to underground. Social and environmental considerations also play a great role in the final decision.

5.4. Reclamation

The desire to carry out mineral development and exploitation in a sustainable manner leads mine planners into planning for mine closure before the first tonne of ore is mined. Planning for reclamation mostly entails designing a mine that is safe in all ramifications, i.e. to say all threats to life and the environment are completely taken care of by ensuring that safe mining methods are used with waste and effluents adequately monitored and treated before discharge or stockpiling. Adequate plans for mine closure are also made to reclaim the mine site restoring it to what is was before the commencement of mining operations or put to other more useful use.

The above considerations form an integrated part of Mining Operation Plan, which has to be submitted to MMSD, see the following page.

FEDERAL REPUBLIC OF NIGERIA
MINISTRY OF MINES AND STEEL DEVELOPMENT
The Nigerian Mineral and Mining Act 2007
REGULATION 108 (6) (c)

MINING OPERATION PLAN

1. Name of mineral title holder
2. Number of mineral title
3. Location of title
4. Address of mineral title holder
5. Name and qualification(s) of technical manager
6. Establishment of acceptable stripping ratio and definition of shape of the excavation and limits of surface mining
7. Development and maintenance of access for equipment
8. Opening up working faces to ensure quality deposits that can furnish required grades at all times
9. Determination of sidewall slope angle
10. Location and gradient of access roads
11. Height of working faces
12. Surface and groundwater control
13. Mine design
14. Mine development plan
15. Mineral production plan
16. Mineral beneficiation plan
17. Mine restoration, reclamation and rehabilitation plan
18. Mine health and safety scheme
19. Mine tailings and waste disposal plan
20. Mine closure plan

Photo shows use of sluice, see figure on page 71

6. Mineral processing

Mineral processing by ASM operators is mostly carried out on a low technological level. At rush mining sites the incentive for ASM operators to invest money in better extraction equipment is often limited. At more permanent mining sites some of the miners are interested in obtaining higher recovery and they invest in better equipment. These miners will often copy extraction equipment which they have seen in other mining sites.

New methods spread slowly, even sometimes very slowly from site to site. There is often a tendency to conservatism among ASM operators. When they have used a certain method for decades they are reluctant to change to new methods. One convincing argument in support of adopting a new method is the prospect of increased earnings. A detailed description of advanced technical equipment for mineral processing is given in Appendix A.

The major metallic and non-metallic minerals (industrial) that are currently exploited in Nigeria by the ASM are listed below with details of processing methods:

Metals/metallic minerals

1. Gold
2. Tantalum ore (Tantalite)
3. Lead, zinc and copper ores
4. Cassiterite (tin ore)

Industrial Minerals

1. Barite
2. Bentonite
3. Gypsum
4. Diatomite
5. Kaolin
6. Calcium carbonate
7. Dimension stone

Gemstones

6.1. Metals/metallic minerals

6.1.1. Gold

Gold is used in jewellery, for coins, dentistry etc.

Flowchart 1. Gold extraction using mercury.

ASM operators mostly extract gold from auriferous quartz veins. Gold grades vary from a few grams up to several hundred grams of gold per tonne. It is thus necessary to mine and treat large amounts of ore in order to extract just a little gold.

The most commonly used gold extraction process is outlined in Flowchart 1.

When the quartz-gold ore has been mined and hoisted to the surface it is crushed down to pebble size. This is often done manually with a hammer (see flowchart). However, in some small-scale mining communities some miners have invested in a jaw crusher, which can do the job in minutes instead of hours. The advantage with a jaw crusher is not only that it is works faster, but it also reduces accidents.

The next step is grinding or milling. This is done in ball or rod mills and can be wet or dry grinding (Flowchart 1). Wet grinding is preferable since it reduces dust emission and makes less noise.

After this come sluicing (Flowchart 1). There are probably as many types of sluices as there are miners and they are not all very efficient (Fig. 6-1-A). If the sluice is not built properly it does not work properly. Fortunately, it does not require very sophisticated materials to improve the sluices, but several pitfalls may result in a reduction of gold recovery, such as using the wrong construction or wrong material.

There are a few parameters which are crucial for obtaining a high recovery:

1. **A constant water flow:** Many ASM operators are not aware that the water flow in a sluice shall be constant. They throw a bucket of water in the sluice, let that drain and then the next bucket is thrown into the sluice. To separate heavy minerals from light minerals in the best possible way, it is vital that the water flow is constant. This can be done easily with a half 200 l drum placed immediately above the sluice as shown in Fig. 6-1-B. The velocity of the water flow is also important and trial and error will show the best speed for that particular sluice and type of ore.

2. **Textile material suitable for catching heavy minerals:** The sluice is covered by a piece of cloth which will catch the heavy minerals. Often ASM operators use old sacks, but this type of cloth is not the best. It is possible to increase gold recovery several times by using other types of cloth, e.g. felt has proved to be a very efficient gold catcher in sluices.

Fig. 6-1-A. A very primitive sluice where buckets of water are thrown on the upper part of the sluice. The result is that many of the heavy mineral grains (gold or tantalite) will be washed out of the sluice and get lost at Tongakura, Kogi State.

3. **The inclination of the sluice:** The inclination of the sluice must be adjustable to be able to find the inclination which yields the best gold recovery with this particular ore. The sluices are mostly in the order of a couple of metres long.

4. **A uniform grain size:** The grain size shall be as uniform as possible. The less uniform the poorer the recovery of gold. This is a question of milling. The longer the milling the more uniform the milled ore is. However, too much milling may cause the gold particles to be smeared on the inner wall of the drum preventing its recovery.

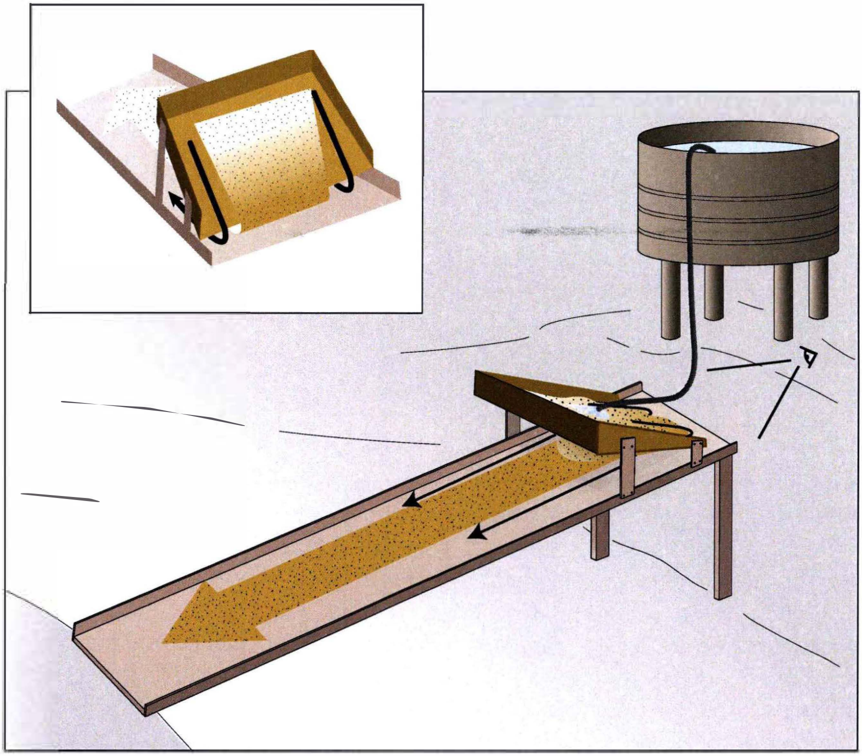


Fig. 6-1-B. The ideal sluice. The tailings are gradually flushed down the sluice with a constant water flow. This simple construction will increase recovery of heavy minerals several times compared with a sluice where the water is flushed down from buckets of water.

The first steps in gold extraction work as follows (Flowchart 1). After milling, the finely milled ore is placed in the box on top of the sluice. With the hose water is gently flushed down on the upper part of the sluice and the ore runs down the sluice. The heavy particles including gold are caught by the cloth on the upper part of the sluice. The lighter particles are flushed further down. Some are captured by the cloth further down and the rest ends in a small dam at the foot of the sluice. The water flow and the inclination must be properly adjuster so only the heavy particles are captured in the uppermost part of the cloth.

When all the milled ore has been flushed down the sluice then the cloth is washed in a large bucket of water (Flowchart 1). The heavy particles then rest at the bottom of the bucket. They are then scooped into a gold diggers pan (Flowchart 1). In the pan the heavy minerals are further concentrated. A skilled ASM operator can make an almost pure gold concentrate with that pan, as the ASM operators in Igila in the Osun state proved. Unfortunately, very few ASM operators worldwide have the skill or patience to make a good gold concentrate with a gold digger's pan. Most use mercury to extract gold from the heavy mineral concentrate. It is not known how widespread the use of mercury is among ASM operators in Nigeria, but there is no doubt that the use of mercury will increase rapidly as seen in many other countries in Africa. It is therefore appropriate to present a fairly detailed description of how to extract gold with mercury below, and how to reduce the health and environmental problems.

6.1.1.1. Amalgamation

Amalgam is gold 'dissolved' in mercury. Amalgamation is a gold extraction technique that has been used by ASM operators for thousands of years. Today, millions of ASM operators use amalgamation every day and the number is swiftly increasing resulting in serious damage to the environment and to mankind.

Amalgamation is a very easy to learn and inexpensive gold extraction method for ASM operators. The method is not used by large-scale mining companies. In its simplest form, mercury is added to a heavy mineral concentrate. The mercury is thoroughly mixed by hand with the heavy mineral concentrate (Flowchart 1). The result is that all gold grains and flakes 'dissolve' in the mercury as an amalgam. The mercury with the amalgam, recovered from the heavy mineral concentrate, is squeezed in a piece of cloth. This process leaves the amalgam, which has a pasty texture, in the cloth, whereas the clean mercury sprinkles through the cloth and can be recovered for later use. The amalgam is then put into an iron cup which is placed in a fire (Flowchart 1). The mercury evaporates and leaves the gold behind. It is not all mercury that evaporates. Some of the mercury is still trapped, giving

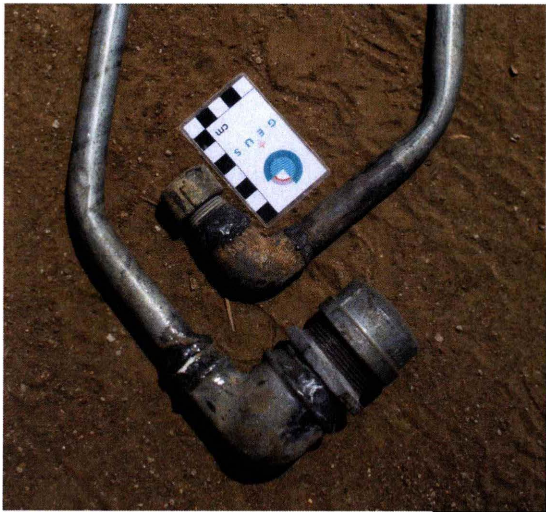


Fig. 6-2. Two retorts made of a few pieces of plumbing tubes. The scale is 10 cm.

Fig. 6-3. The amalgam is placed in the cup of the retort on some ash to get the cup airtight.

Fig. 6-4. The retort with amalgam in the cup is heated in a charcoal burner.

Fig. 6-5. Most of the mercury has evaporated and the gold is left behind.

the gold a pale yellow colour. This pale gold is sold to gold buyers who melt the gold with borax (see below) and thereby drive off the remaining mercury, leaving a nice warm yellow-coloured gold.

The amalgamation method has its serious drawbacks. It is highly toxic to most forms of life (see Chapter 7). Fortunately methods to reduce the amount of mercury released into the environment do exist. One method is to use a so-called retort, which is a simple device constructed to distil mercury. The retort is fairly widespread in South America.

In its simplest form, the retort consists of a few pieces of plumbing tube which can be manufactured by most local black smiths (Fig. 6-2). The procedure is as follows. The amalgam is placed in the small cup which is then tightly screwed on to the rest of the retort (Fig. 6-3). The 'head' of the retort is then placed in a charcoal burner (Fig. 6-4). Air is blown on the charcoal in order to increase the temperature. The end of the tube is placed in a small bowl with water. After some time air starts to bubble out of the end of the tube. After prolonged heating and gentle tapping on the tube, small drops of mercury run out of the tube into the water bowl. After 15 to 20 minutes of heating, the retort is removed from the charcoal burner and is allowed to cool slowly. When the retort has cooled, the cup can be opened and the gold be removed (Fig. 6-5).

Advantage of using the retort: The use of retorts reduces the release of mercury by more than 90%.

Disadvantage of using the retort: It takes 10 to 15 minutes longer than direct evaporation of mercury. This may not seem important, but it is an argument many

ASM operators put forward. It has also been argued that ASM operators fear that they loose gold because they cannot see what happens inside the retort. This prompted UNIDO and other donors to produce retorts of fire proof glass. The problem with the glass retorts is that they cost about US$ 500 and they are very fragile. However, experience tells us that if the ASM operators get a proper explanation they will no longer believe that gold disappears in the retort.

6.1.1.2. Borax

An alternative to using mercury is the so-called borax method. The idea of using borax by ASM operators was born more than thirty years ago in the Philippines, where it presently is used by around fifteen thousand ASM operators. The borax method was recently tested in Ghana through an EU-financed project with good results. The method is simple, easy to learn and does not require purchasing expensive equipment. Borax is a chemical with the formula $Na_2[B_4O_5(OH)_4] \cdot 8H_2O$, which occurs in nature as evaporite deposits. It is environmentally benign, and it is cheaper than mercury. Borax is used by gold dealers to purify the gold they buy from ASM operators.

The method is outlined in Flowchart 2. The first four steps in this method are the same as on Flowchart 1. The ASM operators use a gold digger's pan to produce a very good gold concentrate (Flowchart 2). The concentrate is mixed with borax and a few drops of water in a small plastic bag or piece of plastic. The plastic bag is placed in a pre-heated, borax-cleaned clay bowl together with burning pieces of charcoal. Vigorous blowing increases the temperature and after some time the borax melts and so do all the heavy minerals including the gold. The small droplets of molten gold sink to the bottom and unite to a larger drop of gold (Flowchart 2) which is recovered by the tip of a knife.

6.1.1.3. How can a small-scale gold miner be convinced to use borax instead of mercury?

There are obviously the environmental and health arguments. However, not all miners are willing to embark on new methods in order to save the environment and their health. Arguments put forward saying that they save money because borax is cheaper than mercury will not convince them. The prices of both commodities are negligible compared to the value of the gold they recover. Gold recovered by the borax method does not contain mercury and will thus fetch a higher price than gold recovered by amalgamation. The price difference is probably not enough to motivate the miners to swap extraction methods.

Flowchart 2. Gold extraction using borax.

The most convincing argument is gold recovery. It can be demonstrated that gold extraction using amalgamation result in significant loss of mercury. The explanation is as follows: Most ASM run the tailings through the gold extraction process again and again. Some of them run the tailings through the mill up to ten times in order to extract all the gold. The problem is that a good deal of the mercury is not recovered and will thus be milled. In the mill, mercury will repeatedly be pounded by the hard metal balls and therefore be transformed into what is called mercury flour. Mercury flour is extremely fine mercury particles which have lost the capability to coalesce. Mercury flour cannot be recovered by the ASM and neither can the gold hosted in the mercury flour. It is thus a substantial amount of gold which is lost in mercury flour. Analyses of gold in tailings in Tanzania, which have been through the milling many times, show gold values of more than 50 gram per tonne.

By using borax the ASM may increase their gold recovery significantly as well as reducing the negative impact on the environment and their health. This is what is called a win-win situation.

6.1.1.4. Cyanide gold extraction

Cyanide gold extraction is normally done by large-scale mining companies. There are however, ASM operators who successfully carry out cyanide gold extraction mainly as a second step where tailings are treated in order to recover gold which has not been recovered by other processes. Two types are carried out by ASM operators in order to extract gold from their tailings.

It must be emphasised that cyanide is a very toxic chemical which kills fast. However, a cyanide spill is neutralised fast when exposed to the atmosphere and the sun.

Heap leaching. A heavy-duty rubber or plastic tarpaulin is placed on the ground. A layer of tailings is placed on the tarpaulin. The tailings are slowly sprinkled with a cyanide solution. The set-up is covered by a tarpaulin in order to reduce evaporation (Fig. 6-6). The solution gradually penetrates the heap of tailings and underway it dissolves the gold. The so-called pregnant brines are tapped from the bottom. The brine is placed in a container and mixed with active carbon. Gold is precipitated on the active carbon. The carbon is burned. The ash is mixed with borax in a 30% or more ratio (the higher percentage of borax the easier it is to melt) and is cooked in a blower.

Fig. 6-6. Heap leaching a pile of tailings with cyanide. The plant is sheltered by a blue tarpaulin to reduce evaporation of the cyanide.

Active leaching of tailings. The tailings are mixed with water in the ratio 40% tailings to 60% water. Lime is added to keep the solution alkaline. Cyanide is added and the solution is kept for up to 100 hours depending on the type of ore. Then active carbon is added and the mixture is stirred for a couple of days (Fig. 6-7). The carbon is recovered by filtering. The loaded carbon is placed in a pressurised burner and boiled with cyanide and caustic soda for several hours. It is treated in an electro-winning process using steel wool. The gold will plate the steel wool which will then be digested in nitric acid. The resulting gold dust will then be cooked with borax.

6.1.1.5. The Igoli mercury-free gold extraction process

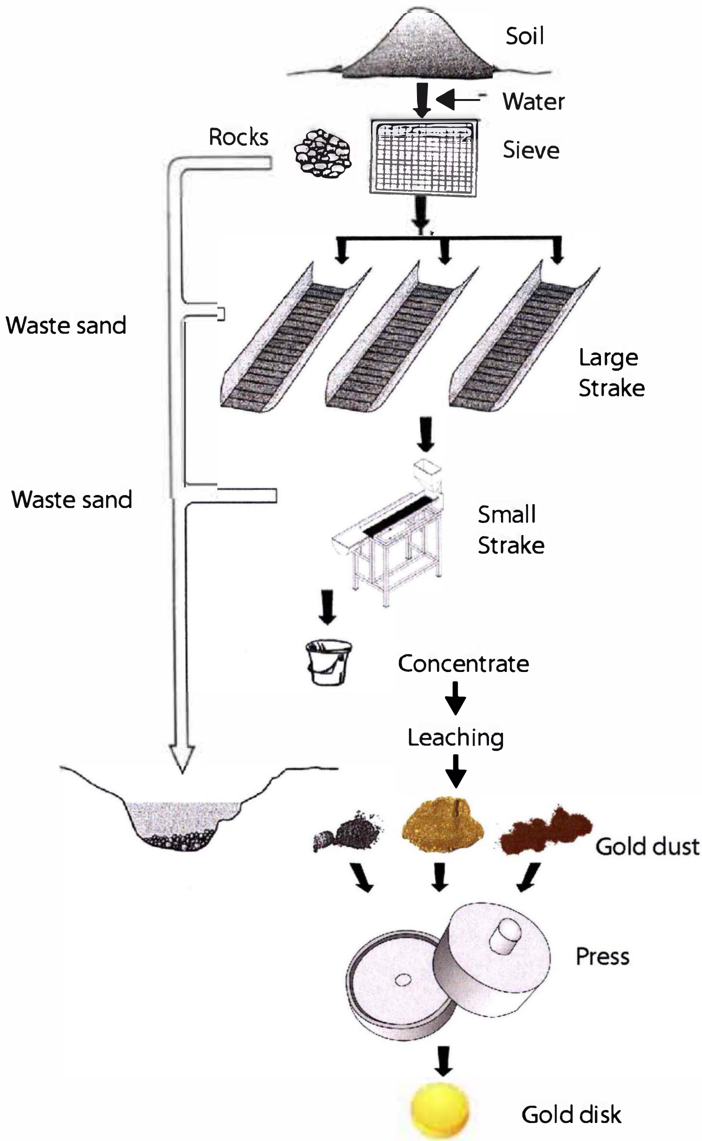
The Igoli process (Flowchart 3), developed by MINTEK, uses chlorine, which is present in chemicals such as bleach (NaOCl) and hydrochloric acid (HCl), to extract gold from concentrates. It has already been successfully used by small-scale miners in Tanzania. Instead of poisonous products such as mercury being discharged into the environment, the chlorine is converted to a harmless salt. The process entails producing a pre-concentrate using a screen mesh (to remove

Fig. 6-7. Active leaching of tailings by cyanide. A tank containing a cyanide tailings mixture which is slowly stirred.

boulders) and strake (sluice) which is then leached using bleach and hydrochloric acid. The leached gold is precipitated using sodium meta-bisulphate to produce gold in powdered form that is pressed to produce a gold disc.

The Igoli process has an advantage in the treatment of refractory ores. It is an environmentally friendly and efficient method to extract gold even from these ores. The income of the miner is increased in this way, and his health and the environment protected.

The strake (sluice) is a flat channel with walls on each side. The bottom of the channel has a rubber mat glued to it. The mat has grooves which are in the shape of the teeth on a wood saw. The teeth must have the perpendicular side facing



Flowchart 3. The Igoli Mercury–free gold extraction method. (Modified from Mintek, April 2006).

downstream. The strake is set at an angle so that a stream of pulp containing the fine gold ore or sand will flow downwards. The walls prevent the mixture from spilling. The strake has hinges on one side so that it can be tilted to wash the concentrate into the gutter on its side. This in turn directs the concentrate into a drum or bucket.

The gold concentrate is subsequently boiled in a solution of hydrochloric acid, sodium hypochlorite and sodium metabisulphate.

6.1.1.6. Advantages and disadvantages of the described gold extraction methods

The amalgamation process
Advantages are:
- It is easy to learn and to carry out
- It does not require investment in equipment
- Mercury is easy to handle

Disadvantages are:
- Long term toxicity
- Low recovery of gold

The borax process
Advantages are:
- It is easy to learn and to carry out
- It does not require investment in equipment
- High gold recovery
- Borax as a powder is easy to transport
- Borax is environmentally benign

Disadvantages are:
- Borax is not readily available in villages

The cyanide process
Advantages are:
- Can recover gold from tailings
- As heap leaching it is not labour intensive
- Toxicity is very short lived

Disadvantages are:
- It is highly toxic and requires utmost care

- Requires substantial investment
- Cyanide is difficult to transport and to get hold of in villages

The Igoli process
Advantages are:
- Can recover gold from complex ore
- No long-term toxicity

Disadvantages are:
- The chemical ingredients are not readily available in local communities
- The chemical ingredients bleach and hydrochloric acids are strongly etching
- Requires substantial investment in technical equipment

6.1.2. Tantalum

Tantalum is a heavy metal occurring in the mineral tantalite. It is used in electronics components such as mobile phones, as alloys in plates and pins for orthopedic surgery.

Tantalite is presently only extracted by ASM operators from soil overlying hard rock tantalum occurrences and from river sand and gravel. Sluicing is an efficient method to concentrate tantalite. The recovery rate of the sluices used today is, however, very poor. Sluices along the same lines as described above should be constructed. When a proper concentrate has been made, there will be many black minerals in the concentrate, mostly magnetite. A simple way to get rid of the magnetite and to produce a cleaner tantalite concentrate is to use a small hand magnet, which removes the magnetite.

6.1.3. Lead, zinc and copper

The lead, zinc and copper minerals are the sources from which these metals are extracted. They are often intergrown, which makes it impossible for ASM operators to separate them. It is thus in general very difficult for the miners to process the minerals apart from handpicking the best samples and knock off the non-paying minerals such as quartz.

The sluice can be used after crushing / grinding to produce a high grade composite concentrate of lead, zinc and copper sulphides. The ASM operators can further separate this composite concentrate into various fractions of lead, zinc and copper sulphide concentrates using froth flotation. Froth separation, however, requires substantial financial investment and much technical knowledge.

Lead is used in the manufacture of batteries, corrosion resistant pipes and linings, alloys, pigments and in radiation shielding.

Zinc is used as:

a. Corrosion protective coatings on iron and steel ('galvanising')
b. An important alloying metal in brass and zinc die-castings
c. A raw material for producing corrosion-resistant paints, pigments and fillers.

Copper is used where high electrical or thermal conductivity is important. It is also used in a variety of alloys, brass, bronze and aluminium bronze.

6.1.4. *Tin*

Tin is mainly used as tin-plate in e.g. cans. It is also used to produce various alloys such as solders, bearing-metals, bronze, type-metal and pewter.

It is exclusively extracted from tin ore (cassiterite) predominantly mined from placer deposits. The mineral which is weathered out of granite is concentrated in rivers at placers where the river is slow running. The lighter minerals from the granite is washed further down the river leaving the heavy cassiterite mineral in the river bed along with other heavy minerals such as magnetite, ilmenite, tantalite and columbite.

The heavy mineral assemblage made of cassiterite and its associated minerals need to be processed before the ASM operators can obtain a concentrate which they can sell. The cassiterite- rich sand is screened. The next step involves sluicing. Jigs can also be used.

6.2. Industrial minerals

The main industrial minerals exploited in Nigeria by artisanal miners and ASM operators are barite, bentonite, gypsum, diatomite, kaolin, calcium carbonate and dimension stone. There are only a few things that ASM operators can do to process these minerals, and thereby add value to their commodities. Processing and adding value to industrial minerals are mainly done on commercial plants. Current processing practices applied to some industrial minerals are outlined below.

6.2.1. Barite

Barite is a heavy mineral composed of barium sulphate that is mostly used as a weighting agent in oil and gas drilling. It is also used in the manufacture of chemicals and glass and as a pigment, filler, etc. It has a theoretical s.g. (specific gravity) of 4.5, but the presence of impurities or inclusions usually lower this to about 4.2–4.35. It is relatively soft with mohs hardness of 3 to 3.5.

It is inert, non-toxic with quartz, iron minerals and calcium carbonate, as its major impurities.

The processing method adopted usually depends on the type of product to be produced. The specifications for the various barite products are listed in Table 6-1.

Barite processing usually starts with sorting in the field to produce high grade barite or jigging after crushing to produce a concentrate containing predominantly barite with the gangue removed as tailings.

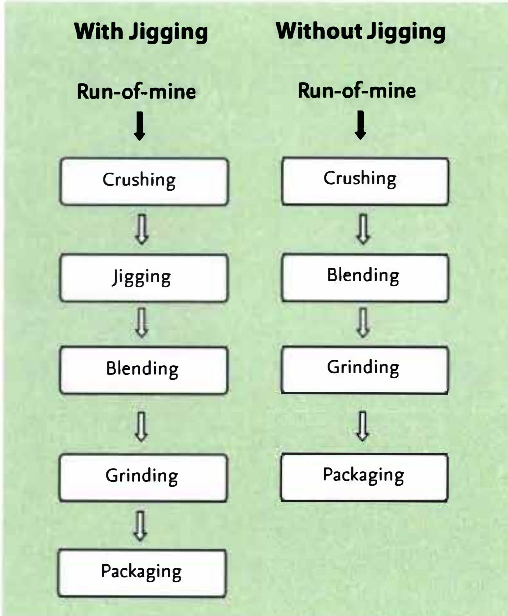
Run-of-mine (ROM) material is generally stockpiled according to specific gravity (s.g.) ranges of 4.00–4.09; 4.10–4.14; 4.15–4.19; 4.20–4.24; 4.25–4.29; 4.30 and above. The various ranges are crushed separately to 100% passing 10 mm and are then jigged or stockpiled. The products produced are then blended to specific gravity requirement before grinding.

Usage	Form (size)	$BaSO_4$	Specific gravity (s.g.)	Fe_2O_3
Weighting agent in oil and gas drilling	-75 µm with an allowance of 3% max.	90%	4.20 (API) but can vary depending on user.	NA
Glass making	100% passing 1.19 mm with 5 – 40% -149 µm fraction	97%	NA	0.15%
Filler for rubber, paint and urethanes	100% passing 44 µm			
Pigment	100% passing 44 µm	94% min.	NA	0.05% max .
Barium Chemicals	840–16000 µm	95% min.	NA	1% (combined Fe)

Table 6-1: Specification of barite products. Source: Carr 1994.

The specific gravity of barite is usually determined by the Le Chatelier flask method as prescribed by the American Petroleum Institute (API), by the density bottle method or the air pycnometer method.

Barite milling entails dry grinding of blended crushed barite to minus 75 μm sieve size with samples of milled barite taken periodically for s.g. determination and sieve analysis to ensure that the product meets the required specifications. Simplified barite processing is shown in Flowchart 4.



Flowchart 4. Barite processing.

Blending usually entails mixing various proportions of low and high s.g. fractions to obtain a required s.g. mix. The right quantities to be mixed are determined using the expression:

required s.g.= $(Q_L{*}s.g_L + Q_H{*}s.g_H)/(Q_L+Q_H)$

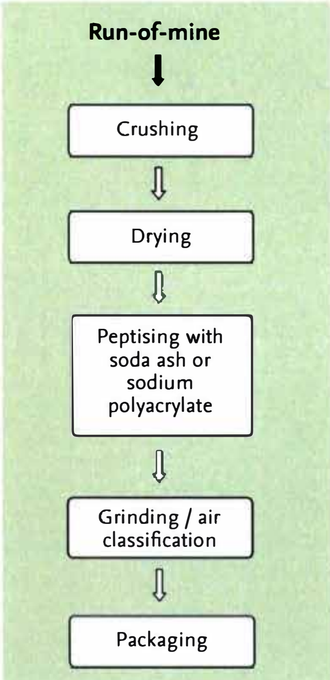
where: Q_L is the quantity of the low s.g. fraction used
Q_H is the quantity of the high s.g. fraction used
$s.g_L$ is the s.g. of low s.g. fraction used
$s.g_H$ is the s.g. of the high s.g. fraction used.

The product obtained after mixing is then sampled and tested to confirm the s.g. before grinding.

6.2.2. Bentonite

Bentonite is a hydrous aluminium silicate composed of the clay mineral, smectite (montmorillonite).

It is used to control the viscosity of drilling fluids. It is also used as binder in foundry sand bond and for iron-ore pelletising. There are two types, Na and Ca



Flowchart 5. Bentonite processing.

bentonite with the sodium bentonite being the most preferred because it swells more and provides better viscosity.

The Nigerian bentonite is mostly the Ca-type with gypsum, quartz and mica as its major contaminants.

Ca-bentonite is mostly peptised using sodium carbonate or sodium polyacrylate and then milled to achieve the proper mixing.

The quality of the product produced is controlled by periodic sampling and testing for fineness of grind as well as the viscosity.

Simplified bentonite processing is shown in Flowchart 5.

6.2.3. Gypsum

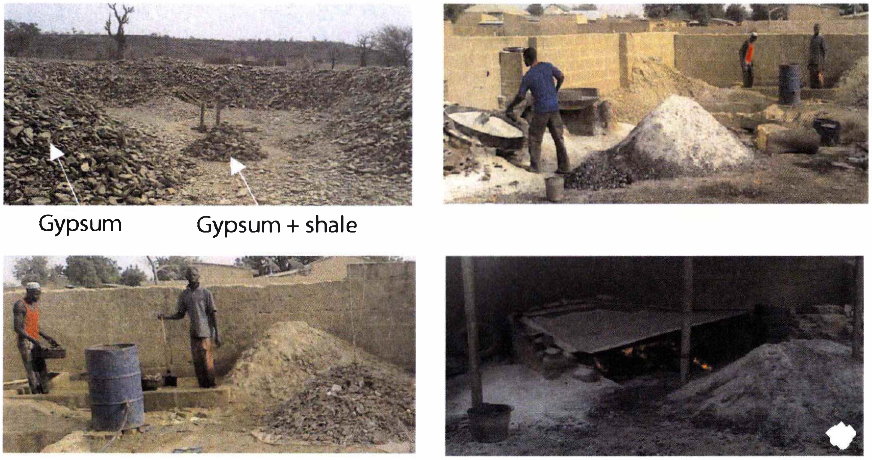
Gypsum is the dihydrate form of calcium sulphate ($CaSO_4.2H_2O$). It is found in association with anhydrite, the anhydrous form of calcium sulphate and shale, etc. While gypsum has a s.g. of about 2.3 and a hardness of 2.0 (Mohs Scale), the anhydrite has a s.g. of about 2.85 and a hardness of about 3.25.

Calcium sulphate is one of the principal constituents of evaporite deposits. When pure, gypsum has 32.6% CaO with 20.9% combined water while the anhydrite has 41.2% CaO with 0% combined water. Gypsum is used in:

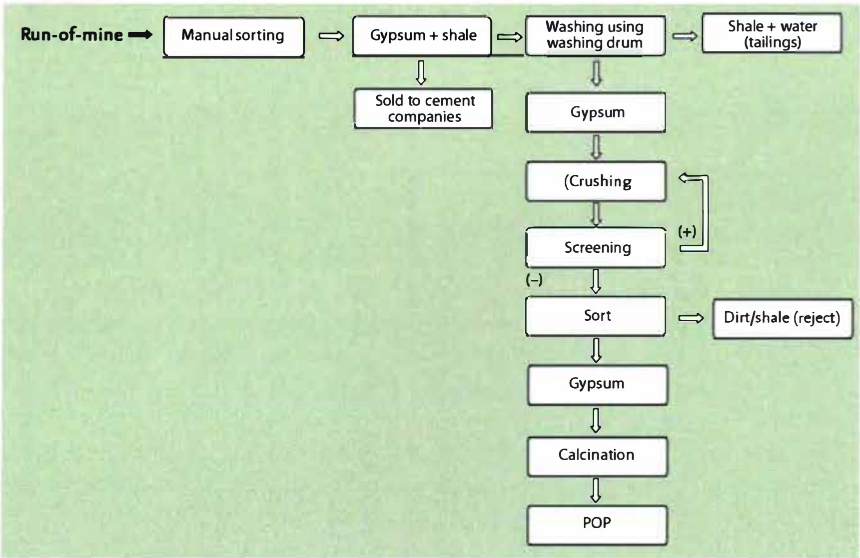
i. Calcined form to produce plaster of Paris (POP), which when mixed with water, can be made into many varieties of plasters, wallboard and moulds.
ii. Raw form to produce Portland cement, condition soil for agricultural purposes, and to produce mineral filler.

Gypsum processing as practiced by ASM operators comprises the following (Figs 6-8 to 6-11):

i. Sorting (manually)/forking to lower the shale content to about 30% in line with cement company specs for local gypsum;



Figs 6-8 to 6-11. Gypsum pit with shale, washing and calcination by ASM operators, Yobe State.



Flowchart 6. Gypsum Processing.

ii. Washing and screening in ponds to produce clean gypsum needed for POP production.

POP production is carried out by crushing washed gypsum, screening, sorting, and calcining in open frying pans (Flowchart 6).

The current practice results in:

a. Inadequate removal of shale content
b. Use of intensive manual labour for sorting, forking and washing in ponds
c. Production of low grade POP due to lack of temperature control resulting in the production of some dead burnt gypsum or insoluble anhydrite that do not take water at any appreciable rate
d. Improper handling of wastes.

The way to optimise this process is:

a. To use a washing drum to scrub and separate slurrified shale from the gypsum thereby lowering the shale content with ease
b. To provide a sump for collecting shale + water (slurry) which would be allowed to settle with the clarified water reused for washing
c. Use a temperature-regulated kettle or rotating kiln with the temperature set at the appropriate calcination temperature of about 150°C.

6.2.4. Diatomite

Diatomite is a very light rock with a density of about 320 to 545 kg/m³. It is soft with a chalky appearance.

Its colour varies from snow-white in a pure, well-bleached and dry deposit, to olive-green or darker where substantial organic remains are still present and where the moisture content is high. It exhibits stratification, caused by either, or both, sedimentation of particularly flat beds or a large number of disc-shaped diatoms, or by seasonal, rhythmic deposition of clay and other impurities.

Diatomite is used in filler and filter applications where the diatomaceous silica remains inert. The fine particulate structure of the diatom skeleton imparts low density, high surface area to milled powders resulting in the provision of high porosity, permeability and clarifying ability required in fil- tration applications. It also imparts absorption capability as well as low thermal conductivity.

Diatomite is processed either by direct milling of the run-of-mine followed by classification or calcination of the run-of-mine (with or without flux addition) followed by milling and classification to produce coarse and fine fractions sold as, respectively, filter aids and filler grades.

Calcination without flux addition is carried out between 870-1100°C with flux cal-

Type	Colour	Density, pcf*		Screen analysis % retained, 106 μm	pH	Median pore size, μm	Permeability, d'Arcy	Typical applications filtration
		Dry	Wet					
Natural	Gray	7.0	16	2.0	7.0	1.5	0.057	Vegetable oil
Calcined	Pink	8.0	18	4	7.0	3.5	0.28	Beer and wine
Flux calcined	White	9.5	18	9	10.0	10.0	2.0	Industrial and portable water

** pounds per cubic foot*

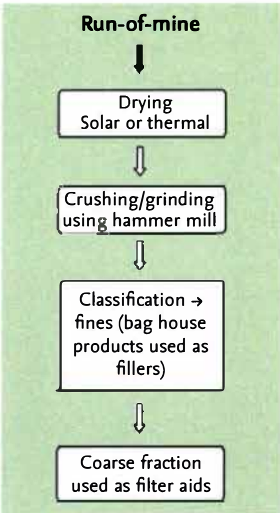
Table 6-2. Typical physical properties of processed diatomite products used as filter aids. (Modified from: Carr 1994)

Physical properties	Paper	Paint (semi-gloss)	Conditioning agent (toxicant carrier)
Loose wet, pcf*	8.0	8.5	8.0
Wet density, pcf*	20	22	24
Moisture content % max.	6.0	0.5	6.0
Retained on 106 μm, wt%	0.5	Trace	Trace
Retained on 75 μm, wt%	8.0	Trace	0.5
Colour	Light grey	White	Buff
pH max.	7.0	10	7.0
Refractive index	1.40	1.46	1.43
Oil absorption	210	105	175
Surface area, m/g	10–20	0.7–3.5	10–20

** pounds per cubic foot*

Table 6-3. Typical physical properties of processed diatomite products used as fillers. (Modified from: Carr 1994)

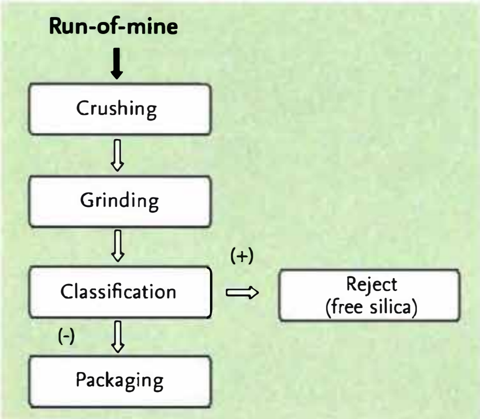
cination (using about 3–7 wt% of feed as flux) carried out at 1200°C. Calcination generally adjusts particle structure and particle size distribution and results in the increase of the refractive index (brightness) of the diatomite especially when flux calcination is carried out with soda ash or sodium chloride. Typical properties of some commercial filter aids and fillers are tabulated below (Tables 6-2, 6-3, Flowchart 7).



Flowchart 7. Diatomite Processing.

6.2.5 Kaolin

Kaolin is a hydrous aluminium silicate clay consisting of substantially pure kaolinite ($Al_4Si_4O_{10}(OH)_8$ with a theoretical chemical composition of SiO_2, 46.54%; Al_2O_3, 39.50%; and H_2O, 13.96%. It is soft with a hardness of 2 to 2.5 and is naturally white or



Flowchart 8. Dry kaolin processing.

can be beneficiated to be white or nearly white. Kaolin fires white or nearly white, and is amenable to beneficiation by known methods to make it suitable for use in ceramics, porcelain, coated paper, rubber and paint.

Kaolin is mostly formed by the alteration of aluminium silicate minerals in a warm and humid environment with feldspar being the most common source mineral.

Two types of kaolin occurrences are known, namely:

i. Primary kaolin occurrence, formed insitu and thus retains the texture form of the parent rock
ii. Secondary kaolin occurrence formed as a result of weathering and deposition of kaolin by sedimentation in fresh or somewhat salty water environments.

Common impurities in kaolins are quartz, mica, illite, smectite, feldspar, goethite and hematite.

Kaolin processing entails the removal of free quartz along with other impurities to produce marketable products using either wet or dry methods. The wet methods are generally used to treat the primary deposits that tend to contain high content of free quartz.

The wet processing method comprises blunging, using hydraulic monitors or blungers, which ensures liberation of the kaolin grains from those of free quartz and other associated minerals thus making it possible for the kaolin grains to be separated from the associated impurities using a combination

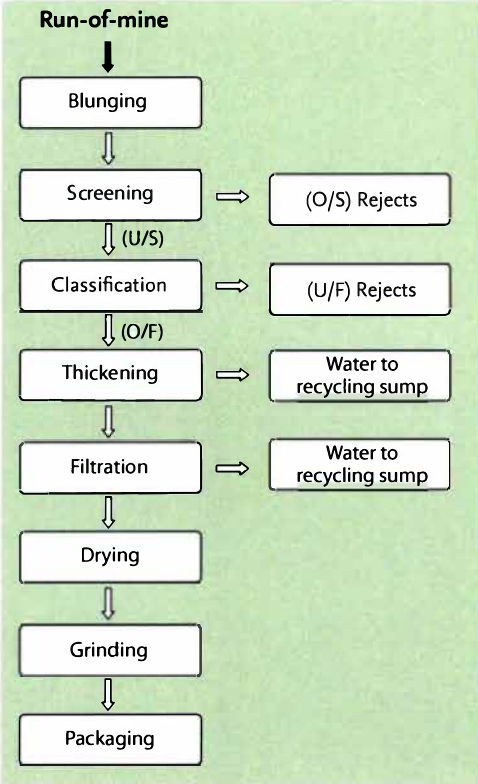
	Brazil fine (secondary)	Cornwall, UK, coarse (primary)
SiO_2	46.0	47.2
Al_2O_3	37.0	37.6
TiO_2	0.98	0.04
Fe_2O_3	1.8	0.68
MgO	0.07	0.20
CaO	0.02	0.08
Na_2O	0.08	0.08
K_2O	0.0	1.37
H_2O	14.3	12.7

Table 6-4: Chemical composition of paper-coating clays of similar brightness. (Modified from: Carr 1994)

of wet-jet sieves and hydrocyclones.

The clay fraction from the hydrocyclones, removed through the over flow, is then thickened, filtered, dried and ground to specification, usually 100% passing 44 μm, if pure enough. Otherwise, it is subjected to further concentration using magnetic separation, flotation, flocculation in combination with bleaching, before filtration, drying and grinding.

Bleaching could be incorporated if the clay needs to be made brighter by using a combination of alum, sulphuric acid and sodium hydrosulphite.



Flowchart 9. Wet kaolin processing.

In the drying process, the properties of the kaolin product are almost entirely dependent on the crude clay quality as delivered from the mine. For this reason, deposits must be selected to have the brightness, grit percentage, and particle size distribution that can be dry processed to make a particular product.

The best practice is to stockpile run-of-mine according to their physical and chemical characteristics and treated separately or blended to the required specs before dry processing.
The upper limit of grit percentage that can be handled in the dry process is usually about 7%.

Dry processing is used to treat kaolin that is essentially pure like the Alkaleri deposit in Bauchi State requiring only crushing, grinding and air classification to produce a market grade.

Typical kaolin product specifications of similar brightness is given in Table 6-4, Flowcharts 8, 9.

6.2.6. Calcium carbonate

Calcium carbonate is generally sourced from carbonate rocks comprising limestone, dolomite and marble. These rocks and their derived products are used as aggregates, fluxes, glass raw material, refractories, fillers, soil conditioners, etc.

Limestone is a sedimentary rock composed principally of the mineral calcite ($CaCO_3$) with dolomite being a sedimentary rock composed mostly of the mineral dolomite ($CaCo_3.MgCO_3$). Other carbonate minerals found in minor quantities in association with limestone and dolomite are siderite ($FeCO_3$), ankerite ($Ca_2 MgFe(CO_3)_4$ and magnesite ($Mg CO_3$).

Typical sieve analysis - glass grade

Size (mm)	% retained cumulative	% passing cumulative
1.68	0.00	100.00
1.19	0.17	99.83
0.84	5.20	94.80
0.30	62.25	37.75
0.15	88.90	11.10
0.07	98.40	1.60
Pan	100.00	0.00

Typical chemical analysis - glass grade

Reported as:	%
$CaCO_3$	97.8
$MgCO_3$	1.25
Fe_2O_3	0.095
SiO_2	0.56
Al_2O_3	0.23
Ni	<0.002
Cr_2O_3	<0.001
SrO	0.03
MnO	<0.01

Table 6-5. Typical physical and chemical analyses of limestone glass grades (sieve and chemical analyses). (Source: Carr 1994).

Carbonate minerals have very similar physical properties making it very difficult for one mineral to be distinguished from the other. The rate of solubility of the different minerals in dilute hydrochloric acid is a most useful technique for identifying carbonate minerals in the field where calcite is found to be much more soluble than dolomite. Hence, if a fresh rock surface is etched, the amount of dolomite left standing in relief can be estimated using a hand lens. X-ray diffractometer is also used to determine the mineralogical composition of a carbonate rock bulk sample.

Carbonate rock processing entails crushing and grinding to size specification such as 100% passing 1.68 mm sieve size for glass-grade limestone.

Typical specifications for various calcium carbonate products are found below:

6.2.7. Dimension Stone

Dimension stone refers to stone that is finished to specific dimensions and shapes and used for their aesthetic appeal, durability and ease of maintenance. Generally, dimension stones are quarried in large rectangular blocks, sawed into slabs for further finishing.

They are used in buildings, monuments, furniture, etc. Other stones (aggregates) are used in natural or broken sizes and shapes which are sorted in size ranges but not finished or dressed to specific dimensions. They are used for e.g. building and paving.

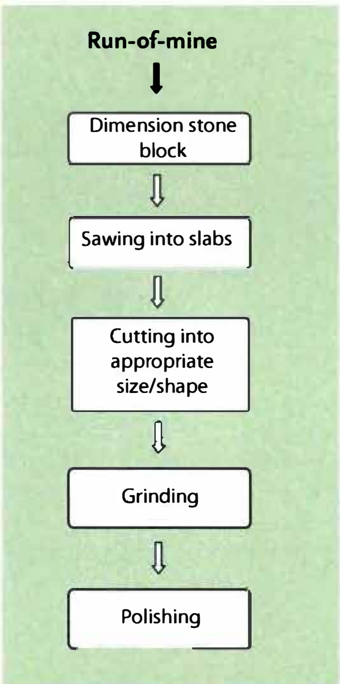
Rocks that are processed and sold as dimension stone include granite, marble and limestone. The suitability of a given stone to be used as dimension stone depends on its physical properties (strength, absence of structural defects, uniform grade) and aesthetic appeal (Table 6-6).

COLOUR	Classic colours	Marble	White, black, pink, green
		Granites	Black, red
	Ordinary colours	Marble	Beige
		Granites	Grey, pink
	Special colours	Marble	Yellow, red, blue
		Granites	Yellow, purple, blue, green
TEXTURE	**Homogenous**	(even drawing)	
	Oriented	(uneven drawing)	
GRAIN SIZE	**Fine** **Medium** **Large**		

Table 6-6. Factors that determine the aesthetic value of dimension stone. (Source: Ragone 2010).

MARBLE TILE		GRANITE TILE	
THICKNESS (mm)	DIMENSIONS (mm)	THICKNESS (mm)	DIMENSIONS (mm)
7	150 × 300	7	150 × 300
10	300× 300	6.5	305 × 305
10	305 × 305	10	300× 300
10	400× 400	10	300× 600
13	400× 400	12	400× 400
15	457 × 457	12	457 × 457
15	600× 300	12	600× 600

Table 6-7. Typical tile dimensions. (Source: Ragone 2010).



Flowchart 10. Dimension stone production.

Dimension stone quarry operations generally involve:

i. Cutting the stone using diamond wire saws, automated jet burner or drilling a series of long parallel holes using pneumatic or hydraulic powered percussion drills
ii. Breaking the stone using wedges and feathers or very light explosive
iii. Removing the stone from its broken position.

ASM operators involved in dimension stone production in Nigeria usually sell their products in block form. The most ideal thing to do is to produce a finished product where the blocks should be sawn into slabs and then cut into suitable sizes and shapes, ground and then polished.

Equipment usually used in producing finished dimension stone include:

i. Gang saw, wire saw or circular saw for primary cut

ii. Circular saws (bridge saws) for secondary cut

iii. Hand-held pneumatic tools, wire saw, carborandom or diamond wheels for shaping

iv. Surfacing machines using impregnated diamonds for grinding

v. Grinding/polishing machine that moves the spindle over the stone for polishing.

Typical tile dimensions for marble and granite finishing are as given in Table 6-7. A typical dimension stone production is as shown in Flowchart 10.

6.3. Gemstones

The gemstones exploited by ASM operators in Nigeria are mainly tourmaline in various colours. The attractive, coloured tourmalines are named rubelites. The mining is underground or in pits, and mining is carried out by blasting. When a face has been handpicked for gemstone quality stones, then drilling and blasting are carried out. In the blasted material, the rubelites are highly fractured, and thus fetch a very low price only. On the surface behind the blasted material non-fractured gemstones occur.

There are types of explosives which do not shatter the rocks very much. If such blasting material is used, then less rubelite would be destroyed. Another way to prevent the fracturing of so many gemstones could be to have experts in blasting to set up patterns for drilling and optimising loading of the drill holes.

Children in Russo, Kaduna State

7. Health and safety issues in ASM

ASM is a dangerous occupation. The number of casualties and health problems among miners is enormous. Two of the reasons that the miners jeopardize their lives and health are lack of knowledge and lack of money. If ASM operators knew how lethal finely ground quartz is to their lungs, they would probably use dust masks, which provide an efficient and inexpensive protection against stone lungs. If the miners had a better economy they could spend money on timbering shafts, walls and roofs in their tunnels in order to prevent collapse of their tunnels.

7.1. Health problems

Numerous health problems trouble the ASM operators ranging from inhaling quartz dust over hearing loss to mercury poisoning.

Occupational health hazards comprise:

1. Stone lungs/silicosis (dust)
2. Lead poisoning (dust)
3. Mercury poisoning
4. Cyanide
5. Radiation
6. Noise

7.1.1. Stone lungs/silicosis

Quartz is the main mineral in most of the gold ores mined by small-scale miners. To liberate the fine gold grains it is necessary to crush and grind the quartz. Grinding is mostly carried out in ball or rod mills. Depending on availability of water the grinding can be done dry or wet. If the grinding is dry there is a major risk of inhaling the fine-grained quartz dust (Fig.7-1a). The dust will over time accumulate in the lungs and eventually cause silicosis also called stone lungs. Breathing is very difficult with stone lungs and if the miner goes on inhaling quartz dust the final result will be death.

There are two ways out of this problem. The easiest is to use dust masks (Fig. 7-2). They are easy to use and inexpensive. They may be difficult to get hold of in ASM communities, but should be available in larger towns.

Another way to reduce the risk of silicosis is to use wet grinding instead of dry grinding. Wet grinding of gold ore is widely distributed in the Philippines (Fig. 7-1b). This will prevent the immediate risk of silicosis. However, precaution must

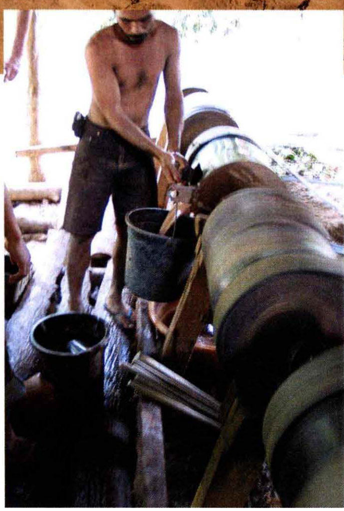


Fig. 7-1a. Dry grinding of quartz-gold ore in a ball mill produces large amounts of dust.

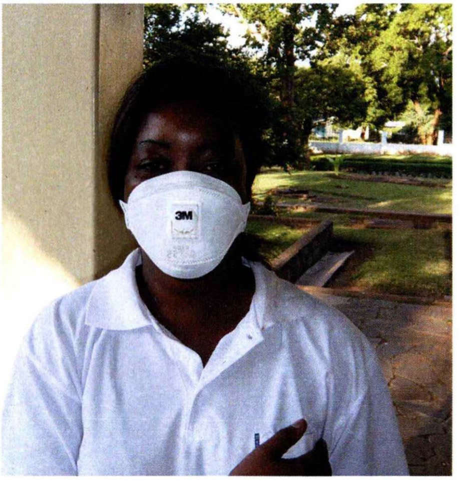
Fig. 7-1b. Wet grinding of quartz-gold ore in a rod mill produces no dust and no noise.

be taken with the tailings from the grinding as the fine quartz dust will be blown around and cause stone lungs in the mining communities, when the tailings dry out. To prevent the tailings from drying out, they should be properly sealed with a layer of mud.

7.1.2. Lead poisoning

In 2010 a major health disaster occurred in Northern Nigeria where a large num-

Fig. 7-2. Dust masks reduce the risk of getting silicosis/stone lungs.



ber of children died. After proper investigation it turned out that they died from lead poisoning and the lead came from small-scale gold mining. The grounding produced not only quartz dust but also lead-rich dust. The grounding took place in the ASM communities and often even inside their houses. Utensils which are used for preparing food were used during processing the ore. During milling of the ore a fine-grained, lead-rich dust was inhaled by many of the inhabitants, especially children. The fine-grained, lead-rich tailings were disposed in or near the communities as dry powder. When windy, the powder was blown around and was not only directly inhaled but also polluted the food. The result was severe lead poisoning of the population leading to around 200 deaths.

This could have been avoided by extracting the gold outside the villages and by securing the lead-rich tailings by covering them with a layer of clay. This would effectively seal off the toxic tailings.

7.1.3. Mercury poisoning

During gold extraction (Chapter 6) with mercury (amalgamation) the metallic mercury is burned off. Some of it will be inhaled by people doing the amalgamation and by the villagers. Mercury vapour which is not inhaled will precipitate with rainfall and gradually be washed into the local drainage system. In the aqueous environment metallic mercury is transformed by bacteria to methylated mercury which is even more toxic than metallic mercury. The methylated mercury (also called organic mercury) enters the food chain and eventually ends up in fish which are eaten by people. In this way the population may get high concentrations of mercury in their bodies (Fig. 7-3).

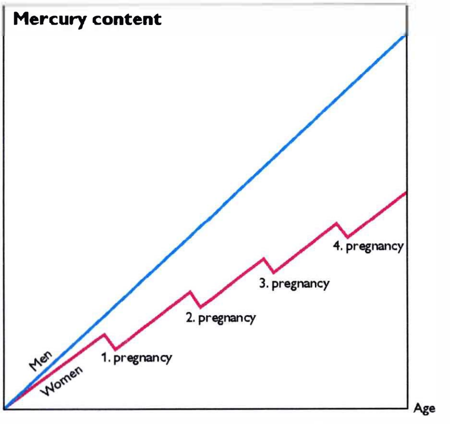
Fig. 7-3. Paths of mercury in the environment and the food chain. ***Hg*** *is the chemical symbol for mercury. The 'story' starts in the lower left corner and moves forward clockwise. An ASM operator burns amalgam and thereby releases metallic mercury. He inhales some of the mercury. The rest of the mercury falls down on the soil with the rain. Then the metallic mercury is converted by bacteria to methylated mercury and enters the food chain through the drainage system and ends up in cows, hens, fish and rice. When eating the food the population is poisoned by mercury.*

7.1.3.1. Health hazards caused by mercury

Metallic mercury is dangerous to the health and must be handed with outmost care. When heated the fumes get into the atmosphere. These fumes cannot be seen or smelled. In the lungs the metal fumes are easily absorbed in the bloodstream, carried around in the body and taken up by various organs.

Classic symptoms of mercury poisoning are tremors. In the beginning the tremors are intentional, that is, only visible when the patient is asked to approach a glass of water to his/her mouth, to move a finger towards his/her nose or to write a signature. Later, the tremors become static, and may spread to the whole body. Erethism is a mental disturbance characterised by acute irritability, abnor-

Fig. 7-4. The build-up of mercury content of men and women from birth to old age. The woman exemplified here has had four pregnancies. In each case the foetus has extracted much of the mercury from the mother.



mal shyness, indecision and overreaction to criticism. Inflammation of gingiva and metallic taste are other symptoms.

When mercury is present in the blood stream of a pregnant woman, it will pass the placental barrier to be concentrated in the foetus. As the foetal period is the most sensitive to environmentally dangerous chemicals such as mercury, pregnant women should never be exposed to mercury. If a pregnant woman is exposed to mercury she may give birth to a mentally and/or physically disabled child (Fig. 7-4).

Methylated mercury can pass the placental barrier and cause development deficiencies in children such as loss of intelligence, decreased language skills, memory and attention. Methylated mercury in adults has also been linked to increased risk of cardiovascular disease including heart attack. It can also cause neurological symptoms such as loss of physical coordination, difficulty of speech, narrowing of the visual field (tunnel vision), hearing impairment, blindness and death.

A simple field test is to ask a person to draw a circle. If the person is poisoned by mercury he/she cannot draw a proper circle due to tremors (Fig. 7-5).

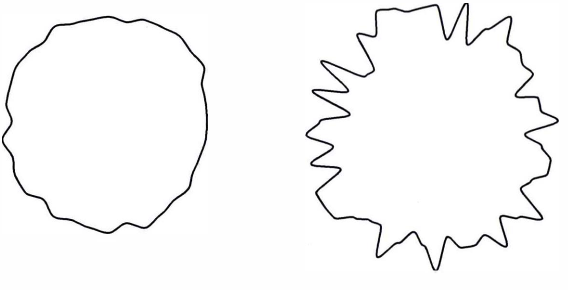


Fig. 7-5. Circles drawn by a person without mercury poisoning (left) and by a person with mercury poisoning (right).

In chapter 3 different gold extraction methods are described several of which will reduce/eliminate use of mercury in ASM.

7.1.4. Cyanide

Cyanide is used for extraction of gold; it is a very toxic agent which kills almost instantaneously. Inhaling or ingestion can be lethal. One of the effects of cyanide in the human body is that it inhibits the uptake of oxygen in the blood. Great care has thus to be taken during storage and use. It is especially important to alert the surrounding community in case of a cyanide spill. If the cyanide finds its way to streams and rivers the water must under no circumstances be used for consumption. However, cyanide disintegrates very fast by interaction with the atmosphere to harmless ingredients. If cyanide was spilled in water used for drinking purposes then it is ok for drinking after a short time.

7.1.5. Radiation

Tantalite/columbite is mined by ASM operators in several places in Nigeria. Today the mineral is extracted from soil overlying hard rock tantalite deposits. The mining itself is not dangerous since it does not involve deep diggings. However, the storage of the ore concentrate may create problems. The mineral columbite/tantalite frequently contains small amounts of uranium. Uranium is radioactive and its radiation produces the radioactive gas radon. Radon produces a number of radioactive daughter products some of which are metals. Radon and its daughter products are inhaled and may damage lung tissue.

As long as the columbite/tantalite is stored outside there is no risk of radiation damage. However, if the tantalite/columbite is stored indoors in houses where people sleep, the radon accumulates and can seriously harm them. It is thus of importance to store the mineral outside or in rooms where nobody lives.

7.1.6. Noise

Noise can be a major problem for small-scale miners, but can be mitigated easily. If the miners use dry grinding in ball or rod mills it not only produces a lot of dust, but also an unbearable noise. Many of the miners doing dry grinding have advanced stages of tinnitus or are almost deaf. If the miners switch to wet grinding there are no noise problems whatsoever. An argument put forward by many miners is that it requires lots of water. It does consume water, but the water can be recycled.

7.2. Safety problems

One of the main problems in underground mining is that most miners support neither roofs nor walls. This is essential to do in order to avoid collapse with risk of severe bruises or casualties and lack of oxygen in tunnels and shafts (Fig. 7-6).

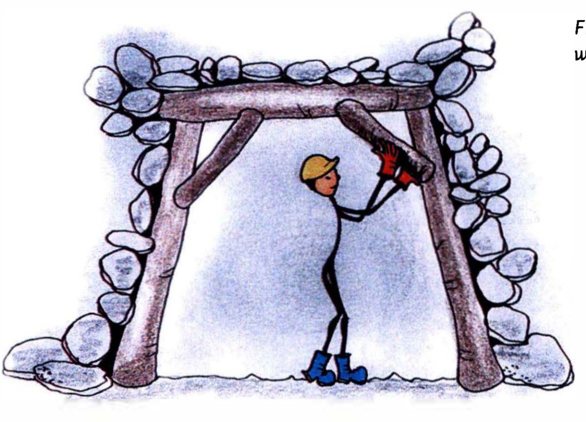
Extracting stones from hard rock deposits is done by hammer and chisel. A major problem is that splinters from the rock may hit the eye and cause blindness if safety goggles are not used. It is therefore important to instruct workers to use safety goggles. (Fig. 7-7).

Pits and tunnels are dangerous working places, but simple inexpensive means, e.g. safety boots, safety helmets and protective gloves, will protect miners against many accidents (Fig. 7-8).

Safety measures should be taken against falling stones and collapsing walls in deep pits. (Figs 7-9 and 7-10).

If accidents do happen it is important to have a first-aid kit near the mining site and someone who has been taught the basics of first aid (Fig. 7-11).

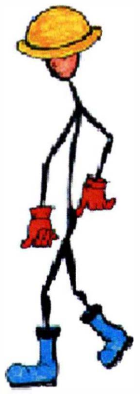
Lack of oxygen is a frequent problem which many ASM operators face. A deep shaft extended by tens of metres long tunnels is a real death trap. If miners do not make shafts at each end of tunnels in order to create ventilation then they are due to suffocate. If miners use compressors or water pumps in the mine then all oxygen may be used by the engines and replaced by carbon dioxide and diesel fumes. If miners work at the bottom of the shaft or in tunnels when the machines are running they have a big risk of suffocating.



Source: Walle & Jennings 2001

Fig. 7-6. Entrance to a tunnel with well-supported walls and roof.

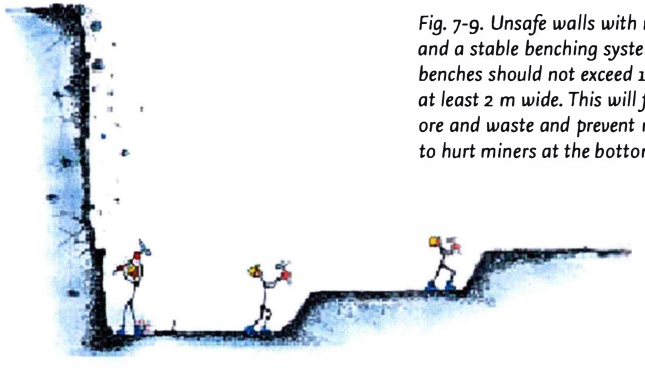
Fig. 7-7. Always use safety goggles



Source: Walle & Jennings 2001

Fig. 7-8. Always use safety helmet, boots and glows.

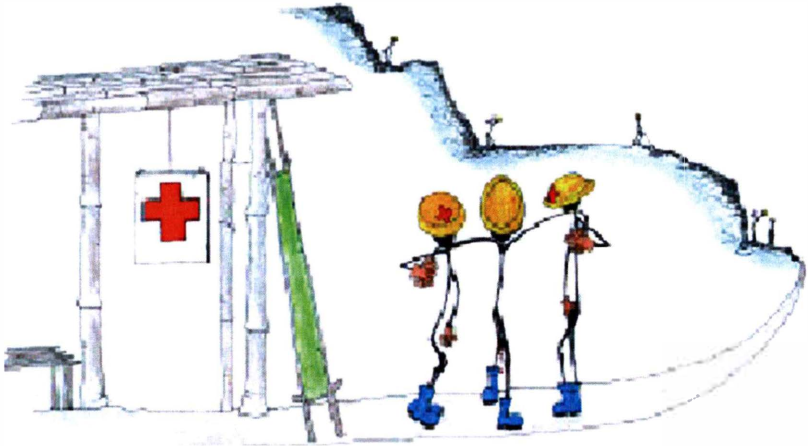
Fig. 7-9. Unsafe walls with rock fall on the left and a stable benching system on the right. The benches should not exceed 1.5 m in height and be at least 2 m wide. This will facilitate carrying up ore and waste and prevent material falling down to hurt miners at the bottom of the pit.



Source: Walle & Jennings 2001

In shorter tunnels a man powered air pump may be sufficient to supply oxygen to the miners. The pump can be engine powered but for lack of funding for such an engine a bicycle powered pump can be used as shown on Fig. 7-12. This type of pump is well known in Nigeria.

Fig. 7-10. Very deep pit with near vertical walls with a high risk of accidents caused by falling stones.



Source: Walle & Jennings 2001

Fig. 7-11. If accidents do happen it is important to have a first-aid kit near the mining site and someone who has been taught the basics of first aid.

Fig. 7-12. Bicycle-powered pump for providing oxygen to tunnels.

Nahuta lead/zinc mining site in Gombe State

Female workers in the barite mine in Azara, Nasarawa State

8. Environmental issues in ASM

Mining may cause environmental risks ranging from waste rock and tailings disposal, land disturbance, dust and noise to water use and pollution. If not managed well, any of these risks could adversely affect the state of health and future livelihood of the populations living near mining operations.

A first step for the Mines Environment and Compliance Department of the Ministry of Mines and Steel Development to mitigate such risks is to engage relevant mining communities and groups through information and education. And at the same time use the legal and regulatory framework, and make direct agreements with the mining operator to establish appropriate environmental performance as well as acceptable working conditions. The key to mitigating environmental risks is setting and monitoring appropriate standards and monitor and enforce compliance.

The environmental costs of ASM activities are in general higher than those of other types of mines – this means that ASM is dirtier per unit of output compared to medium, large and modern mining operations. Another problem of ASM is the great number of individual polluters, concentrated in a determined area, which causes significant local environmental impacts. It is difficult to effectively control, monitor and enforce environmental violations due to lack of resources and the inaccessible nature of the ASM sector.

Common environmental impacts associated with mining include:

- Deforestation, destruction of landforms and soil erosion leading to land degradation
- Pollution of previously potable water
- Changes in river regime and ecology due to pollution, siltation, sedimentation and flow modification
- Destruction of adjacent habitats from influx of migrant workers and encroachments
- Destruction of natural habitats at ASM sites and at waste-disposal sites
- Land instability

Past experience in Nigeria has also highlighted the following environmental impacts:

- Destruction of adjacent habitats through emissions and discharges
- Alteration of the water table

- Soil contamination from treatment residues and chemical spillage including mercury
- Land degradation and ground subsidence due to inadequate rehabilitation after closure and the abandonment of ASM workings and equipment
- Danger from failure of structures and tailings/waste dams

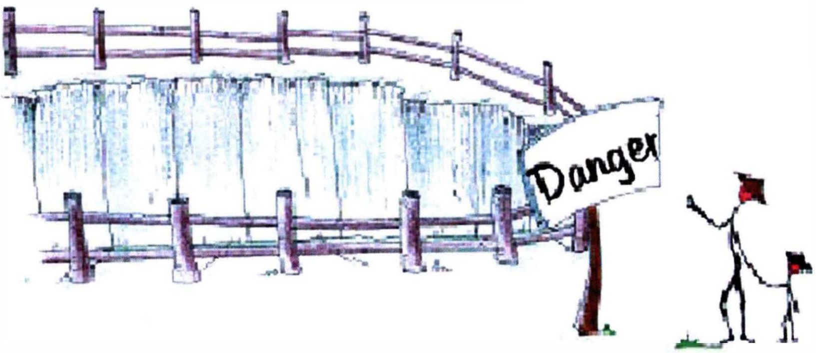
Not all impacts are a direct result of the current mining operation. As has been discussed previously, Nigeria once had a more developed mining sector. Some of these abandoned sites are now being reworked by ASM operators. These legacy sites are apparent all over Nigeria and where the site itself or the tailings can be worked, be it at subsistence or profit making level, it is likely that ASM operators will take over the site.

8.1. Land degradation

During prospecting and exploration for mineral deposits, trenches and ditches are dug in order to trace the ore-bearing structures. The next step in ASM is to dig down to the ore in order to test whether it can be mined with a profit. This often requires removal of large amounts of overburden. Only few of the ASM op-

Fig. 8-1. ASM operation has made this area useless for farming. Yayaarima, Gombe State.

Fig. 8-2. This is a situation where all safety measures have been violated: Steep pit sides, a bridge which can collapse and stones that may fall from above. Nahuta, Gombe State.



Source: Walle & Jennings 2001

Fig. 8-3. Fencing of a pit prevents people or animals from falling into it.

erators consider where they dump the overburden. They merely dump it where it is easiest for them.

Due to ASM operation, a large farmland area may within short time be littered with exploration pits and trenches making the fields useless for farming purposes. The pits need not be very deep. Fig. 8-1. shows badlands due to excavation of exploration and mining pits.

Whether it is possible to get ASM operators to re-establish the surface by filling all pits and trenches is a big question. Many of the pits are so deep and the walls so steep that it will be fatal for a person or an animal to fall into the pit (Fig. 8-2). An absolute minimum requirement from the environmental authorities is that the miners fence off active as well as abandoned pits and trenches (Fig. 8-3).

Siltation

When ASM operators remove large amounts of overburden, the area is more prone to soil erosion. During the rainy seasons large amounts of fine-grained material, clay and sand will be transported by water to small and large streams.

Several of the ASM operations require fairly large amounts of water for extraction purposes such as sieving ore for extracting precious and semiprecious stones or gold. The need for large amounts of water often makes small-scale miners move that part of the processing to the nearby streams. This will add considerable

Fig. 8-4. Concrete-lined basin for washing eluvial material containing spessartine. The fine-grained material deposited in the basin is prevented from being washed into the drainage system.

amounts of sand, clay, crushed and ground rock material to the streams.

This clay and sand from overburden and mineral processing will tend to clog up the rivers and cause them to change course which may result in flooding. The large amounts of sand and clay in the river water may also influence the living conditions of the fish such that less fish can be caught.

Can siltation of drainage pattern be avoided? It is not possible to avoid siltation completely but it can certainly be significantly reduced. This requires that the ASM operators are instructed in how to dump the overburden and the tailings from the mineral extraction.

A good example of how to reduce siltation is shown in Fig. 8-4. A concrete-lined basin has been constructed to avoid silt from the washing of spessartine ore to be transported downhill into the drainage system.

As regards the overburden it is important to teach ASM operators to use appropriate dumping sites, i.e. avoid dumping it on steep slopes, and seal the dumping sites with stone fences. Sealing of dumping sites can also be done fairly easily by introducing appropriate vegetation. Some sorts of grasses and bushes grow fast and their roots consolidate the dumped overburden.

Tailings dumps from ASM operations pose special problems, firstly, because the material often is quite fine-grained and secondly, because they may be situated next to rivers and streams. It is very important that the tailings dumps are fenced off from the streams. The fencing may consist of rocks or plastic sacks filled with tailings material. It is also important that each tailings dump is of limited size. This is to avoid a major disaster if, during heavy rain falls, a tailings dump breaks and discharges its content into nearby streams. Introduction of vegetation such as fast-growing grass or bushes is important. The roots of the grass and the bushes will keep the tailings in place and thus prevent siltation of streams and rivers. The forestry authorities are able to advice on suitable plants.

8.2. Deforestation

Open-pit small-scale mining in Nigeria does not require much wood apart from charcoal for cooking. ASM communities will take a toll of the nearby forests, but not much more than if the same people had other types of jobs. If, however, ASM operators learn how to support their pits by timber then a significant deforestation may take place. Some miners, e.g. amethyst miners, do underground work with small tunnels from pit to pit. This is a way to increase recovery without digging too many new pits. Unfortunately the tunnels are rarely supported and they often cave in with fatal results.

Such fatalities could be avoided if the miners learned how to support walls and roofs in tunnels and steep sides in deep excavations. This would require large amounts of timber which would be taken from nearby forests, causing considerable deforestation.

Deforestation can be a serious problem if not tackled in the right way. It is obvious that small-scale miners should not be talked into not using timber for supporting their working areas. What can be done in deforestation is to involve officers from the Forestry Authorities. They can teach the small-scale miners which types of trees are best for their purpose and can also teach them to plant replacement trees for the trees they use (Fig. 8-5).

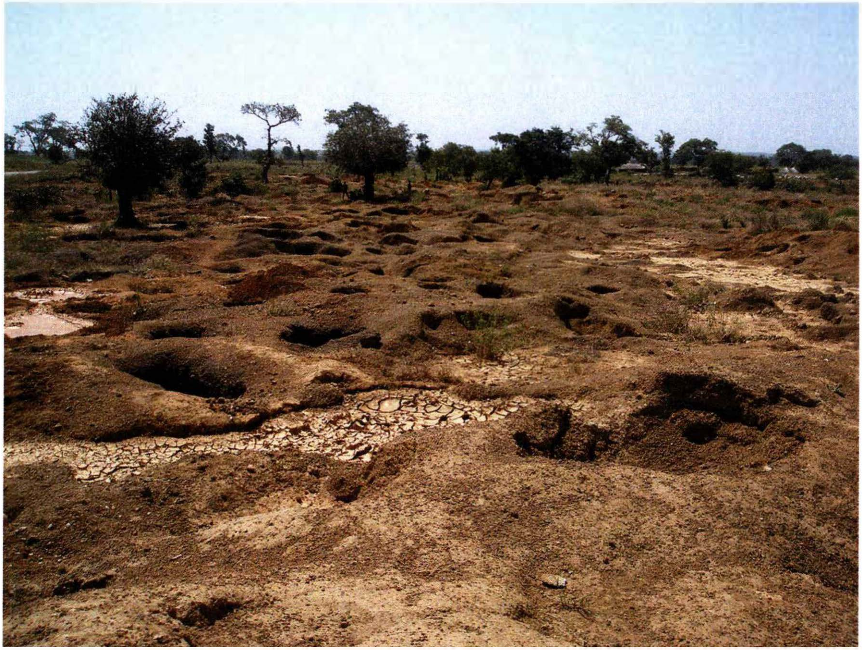


Fig. 8-5. Pit mining leaves only a few trees in the area. Yayaarima, Gombe State.

8.3. Dust

Dust generated by rock, metal and coal mining can be harmful. Using wind to separate metal from ore, or using machinery that generates rock dust, can lead to silicosis. Silicosis is a disease caused by inhaling silicates in the dust of crushed rocks; it can severely decrease workers' lung capacity and productivity, and it sometimes results in their deaths. For a detailed description of occupational health issues related to dust, refer to chapter 7.

Suggested mitigation strategies:

- Maintain tree or vegetation cover to capture dust and prevent dust clouds from traveling long distances
- Ventilate underground mines so dust can escape and ease working conditions
- Avoid crushing or grinding ore in the home
- Provide all workers with face masks.

8.4. Noise

Mining activities can involve equipment that can be very noisy or cause strong vibrations. This can affect workers' hearing and health, as well as the community around the working site. This may work against the enterprise's ability to expand production in the future. For a detailed description of occupational health issues related to noise, refer to chapter 7.

Suggested mitigation strategies:

- Provide earplugs for workers
- Repair and maintain machinery so that excessive grinding or squeaking is minimised. This also reduces fuel costs
- Provide protective insulation or cushioning to those working with vibrating machinery
- Use machinery efficiently. Do not run machinery longer than necessary. This saves energy and reduces environmental damage
- Try to use noisy machinery only at times when the surrounding community is least likely to be disturbed. For example, it may be better to operate such machinery during the daylight hours.

8.5. Chemical pollution – mercury

One latent environmental (and human health) impact is contamination from anthropogenic mercury that can be attributed to the direct discharge from the amalgamation of gold concentrates. This discharge creates areas of very high mercury concentration – hot spots – due to the low mobility of mercury.

Fortunately, in Nigeria mercury is currently not used extensively by artisanal miners to amalgate the gold gravity concentrates. It is probable that in some areas of gold mining activity, the high content of organic acids in soils and surface waters will favour oxidation of such metallic mercury. Indeed, past studies in other countries have demonstrated that sediments and watercourses near mercury emission sources are significantly contaminated.

In addition, mercury associated with suspended particles in streams and rivers can be transported far downstream, and could reach the major watercourses of the Benue and Niger Rivers. Part of the mercury emitted is transformed by microorganisms (usually in an anaerobic environment) into methyl mercury which is highly soluble in water and rapidly bio-accumulates in the aquatic environment. For a detailed description of occupational health issues related to the use of mercury, refer to chapter 7.

8.6. Mine waste

Mine wastes often pose serious threats to human health and wildlife, and have persistent and hazardous impacts on groundwater, surface water and soils. ASM operators often use inefficient extraction methods that result in substantial loss of the mineral. Finding and removing ore from pits with inadequate or poorly operated machinery reduce yields. Crude processing technologies can lead to lost earnings and more waste.

Suggested mitigation strategies:

- Maintain machinery. To maximise efficiency, make sure machinery is working properly and train workers in operating and maintaining it. Ensure that operators are keeping maintenance logs
- If little or no machinery is used, consider low-cost technologies that may increase yields. Improving separation methods, such as sluices or gravity centrifuge machines, increases productivity and reduces waste
- Check rock waste or the extraction area to see if the mineral is being wasted or if potentially valuable mineral veins are being destroyed. Train labourers in the proper techniques for identifying and removing ore.

8.7. Mine closure – long-term hazards

The environmental impacts of even a short-term mining operation often last many years, even centuries, beyond the working life of the mine. Unless they are mitigated, contaminated waste, hazardous mine structures and disturbed land can pose problems long after mining operations close. Adequate waste disposal and careful mine closure represent additional cost to the mining operation, but may reduce community and government opposition to future mining activities.

Suggested mitigation strategies:

1. Seal underground mines. Cover entrances to underground mines so they do not present safety hazards
2. Construct waste disposal sites that will last. Make sure tailings ponds or chemical waste dumps are secure and can withstand severe weather.

8.8. Awareness of environmental impacts

The environment is not one of the most immediate concerns of ASM operators and is only really considered when it begins to directly impact on their lives, such as pollution of drinking water sources. ASM activities is in some areas considered a supplementary income generating activity and for many at site level a purely subsistence level activity driven by the need for financial gain, however small. As a result, the long term implications, such as the direct and indirect environmental impacts of mining activities is often not fully appreciated and/or addressed. For this reason, it is important that any environmental obligations do not result in time consuming or financially restrictive constraints at the ASM level.

There are a number of sites where formal operators are aware of their environmental obligations and they suggested they would rehabilitate the land when they finished working. This was not actually witnessed on any site but the explanation could be that the locations are still being actively worked.

Effective monitoring and evaluation are essential to any plans and systems put in place. Involving the miners and the local community in the development, operation and monitoring of environmental schemes will increase ownership and hopefully success of these environmental schemes. Each site needs to have its own plan, tailored to each specific situation.

The Mines Environment Compliance Department is responsible for:

- Reviewing all plans, studies and reports required from holders of mineral titles in respect of their environmental obligations
- Monitoring and enforcing compliance by holders of mineral titles with all applicable environmental requirements and obligations
- Performing periodic environmental audits to ascertain that all regulations and obligations are being met by mineral title holders.

To ensure that mining activities do not cause further damage to water supplies and the land, the level of awareness amongst ASM operators needs to be raised. In this respect, generic sensitization plans need to be developed and implemented to ensure that miners recognize the negative effects of the mining activities, how they can be prevented and/or remediated should damage occur. It is important to forge links between the federal-level and state-level ministries responsible for environmental protection to help educate and influence the sector. The responsibilities of the Mines Environment and Compliance Department include reviewing all plans, studies and reports required from title holders in respect of their environmental obligations, monitoring and enforcing compliance by title holders with all applicable environmental requirements and obligations and performing periodic environmental audits to ascertain that all regulations and obligations are being met.

The extension services cover the provision of the EIA report and guidance on waste and tailings disposal. This alone, however, is unlikely to address the current environmental impacts that are taking place. The development of an EIA is a long way from taking mitigating measures to preventing such impacts. It is also likely that given the complexity of the process, the EIA will never be seen or discussed with the labourers working the site and contributing to the environmental impacts.

8.9. Environmental Impact Assessment

An Environmental Impact Assessment (EIA) of an ASM operation involves studying a proposed mine to investigate whether it will have any positive or negative impacts on the environment and human health. It includes indentifying ways to mitigate (avoid, reduce, restore, remediate, compensate) and how to monitor these impacts. The main objective of an EIA is to make sure that potential problems are identified and addressed before mining actually begins.

The main parts of an EIA for ASM are:

1. Identification of the impacts of a mining activity. Impacts are defined as 'negative' or adverse impacts and as beneficial impacts
2. Prediction of the extent of the impact of mining. Prediction involves an analysis of the degree to which the mining activity may negatively or positively impact the environment and community, if implemented
3. Evaluation of significance of impacts. As every mining operation has an environmental impact, evaluation involves the determination of how serious this impact is
4. Mitigation seeks to define what can be done to reduce the adverse impact of the mining activities (i.e. avoid, reduce, restore and/or compensate).

According to the Statutory Requirements of the Minerals and Mining Act, 2007, the operator needs to obtain a Water Use Permit from MCO, if required. The op-

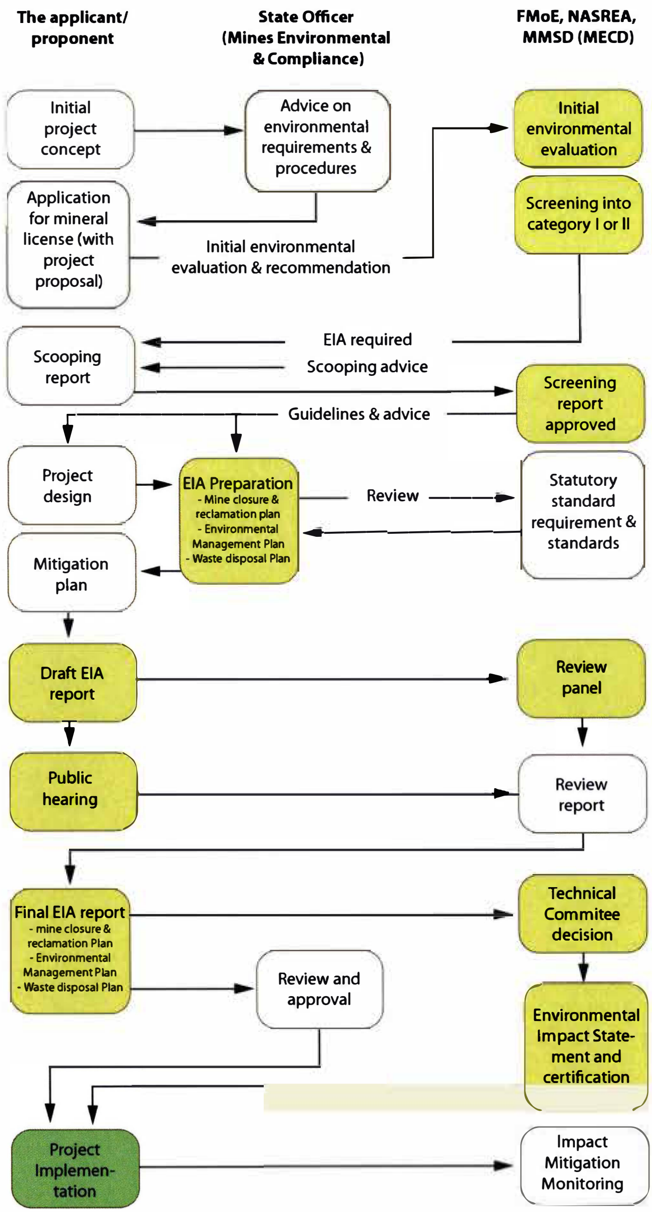


Fig. 8-6. Illustration of the EIA process for a mining/quarrying project.

erator is also required to prepare an Environmental Impact Assessment Statement and a mitigation plan which should define the actions needed to minimise the negative environmental impact of the mining operations to be approved by the Federal Ministry of Environment. Once approved, the Environmental Impact Assessment Statement is submitted to the Mines Environmental Compliance Department at MMSD.

The ASM operator and the host community are required to sign a Community Development Agreement which should be submitted to the MECD for approval. The ASM operator is required to prepare and submit to the MID for approval, a detailed work programme comprising production schedules of the operations, stripping ratio, pit limit, mine plan and design, mining and processing methods to be used amongst others. Copies of this report should also be submitted to MCO and MECD.

Following the submission and approval, the ASM operator is required to prepare mandatory periodical reports for submission to the MID, MCO and MECD.

The operator is required to define and organise an effective management system for tailings and other mining waste disposal by ensuring that all discharges into the environment are within the threshold limits as specified by Federal Environmental Protection Agency Act.

8.10. Wastewater management

Water is needed mainly for processing minerals but also for wet drilling and dust down. Miners also need clean water for drinking, cooking and washing.

After mineral processing, effluents (wastewater) contain fine tailings material (making it silty) and sometimes they may contain chemicals if they are used in processing (e.g. cyanide and mercury). This may need to be treated before it is re-used or discharged into rivers and lakes. Mine wastewater should be re-used whenever possible, which means that it has to be intercepted (using ditches, trenches and/or pipes) and collected into ponds, tailings dams, abandoned pits or reservoirs).

Before re-use in processing or discharged into natural waters, most effluents need some form of treatment. The most common forms of treatment are: sediment basins, wetlands and chemical treatment. When water is just silty, the simplest way to treat it is by using sedimentation.

Runoff rainwater at the mine site should also be diverted from entering pits by using diversion trenches. The area surrounding the mine should be well drained to carry away water from the mine area to collect it for re-use.

The management of run-off water and wastewater depends on the properties of the water and its intended uses.

A High level of clay and silt. If large quantities of clay and silt are discharged into rivers and lakes it may cause flooding, kill fish and make the water unsafe for domestic use farther downstream. The best practice is to deposit the water in sedimentation ponds to allow for the effluent particles to settle.

Acid Rock Drainage. The best way to deal with Acid Rock Drainage (ARD) is prevention. If it does occur, effluent and mine drainage that contains acid and dissolved metals can be treated by adding lime, limestone or dolomite to the polluted water. Constructed wetland is usually a cheaper option and can be used to neutralise acid and precipitate heavy metals into solid form.

Oil, grease, petrol and diesel products. This waste type should be collected separately from other waste types. It is important that the operator has measures in place at the site to prevent leaks and spills. Water containing small amounts of these chemicals can be treated using wetlands, but these have to be well designed to ensure that the water is below the pollution threshold.

Drinking water. The simplest way to treat drinking water is to boil it, but this consumes a lot of fuel wood and will not help with silty water or the presence of metals or other pollutants.

Sedimentation or settling pond/basins are constructed (or they could be abandoned pits) to reduce the level of suspended solids such as fine particles, sediment and silt before the water is either reused or discharged in natural waters. In the design of a sedimentation basin, due consideration to capacity (volume of water), retention time needed to settle out particles and how and when silt will be collected is required.

Chemical treatment can be used to make water clean enough for discharge into natural waters, re-use and domestic uses. Clay and silt can be made to stick together by adding lime, aluminium sulphate or gypsum. It is more efficient to first settle out the big particles in sedimentation ponds and then use chemicals to bind the fine particles together. ARD can be treated with lime, limestone or dolomite. When sufficient quantities have been added, the acids are neutralised and metals will precipitate (form a solid) into gypsum waste. However, this form of treatment generates large quantities of sludge that have to be contained in settling basins or abandoned pits.

Drinking water contamination with bacteria or viruses that cause diarrhoea can be treated with small amounts of chlorine or even household bleach (sodium hypochlorite).

Wetland treatment. A constructed wetland is an excavated basin or pond where wetland vegetation is planted. As water passes through the wetland, its quality is improved by the time it is discharged into natural waters. For silty and clay-rich water, wetland can provide the calm water that is needed to help particles to settle out. For ARD water with high levels of acidity, wetlands can help neutralise the acidity and help raise the pH value and remove heavy metals.

8.11. Tailings management

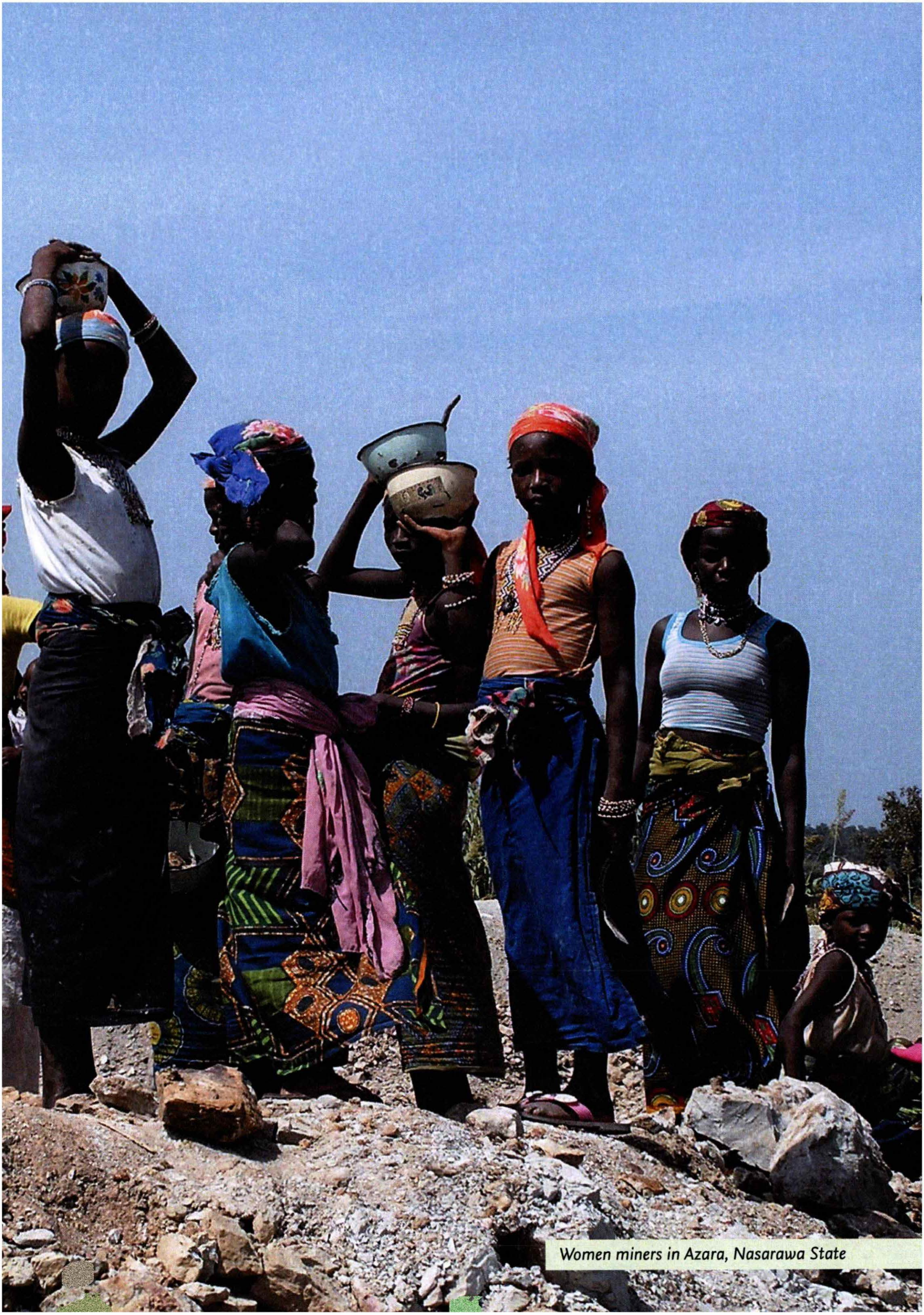
Tailings are often the most significant environmental liability for a mining project, large or small. Tailings also represent an external cost of mining, and this is particularly true of mining operations which do not take adequate steps to make tailings areas environmentally safe after mine closure.

Tailings are the materials left after the process of separating the valuable fraction from the uneconomic fraction of an ore. The extraction of minerals from ore can be done in two ways: placer mining, which uses water and gravity to extract the valuable minerals, or hard rock mining, which uses pulverisation of rock, and possibly the use of chemicals. In the latter case, the extraction of minerals from ore requires that the ore be ground into fine particles, so tailings are typically small and range from the size of a grain of sand to a few microns. In the case of placer mining, mine tailings are usually produced at site or at the mill in slurry form (mixture of fine mineral particles and water).

In order to prevent the uncontrolled release of tailings material into the environment, larger mines usually have a disposal facility which quite often takes the form of a dam or pond. This is a convenient method of storage when the tailings are in the form of slurry when discharged from the concentrator. These facilities often require the clearing of more land than the rest of the mine (including open-pit operations) combined, and failure of the tailing dam wall can result in a massive release of tailings and are therefore of great environmental concern. (Slightly modified from: *http://en.wikipedia.org/wiki/Tailings*).

For ASM, typically, the bulk of tailings products will be barren rock, crushed and ground to a fine size ranging from coarse sand down to a talcum powder consistency. Many ASM operators simply dump their tailings wherever it is convenient, usually close to the pits being mined. Rather than careless dumping, ASM operators can backfill tailings into abandoned open pits. This option is usually the easiest and cheapest option for them, but sometimes depleted mines may not be available. Once the pits have been mined, the tailings surface can be covered with topsoil and re-vegetation commence.

Barite mining operation in Azara, Nasarawa State



Women miners in Azara, Nasarawa State

9. Socio- economical profile of ASM

The findings presented in this chapter are partly based on existing studies of ASM in Nigeria as well as field work undertaken during the preparation of the handbook (Fig. 9-1).

The mineral sector in Nigeria is dominated by artisanal and small-scale mining (ASM) operations, mainly informal, working with rudimentary methods with limited technical training, social provision or environmental consideration. ASM operations are widespread and present to varying extents in all thirty six states and the Federal Capital Territory (FCT).

ASM is an essential livelihood option for many rural people and ASM plays an important role in augmenting poverty in many rural areas. The impact of ASM is also very seasonal, with substantial mining activities taking place during the dry season. Whether driven by necessity or by the promise of earning money above and beyond the national average, ASM and the direct and indirect employment opportunities it presents must not be underestimated. The majority of the ASM workforce is casual labour, paid daily with little long-term commitment to specific sites and/or the mining sector.

Fig. 9-1. Interviews of ASM operators during field work. Yayaarima, Gombe State

9.1. Social impact of ASM

ASM has profound impact on all aspects of the social structure and functioning of those engaged directly in the work, and those communities close to ASM sites. ASM operations may be highly seasonal due to rainfall and the need for water for mineral processing or due to flooding of mining areas during the rainy season. ASM is in many areas a supplementary source of income for farmers, and this promotes seasonal work patterns.

ASM is frequently migratory. Metal and gemstone ASM operations provide labour opportunities for large numbers of men who live in camps in connection with the mines. Over time, these camps may disappear or may transform into more permanent settlements, depending on the scale of the mineral resource and the duration of mining activity.

As the camps are established, service providers (often women) move to the camps to seek employment e.g. in minerals transporting, washing, sorting and grinding. Women also come to trade essential goods, provide tools and materials, set up restaurants, or to gain employment in the sex trade.

Mining camps can be highly vibrant economic entities, albeit sometimes short-lived. They can often cause rampant local inflation. If camps become established on an ad-hoc basis, particularly in response to a minerals 'rush', or if they overrun an existing village or community, sanitation and hygiene conditions are often poor creating health hazards for the inhabitants. This is compounded by the often promiscuous lifestyle associated with some ASM operators where daily cash payment for minerals is sometimes used for alcohol, drugs and to pay sex workers. All of this can compound the risk of the spread of sexually transmitted diseases, including HIV/AIDS. The migratory nature of the ASM workforce can also give rise to polygamy if miners abandon families or start new families in mining areas.

9.2. Economic impacts of ASM

First and foremost, ASM provides a source of income and revenue for rural people across Nigeria, both directly and indirectly. The miners themselves typically receive a very small percentage of the value of their product, but the revenue chain may be long and complex, therefore many people may gain an income from the production, transport, processing and re-selling of the minerals. External perceptions of this chain are often that there are only two broad categories of actors – the exploited, impoverished miners and the predatory, wealthy traders – but this limited analysis fails to recognise that, often, it is more likely that there are much higher numbers of people all making a small income at various levels. It is certain that the miners are often exploited. Miners may restrict their activity to the physical extraction of the minerals. Those employed as washers and transporters may only work in these activities, not in the mines themselves. If the mine is remote from its market, the presence of traders or their agents ensures that miners do not leave the mines to travel to their buyers.

The role of mineral traders and 'middlemen' is crucial for the functioning of the chain in many instances. Traders typically provide pre-financing which enables the miners to purchase tools, and to support their families during periods of transition or when mineral returns are low. Whilst this access to credit is an essential function, it also creates debt relationships which, at their most benign, can result in preferential pricing for the traders or, at worst, can result in a debt burden which acts as a trap prohibiting exit from the sector. A key issue limiting the economic return is the often inefficient exploitation and beneficiation methods used, which also curtail the life of the mine. ASM methods are only suitable for certain types of resources and, if they are used on ore bodies which have a profile better suited to industrial exploitation, the potential overall return to the national economy may be significantly reduced.

9.3. ASM and poverty

The link between ASM and poverty is profound and complex. Those who constitute the majority of the ASM community at the level of resource extraction, basic processing and local trading, generally live in poverty. They are often driven into ASM by poverty and the income they receive from ASM can improve their daily subsistence, thus reducing their impoverished status in the immediate term.

However, the nature of the activity is such that it is exploitative:

- It draws people away from other more sustainable activities such as agriculture
- It does not always produce long-term wealth for these individuals
- It may create debt
- It uses resources inefficiently and is not sustainable.

The majority of the Nigerians who work as miners, sorters, transporters and traders in ASM generally live on N1500–3000 a day. Even where their income exceeds that, they are often living in areas of high prices and cost of living, so their income is marginal. They live in poverty but, without ASM, their situation could be even worse.

ASM is particularly labour-intensive and thus provides employment and incomes to large numbers of people who are generally uneducated, poor and live in remote areas where few opportunities exist for formal employment. For many ASM workers, mining is a supplementary source of income, not their sole livelihood. ASM can be an important economic activity during the non-agricultural season, or it can provide a cash income to subsistence farmers. In some areas, ASM has been a livelihood option for generations and is considered by many of those engaged in it an ancient practice.

As a general guideline, miners typically receive a relatively small percentage of the local sales value of their product. A larger proportion of this money enters local circulation (through a variety of actors, the largest proportion being through the trader) where it pays for services directly associated with the mining activity such as provision of tools, equipment, fuel, food, housing. It also creates other types of jobs, purchases goods (essential basics and luxury items) from local suppliers, creates a demand for transport services, and stimulates local economic activity. Thus, despite exploitation of the workers in the mines, at a certain level ASM generates a high level of social access to the economic value of their product by generating a significant cash flow through the community.

9.4. Organisation of ASM

Manual labourers make up the largest number of people on sites and work mainly on a casual basis, with no strong ties to a specific site whether formal and informal. The nature of the work, determined by the mineral but also by the labourer's roles, the origin of the miners, their approach to the mining (short or long term) determinates whether people work as a group or individually. A site might have a mix of people working individually or as a group. While men might physically remove the minerals from the ground on an individual basis, they may employ a team of people to work with them, mainly women and children. The man usually takes responsibility for paying these people based on the money he receives from the buyer/company.

There are often technical, financial and social/cultural reasons for working as a group:

Technical aspects

- Scale and geological aspects of deposit require people to work together e.g. digging pits and removing material, working in the pit on rotational basis, hauling material to the surface
- Production cannot meet demand so miners come together to sell minerals.

Financial aspects

- One person might finance the group, employing people to work for them, within a formal or informal structure
- If miners are not able to start their own pit/section joining with other people and divide the costs
- Pooling production to increase revenue - work for one person at a time on a rotational basis every three to four days.

Social/cultural aspects

- Common personal aims and goals bring people together, working with people with the same approach/work ethic and dedication is favourable
- Same community/place of origin.

The organisation of groups also depends on the number of people present and the requirements of the site. Responsibility is based on either financial backing, experience or land/site ownership. Finance is also a strong linking factor and a group might be supported by an external party/'Supporters', normally a buyer is that is the market chain link.

Level of conflict

The influx of migrant miners to communities with a different ethnic and religious make up may be expected to provoke conflict. In practice, none of the key respondents at the sites visited during the field work mentioned any ethnic or religious conflicts between communities and miners.

The reasons for this are likely to be that:

- Migrants are identified as miners (rather than as an ethnic or religious group) in their dealings with the community
- Migrant mining groups tend to be comprised of a diverse ethnic and religious mix of people drawn from neighbouring states
- Small migrant mining groups (regardless of their origin) are required to pay compensation to the traditional authority while the community is typically in no position to challenge mass migrations
- Conflict has generally been between the police and migrant miners – again without distinction to their origin

It therefore appears that existing traditional systems and practices still function effectively. When questioned, a number of respondents explained that migrants were expected to adhere to the indigenous community rules and regulations and this may help to explain why so little conflict has arisen between the two groups.

Fig. 9-2. Female miner at the gold mine site in Russo, Kaduna State.

There may also be a shared understanding of the need to engage in ASM as a key livelihood and this may help to prevent any conflicts on ASM sites and the localities.

9.4.1 *Seasonality*

The ASM sector is seasonal in some areas and in such situations has strong links with agriculture. Farming remains a primary livelihood for miners in some rural communities, where people turn to mining/quarrying during the dry season when farming is not intensive. Mining is, for others, a primary livelihood. This is often related to areas where demand for the mineral is high and/or the mineral value is high, or there is a lack of other livelihood options available. The money earned from mining is in some cases reinvested in farming, in particular at sites mined by indigenous communities themselves where income from farming is supplemented by income from mining. Where financial returns from mining are sufficiently high and miners can work throughout the year, some miners will pay others to maintain their farmlands, and continue to work in the mines themselves.

While seasonality is mainly linked to informal mining, formal mine sites are also being hindered by lack of finances preventing mechanisation and lease/purchasing of the necessary equipment to work during the rainy season.

9.5 Women in ASM communities

In Nigeria, women make up a large percentage of the workforce and are involved in many aspects of ASM activity including associated ancillary activities. Women involved in ASM have had varying degrees of success (e.g. there are few female-owned mine sites). However, most of the women participating in ASM work as labourers have limited education, have families to support, are poor and may come from a religious or traditional background that prevents them from asserting their formal rights and participating in the decision-making process. This is especially true in the northern part where stricter religious beliefs restrict their involvement in these processes. Therefore, this limits their ability to access the potential benefits that ASM might bring. These constraints also vary geographically (Fig. 9-2).

The work that most women undertake on an ASM site is in general unskilled, flexible in terms of employment, paid on a daily or weekly basis and therefore does not require any academic or practical experience. This makes it an accessible alternative as it allows women to generate cash income over short spans of time. Even if families/individuals have other forms of informal employment (e.g. farming), ASM activities will often be undertaken by women alongside this to support such livelihoods.

Sexual Gender Based Violence (SGBV) is violence directed to a person on the basis of his gender or sex. SGBV can be a major issue as an individual, in personal relationships, within your mining group or at community level. When women and men, children and the elderly, are vulnerable to becoming victims of SGBV, they may be living in constant fear! This is not only stressing to the victim, but also to the family, friends and neighbours and it affects the health of individuals in the community.

Any member of the community can be a victim of SGBV - your daughter, son, wife, husband, mother, father or friend may be at risk! Most SGBV acts are committed by members of the communities!

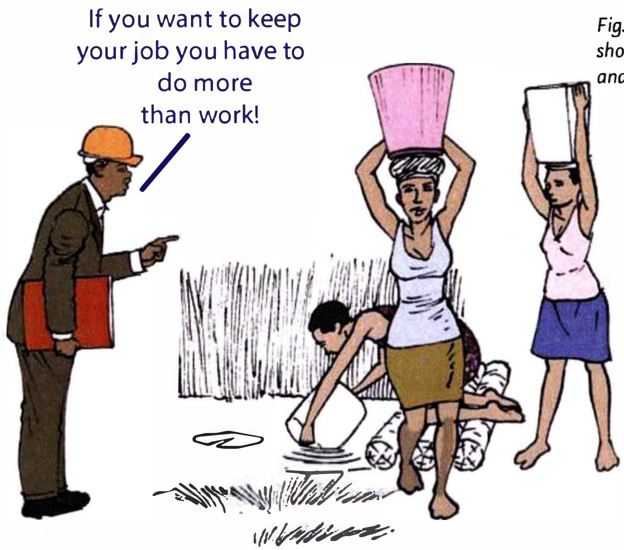


Fig. 9-3: Women workers should report sexual threats and intimidations.

Source: TACC 2008

There are many acts of SGBV and they can be physical, social and psychological forms of violence. Watch for these acts at your mine or in your community! The different acts include /Fig. 9-3):

- Intimidation or humiliation. This may be in the form of demeaning or degrading comments, insults, forcing victims to engage in humiliating acts in public or denial of basic expenses for family survival
- Sexual threats or harassment by middlemen, supervisors or mine owners. This includes creating an offensive or hostile environment, such as demanding for sexual favours, making sexual comments, or threatening someone with loss of their job if they do not provide sexual favours
- Discrimination or denial of opportunities, especially for women to access certain areas or activities of the mine. This can include denying vulnerable female and male workers from getting agreed salaries or payments
- Exploitation. Often women, the elderly or children are exploited by giving them lower pay for equal work, giving them only lower paid positions or putting them in dangerous situations.

9.6. Child labour in ASM communities

Because of poverty, poor education and poor governance, child labour has become a key to survival for many impoverished families. This is reflected in the number of children that can be found working at ASM sites across Nigeria. Whilst

Fig. 9-4. Young girls sorting lead/zink in Nahuta, Gombe State.

the eradication of child labour should be the ultimate aim of any child labour policy, the intricacies and motivating factors for child labour have to be fully understood to ensure that appropriate legislation is implemented to tackle the root causes of the problem (Fig. 9-4).

Research obtained during the field work and confirmed by other studies has shown that there are a number of factors that contribute to the presence of child labour on ASM sites:

- Worsening poverty in rural areas: children work in the mines as part of a key livelihood strategy for families that need to supplement their income in order to subsist

- Poor access to both primary and secondary education (in terms of both distance and cost)
- Incidences of child labour are reported to be higher on sites that are located far from schools.

As well as the specific physical and welfare risks that children face when working in mines, they also risk being excluded from education and therefore their prospects and potential for future employment in a sector other than ASM are reduced. On the other hand, ASM may be the means by which children or their families earn the money for school fees.

9.7. Occupational health and safety

ASM is notoriously associated with poor health and safety standards. The unregulated nature of ASM sites means that often no one is responsible for health and safety and without guidance and training on such aspects, sites operate unchecked, resulting in potentially dangerous working conditions for labourers.

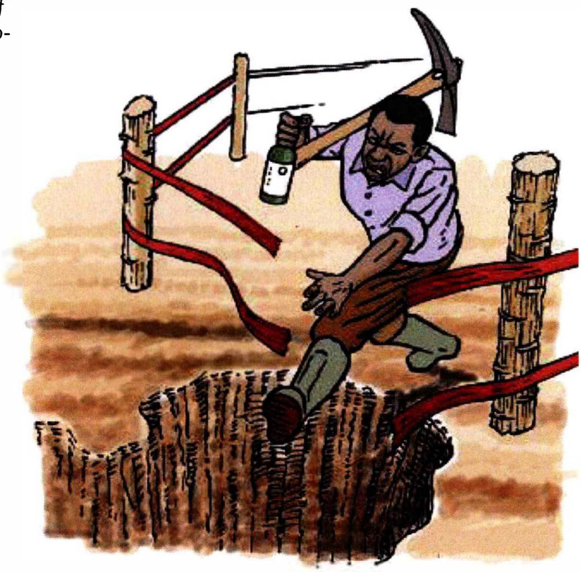
Observations from the field work confirm that although miners are hard working and courageous they are often reckless and are particularly vulnerable to exposure of dust, effects of noise and vibration, shaft/bench collapses and rock falls, poor ventilation, over exertion, inadequate work space and inappropriate equipment. The risks miners face on site come from the site itself and the physical method of mining, the hours worked and the nature of the work.

Health and safety impacts are related to their physical and mental well-being (especially when the use of drugs is involved) and those of their dependents, when present on site with them. Accidents are commonplace, varying in severity from cuts, grazes to more serious accidents including fatalities. Listed below are some of the common situations divided into risks from the mining methods, personal practices and services, see further in chapter 7.

9.8 Alcoholism and drug abuse in ASM communities

The use of drugs and alcohol by miners whilst carrying out ASM activity was reported at a number of sites across different sites. The field work undertaken indicates that drugs are used to dull senses to the hardship and danger of the work. They are also used as stimulants to assist the miners to carry out long shifts of hard labour. The following drugs were observed used: marijuana, prescription drugs (e.g. Trimol), performance enhancing drugs (originating from China) and alcohol. Drug use is a sensitive subject to discuss, particularly in the Islamic areas

Fig. 9-5. Accidents, on and off the job, can be caused by alcohol and drug abuse.



of the North, and information was limited to the few individuals who were open to talking about such issues. Therefore, the use of drugs could be far more widespread across the states (Fig. 9-5).

Depending on the type of drugs used and whether a person is in the intoxication stage or withdrawal stage, signs of abuse can include:

- Blood-shot eyes
- Excessive happiness (euphoria) when high from using drugs or alcohol
- Poor coordination, such as staggering and slurred speech
- Seeing things which do not exist (hallucinations)
- Suspicion and paranoia (believing that people are out to get them)
- Body weakness and drowsiness
- Extreme irritability, violence and aggression (e.g. from cocaine or alcohol)
- Easily getting involved in unprotected, unplanned sex

9.9 HIV/AIDS in ASM communities

The HIV/AIDS epidemic affects the most productive segment of the labour force (people in the 15–49 years age group). This means that families, communities and the entire nation are deprived of young and productive people. This has serious impacts on Nigeria! The loss of skilled and experienced workers and reduction in productivity slows economic and human development at household, community and national levels!

Many conditions in ASM communities make female and male miners, their spouses and other residents especially vulnerable to high-risk behaviour and spread of HIV/AIDS! This is mainly because:

- Many miners are youth and orphans, who have left school (by choice or lack of school fees) and use money from mining for drugs and alcohol, which can lead to unprotected sex with different partners
- Youth and orphans can be vulnerable to sexual exploitation by miners at the mine site and community
- Some female and male miners travel back-and-forth to remote areas to work, away from their homes and spouses. While in the mining area, they may have one or more partners
- Some miners migrate, travelling from mine site to site, and have multiple sex partners in different areas
- Many miners are single mothers or girls, whose incomes are often much lower than male miners. To make extra income, some women and girls engage in the sex trade at the mine site or community in addition to mining.

9.10. Community Development Agreement

Community development activities span all phases of the mining project cycle as an all-pervading particular challenge. It is important to note that relationships between mining operators, local communities, and other stakeholders begin long before the initiation of the mining operation. Mining operators would be wise to invest in establishing good local relationships at the earliest stages possible.

A legal document which will guide operators, investors and other stakeholders in mining is essential to the development of the sector hence the Community Development Agreement (CDA) must be underscored. The CDA should be concluded with the host community before the commencement of operation which will ensure the transfer of social and economic benefits to the community.

The host community in relation to any mineral title should be identified as the community where the mineral title area is located or the community closest to it. The signatories to the CDA should be representatives chosen freely by majority of the community while the head of the community, prior to the signing of the agreement should submit to the MMSD the full names and addresses of the representatives of the community who should not be less than three (3) and not more than seven (7).

The CDA should also address the following issues:
- Programmes for the development of the community in areas such as educational scholarships, technical training and employment opportunities for indigenes of the communities as well as financial or other forms of contributory support for infrastructural development and maintenance based on the needs of the people. For instance, health or community services, roads, water and power
- The modalities for the implementation and monitoring of the programmes contained in the agreement
- Conflict management or resolution
- Compensation for damages and pollution
- Rights of the holder in relation to the mining area

If the community and the holder are unable to agree on any aspect of the CDA, the matter should be referred to the Minister for resolution. The agreement should be reviewed by the parties every five (5) years.

The above-mentioned CDA might seem unrealistic to a minor artisanal mining operator, but the Mining Act does not distinguish between artisan, small-scale mining or large-scale mining operators. The enforcement of this demand from the MMSD might vary from type to type of mining operators.

10. Business planning for ASM

Developing business skills for ASM means developing capabilities that help ASM operators to improve and increase productivity and profits from mining. The success of an ASM operation depends on personal characteristics, skills and the situation in which the mining itself takes place. Assisting ASM operators in developing their business skills helps ASM operators to:

- Make more money through better planning and management
- Market, promote and sell minerals at the right price

10.1. Planning an ASM business

Many people work in ASM as an additional source of income, while others rely mainly on ASM for their livelihood.

Whether they are independent miners or part of a cooperative or company, most men and women working as ASM operators do not have formal training in business matters.

When planning to make a business it is a good idea to first consider the legal form of the business, as this makes a huge difference in the:

- Cost of starting and registering a business
- Level of difficulty in starting the business
- Financial risks involved
- Taxation of profits

There are four common ways to structure and organise a business and each form of business type has its advantages and disadvantages:

1. Sole proprietorship

Means that an individual alone owes the business and makes all the decisions. The individual owner is also personally responsible for all debts and paying taxes. Compared to all other forms of business types, this option is easy and cheap. The challenge many entrepreneurs face is that, as an individual they may not be able to generate the money required to start and run a mine.

2. Partnership

When two or more people decide to run a business together, they form a partnership. Partners make decisions together (unless they have agreed otherwise) and, as co-owners share the financial risk, debts and are responsible for paying

Table 10.1. Key Terms

Budget: A detailed plan of income and expenses expected in an ASM business over a certain period: month, year

Business plan: A written document summarizing the aims and objectives of the ways and means to achieve the business goals over a specific period of time

Cost: The economic value or payment to acquire, possess or use an object or an activity in a business

Commodity: An article that is exchanged for money, e.g. a mineral

Market: A place where buyers and sellers meet to exchange goods for money. It also refers to the prospective customers

taxes. Like sole proprietorship, a partnership is usually cheap and inexpensive. Good partners can bring skills, experience and money to the business. However, some partners might have no money or be poor managers and one partner may end up having to pay all debts. Entering into a partnership agreement before a business is formed will help to avoid future misunderstandings. A partnership agreement should define:

- What type of business the partners are in
- How profit and losses will be shared
- What the duties of each partner are

3. Limited company

A limited company is owned by two or more owners called shareholders. The owner can be investor(s) in the business, and may or may not be active in the business. The company appoints a board of directors, who make many of the decisions and appoint managers to run the business on a daily basis. The owners, board of directors and manager can all be the same people. The shareholders can be paid a salary from the company which is taxed like any salary.

4. Cooperative

A cooperative is formed by a number of people who decide to work together for a common purpose. This purpose might be for profit (running a mine) or for providing services for cooperative members (pooling resources to provide health care insurance for members).

Figure 10 - 1: Why work alone? When you can form and register an association or cooperative and get the benefits.

Source: IACC 2008

In Nigeria, mining cooperative must be registered with the Ministry of Mines and Steel Development, ASM mining department. This form of ownership can be more complicated than sole ownership or partnership. The personal debts of the cooperative are usually only what the members have paid into the cooperative and the cooperatives profits are taxable. Profits are divided among the cooperative members.

Cooperatives are beneficial because all members bring their skills and experience to the group and it is usually easier to get outside support (training, funding etc.) as an organisation than as an individual. Cooperatives operate using principles like voluntary and open meetings, democratic member control, member economic participation, autonomy, and independence, education and training and concern for the community (Fig 10-1).

Access to capital is a major challenge faced by all ASM operators. When legal concession for mineral rights is held, it may be possible to access financing though a joint venture, business partnership or limited company.

10.2. Marketing and selling

The answer to the question 'can the product be sold?' should be found before setting up an ASM business. If there is nowhere to sell a product or the price is too low, there is no point in setting up the business in the first place.

For gemstones, gold, tantalite and columbite, there will always be an international demand and the main challenge is to find a buyer that will give you a fair price. For other products, such as limestone dimension stone, demand is high in Nigeria but varies from state to state and getting the product from one location to another can be expensive.

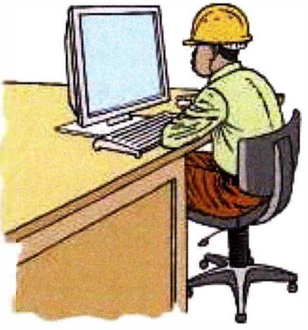
Table 10.2. What is a market?
Markets for minerals are the customers, people or other businesses that are willing to pay money for your minerals

Value added mineral products such as jewellery, pottery and stone carvings, can give a much higher price than the unrefined mineral, but finding a market for these goods can be difficult. In all cases, developing skills in marketing and selling is critical to the success of the ASM business.

10.2.1. *Marketing*

You need marketing skills to identify and develop a mineral product to satisfy the customers or buyers demand. To identify a market, you should understand the nature of your market:

Figure 10-2. The internet is a great source of market information.



Source: TACC 2008

1. Who your customers are – who buys minerals?
2. How large your market is – how much do customers buy?

You also need to know:

3. What kind of mineral products do the customers want?
4. What kind of prices are they willing to pay?
5. Where are the buyers/customers? Where and when do they buy?
6. How often and how much do they buy at a time?
7. Who are the main competitors that are selling similar minerals?
8. How good are your competitors?

Figure 10-3: Before you invest in any mining activity find out if a market exists, and that you can meet market demand and still make a profit!

If you can find the answers to these questions (Fig 10-2), it helps you to decide what prices to charge, how to get your mineral products to the buyers.
Your current market:

- How many customers do you have?
- How much do they buy?

The current market is the amount of product that you are selling now. At the end of each week, month, have you sold everything? If the answer is yes, you can possibly increase production!

If you are able to raise production you need to consider if you will be able to sell it all? If yes, to whom? If your ASM operation has a surplus of unsold minerals at the end of each week or month, you need to find more buyers. This means doing market research (steps 1-6 below).

When doing market research:

1. Talk to buyers: Why do they buy from you? Are they satisfied with the product? Are there other minerals they would like to buy?
2. Find out why other buyers have stopped buying. Are there better quality minerals, better service, better distribution or better price elsewhere?
3. Study competitors to find out what minerals or services they sell, at what price and how they attract buyers
4. Ask professional people such as the State Mining Association, on how best to produce, sell and identify markets
5. Read newspapers, trade journals and magazines to know which minerals sell best

6. Contact the State ASM officer, Mineral Buying centre, State mining association to get information about current international prices (Fig 10-3)

10.2.2. *Selling*

Selling is the process of exchanging minerals for cash. The selling process involves four Ps:

Product, **P**rice, **P**lace and **P**romotion

Product
This is a metal, mineral or mining related product (such as equipment) that you produce. The product should be of good quality and is in sufficient quantity to sustain market demand. Poor quality products often lose their markets because buyers want value for money. Good mineral products can be:

- Cassiterite concentrate should contain at least 60% of tin
- Gold produced should have less than 15% impurity
- Dimension stones should be cut to equal thickness, widths and lengths

Price
In the mining business, the selling price is based on a combination of the operating costs and a percentage for your profits. You should be able to recover the money you invest in the mine and at the same time make some profit from the business.

Place
"Placing" a product refers to the method used to distribute the mineral product. For precious metals, this will be through a dealer (licensed or not). Many ASM operators find it convenient to sell their products directly at site. This is a reasonable approach for mining businesses such as quarrying, brick making and sand mining. For ASM businesses such as limestone, ASM operators can distribute their products through retail shops located in strategic towns and trading centres.

Promotion
Refers to the process of making the minerals that you produce known to potential and existing buyers. This can be achieved in a number of ways:
- Maintaining constant and good relations with buyers
- In some cases, discounts could be extended to regular customers (industrial minerals and their end-products)

- Placing radio adverts can be considered since they reach a wide audience (not recommended for precious metals and gemstones)

10.3. Costing and buying

When it comes to costing, you need to consider how much does it cost to produce say one tone of lime, one kilogram of cassiterite or a bucket can full of crushed stone?

Understanding costing and buying tells you whether the mine will be profitable. For example, the price of gold may be high, but if the costs of producing one kilogram are higher than the value of gold, you will lose money.

Improving your skills in buying the right tools, equipment and materials can help to reduce production costs and potentially increase your profits or turning losses into profits.

10.3.1. What is costing?

Costing is the way you calculate the total costs of making and selling a product or providing a service. With a mine determining your production costs tells you if you have the financial resources to run the operation effectively and efficiently. The costs of mining and mineral processing usually include:

- Equipment, tools and machinery
- Materials (e.g. for construction)
- Purchase of supplies, goods and materials to operate the mine (e.g. fuel)
- Initial licensing, taxes, rents and royalties and other fees

10.3.2. How costing can improve business

Figuring out the mining costs is easy and will help you to:

- Estimate how much money is needed to start and operate a mine
- Budget for the various mining activities to ensure that you have sufficient funds in place to operate effectively
- Determine if your mining business is profitable or not
- Identify specific areas of the mining business where cost reductions are needed, resulting in greater profits
- Determine the minimum production level (break even) point for your business in order to make a profit

- Know how long it will take to complete a business loan or lease payment
- Develop a solid business plan

10.3.3. Types of costs

There are many different types of costs involved in ASM operations. These are divided into two broad categories: direct and indirect costs.

Table 10.3. Accurate costing

1. Keep proper record of all receipts made during the course of a business activity
2. Record all payments at the end of every day to avoid paper piling up
3. Always cross-check and audit

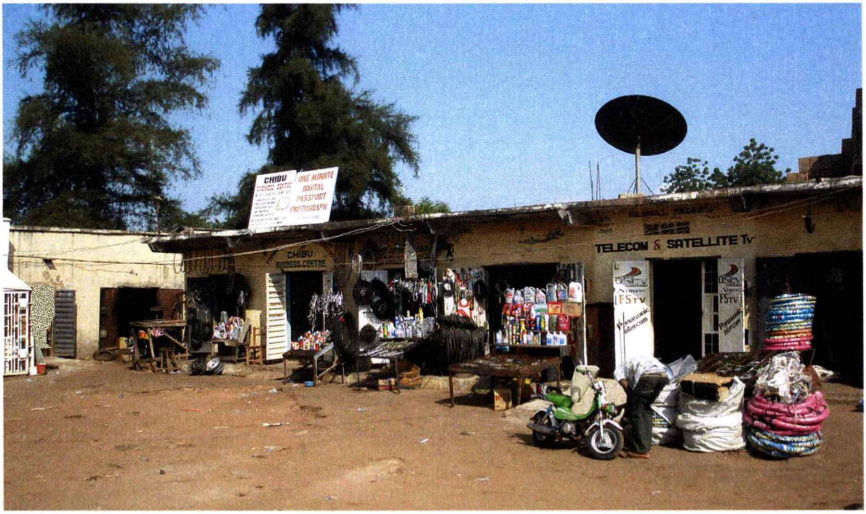
Direct costs
These are costs that are directly related to a specific activity in the mineral production chain:

- Labour for digging, hauling, crushing, and processing rock
- Equipment and tools used for extraction, hauling and processing
- Water and chemicals used in processing
- Construction of tailings dams and drainage system

Indirect costs
Sometimes also called 'overhead' costs, these are costs that cannot be attached to any specific activity but they affect the whole business:

- Rent, lease fees, licensing fees royalties and taxes
- Total fuel and lubricant costs
- Energy and portable water costs
- Transport of supplies to and from the mine
- Lost time due to bad weather or illness
- Maintenance of equipment
- Machine depreciation – decline in value of a machine due to wear and tear
- Construction of shelters for workers
- Meal costs at work
- Insurance
- Interest on loan
- Indirect labour costs (site security, accounting/administrative costs)
- Stationary

- Telephone
- Construction of pit latrine
- Labour for cleaning up the site



Source: TACC 2008

Figure 10-4. Even when you buy clothes from a local shop, you still think about quality, the right price, and when you need it! (Photo from Kaduna)

10.3.4. Buying

Purchasing of tools, equipment, machinery and other items needed for mining. Some items are consumables, such as explosives, beans, maize, and first-aid kit. In every business certain items are needed before and throughout the life of the business.

Using good buying methods can be the difference between profits and losses. There are four sound principles of buying (Fig 10-4):

- Buying the right quality
- Buying the right quantity
- Buying at the right price
- Buying at the right time

10.4. Business plan

A business plan is a statement of your business goals and a plan for how you will achieve these goals. In an ASM business, the business plan is integrated with the mining plan for the site – the main goal is to operate a profitable mine until the mineral resource is depleted. This involves looking at how the mine is technically developed over time while also considering the management, administrative and financial operation of the mine.

Why develop a business plan?

The main reasons to develop a business plan are to:

- Help estimate how much money is needed to set up or expand an operation
- Submit it to potential investors and other sources of financing
- Understand how much profit is really being made and foresee how much profits can be expected to be made in a certain period of time
- Provide information that helps to serve buyers better. If a reliable schedule of production exists, buyers will know how much is available when.
- Identify areas where costs are too high

A business plan helps you to improve your business in many ways:

- If the business is going well, planning helps you to do even better. You can see problems before they happen and prevent them from happening.
- If your business has problems, planning can help you to solve them.

The level of detail in a business plan depends on the size of operation. When planning for an ASM operation you should answer these questions:

- What is the size and grade of the deposit? What methods will be used to mine the deposit?
- Where will you establish infrastructure (mine waste, access roads etc.)? How much will it cost?
- What tools, equipment and machines would be needed and where will they be bought?
- When do you need the equipment and for how long?
- How much do they cost to buy? How much do they cost to maintain?

- How much can you realistically expect to produce in a day, week, month or year?
- Where will the mineral product be sold and at what price?
- How much is to be paid in taxes, licences, rents, royalties or other fees?

All this information will help to determine how much it will cost to start and operate the mine and to calculate how much profit can be expected.

Even if your mine is already operating, a business plan should be developed and updated regularly. Similarly, it is wise to ask the same questions each time changes are being planned e.g. buying new equipment or tools.
Business plans can be very simple and short or very comprehensive and long, depending on the scale of our mine.

The level of detail in a business plan depends on the size of the project. The contents of the plan look quite complicated, but for a small operation, it can be short and simple.

Table 10.4. A typical business plan includes:

1. **Cover page**. With title of mine or project, name of the organization, date

2. **Executive summary.** A brief summary of the contents of the plan. Make sure it is **very well written.**

3. **Background and purpose**. Summaries: (i) the history of the company/ cooperative and mining project, (ii) current status of the company/ cooperative and mining project, (iii) objectives of the mine or project and (iv) business goal of the company/cooperative.

In this section you should provide a brief overview of the history and current status of the company/cooperative and mining project. You should also describe what the goals of the mine or project are e.g. to exploit the lead/zink deposit with due care and attention to the environment. You should also state what the business goals are, e.g. to provide a steady income for all members of the cooperative.

4. **Market analysis.** The overall market for the product, who the expected customers are, the competition and expected sales forecasts.

In this section, you should demonstrate that you have done a minimum level of market research and that you know the current market situation and have calculated your forecasted sales. Refer to section 10.2 above.

5. **The operation**. A technical description of the mine or proposed mine, how it is or will be mined, ore reserves, how the mine will be closed and environmental problems managed. Refer to chapter 7 on how to operate a mine and chapter 8 on managing environmental risks.

6. **Financial data**. Current financial position of the company/cooperative, organisation and costs. Costs and payment history (sales & costs sheets), cost control measures, break- even analysis and financial projects (how much profit and costs are expected in the future).

7. **Organisation structure and management**. Key personnel, organisation directors, board members, professional advisers, key future personnel, and labour force (current and projected)

8. **Ownership**. Who owns the project or mine? What percentages will the different parties hold? How will these partnerships be terminated (exit strategy)? What are the royalty and licensing agreements?

9. **Risk factors**. Identify clearly all potential risks to the mine or project and how they will be addressed. This includes: changes in commodity prices, problems with labour, suppliers or distributors, social conflict, environmental accidents, lack of capital, other risks.

10. **Conclusion**. Summarise key points and include a timetable of when funding is needed for future developments.

11. **Appendices**. The report appendices should include: photographs, sales and costs plans, cash flow plans, statements of current profit and losses, and break-even statements (the minimum production and revenues needed to cover costs).

10.5. Micro finance

The term microfinance is defined as the supply of financial services to microenterprises or poor families. Microcredit is normally defined as a short-term, high-priced (interest rate) loan for working capital to the self-employed poor. The main reason for the high interest rate is because of the high cost of handling many small loans.

Various ASM finance programmes may face certain challenges, when wanting to enter into cooperation with traditional financial institutions. The conditions of life for ASM operators have some characteristics, such as lack of land tenure, marginal legal status, limited lifespan, along with poor financial and business planning skills. Further, the mining areas may be remote and fall outside areas targeted by development programmes and ASM is generally carried out with little access to geological assessment skills with which to identify or confirm the scale or value of the resource. Therefore, there are few guarantees of making repayment to the financial institution.

As credit-worthiness is an essential pre-requisite for any loan to be extended or for other financial services to be accessed, artisanal miners rarely make it through the screening process. In the absence of traditional credit sources, the next obvious option would be credit through microfinance institutions.

10.6. Micro grants to ASM and mining communities

Access to finance is essential to enable the formalisation, improved production, and strengthening of ASM, and its potential transformation into regular mining activity. However such finance is difficult to come by at all levels. As an ASM, you might present a suite of factors which make you unattractive to formal lenders (banks and micro-financing institutions):

- You may already be in debt
- You lack collateral
- You lack a viable business plan demonstrating why you need the credit or how it will be effectively used

Given these constraints, many ASM operators turn to the most accessible local source of funds, namely pre-financing by traders increasing the problems of debt even more as these loans may demand high rates of interest and sale.

When looking for funding remember that:

- Mining is a business and no matter whether you are an artisanal miner working with basic tools or a small, organised company – the mine is a business.
- Depending on the scale of your mine and resources, you should form and register as a cooperative, association, company, partnership or sole proprietorship (See *Section* 10.1.)

- Most funders require that organisations be proven to be active and effective for at least 1-3 years (even without outside funds). Form a real organisation with real objectives and demonstrate your commitment through action! If you prove yourself once (even with small funds) by using and managing funds properly, you are much more likely to get repeat funding or funding from new sources.
- Banks and financing institutions keep black lists of organisations (and even individuals) that have been irresponsible or poorly managed funds and many banks share this information with each other. People who are untrustworthy or misuse funds are unlikely to ever get funding again!
- You will not get funding (or the funding will be useless) *unless* you have a market for your products (See *Section 10.2.*).

The World Bank funded SMMR programme under the Ministry of Mines and Steel Development administers an ASM grant scheme designed to finance equipment, training and promoting access to finance and product markets. A minimum of ten miners must form a cooperative society to access the fund, and USD 50,000, about N7,5m, is the maximum value any group can get. The credit is not paid in cash, but is paid directly for services and purchases and must be matched by the cooperative. The grant scheme also comprises funding for community grants for the financing of social infrastructure. The state ASM officer is able to provide advice on the procedures of how to apply for matching grant funding.

Glossary

Adit: Horizontal or nearly horizontal entrance to a mine.

Alteration: Any physical or chemical change in a rock or mineral (milder and more localised than metamorphism).

Base metal: This includes copper, zinc, lead and nickel. Base metals are capable of combining with acid to form a salt.

Bedding: Arrangement of sedimentary rocks in roughly parallel layers or 'strata' (which formed as the original sediments were deposited).

Benefication: Crushing and separating ore into valuable substances or waste by any of a variety of techniques.

Budget: A detailed plan of income and expenses expected in an ASM business over a certain period, e.g. a month, six months or a year.

Business plan: A written document summarising the aims and objectives of the business with descriptions of the ways and means to achieve defined business goals over a specified period.

Classification: The grading of particles (that are too small to be screened) in accordance with their size, shape and density by control of their settling rate through a fluid medium (water, slurry) or air.

Clay: A sediment or soil that is plastic when wet and is made up of fine-grained minerals that are mainly hydrous aluminium silicates.

Cleavage: The tendency of some minerals to break along one or more smooth, regular surfaces related to their crystal structure.

Commodity: This refers to e.g. minerals or mineral products that are exchanged for money.

Community: A group of people living together as a smaller social unit within a larger one and having interests, work etc. in common.

Community health: Systems within the community that ensure community members enjoy a state of good health.

Concentrate: Enriched ore material collected after removal of waste by beneficiation/separation in the mineral processing. The higher grade material produced from concentration or separation processes.

Cut-off grade: The lowest grade of rock that will be mined from a deposit. Below this grade, all rock is 'waste rock'. This grade is mainly based on the costs of mining and mineral prices (value of the ore). This means that there is no profit when mining rock below this grade.

Density: A measure of a quantity (usually mass) per unit volume. For example, the density of granite is about 2.41 tonnes per cubic metre, and the density of gold is 19.5 grams per cubic centimetre.

Depletion: To use up completely or exhaust. In mining, this usually refers to ore reserves being mined out.

Deposit: A body of rock or soil containing a high percentage of economically valuable minerals (it is mineralised). The characteristics of a deposit need further study to be called an ore body.

Discharge: To dump, dispose of, emit or release a liquid (like waste water), a slurry (like tailings) or a gas (like diesel fumes).

Emissions: Usually refers to gases, vapours or fumes released by e.g. diesel and mercury.

Exploration: The search for deposits of useful minerals through sampling, analysis, interpretation etc.

Feed size: The size (diameter) of crushed or ground ore that is fed into mineral processing steps like crushing, grinding, classification, separation or washing units. Most machines will only accept a rock of a maximum size (you could not fit a whole pumpkin into your mouth, could you?).

Gangue: Minerals in the ore that are not particularly valuable. As far as possible, concentration and separation processes separate such minerals from the valuable ones.

Gender: The state of being male or female. The behaviours, attitudes, values, beliefs, etc. that a particular socio-cultural group considers appropriate for males and females. Gender beliefs are changeable and can be different from community to community and in different situations.

Hazard: A potential danger. The capacity of a substance, an activity or an event to produce ill health, safety risks and adverse environmental effects.

Health: A state of complete physical, mental and social well-being of an individual and not merely an absence of disease or infirmity. This also includes the ability to lead a socially and economically productive life.

HIV/AIDS: HIV (Human Immunodeficiency Virus) is a virus that is spread from person to person through infected blood, semen or vaginal secretions.
Infected pregnant women can pass HIV to their babies during pregnancy, delivery or through breast feeding. AIDS (Acquired Immune Deficiency Syndrome) is the illness caused by HIV.

Host rock: The rock in which an ore deposit occurs.

Igneous rock: A rock formed during solidification (cooling) of magma (hot molten rock).

Liberation: Release of valuable minerals from gangue minerals in ore by crushing, grinding or natural size reduction.

Metamorphism: A physical and chemical change in rocks caused by pressure and temperature over time.

Metamorphic rock: A rock formed deep in the crust from the application of pressure, heat, effect of superheated fluids or any combination of these applied to any pre-existing rock.

Middling: During mineral processing of metallic ores, the part of the product of separation/concentration that is neither concentrate nor gangue (but a combination of these). More separation is needed to recover valuable minerals from middlings.

Mine: An opening or excavation in the earth made for the purpose of extracting minerals.

Mineral: A naturally occurring element with a definite physical and chemical composition.

Occupational safety: involves a positive sense of security in an environment which is free from hazards of all types. It also covers all activities involved in the implementation of programmes for safety promotion, preventive measures, hazards and risk identification and control at the work place.

Ore: A rock from which one or more useful minerals can be extracted. A natural deposit that contains economically valuable minerals in high enough concentrations to mine them at a profit

Ore body: A deposit whose limits (depth, length, width, ore grade, etc.) have been determined using exploration methods. A continuous, well-defined mass of rocks containing enough ore to make mining economically possible.

Ore grade: Percentage of metal or mineral in an ore (e.g. limestone ore containing 68% calcium carbonate $CaCO_3$). If the grade is low, it is usually described as grams per tonne (e.g. gold ore containing 9 g/t gold), but if the grade is higher, it is expressed as a percentage (like ore containing 6% cassiterite).

Outcrop: A mass of bedrock that is exposed or visible at the surface of the earth.

Overburden: Soil and weathered or unweathered rock that overlie a deposit of ore that is to be mined.

Placer: A deposit of heavy minerals (like gold, cassiterite, heavy gemstones, etc.) that has been eroded from rock and concentrated through gravity separation (usually by rivers and streams).

Poverty: Refers here to human poverty which includes lack of assets, dignity, autonomy and time in addition to income poverty.

Prospecting: Searching for mineral deposits. Finding places where valuable minerals occur.

PPM: Measure of concentration, mainly of precious metals, in an ore deposit. PPM (parts per million) equals gram per tonne.

Reclamation: Rehabilitation of the area of land affected by mining, that can include things like stabilization of slopes, creation of safety benches, planting of forests, re-vegetation of waste rock piles, capping and re-vegetation of tailings dams, planting of crops and enhancement of wildlife and aquatic habitats.

Rehabilitation: Also called reclamation. The return of disturbed land to a stable, productive and self-sustaining condition, after taking into account beneficial uses of the site and surrounding land.

Recovery: The percentage of valuable minerals derived from an ore through mineral processing. Most processes are not 100% efficient, so a percentage of valuable minerals often end as waste.

Reserve estimation: An estimate of the amount and quality of ore in a deposit. This is one of the main factors for determining whether to build a mine or not.

Reserves: The amount of ore in a deposit. Usually, it is stated as tonnes of ore at a specific grade (e.g. 5000 tonnes containing 8 g/t of gold or 100,000 tonnes containing 75% calcium carbonate).

Risk: The probability that a substance, an activity or an event will produce ill health, safety risks and adverse environmental effects under a given set of circumstances.

Rock: A naturally occurring combination of minerals.

Safety: The application of techniques to ensure that an environment is free from any form of threat or risk. The absence of an unacceptable level of harm, allowing for planned or unplanned events and their likely consequences.

Schistosity: Layers where minerals are aligned along the same directions. Foliation where minerals are visibly separated into bands. Basically, bands can be straight or wavy 'layers'.

Sedimentary rock: A rock formed from the accumulation and solidification of sediments (that can originally be made up of minerals or rock particles eroded from other rocks or animal or plant debris).

Shaft: An excavation made for mining ore, raising ore, rock or water, hoisting up and lowering workers and materials, or for ventilating underground workings.

Sieve: A mesh or screen used to separate large particles from smaller ones.

Silicosis: A respiratory disease that develops from repeated exposure to dust with silica-containing minerals (especially quartz).

Sizing: Separation of solids into two or more products on the basis of their sizes. Main methods of sizing are 'screening' and 'classification'.

Smelting: Obtaining a metal from an ore or concentrate by melting the material at high temperatures. Fluxes are added that, in the presence of high temperatures, reduce the metal oxide to metal. A *flux* is a substance that promotes the fusion of two other substances. Smelting results in a molten layer containing the heavy metal values and a slag layer containing impurities.

Stakeholder: Any person, group or institution that has an interest in, or who (directly or indirectly) stands to gain or lose from a given development activity or policy.

Tailings: The fine-grained waste or residue from mineral processing. It is mostly made of gangue minerals. Tailings are kept in a 'tailings dam' or 'tailings impoundment'.

Tinnitus: hearing disease that may be caused by extensive exposure to noise.

Topography: The study and mapping of features on the surface of the ground, like rivers, mountains, lakes, roads and towns.

Vein: A mineralised zone having a more or less regular shape in length, width and depth to give it a tabular form.

Waste rock: Relatively non-valuable rock that is separated and removed from ore during mining. Waste rock is dumped in waste rock piles (or waste dumps). Although it often contains *some* economically valuable minerals, it is not ore.

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Appendices A-C

Appendix A

Advanced mineral processing technologies

Mineral processing by ASM operators is mostly carried out on a low technological level. At rush mining sites the miners show little incentive to invest money in better extraction equipment. In more permanent mining sites some of the miners are interested in obtaining higher recovery and they invest in better equipment. In this case the miners will copy extraction equipment which they have seen in other mining sites.

New methods spread slowly and sometimes very slowly from site to site. There is often a tendency to conservatism among ASM operators. When they have used a certain method for decades they are reluctant to change to new methods. One convincing argument to adopt new methods is if they increase earnings.
Mineral processing is generally defined as a process that physically separates the minerals using differences in their physical properties to produce mineral concentrate(s) containing predominantly valuable mineral and tailings containing the predominantly non-valuable fraction.

The two fundamental operations in mineral processing are liberation and concentration:

Liberation

Liberation or release of the valuable minerals from their waste gangue is accomplished by comminuting that involves crushing and if need be, grinding to such a particle size that the product is a mixture of relatively separate particles of mineral(s) and gangue.

Crushing refers to breaking of rock lumps or boulders to smaller sizes by compressive and impact forces using jaw or gyratory crushers or simply sledge hammers.

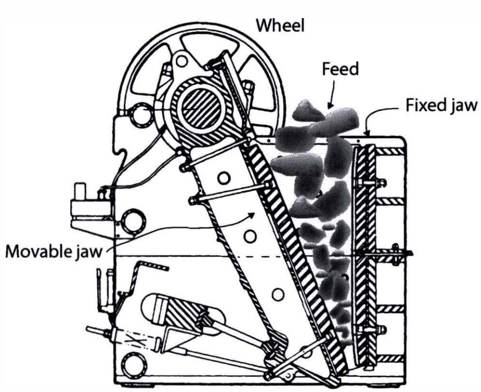

Fig. A-1. Jaw Crusher (Source: Wills & Napier-Munn 2006)

Products from crushers can be further reduced to fine sizes by grinding using rod or ball mills or simple pestle and mortar to finally effect liberation of values from gangue.

Concentration

Concentration refers to the separation of mineral values from the gangue. This is generally accomplished by using the differences in physical properties between the associated minerals. The physical properties of minerals generally used in effecting mineral separation are:

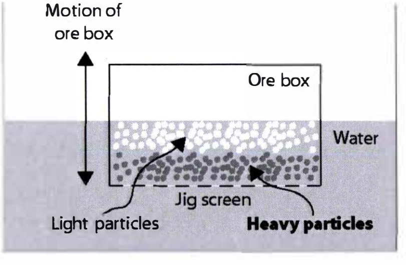

Fig. A-2. Hand Jig (Modified from Wills & Napier-Munn 2006)

Density - the process of separating minerals using the density difference between the associated minerals is called gravity separation. In this process, homogeneously sized mineral particles are allowed to settle or fall in a fluid medium (air or water) resulting in the heavier particles settling at a faster rate than the lighter ones leading to the formation of layers of heavy and light minerals that can be subsequently separated into fractions.

Generally, gravity concentrating operations allow particles to be held slightly apart so that they can move relative to each other and therefore to separate into layers of heavy and light minerals. The gravity separation method is usually named after the particular way in which the particles are separated, e.g. jigging and shaking table.

Not all mineral combinations (associations) are amenable to gravity concentration methods. To determine the suitability of gravity separation processes to a particular ore type, a *Concentration Criterion* is commonly used defined as

$$\text{Concentration Criterion (CC)} = \frac{(\text{s.g. of heavy mineral - s.g. of fluid})}{(\text{s.g. of light mineral - s.g. of fluid})}$$

where s.g. is the specific gravity determined using density bottles or Le Chaelier's Flask Method.

As a guide, the following concentration ratios can be used as a guide for gravity separation (Gupta, 2006).

Concentration criterion guide for gravity separation

Concentration criterion	**Suitability to gravity separation**
CC > 2.5	Easy down to 75 μm
1.75 <CC< 2.5	Possible down to 150 μm
1.5 <CC< 1.75	Possible down to 1.7 mm
1.25 <CC< 1.5	Possible down to 6.35 mm
CC<1.25	Impossible at any size

Examples of minerals that can be upgraded by gravity separation methods are cassiterite, barite, tantalite/columbite, lead-zinc-copper ores, etc.

Magnetic property – the method that uses difference in magnetic property between the associated minerals is known as magnetic separation that uses magnets to effect separation. This involves using a low intensity magnet to remove a highly magnetic mineral such as magnetite from a non-magnetic material or a high-intensity magnet to separate weak or moderately magnetic minerals such as columbite/tantalite from non-magnetic minerals, such as cassiterite. Examples of magnetic separators include a cross-belt magnetic separator (BNF magnetic separator), rare-earth roll and rare-earth drum magnetic separators.

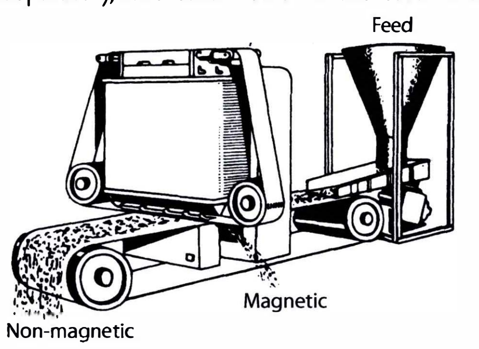

Fig. A-3. Cross Belt Magnetic Separator (Source: Wills & Napier-Munn 2006)

Electrical Conductivity – minerals can be separated by using differences in their electrical conductivity. Minerals deposits that can be treated in this way include alluvial deposits containing monazite, zircon, quartz, cassiterite, ilmenite and magnetite.

High tension separators operate on feeds containing between 60 and 500 μm particles size range.

Surface property – the concentration technique that uses differences in the surface property of the associated minerals is called froth flotation. In this process, a particular type of mineral is selectively attached to air bubbles and floated to the surface of the pulp as froth by the addition of collectors that make them hydrophobic

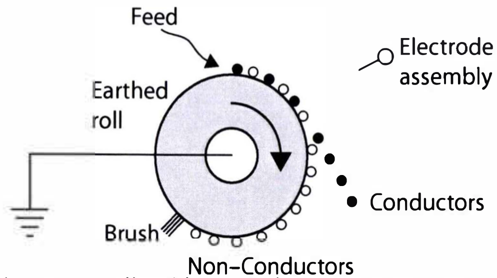

Fig. A-4. Principle of high tension separation (Wills & Napier-Munn 2006)

(water-repellent) leaving the remaining minerals in the pulp as aerophilic (water-loving) minerals.

Flotation can be direct where the valuable mineral is floated or indirect where the unwanted gangue is floated. Frothers and regulators are the other reagents that are used in flotation process.

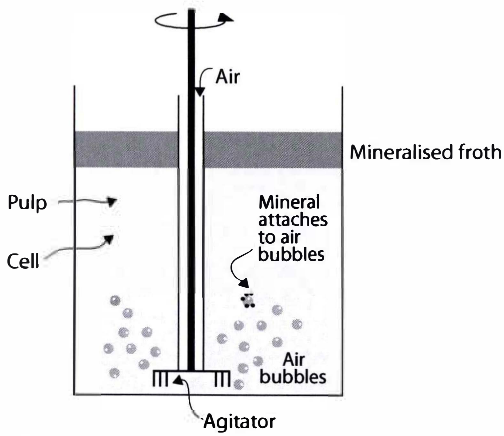

Fig. A-5. Principle of froth flotation (Source: Wills & Napier-Munn 2006)

Flotation is applied to relatively fine particles (about 75 μm because the weight of large particles will tend to be greater than the adhesive force between the particle and the air bubble resulting in the bubble dropping the particle.

Optical property – separation process based on the difference in optical property is called sorting which is mostly done by hand by the ASM operator but could also be done by a machine which principally uses optical laser scanner and air ejectors.

Sampling

Sampling refers to the collection of a representative sample from a given mineral assemblage for tests, etc. This can be done by grab sampling of a stockpiled material or by cutting samples from moving material streams at the free fall point as shown in Fig. A-6 below. Samples can be further reduced to manageable quantities using coning and quartering as well as riffling methods.

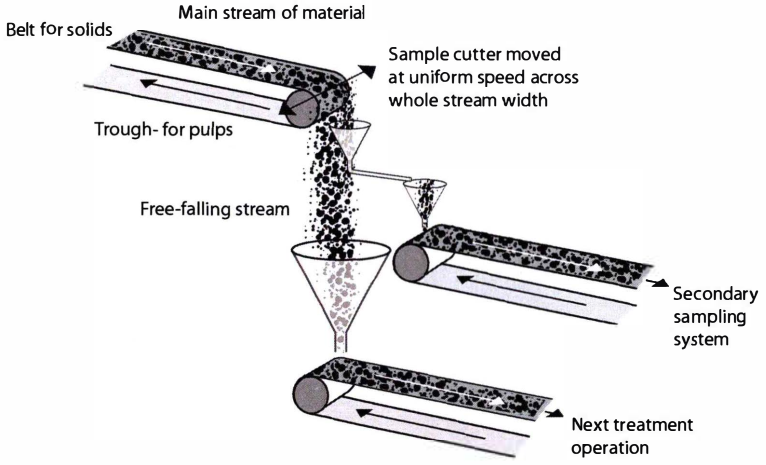

Fig. A-6. Sampling using moving cutter (Source: Jones 1987)

Tailings

Tailings disposal refers to the doing away with solid-waste material generated by the mineral processing plant during the course of producing the required mineral product. Tailings have adverse visual effect on the landscape in addition to major ecological effect associated with water pollution arising from the discharge of water contaminated with solids, heavy metals, mill reagents, sulphur compounds, etc. This makes it necessary for waste generated by the processing plant to be disposed of in both environmentally acceptable and if possible, an economically viable manner (Wills' 2006). Mineral processing will never be able to extract all the valuable commodities from the mined material. However, in the future more advanced extraction techniques may be able to extract more value from the tailings. It is thus of importance to store the tailings in a way that they can be processed again.

Appendix B

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Check list for monitoring and environmental compliance of ASM operators in Nigeria

General information	
Name of ASM operator	
Address	
Mineral(s) mined/processed	
Nature of operation	
Name, phone and e-mail og contact person	
Prospecting/reconnaissance	
How many trenches and pits have been dug since prospecting started?	
Was the dug-out material deposited on a safe site so it cannot be washed down slope during heavy rainfall?	
Have trenches been refilled after use?	
Have badlands been reclaimed (e.g. plants or trees planted)?	
Hard rock mining	
Earth removal activities	
How much overburden has been removed since last inspection?	
Has the overburden been deposited at a safe place with no risk of being washed down slope during heavy rain?	
Have tailings been deposited at a safe place with no risk of being washed down slope during heavy rain?	
Excavation	
Arial extent of pit	
How deep is the pit?	

Is the pit filled with water for extended periods?	
Are there high steep walls which could cave in or cause rock fall?	
Is benching used during excavation?	
Does the bench size exceed 1.5 m in height and 2 m in width?	
How much has been excavated since last inspection?	
Has the pit been fenced in?	
Underground mining	
Is tunnelling used in the mining operation?	
Are roofs and walls of the tunnels properly supported?	
Alluvial mining	
What type of mineral ore (sulphide bearing or non sulphide, etc.) is being treated?	
Is the ore (soil with precious minerals or metals) processed at the mining site or carried to nearby streams?	
Has a dam been constructed at or near the mining site for washing the precious stones?	
Is the water in the dam blocked from running down into the drainage system?	
If the ore is carried to a nearby stream, is the processing carried out in a way to prevent siltation of the river, such as settling ponds?	
Is water conservation (recycling) being practiced?	
Is the quality of water being discharged into the stream monitored for heavy metal(s) content and suspended particles amongst others so that their levels fall within threshold limits? {Total suspended solids <50mg/L; Lead (Pb) <0.2mg/L; Mercury (Hg) <0.002mg/L; Arsenic < 0.1mg/L; pH 6 – 9; etc}	
Placer mining	
How much sand and gravel has been processed since last inspection?	
Where was the processed sediment deposited?	
Which measures have been taken to restore the river bed?	
Which measures have been taken to prevent siltation of the river?	
Deforestation	
Have the miners cleared large areas for trees?	
What do they use the wood for: cooking or mining purposes?	

What are their plans for planting trees?	
Closing down mining operations	
Has the pit been refilled, and the ground levelled?	
If the pit has not been refilled have measures been taken to prevent people or animals from falling into the pit, e.g. fencing?	
Has removed overburden been brought back to cover the levelled working areas, and have measures been taken to regain vegetation?	
Has removed tailings or host rock been deposited in a way to prevent them to be washed into the drainage system during heavy rain?	
Have trees or plants been planted on dumps of overburden/tailings in order to reclaim the land?	
Has Forestry been consulted in order to plant the best trees or plants for reclaiming the mining site?	
Has the mining site been cleared for mining equipment, garbage and other items related to the mining operation?	
Safety measures	
Do ASM operators use protective clothing, footwear and hand gloves?	
Do ASM operators use hard hats?	
Do ASM operators use safety goggles?	
Is a first aid kit easily available?	
Are dust masks used during crushing?	

Appendix C

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HOW TO START AS AN ASM OPERATOR

Step 1
Obtain appropriate permit forms from:
Mining Cadastre Office (MCO), Ministry of Mines and Steel Development Abuja
Or
Zonal Offices of Mining Cadastre Office
Located at Jos, Ibadan, Kano, Maiduguri, Enugu and Port Harcourt;
Or
State Offices of the Ministry of Mines and Steel Development.

The various permits and forms are:

- *Reconnaissance Permit* - This permit confers the right to the applicant to prospect for minerals in a non-exclusive area granted in line with laid down regulations;
- *Exploration Licence* – This permit confers the right to the applicant to exclusively delineate the mineral area, determine the mineral reserves as well as determine the viability of exploiting the discovered mineral deposit in an approved area in line with laid down regulations;
- *Small Scale Mining Lease* – This permit confers the right to the applicant to exclusively mine and process minerals from the area covered in line with laid down regulations;
- *Quarry Lease* – This permit confers the right to applicant to exclusively extract and process rocks / minerals (industrial) from the area covered in line with laid down regulations;
- *Water Use Permit* – This permit confers the right to the applicant to use water for mining / mineral processing activities needed to exploit the mineral deposit in line with laid regulations.

Step 2
Complete forms in triplicates and submit to MCO, Abuja with necessary attachments as listed in table 4.1. Ensure that submitted forms have been duly stamped by MCO registry and certified as correctly completed.

Step 3
Monitor the progress of application by phone so as to respond to queries that might arise following the processing of submitted applications (e.g. overlapping issues, improper coordinates, etc.).

Step 4
Promptly pay up annual service fees as demanded by MCO following approval of application.

Step 5
Submit a copy of Permit Licence to the State Mines Office in charge of area covered indicating intentions to commence activities in line with the work plan submitted along with the application for permit and regulations governing mineral prospecting, exploration and exploitation activities.

Step 6
Inform land owners of proposed date of commencement of activities in line with the work plan submitted along with the application for permit and regulations governing mineral prospecting, exploration and exploitation activities.

List of MMSD offices to contact for further information:

ASM Department
Metals and Minerals Complex
No.2 Luanda Crescent
Wuse II, P.M.B. 107, Abuja,
Tel. 08033108773 (Director)
E-mail: azubikeo2003@yahoo.co.uk
info@mmsd.gov.ng

Mining Cadastre Office
No 37 Lobipo Crescent,
Off Adetokumbo Ademola Crescent,
Wuse II, Abuja.
Tel. 08035808551 (DG)
E-mail: amatetng@yahoo.ca
info@mmsd.gov.ng

Mine Inspectorate Department
Metals and Minerals Complex
No.2 Luanda Crescent
Wuse II, P.M.B. 107, Abuja,
Tel.: 080331409151 (Director)
E-mail: id_umar@hotmail.com
info@mmsd.gov.ng

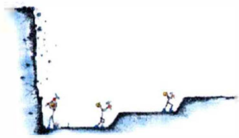
Mines Environment Compliance Department
Metals and Minerals Complex
No.2 Luanda Crescent
Wuse II, P.M.B. 107, Abuja,
Tel. : 08037872053 (Director)
E-mail: info@mmsd.gov.ng

Important environmental and health concerns related to ASM

ASM operations create a number of environmental problems which must be mitigated as much as possible:

1. Land degradation. Exploration and mining pits damage the surface and prevent future use for farming. Deep pits without fencing pose risks for people and cattle. Benches should not be more than 1.5 m high and at least 2 m wide. This will facilitate walking up the bench with heavy load and prevent stones from falling down hurting the miners at the bottom of the pit.

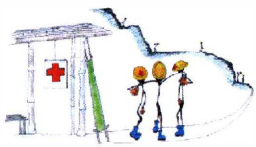
Fence your pit



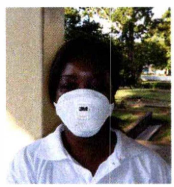
Avoid high steep walls.
Use benching

2. Siltation of rivers. Before mining an ore body the overburden must often be removed and deposited elsewhere. The dumps of overburden or tailings have to be protected to prevent the material from being washed into the rivers during heavy rainfall. If the material is washed into the rivers they may clog up or become full of fine-grained material which will disturb the fish stock in the rivers.
3. Deforestation. Underground mining ought to use timber for supporting walls and tunnels.
4. Crushing rocks create a lot of dust. If the crushed rock has high contents of quartz (silica) the dust may cause stone lungs or silicosis. This can be easily avoided by using a simple low cost dust mask.
5. Mining with hammer and chisel in hard rock may damage your eyes if you do not protect them.

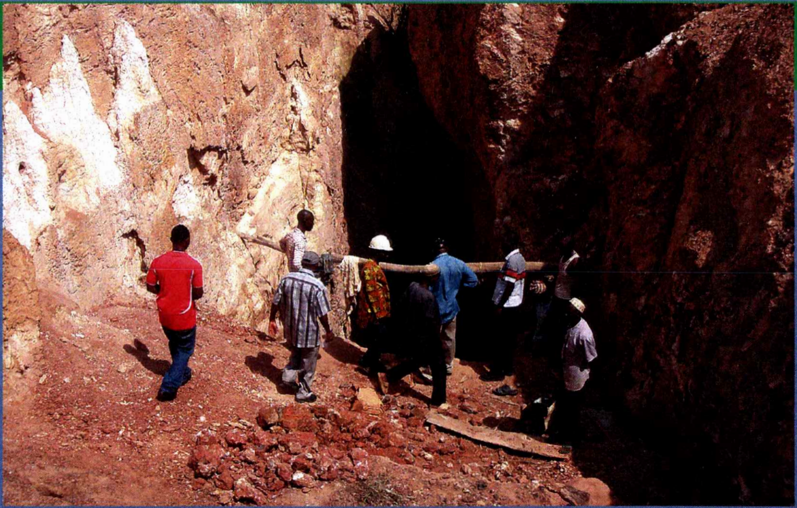
Use safety goggles



Have emergency equipment ready



Use of dust mask will prevent (silicosis) stone lungs



This ASM Handbook has been written to help improve the performance of ASM operators in Nigeria. Every chapter responds to needs and issues that Nigerian female and male miners have said are important to them.

ASM operators throughout Nigeria face many challenges, the most important being lack of training and information in:

- Geology
- Mining methods
- Mineral processing methods
- Business skills to improve mining operations
- Safety and health practices
- Environmental management.

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