



NIGERIA MARITIME UNIVERSITY

Okerenkoko, Warri South-West, Delta State

Department of Marine Geology

MGY 405

Ocean Mineral Deposits and Mining in Nigeria

Lecture Note

*Polymetallic Massive Sulphide Deposits at the Modern Seafloor and their Resource Potential
The Nigerian Minerals and Mining Act 2007 and Regulations 2011*

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First Semester, 2026/2027 Session

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Course information

This note covers two parts of MGY 405. The first is the geology and resource potential of the polymetallic massive sulphide deposits forming today on the ocean floor. The second is the legal framework for solid minerals in Nigeria, set out in the Nigerian Minerals and Mining Act, 2007 and the Nigerian Minerals and Mining Regulations, 2011, which are treated together. The other ocean mineral deposits and their mining are covered in the other part of the course.

Item	Detail
Course	MGY 405: Ocean Mineral Deposits and Mining
Level	400 level, first semester, 2026/2027 session
Department	Marine Geology
Institution	Nigeria Maritime University, Okerenkoko, Warri South-West, Delta State
Lecturer	Dr. Daniel Tuoyo Amiwero
Part covered by this note	Polymetallic massive sulphides at the modern seafloor; the Nigerian Minerals and Mining Act and Regulations

Learning outcomes

At the end of this part of the course, you should be able to:

1. Describe the discovery, tectonic settings and global distribution of seafloor massive sulphide deposits.
2. Explain how hydrothermal circulation forms black smoker chimneys, sulphide mounds and stockwork zones.
3. Describe the mineralogy and metal contents of seafloor sulphides in different settings and compare them with volcanogenic massive sulphide deposits on land.
4. Assess the size, grade and resource potential of seafloor sulphides, and calculate contained metal.
5. Outline the methods of exploring for and mining seafloor sulphides and the environmental issues they raise.
6. Explain the maritime zones of the Law of the Sea and the regime of the International Seabed Authority for polymetallic sulphides.
7. Explain the ownership of minerals, the institutions and the mineral titles established by the Nigerian Minerals and Mining Act and Regulations, and describe how a title is obtained and maintained.
8. Summarise the fiscal, environmental, community, safety and enforcement provisions of the Nigerian mining law, and apply them to coastal and offshore minerals.

Why this matters to a marine geologist

Metals such as copper, zinc, gold and silver are being deposited on the ocean floor today by hot springs on mid-ocean ridges and volcanic arcs. These deposits are natural laboratories for understanding many of the world's ancient ore deposits, and some may one day be mined. Whether they are mined, and how, depends as much on law, economics and environmental protection as on geology. Nigeria's own law vests in the Federal Government all minerals on

land and in its territorial waters, continental shelf and Exclusive Economic Zone. A marine geologist working in exploration, mining, consulting or government needs to understand both the science of ocean minerals and the rules under which mineral rights are granted and regulated.

Section 1: Polymetallic massive sulphide deposits at the modern seafloor and their resource potential

Seafloor massive sulphides (SMS), also called **polymetallic massive sulphides**, are accumulations of metal sulphide minerals formed on and just below the seabed by hot, metal-rich fluids venting from the oceanic crust. They contain copper, zinc and lead, often with gold and silver, and sometimes cobalt and other trace metals. They are the modern equivalents of the **volcanogenic massive sulphide** (VMS) deposits mined on land for thousands of years, and they are one of the three main types of deep-sea mineral deposit, with polymetallic nodules and cobalt-rich ferromanganese crusts.

1.1 Discovery and history

The story of seafloor sulphides began in the Red Sea. In the mid-1960s, research vessels found pools of hot, dense brine in deeps along the axis of the Red Sea rift. The largest, the **Atlantis II Deep**, contains thick layers of metalliferous mud rich in zinc, copper, iron, silver and gold, deposited from the brine. It is still the largest known metal accumulation on the modern seafloor.

The first hot springs on a mid-ocean ridge were seen in 1977, when the submersible *Alvin* dived on the Galápagos Rift and found warm water venting from the basalt, surrounded by unexpected communities of giant tube worms, clams and mussels. In 1979, on the East Pacific Rise at 21°N, *Alvin* found **black smokers**: chimneys several metres high venting black, particle-laden fluid at about 350 °C, standing on mounds of massive sulphide. This discovery confirmed that seafloor spreading forms ore deposits and transformed thinking about ore genesis and the origin of life.

At first it was thought that only fast-spreading ridges, with abundant magma, could form sulphides. In 1985, high-temperature venting was found at the **TAG** (Trans-Atlantic Geotraverse) hydrothermal field on the slow-spreading Mid-Atlantic Ridge at 26°N. Its active mound, about 200 m across and 50 m high at a depth of about 3,650 m, is one of the largest known on a mid-ocean ridge. Other major Atlantic sites, such as Snake Pit, Logatchev, Lucky Strike and Rainbow, soon followed. From the mid-1980s, many deposits were also found in the back-arc basins and volcanic arcs of the western Pacific, including the Okinawa Trough, the Lau and Manus basins and the Kermadec arc.

Today several hundred active and inactive hydrothermal vent fields are known from all the oceans, and many host sulphide deposits. Yet only a small fraction of the roughly 60,000 km of mid-ocean ridges, and even less of the volcanic arcs, has been surveyed in detail, so many more deposits remain to be found.

1.2 Seafloor sulphides and ancient deposits on land

Massive sulphides on land have the same origin as those forming today. They were deposited on ancient seafloors and later preserved in the rock record by burial, or uplifted onto land, commonly in ophiolites and volcanic belts. Famous examples include:

- the copper deposits of the **Troodos ophiolite** in Cyprus, formed at an ancient spreading centre and mined since the Bronze Age (the word “copper” comes from the Latin name for Cyprus);
- the **Kuroko** deposits of Japan, formed in a volcanic arc setting;
- the giant deposits of the **Iberian Pyrite Belt** in Spain and Portugal, such as Rio Tinto and Neves Corvo, hosted by volcanic and sedimentary rocks;
- **Kidd Creek** and the Noranda deposits of the Canadian Shield, in Archaean volcanic belts.

Land VMS deposits are classified by their host rocks, which reflect their tectonic setting: mafic (ophiolite or Cyprus type), bimodal (mixed basalt and felsic volcanics, arc and back-arc types such as Kuroko) and siliciclastic (sediment-dominated). The modern seafloor shows the same range. Studying active systems therefore helps geologists explore for ancient deposits on land, and land deposits show what seafloor deposits look like in three dimensions.

1.3 Tectonic settings

Seafloor sulphides form wherever seawater can circulate through hot volcanic rock near a magma source. The main settings are (Figure 1.1):

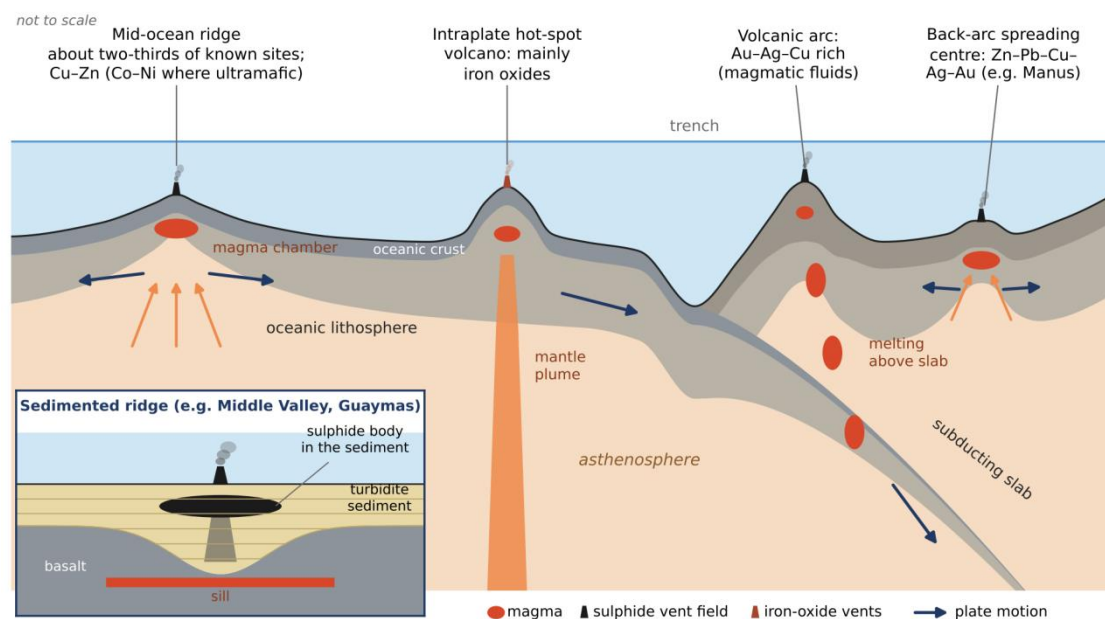


Figure 1.1. Tectonic settings of seafloor massive sulphide deposits: mid-ocean ridges (including sedimented ridges), intraplate hot-spot volcanoes, and the arc volcanoes and back-arc spreading centres above subduction zones.

Mid-ocean ridges. About two-thirds of known sites lie on mid-ocean ridges.

- On **fast-spreading ridges** such as the East Pacific Rise, magma is abundant and eruptions are frequent. Vent fields are numerous but deposits tend to be small, because lava flows bury them and the plumbing changes often.
- On **slow-spreading ridges** such as the Mid-Atlantic Ridge, vent fields are fewer and farther apart, but the long-lived faults that focus fluid flow allow large deposits such as

TAG to grow over thousands to tens of thousands of years. Some Atlantic deposits, such as Logatchev and Rainbow, are hosted by **ultramafic rocks** (serpentinised mantle peridotite) exposed by large detachment faults; these are notably rich in copper and can contain significant cobalt, nickel and gold.

- On **sedimented ridges**, such as Middle Valley and Escanaba Trough off western North America and the Guaymas Basin in the Gulf of California, the ridge is buried by sediment. Hydrothermal fluids deposit much of their metal below the seafloor within the sediment, producing some of the largest deposits.

Back-arc basins. Behind volcanic arcs, the crust is stretched and new spreading centres form, as in the Lau Basin, the Manus Basin, the North Fiji Basin, the Mariana Trough and the Okinawa Trough. The volcanic rocks range from basalt to dacite and rhyolite. Their sulphides are commonly richer in zinc, lead, silver, gold, arsenic and antimony than those of mid-ocean ridges. The **Solwara 1** deposit in the Manus Basin, in the territorial waters of Papua New Guinea, is the best-known example.

Volcanic arcs. Submarine arc volcanoes, such as Brothers volcano on the Kermadec arc north of New Zealand and the Sunrise deposit in the Izu–Bonin arc south of Japan, host sulphides formed partly from magmatic fluids. These can be exceptionally rich in gold. Samples from **Conical Seamount**, near Lihir Island in Papua New Guinea, average about 26 ppm gold, with some samples above 200 ppm.

Intraplate volcanoes. Hot-spot volcanoes such as Kama‘ehuakanaloa Seamount (formerly Lō‘ihi) off Hawaii have hydrothermal activity, but deposit mainly iron oxides and little sulphide.

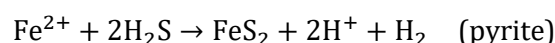
A key fact for resource assessment is that **most of the known high-grade deposits, and all of those so far considered for mining, lie within the Exclusive Economic Zones of coastal states** in the western Pacific, rather than in the international seabed area (Section 1.10).

1.4 How seafloor sulphides form

Hydrothermal convection. The process is driven by the heat of magma beneath the ridge or volcano (Figure 1.2):

1. **Recharge.** Cold seawater (about 2 °C) seeps down through cracks and faults in the oceanic crust over a wide area.
2. **Heating and reaction.** As it descends to depths of 1 to 3 km, close to the top of the magma chamber, the water is heated to 350 to 400 °C or more. In this **reaction zone** it reacts with the hot rock. Magnesium and sulphate are removed from the seawater, the fluid becomes acidic (pH about 3 to 4) and reducing, and it leaches metals (Fe, Cu, Zn, Pb, Au, Ag) and sulphur from the rock. The metals are carried as chloride complexes.
3. **Discharge.** The hot, buoyant fluid rises rapidly along narrow pathways and vents at the seafloor. At great water depths the high pressure prevents boiling. Where the fluid does boil or separates into a brine and a vapour, as at shallower arc volcanoes, metals can be deposited at depth.
4. **Precipitation.** When the fluid meets cold seawater, it cools suddenly and its acidity is neutralised. Metal sulphides precipitate as fine particles, which give black smokers their colour, and build chimneys and mounds.

Typical precipitation reactions are:





Anhydrite has an unusual **retrograde solubility**: it is less soluble in hot water than in cold. When seawater is heated above about 150 °C around a vent, anhydrite precipitates from it. It forms the first framework of a new chimney, and much of the inner part of active mounds.

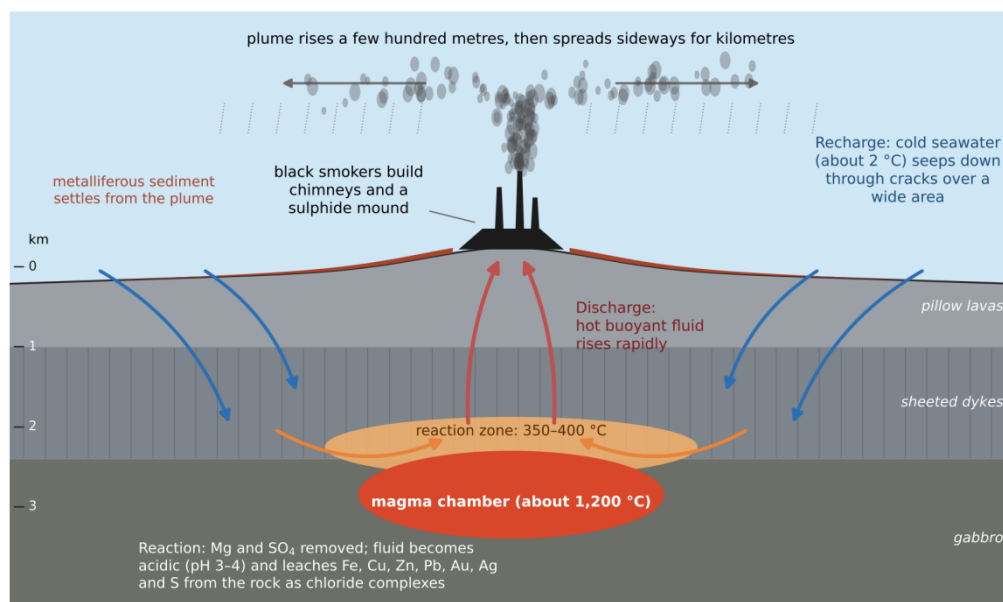


Figure 1.2. Hydrothermal convection at a mid-ocean ridge. Seawater is drawn down through the crust, heated and changed in the reaction zone above the magma chamber, and rises to vent as black smokers that build sulphide chimneys and mounds; fine particles drift away in the plume.

Chimneys. A black smoker chimney begins as a ring of anhydrite around the vent. Sulphides then precipitate inside this wall as hot fluid flows through it. Chalcopyrite (copper-iron sulphide) lines the hot central channel, with pyrite and sphalerite towards the cooler outside. Chimneys can grow several centimetres a day and reach heights of tens of metres, but they are fragile and often collapse. **White smokers** vent cooler fluids (100 to 300 °C) and deposit zinc sulphides, barite and silica. **Diffuse venting** of warm water through cracks supports most of the vent animals.

Mounds and stockworks. Collapsed chimney debris accumulates into a sulphide **mound** (Figure 1.3). Hot fluids continue to flow through the mound, depositing new sulphide in its pores and dissolving and re-depositing earlier minerals. This **zone refining** concentrates copper in the hot core and base of the mound, and moves zinc, lead, gold and silver towards its cooler top and margins. Beneath the mound, a pipe-shaped **stockwork** of altered, veined rock marks the path of the rising fluids. When venting stops, the exposed sulphides slowly oxidise to an iron oxide crust and red metalliferous sediment.

Plumes. Only a small part of the metal vented is trapped in chimneys and mounds. Most is carried away in the hydrothermal **plume**, which rises a few hundred metres above the seafloor until it reaches neutral buoyancy and then spreads laterally for kilometres. The particles settle as iron- and manganese-rich **metalliferous sediments**. Plumes are easy to detect from a ship, which makes them the main guide in exploration (Section 1.7).

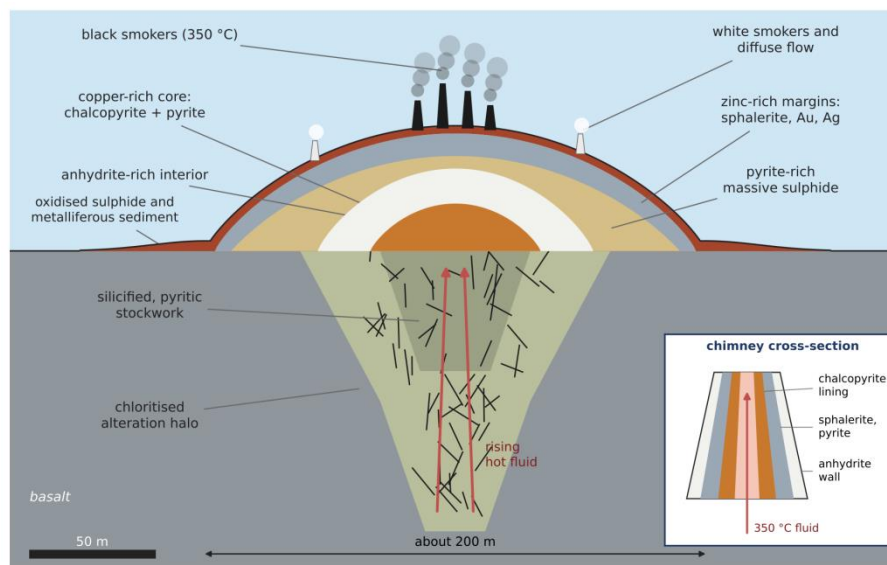


Figure 1.3. Cross-section of an active sulphide mound of the TAG type, with black smoker chimneys on top, an anhydrite-rich interior, a copper-rich core, zinc-rich margins, a silicified stockwork zone beneath, and oxidised sulphide and metalliferous sediment around it.

1.5 Mineralogy and metal contents

Group	Minerals	Notes
Iron sulphides	Pyrite, marcasite, pyrrhotite	Usually the most abundant minerals
Copper sulphides	Chalcopyrite, isocubanite, bornite	Hot (>300 °C) cores and chimney linings
Zinc and lead sulphides	Sphalerite, wurtzite, galena	Cooler parts; abundant in back-arc deposits
Sulphosalts	Tennantite, tetrahedrite, enargite	Arc and back-arc deposits; carry As, Sb, Ag
Precious metals	Native gold, electrum, silver minerals	Mainly in back-arc and arc deposits
Gangue minerals	Anhydrite, barite, amorphous silica (opal), talc	Anhydrite dissolves when venting stops
Oxidation products	Iron oxides and oxyhydroxides, atacamite	On the surface of inactive deposits

The metal contents vary systematically with the setting, because the host rocks and the fluids differ:

Setting	Typical host rocks	Characteristic metals
Basalt-hosted mid-ocean ridge	Basalt	Cu, Zn, Fe; low Pb; gold usually low (average about 1 ppm)
Ultramafic-hosted mid-ocean ridge	Serpentinised peridotite	High Cu; Co, Ni; locally high Au
Sedimented ridge	Basalt beneath turbidites	Zn, Pb, Fe; some deposits large
Back-arc basin	Basalt to rhyolite	Zn, Pb, Cu, Ag, Au, As, Sb, Ba

Setting	Typical host rocks	Characteristic metals
Volcanic arc	Andesite, dacite, rhyolite	Au, Ag, Cu, As, Hg; locally very gold-rich

Seafloor sulphides typically contain several per cent copper and zinc combined, far higher than most land deposits being mined today, although individual samples are biased towards the high-grade chimneys exposed at the surface. They also carry trace metals now regarded as **critical** for modern technology, including cobalt, indium, gallium, germanium, selenium and tellurium.

Worked example: contained metal. The amount of metal in a deposit is the tonnage multiplied by the grade:

$$\text{Contained metal} = \text{Tonnage} \times \text{Grade}$$

In 2012 the Solwara 1 deposit was reported to have an indicated resource of 1.03 million tonnes at 7.2% Cu and 5.0 g/t Au.

$$\text{Copper} = 1.03 \times 10^6 \text{ t} \times 0.072 = 74\,200 \text{ t}$$

$$\text{Gold} = 1.03 \times 10^6 \text{ t} \times 5.0 \text{ g/t} = 5.15 \times 10^6 \text{ g} = 5.15 \text{ t} \approx 166\,000 \text{ troy ounces}$$

using 1 troy ounce = 31.1 g. The grades are high, but the tonnage is small compared with a large land copper mine, which may produce several times this amount of copper every year. Multiplying the contained metal by the metal price, and adding up all the metals, gives the **gross in-situ value**, $V = \sum_i T g_i P_i$. This always overstates what a mine could earn, because not all of the resource is mined, metallurgical recovery is less than 100%, and the costs of mining, processing and transport must be paid.

1.6 Size of deposits and global resources

Most seafloor sulphide deposits are small. Many vent fields contain only a few thousand to a few tens of thousands of tonnes of sulphide, and only a few deposits have been drilled well enough to estimate their size (Figure 1.4):

- **TAG mound**, Mid-Atlantic Ridge: drilling by the Ocean Drilling Program in 1994 indicated about 2.7 million tonnes of massive sulphide above the seafloor and about 1.2 million tonnes in the stockwork beneath.
- **Middle Valley**, a sedimented part of the Juan de Fuca Ridge: drilling outlined about 8 to 9 million tonnes of sulphide, much of it within the sediment.
- **Solwara 1**, Manus Basin: about 2.6 million tonnes of indicated and inferred resources, at high copper and gold grades.
- **Atlantis II Deep**, Red Sea: about 94 million tonnes (dry, salt-free) of metalliferous mud with about 2.0% Zn, 0.5% Cu, 39 ppm Ag and 0.5 ppm Au. It is a different type of deposit, a brine-pool sediment rather than a massive sulphide mound, but a pilot mining test in 1979 showed that the mud could be pumped from about 2,000 m depth.

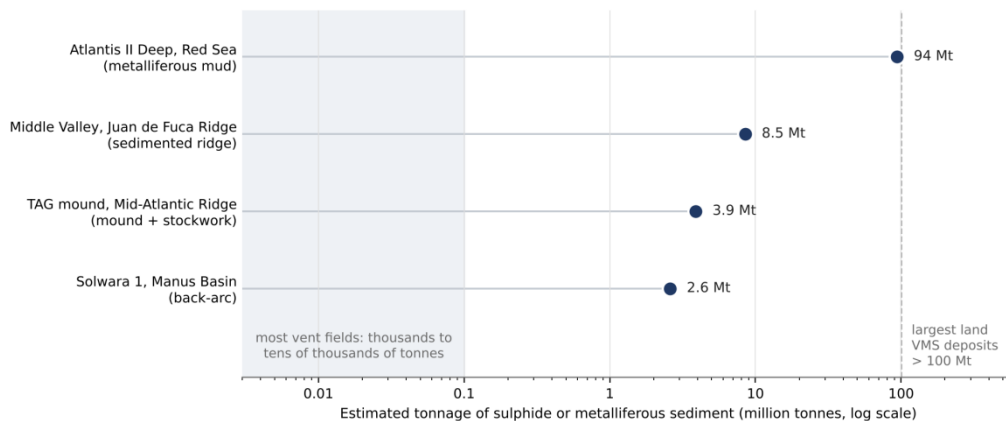


Figure 1.4. Estimated sizes of selected seafloor deposits (logarithmic scale). Most seafloor deposits are far smaller than these.

By comparison, the largest VMS deposits on land, such as those of the Iberian Pyrite Belt and Kidd Creek, contain more than 100 million tonnes of ore. No seafloor sulphide deposit of this size has been found, although some may exist beneath sediment or buried by lava where they cannot easily be seen.

Global estimates. Using the known distribution of vent fields and the sizes of drilled deposits, Hannington and others (2011) estimated that the neovolcanic zones of the ridges and arcs contain about 600 million tonnes of seafloor massive sulphide, holding about 30 million tonnes of copper and zinc combined. This is roughly equal to one year of world production of the two metals, and small compared with the metal in massive sulphide deposits on land. Most of this tonnage is concentrated in a small number of the largest deposits. The estimate does not include inactive deposits buried away from the ridge axes, which are hard to find and could add substantially to the total.

1.7 Exploring for seafloor sulphides

Exploration works from the regional scale down to the individual deposit (Figure 1.5):

1. **Regional surveys from ships.** Multibeam echo-sounders map the bathymetry and identify volcanic and faulted terrain. Instruments towed through the water column, or attached to a CTD (conductivity, temperature, depth) frame, detect hydrothermal plumes by their particles (light scattering or turbidity), chemical anomalies such as reduced oxidation-reduction potential, dissolved manganese, methane and helium-3, and small temperature anomalies.
2. **Near-bottom surveys.** Autonomous underwater vehicles (AUVs) fly 50 to 100 m above the seabed to map it in high resolution, measure magnetics (sulphide deposits and altered rock beneath them are commonly demagnetised) and track plumes to their source. Towed cameras and sonar locate chimneys and mounds.
3. **Observation and sampling.** Remotely operated vehicles (ROVs) and crewed submersibles inspect and sample the deposits.
4. **Geophysics and drilling.** Electrical and electromagnetic surveys and self-potential measurements over the seabed detect conductive sulphides beneath it. Drilling, from drill ships or by remotely operated seabed drill rigs, is the only way to determine the thickness and grade of a deposit in three dimensions, and so its tonnage.

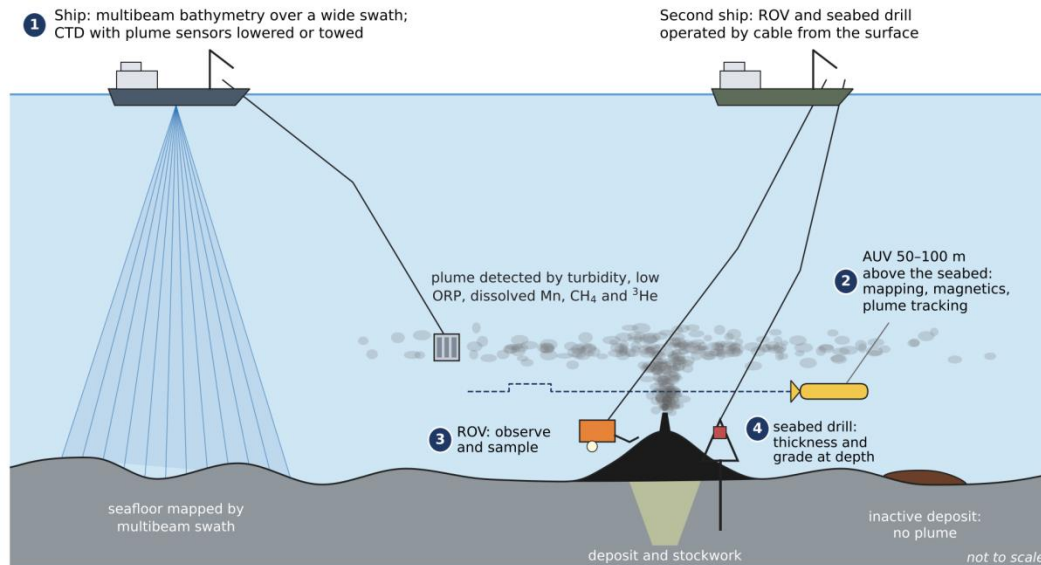


Figure 1.5. Exploration for seafloor sulphides at different scales: ship-based mapping and plume detection, near-bottom surveys by AUV, sampling by ROV, and seabed drilling to measure the third dimension.

The main challenge is that **active** deposits, with their plumes and vent animals, are the easiest to find, but **inactive** (extinct) deposits are more attractive for mining. Inactive deposits have no plume, are not hot or acidic, and support fewer specialised animals, but they can be found only by detailed mapping, geophysics and sampling.

1.8 Mining technology

No seafloor sulphide deposit has yet been mined commercially. The most advanced plan was the **Solwara 1** project of Nautilus Minerals in the Bismarck Sea, Papua New Guinea, at a water depth of about 1,600 m. Its system, typical of current concepts, has three parts (Figure 1.6):

- **Seafloor production tools.** Large remotely operated machines on tracks: an *auxiliary cutter* to prepare the rugged surface, a *bulk cutter* to cut the sulphide, and a *collecting machine* to gather the cut material as a slurry. The three machines were built and tested in 2016.
- **Riser and lifting system.** A subsea pump pushes the slurry up a vertical pipe (riser) to the surface.
- **Production support vessel.** The ship dewateres the ore, returns the filtered seawater through pipes to near the seabed, and transfers the ore to barges for shipment to a processing plant on land.

The project failed for financial reasons. Its specialised vessel could not be paid for, and Nautilus Minerals went into bankruptcy in 2019. The project's assets passed to a creditor company, and the Papua New Guinea government, which had taken a 15% stake, was left with large debts and later called for a moratorium on deep-sea mining. In 2017 Japan carried out the first test of lifting crushed sulphide ore from the seafloor, recovering about 16 tonnes from a deposit off Okinawa at a depth of about 1,600 m.

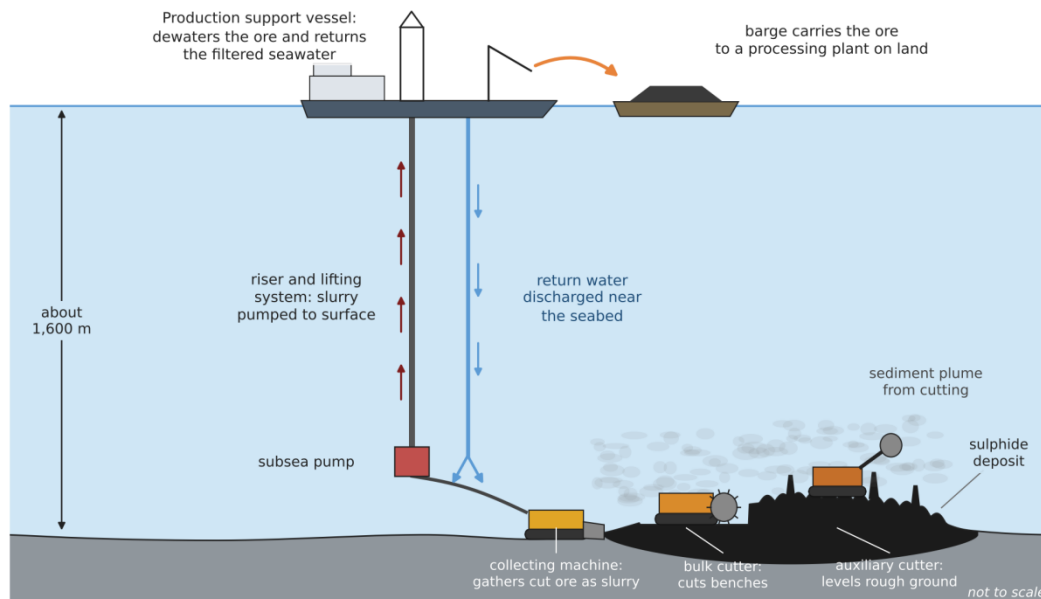


Figure 1.6. A seafloor sulphide mining system of the type planned for Solwara 1: seafloor production tools, a riser and lifting system, and a production support vessel, with return water discharged near the seabed.

Advantages and challenges. Seafloor sulphides have attractions compared with land deposits: high grades at the surface, no overburden to remove, no communities to resettle, little permanent infrastructure, and mobile equipment that can be moved from one deposit to the next. Against these are the small size of most deposits, the difficulty of estimating tonnage without dense drilling, the cost and risk of working at depths of 1,000 to 4,000 m, uncertain metal prices, and the environmental and regulatory uncertainties discussed below.

1.9 Environmental issues

Active vents support unique **chemosynthetic** ecosystems, in which bacteria use the energy of hydrogen sulphide and methane to produce food without sunlight. Animals such as giant tube worms, vent mussels and clams, swarming shrimp and the armoured scaly-foot snail are found nowhere else. Many species are endemic to a single vent field or region. In 2019 the scaly-foot snail of the Indian Ocean vents became the first deep-sea species to be listed as endangered on the IUCN Red List, because of the threat of mining.

Potential impacts of mining include:

- direct destruction of the habitat and the animals on the mined deposit;
- **sediment plumes** from cutting and from the return water, which can smother animals and carry fine sulphide particles away from the site;
- release of dissolved metals and acid, as fresh sulphide surfaces oxidise in seawater;
- noise, light and vibration, and changes to the flow of hydrothermal fluids.

Some active vent communities recover within years after natural volcanic eruptions, but recovery at slow-spreading ridges, and at inactive sites, may take much longer. Proposed safeguards include detailed baseline studies, environmental impact assessment, protected reference areas and set-asides, and a preference for inactive deposits. Many scientists and organisations, and 45 countries by mid-2026, have called for a moratorium or precautionary pause on deep-sea mining until its effects are better understood.

1.10 The legal regime and resource potential

Maritime zones. The United Nations Convention on the Law of the Sea (UNCLOS) of 1982, which entered into force in 1994 and which Nigeria ratified in 1986, defines the maritime zones (Figure 1.7):

- the **territorial sea**, up to 12 nautical miles from the baseline, under the full sovereignty of the coastal state;
- the **contiguous zone**, up to 24 nautical miles;
- the **Exclusive Economic Zone (EEZ)**, up to 200 nautical miles, in which the coastal state has sovereign rights over the resources of the water, seabed and subsoil;
- the **continental shelf**, the seabed and subsoil to 200 nautical miles or, where the continental margin extends farther, to an outer limit of 350 nautical miles or 100 nautical miles beyond the 2,500 m depth contour;
- **the Area**, the seabed and subsoil beyond the limits of national jurisdiction, whose mineral resources are the “common heritage of mankind” and are administered by the **International Seabed Authority (ISA)** in Kingston, Jamaica.

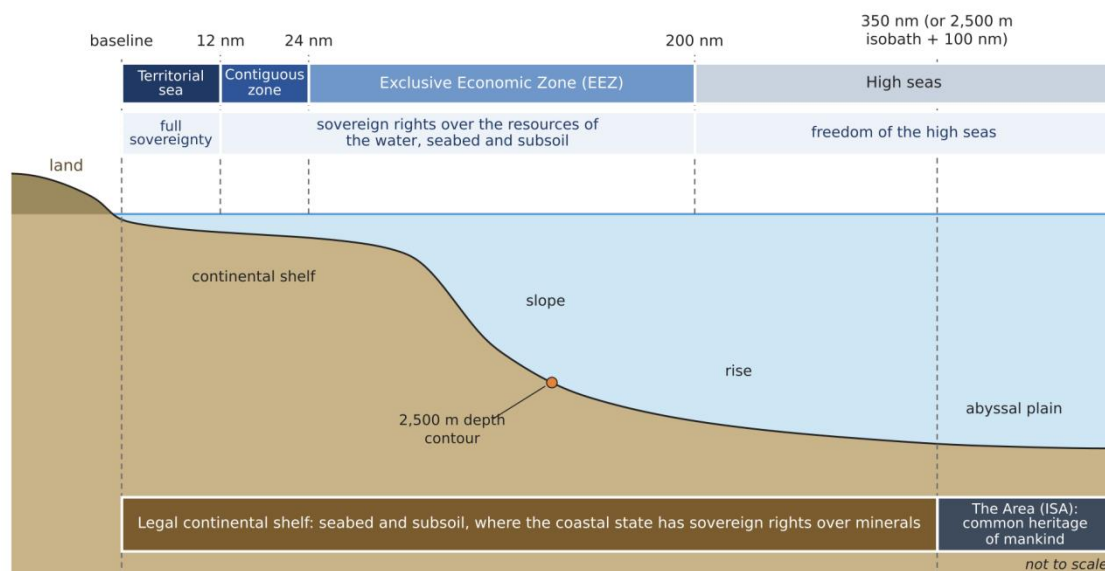


Figure 1.7. The maritime zones defined by UNCLOS, and who controls seabed minerals in each.

Within its EEZ and continental shelf, a coastal state regulates seabed mining under its own law, as Papua New Guinea did for Solwara 1. In the Area, exploration and mining require a contract with the ISA, sponsored by a state that is party to UNCLOS.

ISA regulations for polymetallic sulphides. The ISA adopted its *Regulations on Prospecting and Exploration for Polymetallic Sulphides in the Area* in 2010. An exploration area may consist of up to 100 blocks, each of about 10 km × 10 km and no greater than 100 km², with a total area of not more than 10,000 km². The contractor must relinquish at least 50% of the area by the end of the eighth year and 75% by the end of the tenth year, until no more than 2,500 km² remains. Seven exploration contracts for polymetallic sulphides have been granted:

Contractor	Sponsoring state	Location	Contract from
China Ocean Mineral Resources Research and Development Association	China	Southwest Indian Ridge	2011

Contractor	Sponsoring state	Location	Contract from
Government of the Russian Federation	Russia	Mid-Atlantic Ridge	2012
Government of the Republic of Korea	Korea	Central Indian Ridge	2014
IFREMER	France	Mid-Atlantic Ridge	2014
Federal Institute for Geosciences and Natural Resources (BGR)	Germany	Central Indian Ocean	2015
Government of India	India	Central Indian Ocean	2016
Government of the Republic of Poland	Poland	Mid-Atlantic Ridge	2018

The ISA has been negotiating regulations for exploitation (the “mining code”) since 2014. At its session in July 2026, the ISA Council again did not adopt them, and negotiations are to continue in 2027. Without these regulations, no commercial mining can take place in the Area.

Resource potential. Taken together, the evidence suggests that:

- seafloor sulphides are a real but modest resource. Their total metal content is small compared with land deposits, but individual deposits can be rich in copper, zinc, gold and silver;
- perhaps only a small number of the known deposits, mostly in the EEZs of Pacific island states and Japan, are large and rich enough to be considered for mining, and their size is uncertain until they are drilled;
- inactive deposits away from the ridge axes may hold much more metal than active ones, but are still poorly known;
- the economic, technical, environmental and legal obstacles remain large, as the failure of Solwara 1 showed.

Nigeria. Nigeria’s continental margin is a passive margin far from any active spreading centre, and its oceanic crust, formed at the Mid-Atlantic Ridge during the Cretaceous, is buried beneath kilometres of Niger Delta sediment. Seafloor sulphides are therefore not expected within Nigeria’s EEZ. However, Nigeria is a party to UNCLOS and a member of the ISA, and could sponsor exploration in the Area. Its own Minerals and Mining Act applies to the minerals of its territorial waters, continental shelf and EEZ, such as sand and gravel and heavy mineral sands, and is the subject of Section 2.

1.11 Key points of Section 1

- Seafloor massive sulphides form where seawater circulates through hot volcanic crust and vents as hot, metal-rich fluids at mid-ocean ridges, back-arc basins and volcanic arcs.
- Black smoker chimneys collapse to form mounds; zone refining concentrates copper in the core and zinc, gold and silver at the margins; a stockwork lies beneath.
- Metal contents depend on setting: ridges are Cu–Zn rich, ultramafic-hosted ridges add Co and Ni, back-arc and arc deposits are rich in Zn, Pb, Ag and Au.
- Most deposits are small; the global resource is about 600 million tonnes of sulphide in the neovolcanic zones, containing about 30 million tonnes of copper and zinc.

- Exploration uses plume detection, AUV mapping, ROV sampling and drilling; no deposit has yet been mined commercially, and the Solwara 1 project failed in 2019.
- Most high-grade deposits lie in national EEZs; in the Area, the ISA has granted seven sulphide exploration contracts but has not yet adopted exploitation regulations.

Section 2: The Nigerian minerals and mining legal framework

Solid minerals in Nigeria are governed by the **Nigerian Minerals and Mining Act, 2007** (Act No. 20 of 2007, assented to on 29 March 2007) and the **Nigerian Minerals and Mining Regulations, 2011**, made by the Minister under section 21 of the Act. The Act sets out the principles: who owns minerals, which institutions administer them, what rights may be granted and on what conditions. The Regulations supply the detail: application procedures, forms, fees, royalty rates, reporting, health and safety, and environmental and community requirements. This section treats them together, topic by topic. References to “s.” are to sections of the Act and to “Reg.” are to regulations of the 2011 Regulations.

2.1 Background and structure

Mining law in Nigeria developed from the colonial Minerals Ordinance through the Minerals Act of 1946 and the Minerals and Mining Decree No. 34 of 1999, which the 2007 Act repealed (s. 161). The 2007 Act was part of a reform of the solid minerals sector intended to attract private investment, end government operation of mines, and replace discretionary grants with a transparent, first-come-first-served system of mineral titles managed by an independent cadastre.

The constitutional basis is section 44(3) of the 1999 Constitution, which vests the entire property in and control of all minerals in the Government of the Federation, and item 39 of the Exclusive Legislative List, which places “mines and minerals” under the National Assembly. Mining is therefore a federal matter, although States and local governments have roles in land, compensation and community matters.

Act (2007): 6 chapters, 165 sections	Regulations (2011): 6 parts, 232 regulations, 6 schedules
Ch. 1: Ownership, administration, incentives, exploration, mining, quarrying, roads, accidents	Part I: General provisions (compensation, social obligations, disputes, reports, sanctions)
Ch. 2: Small-scale mining	Part II: Mineral title administration (Mining Cadastre Office)
Ch. 3: Possession and purchase of minerals	Part III: Mines operations (Mines Inspectorate)
Ch. 4: Environment and host communities	Part IV: Mine health and safety
Ch. 5: Offences and penalties	Part V: Mines environmental management
Ch. 6: Miscellaneous (transfer, renewal, revocation, closure, interpretation)	Part VI: Artisanal and small-scale mining
	Schedules: 1 Fees; 2 Designation of title areas; 3 Forms; 4 Royalty rates; 5 Inspectorate templates; 6 Environmental templates

2.2 Ownership, scope and access to land

Ownership. Section 1(1) vests “the entire property in and control of all mineral resources in, under or upon any land in Nigeria, its contiguous continental shelf and all rivers, streams and watercourses throughout Nigeria, any area covered by its territorial waters or constituency and the Exclusive Economic Zone” in the Government of the Federation for and on behalf of the people of Nigeria. Property in a mineral passes to the person who lawfully wins it, upon its recovery (s. 1(3)). No person may search for or exploit minerals, or divert water for mining, except under the Act (s. 2).

This makes the Act directly relevant to marine geology: the Regulations confirm that “all areas within the land borders, territorial waters, the continental shelf and in the exclusive economic zone of Nigeria are available areas” for mineral titles, except areas already under title or closed to mining (Regs. 47 and 58). Quarrying, explicitly including **sand dredging** in navigable waterways for industrial use, requires a lease under the Act wherever it takes place, on land or offshore (s. 76).

What counts as a mineral. “Minerals” means any substance in solid, liquid or gaseous form formed by geological processes, including rocks, coal, bituminous shales, tar sands, mineral water, and the mineral content of tailings and waste piles, but **excluding petroleum** and water without mineral content (s. 164). Oil and gas are governed separately, now by the Petroleum Industry Act, 2021.

Excluded land. No mineral title authorises operations on land (s. 3):

- used for military purposes, except with the President’s approval;
- within 50 m of an oil pipeline licence area;
- occupied by a town, village, market, burial ground, or ancestral, sacred or archaeological site, or within 50 m of a railway, public building, reservoir, dam or public road;
- protected as a museum, monument or national park;
- already under a subsisting mineral title;
- designated as closed to mining.

Priority of mining. The use of land for mining has priority over other uses and is an “overriding public interest” under the Land Use Act. When a mining, small-scale mining or quarry lease is granted over land held under a right of occupancy, the State Governor must revoke that right within 60 days (s. 22), subject to compensation.

Boundaries. Every title is bounded by vertical planes extending downwards from its surface boundary to unlimited depth (s. 145; Reg. 108).

2.3 Institutions

The Act creates a set of institutions with separate functions (Figure 2.1):

- **The Minister** responsible for solid minerals (now the Minister of Solid Minerals Development) ensures the orderly and sustainable development of mineral resources, sets policy, monitors Community Development Agreements, makes Regulations, and grants Mining Leases (ss. 4, 21, 65).
- **The Mining Cadastre Office (MCO)**, a body corporate headed by a Director-General, is the **sole agency** for the administration of mineral titles. It receives and decides applications, keeps the cadastral registers and maps, collects fees, and suspends or revokes titles (ss. 5 to 15). The Minister must ensure its independence (s. 15).

- **The Mines Inspectorate Department** supervises exploration and mining operations, enforces health and safety rules, inspects operations, and handles royalty returns and the possession and export of minerals (s. 17).
- **The Mines Environmental Compliance Department** reviews environmental plans, monitors and audits compliance, approves Environmental Protection and Rehabilitation Programmes and Community Development Agreements, and certifies mine closure (s. 18).
- **The Artisanal and Small-scale Mining Department** registers mining co-operatives and provides extension services to small-scale miners (s. 90(3); Regs. 230 and 231).
- **The State Mineral Resources and Environmental Management Committee (MIREMCO)**, one in each State, chaired by a representative of the Mines Environmental Compliance Department and including representatives of State ministries, the local government and the Federal Ministry of Environment. It advises the Minister on compensation, pollution, land degradation and conflicts, meets at least once every three months, and may co-opt representatives of host communities (s. 19; Reg. 163).
- **The Nigerian Geological Survey Agency (NGSA)** receives and archives all geoscientific data, maps, cores and samples acquired by titleholders (s. 43).
- **The Solid Minerals Development Fund**, managed by a Board with the Central Bank of Nigeria as custodian, funds human and physical capacity, geoscientific data, mining institutions, extension services for artisanal miners, and infrastructure (ss. 34 to 42).
- **The Environmental Protection and Rehabilitation Fund**, run by trustees appointed by the Minister, guarantees titleholders' environmental obligations (s. 121).
- **The Federal Ministry of Environment** approves environmental impact assessments, and **the Federal High Court** tries offences and resolves disputes (ss. 119, 141, 142).

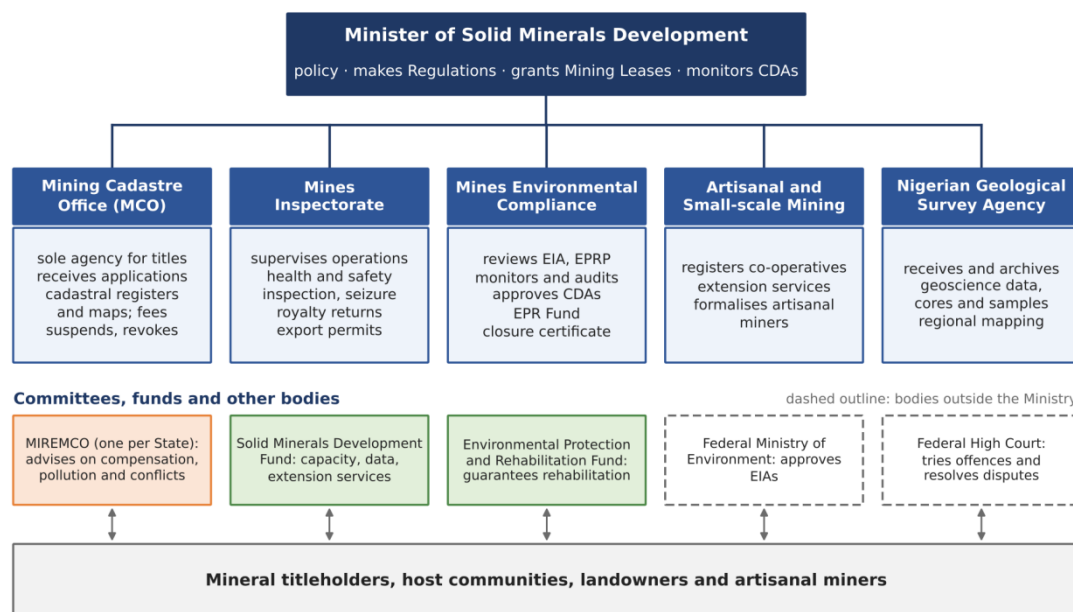


Figure 2.1. The main institutions under the Nigerian Minerals and Mining Act and Regulations, and their responsibilities.

2.4 Mineral titles

The right to search for or exploit minerals can be obtained only through one of six **mineral titles** (s. 46). They form a ladder from the regional search to production (Figure 2.2):

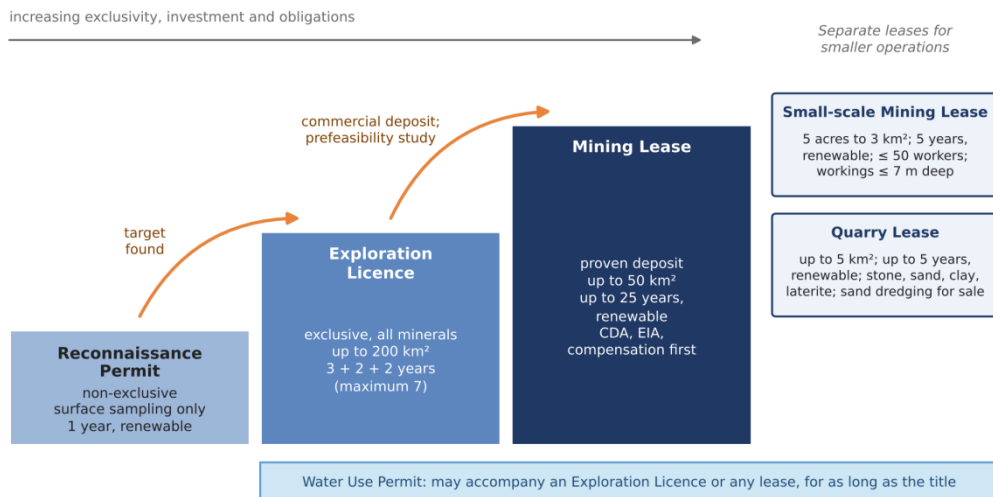


Figure 2.2. The ladder of mineral titles, with their maximum areas and durations. A Water Use Permit may accompany an Exploration Licence or any lease.

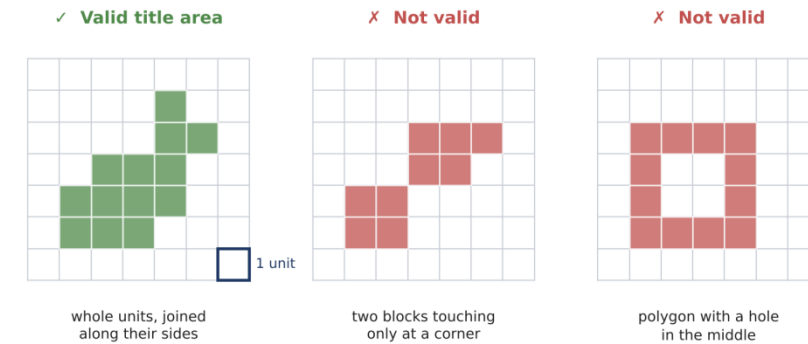
Title	Who may hold it	Maximum area	Duration	Main rights and limits
Reconnaissance Permit	Nigerian citizen, company or mining co-operative (s. 47)	All land available for mining	1 year, renewable yearly without limit (s. 57; Reg. 33)	Non-exclusive search; surface samples only; no drilling or excavation; not transferable (ss. 56, 58)
Exploration Licence	Company, mining co-operative, or Reconnaissance Permit holder for the area (s. 48)	200 km ² (s. 59; Reg. 40)	3 years, renewable twice for 2 years; maximum 7 years (s. 62; Reg. 37)	Exclusive exploration for all minerals; bulk sampling and trial processing; exclusive right to apply for leases in the area (ss. 60, 61)
Small-scale Mining Lease	Citizen, co-operative, company or Exploration Licence holder (s. 49)	5 acres to 3 km ² (s. 90)	5 years, renewable without limit (Reg. 50)	Artisanal and small-scale mining only (Reg. 48)
Mining Lease	Company that has proved a commercial deposit and met its Exploration Licence conditions (s. 50)	50 km ² (s. 67)	Up to 25 years, renewable (s. 66; Reg. 60)	Exclusive mining, processing and sale of the minerals (s. 68)
Quarry Lease	Citizen, co-operative, company, or person extracting construction materials for public works (s. 51)	5 km ² (s. 77)	Up to 5 years, renewable (s. 77; Reg. 71)	Extraction of quarriable minerals such as stone, sand, laterite, limestone, clay (s. 75)
Water Use Permit	Holder of, or applicant for, an Exploration Licence or lease (s. 52)	As needed	As long as the associated title (Reg. 81)	Use of water for mining operations

Some important details:

- **Small-scale mining limits.** A Small-scale Mining Lease may not involve extensive and continued use of explosives or toxic chemicals, more than 50 workers in a typical day, or underground workings more than 7 m deep or galleries more than 10 m from a shaft (Reg. 48).
- **Mining Lease conditions.** An application for a Mining Lease must be made by the Exploration Licence holder during the currency of the licence (Reg. 56), with a prefeasibility study describing the mining scheme, production profile and products (Reg. 57). The Minister must decide within 45 days (s. 65). The holder must begin mine development within 18 months and production within 36 months of meeting the requirements of the Act (s. 70), and must at all times employ a qualified and experienced mining engineer, registered with the Council of Nigerian Mining Engineers and Geoscientists (COMEG), to supervise the operations (s. 73; Reg. 139).
- **Renewal of Mining Leases.** The Act provides that a Mining Lease is for 25 years and “renewable every twenty-four years” (s. 66), while the Regulations allow renewals for further periods of up to 25 years each, with no limit on their number (Reg. 60). Where Regulations appear to differ from the Act, the Act prevails.
- **Competitive bidding.** The Minister may designate areas, such as areas containing “security minerals” (radioactive minerals with at least 0.05% uranium or thorium), in which Exploration Licences and Mining Leases are granted only by open competitive bidding (s. 9; Regs. 4 and 24).
- **Technical and financial capability.** Applicants must show sufficient working capital, by bank statement and reference letter, and must employ COMEG-registered geoscientists or mining engineers, or for small-scale and quarry leases persons with at least a certificate in mining or quarrying (s. 54; Regs. 26 and 27). Titles are refused to applicants with a controlling shareholder convicted of an offence under the Act within the previous five years (s. 53; Reg. 23).

2.5 The cadastre and the application procedure

Cadastral units. For the cadastre, the surface of Nigeria is divided into **cadastral units**, pseudo-squares of 15 seconds of latitude by 15 seconds of longitude, defined on the official 1:50,000 topographic maps on the Minna datum (Regs. 106 and 107). A title area must be a single polygon of whole cadastral units, each sharing at least one side with another, with no holes; polygons touching only at a corner cannot be combined in one title (Schedule 2) (Figure 2.3).



One cadastral unit = $15''$ of latitude $\times$ $15''$ of longitude $\approx 463 \text{ m} \times 461 \text{ m} \approx 21 \text{ ha}$ at 6° N (Minna datum, 1:50,000 maps)

Figure 2.3. Cadastral units and the rules for a valid title area: whole units, contiguous along their sides, in one polygon with no holes.

Worked example: size of a cadastral unit. One second of latitude is about 30.9 m, so 15 seconds is about 463 m. A degree of longitude shrinks with latitude by the factor $\cos\phi$, so at latitude $\phi = 6^\circ \text{ N}$ (near Okerenkoko) 15 seconds of longitude is about $463 \times \cos 6^\circ = 461 \text{ m}$.

$$A_{CU} \approx 0.463 \text{ km} \times 0.461 \text{ km} = 0.213 \text{ km}^2 \approx 21 \text{ hectares}$$

The maximum Exploration Licence of 200 km^2 therefore contains about $200/0.213 \approx 940$ cadastral units, and a 10 km^2 Mining Lease about 47.

The procedure. The steps for exclusive titles are similar (Regs. 32 to 108; Figure 2.4):

1. **Search the cadastral map** to confirm that the area is free. The maps are open to the public (Reg. 107).
2. **Submit the application** in the prescribed form, in triplicate, with the processing fee and documents: certificate of incorporation, attestation of no criminal conviction, evidence of working capital and technical competence, and for a Mining Lease the prefeasibility study.
3. **Completeness check and registration.** An incomplete application is rejected. A complete one is given an identity code and its date, hour and minute are entered in the **Priority Register**; this time stamp decides priority between competing applicants on a **first come, first served** basis (s. 8).
4. **Review.** Any overlap with existing titles or closed areas is excluded and the applicant is asked to amend the area. The MCO may request corrections, normally within 7 days.
5. **Decision.** Reconnaissance Permits and Exploration Licences are decided within 30 days (ss. 55, 59) and Mining Leases within 45 days (s. 65). The applicant is notified and must pay the first annual service fee and collect the title, otherwise the approval lapses.
6. **Publication.** Grants and revocations are published in the Gazette, at the MCO and in a national newspaper within 30 days (Reg. 31).

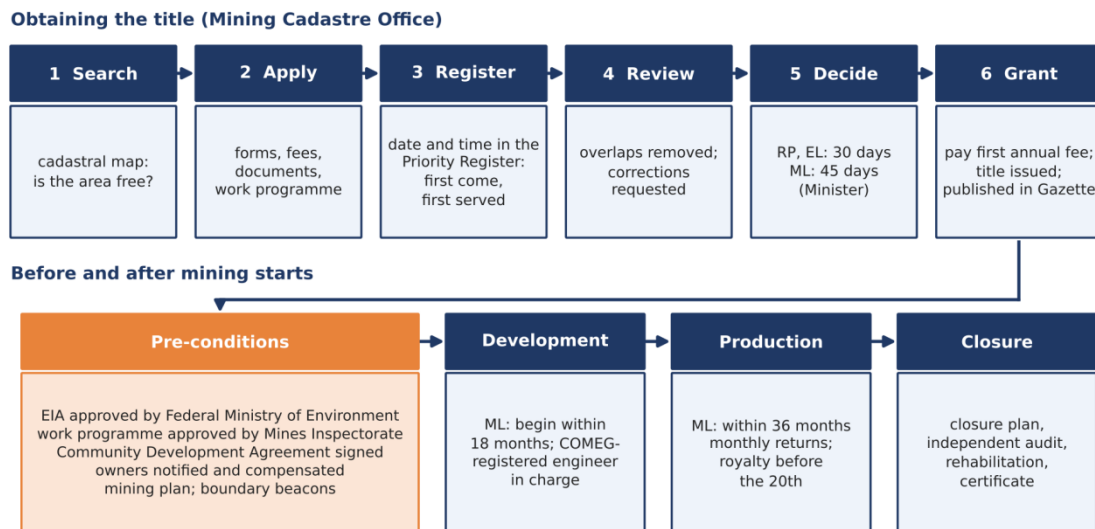


Figure 2.4. From application to production: the main steps and the pre-conditions that must be met before mining operations begin.

Pre-conditions for operations. Holding a lease is not enough to start mining. Before development begins, the holder must (s. 71; Reg. 118):

- submit an Environmental Impact Assessment approved by the Federal Ministry of Environment, with mitigation plans;
- have its work programme approved by the Mines Inspectorate Department;
- conclude a Community Development Agreement approved by the Mines Environmental Compliance Department (not required for an Exploration Licence);
- notify, compensate or offer compensation to land owners and occupiers;
- submit a plan of mining operations, place boundary markers and resolve any boundary disputes.

Operations must then begin within 36 months for a Mining Lease, 12 months for an Exploration Licence, 6 months for a Quarry Lease and 3 months for a Small-scale Mining Lease (Reg. 118).

2.6 The fiscal regime

Incentives. Part III of the Act offers incentives to mining companies:

- a **capital allowance** of 95% of qualifying capital expenditure (exploration, development, processing, feasibility studies and infrastructure) in the year it is incurred, with losses carried forward for up to four years (s. 24);
- exemption from **customs and import duties** on plant, machinery and equipment imported for mining (s. 25);
- expatriate quota and permission to retain part of foreign exchange earnings and to transfer loan repayments and capital abroad (ss. 25 to 27);
- a **tax relief period** of three years from the start of operations, which the Minister may extend by two more years (s. 28);
- a tax-deductible **reserve** for environmental protection, rehabilitation and mine closure (s. 30);
- an annual **capital cost indexation** of 5% for mines that began production within five years of the Act (s. 32).

Royalty. All minerals obtained in exploration or mining are liable to royalty (s. 33). The rates in Schedule 4 of the Regulations are **ad valorem**, a percentage of the value of the mineral: generally **3%** for metallic ores and energy minerals (for example gold, cassiterite, columbite, tantalite, iron ore, lead and zinc, wolframite, ilmenite, rutile, bauxite, coal) and **5%** for industrial minerals, construction materials and gemstones (for example barite, limestone, gypsum, kaolin, granite, stone aggregates, sand, salt, zircon sand and most gemstones). The Minister may waive royalty on scientific samples and, with the approval of the Federal Executive Council, defer it (s. 33). Holders of Mining, Quarry and Small-scale Mining Leases must render **monthly production returns** and pay royalty before the 20th day of the following month (Reg. 123). A royalty rate of 5% was introduced for lithium ore in 2022 and reduced to 3% in 2024.

Fees. The MCO charges application processing fees and an **annual service fee** per cadastral unit (s. 10; Reg. 98). Failure to pay leads to a 30-day default notice and then revocation (s. 12; Reg. 98(5)). The amounts in Schedule 1 of the 2011 Regulations included, for example, processing fees of ₦20,000 for an Exploration Licence and ₦50,000 for a Mining Lease, and annual service fees per cadastral unit of ₦1,000 (years 1 to 3), ₦1,500 (years 4 and 5) and ₦2,000 (years 6 and 7) for an Exploration Licence and ₦25,000 for a Mining Lease. In July 2024 the Ministry of Solid Minerals Development announced substantially higher fees, for example ₦3,000,000 to apply for a Mining Lease and ₦600,000 for an Exploration Licence of up to 100 cadastral units. Always check the current schedule with the MCO.

Worked example: fees and royalty. (a) Using the 2011 Schedule, a company holds an Exploration Licence of 150 km². At latitude 6° N this is about $150/0.213 = 704$ cadastral units, so its annual service fee is:

$$\text{Years 1 to 3: } 704 \times \text{₦1,000} = \text{₦704,000 per year}$$

$$\text{Years 4 and 5: } 704 \times \text{₦1,500} = \text{₦1,056,000 per year}$$

(b) A quarry sells 20,000 tonnes of stone aggregate in March at ₦15,000 per tonne. The royalty rate for stone aggregates is 5%:

$$\text{Royalty} = 0.05 \times (20\,000 \times \text{₦15,000}) = 0.05 \times \text{₦300,000,000} = \text{₦15,000,000}$$

It must be declared and paid before 20 April.

The Solid Minerals Development Fund. The Fund is financed by appropriations, grants, donations and loans, and is used for capacity building, geoscientific data, equipping mining institutions, extension services to artisanal miners, and infrastructure in mining areas (ss. 34 and 38). Its Board comprises a chairman appointed by the President, representatives of the Central Bank and the Bankers' Committee, three representatives of private mining operators and processors, and a secretary (s. 35).

2.7 Environmental obligations and mine closure

General duties. Every titleholder must have regard to the effect of its operations on the environment and prevent pollution (s. 111), and must, as far as reasonably practicable, minimise, manage and mitigate environmental impacts and rehabilitate and reclaim disturbed land to its natural or a predetermined state (s. 118).

Environmental Impact Assessment. Holders of Exploration Licences, Small-scale Mining Leases, Mining Leases, Quarry Leases and Water Use Permits must submit to the Mines Environmental Compliance Department an environmental impact assessment approved by the Federal Ministry of Environment before operations start, and again when applying to extend or convert a title (s. 119). The Regulations clarify the scope (Regs. 157 to 160):

- exploration involving **trenching, pitting and drilling** requires a detailed EIA;
- preliminary exploration by satellite and airborne data, geological mapping, and ground geophysical and geochemical surveys does **not** require an EIA;
- an EIA report must describe the project, its justification and regulatory framework, the baseline environment (climate, soils, hydrology, hydrogeology, ecology and socio-economic conditions), the predicted impacts, mitigation, monitoring, closure and decommissioning, and must be prepared by qualified multidisciplinary specialists under the Environmental Impact Assessment Act.

Environmental Protection and Rehabilitation Programme (EPRP). Each titleholder must also submit an EPRP setting out specific rehabilitation actions, inspections and reports, the estimated total cost of rehabilitation and of each action, and a timetable for restoring the title area to a safe condition suitable for future use (s. 120; Reg. 180). The Mines Environmental Compliance Department must decide within 60 days, failing which the programme is deemed approved; a holder whose programme is rejected twice may go to arbitration (s. 120).

Environmental Protection and Rehabilitation Fund. To guarantee that rehabilitation is paid for, holders contribute to a fund managed by independent trustees, beginning within one year of approval of the EPRP (s. 121). Contributions depend on the scale of the operation's impact, are paid over five years, and the Regulations provide that 5% of the total project cost is set aside for the purpose (Regs. 184 and 185). Any surplus is refunded once an independent audit certifies that rehabilitation is complete (s. 121(11)). Failure to pay leads to a demand notice, court action and suspension of the lease (s. 122).

Water and waste. No person may pollute any watercourse within or beyond a lease area (s. 123); water used in mining must leave the area free of injurious substances (s. 124); tailings may be deposited in natural watercourses only within prescribed limits or under a permit (s. 126; Regs. 124 and 125); water supplies and river banks may not be altered without permission and must be restored (ss. 127 and 128). The Regulations also contain detailed rules on the classification, construction, drainage, monitoring and closure of waste dumps, on acid mine drainage, heap leaching, hazardous liquids, air and water quality monitoring, and on the special precautions required for radioactive minerals (Regs. 164 to 224).

Mine closure. A holder intending to abandon or permanently stop production must give three months' notice with a report and plans; on closure it must seal, fence or cover every shaft and adit, make tailings and water storage areas safe, and demolish or secure hazardous buildings and plant (s. 159). The Regulations require that a **closure plan** be developed at the feasibility stage and updated during the life of the mine, with a defined post-closure land use, risk analysis for disasters such as floods, and a schedule of closure activities; an application to close must include an independent environmental audit, and the Mines Environmental Compliance Department issues a **closure certificate** (Reg. 225). Records of closed mines, and approved EIAs, are open to the public (Regs. 226 and 227). Obligations, including environmental obligations, survive the transfer, surrender or revocation of a title (ss. 147, 150, 155, 157).

2.8 Host communities, land and compensation

Community Development Agreement (CDA). Before development begins, the holder of a Mining Lease, Small-scale Mining Lease or Quarry Lease must conclude a CDA with the host community to ensure the transfer of social and economic benefits (s. 116). It may cover:

- scholarships, apprenticeships, technical training and employment for indigenes;

- support for infrastructure and services such as education, health, roads, water and power;
- support for small and micro enterprises;
- agricultural product marketing;
- environmental and socio-economic management and local governance.

The CDA must set out how the community will participate in planning, implementing and monitoring it (s. 117), and is reviewed every five years (s. 116(5)). Under the Regulations (Reg. 193), the host community is the community where the title area is located or the one closest to it; the community chooses 3 to 7 representatives, verified by the Ministry with the MIREMCO and the local government chairman; the CDA is signed by the holder and those representatives and approved by the Minister; disagreements are referred to the Minister; and the holder submits a Community Development Action Plan and reports on progress every six months (Reg. 18). The Regulations also require holders to identify recognised community leaders, consult the community before operations begin, explain the benefits and the measures to prevent pollution, and promote peaceful relations (Reg. 13).

Compensation. Titleholders must pay reasonable compensation to owners and occupiers for disturbance of surface rights, damage to land, and loss of crops, economic trees, buildings and works, on the basis of a valuation by a Government licensed valuer (ss. 107 and 113). Compensation is determined by the MCO after consultation with the MIREMCO (s. 108). Owners and occupiers must be involved in the assessment; compensation for damage to land is based on the reduction in its market value; owners are compensated for their ownership and developments, and occupiers for their developments and use of the land (Regs. 11 and 12). If compensation is not paid within six months of the grant, the title may be suspended and then revoked (s. 109). Anyone who suffers loss may refer the matter to the Federal High Court (s. 113(4)).

Surface rent and other rights. Mining lessees pay an annual **surface rent** to the owner or occupier, at a rate proposed by the owner and approved by the Minister, or fixed by the Minister, and revised every five years (s. 102; Reg. 100). Owners and occupiers must be notified of applications (s. 100), may continue to graze livestock and farm where this does not interfere with mining (s. 72), and no operations may damage sacred areas or objects of veneration (s. 98). Communities may continue to win salt, soda, potash and galena where this has been their custom (s. 97), and local people may extract sand, clay, laterite and stone for their own use without explosives (s. 99).

2.9 Inspection, health and safety, and trade in minerals

Inspection and enforcement. Officers of the Mines Inspectorate may enter any title area to inspect operations (s. 20), may arrest without warrant anyone committing an offence and seize tools, vehicles and illegally won minerals (s. 146), and may order operations to be suspended where there is danger to life or property (s. 146(4)). Titleholders must keep correct plans and records, submit half-yearly reports on their operations and expenditure, report any new mineral discovered, and lodge all geoscientific data, cores and samples with the NGSA (s. 43; Reg. 18). Cores may not be destroyed without the Minister's permission, and submitted data remain confidential for up to five years (s. 43).

Accidents. Accidents causing death or serious injury must be reported at once to the police or the Mines Inspectorate, and the site left undisturbed (s. 84). The Minister sets up a panel of at

least four members to inquire into the cause, including any negligence and how future accidents can be prevented (ss. 85 to 87; Reg. 14).

Health and safety. Part IV of the Regulations sets out detailed rules for surface and underground workings, ventilation, lifting and winding equipment, haulage, machinery, electricity, protective equipment, mine fires, first aid, occupational health services and the recording of accidents and diseases (Regs. 140 to 153).

Possession, purchase and export. No person may possess minerals unless they were won from that person's title area or the person holds a permit, or is an authorised agent (s. 93), and no person may buy minerals without a licence (s. 94). The products of small-scale mining must be sold to licensed **mineral buying centres**, which keep records of the mines from which minerals came (ss. 95 and 96; Reg. 232). Commercial exports require a permit from the Mines Inspectorate, supported by evidence of the source of supply and of royalty payment (Reg. 131); samples for analysis need a separate permit (Reg. 132). Customs officers must seize minerals presented for export without a permit and hand them to the Mines Inspectorate within 72 hours (Reg. 132(3) and (4)). Exporters must declare the State from which a mineral was extracted (s. 143).

Radioactive minerals. Any discovery of a radioactive mineral must be reported immediately; the Nuclear Safety and Radiation Protection Act applies, and a titleholder has no right to mine "security minerals" discovered in its area (ss. 44 and 64(4)).

2.10 Artisanal and small-scale mining

A large share of Nigeria's mineral production, including gold, gemstones, tin, columbite and construction minerals, comes from **artisanal** (non-mechanised) and **small-scale** miners. The Act aims to bring them into the formal system by:

- defining artisanal and small-scale mining and providing a dedicated Small-scale Mining Lease (ss. 49, 90, 164);
- encouraging **mining co-operatives**, which may hold most titles; a co-operative wishing to register with the Artisanal and Small-scale Mining Department must have at least 10 trustees and officers (Reg. 230);
- providing **extension services** to registered co-operatives: geological assessment of their deposits, mineral testing and grading, reserve evaluation and feasibility reports, mine design, training, equipment hire, processing technology, environmental guidance, and health and safety (s. 91; Reg. 231);
- giving access to the Solid Minerals Development Fund (s. 34(2)(d));
- requiring small-scale lessees to rehabilitate mined-out areas (s. 90(2)).

The importance of formalisation was shown tragically in Zamfara State in 2010, when lead poisoning from the processing of lead-rich gold ore by artisanal miners killed several hundred children. Illegal mining, the use of mercury and cyanide, and smuggling remain major challenges for enforcement.

2.11 Managing a mineral title

Action	Main provisions
Transfer and assignment	Approval by the Minister and registration with the MCO; deemed approved if the MCO does not act within 30 days; no approval needed for assignment to a guaranteed affiliate; the transferor remains liable for earlier obligations (s. 147; Reg. 91)

Action	Main provisions
Renewal	Application before expiry (for example 3 months for an Exploration Licence, 12 months for a Mining Lease); the title remains in force until the decision; late filing fee (s. 148; Regs. 38, 61)
Suspension	Up to 60 days, after 30 days' notice, for non-payment, breach of conditions or false statements (s. 149)
Surrender and relinquishment	Whole or part of the area may be given up; fees are reduced in proportion, but earlier liabilities remain (ss. 150, 157)
Consolidation	Contiguous titles may be combined into one (s. 158)
Additional minerals	Discovery of a mineral not in the title must be reported within 30 days with a programme for its exploitation (s. 64)
Revocation	On conviction, breach of the Act or conditions, failure to show cause, insolvency, no progress, or discontinued operations for six months; after 30 days' notice; obligations continue after revocation (ss. 151, 155)

2.12 Offences, sanctions and disputes

Offences. It is an offence to explore, mine or quarry other than under the Act, to make false or misleading statements in applications or reports, or to remove, possess or dispose of minerals contrary to the Act (s. 131). A titleholder convicted of such an offence is liable to revocation of its title, a fine of not less than ₦20 million and imprisonment of not less than five years, with a further ₦20,000 for each day a continuing offence lasts (s. 133). Other offences include **salting** (planting or adding minerals to mislead investors or buyers) (s. 134), using false scales or assay weights (s. 135), falsely claiming to hold a title in order to attract investment (s. 136), interfering with beacons (s. 137) and obstructing lawful operations (s. 138). Directors and officers of companies may be personally liable (ss. 139 and 140). Offences are tried by the Federal High Court (s. 142).

Administrative sanctions. For breaches that are not criminal, inspectors may impose penalties under the Regulations (Reg. 20). For example:

- unlicensed exploration, mining or sale: confiscation of all income or products and a fine of twice the value of the minerals;
- failure to submit a minimum work programme before operations: ₦100,000 to ₦500,000;
- continuing environmental or safety violations: suspension for up to 60 days, then termination or closure of the mine;
- deliberate under-reporting of production or sales to reduce royalty: a fine of ₦100,000 to ₦250,000, plus the unpaid royalty and a penalty equal to it;
- contravention of the environmental provisions: on conviction, a fine of up to ₦20 million or imprisonment of up to five years, or both.

Disputes. Disputes between a titleholder and the Government are to be settled amicably first; genuine investment disputes are then resolved under the Nigerian Investment Promotion Commission Act, which allows international arbitration, and other disputes go to the Federal High Court (s. 141). Disputes between titleholders, applicants and third parties, for example over boundaries or compensation, may be referred to a committee set up by the Minister (Regs.

15 and 16). A person aggrieved by a decision of the Ministry or its agencies may appeal to the Minister within seven days, and then to the Federal High Court (Reg. 17).

2.13 Applying the law to coastal and offshore minerals

For the marine geologist, the most important features of the law are:

- **Offshore scope.** The Act and Regulations apply to minerals in Nigeria's rivers, territorial waters, continental shelf and EEZ (s. 1; Regs. 47 and 58), so the same titles, cadastre, royalties and environmental rules govern offshore and coastal minerals as land minerals.
- **Sand and gravel dredging.** Dredging of sand from rivers, creeks and the sea for sale or industrial use is a quarrying operation requiring a Quarry Lease (s. 76), whereas dredging only to improve navigation, without sale, is excluded. The large-scale sand dredging around Lagos, Warri and other Niger Delta cities therefore falls under this law, as well as under the laws on inland waterways and the environment.
- **Heavy mineral sands.** Beach and offshore placers of ilmenite, rutile and zircon are minerals under the Act, with royalties of 3% (ilmenite and rutile) and 5% (zircon sand) (Schedule 4).
- **Gaps.** The law was written mainly for mining on land. It says little about the specific environmental risks of seabed mining, such as sediment plumes and impacts on fisheries, or about coordination with maritime and petroleum regulators. Any future offshore mining project would need careful environmental assessment and cooperation between the Ministry of Solid Minerals Development, the environmental and maritime authorities, and the petroleum regulators whose licences cover much of the continental shelf.
- **Comparison with the ISA regime.** Seabed minerals beyond Nigeria's continental shelf fall under the ISA, whose exploration contracts and relinquishment rules (Section 1.10) are similar in principle to Nigeria's exploration licences but on a much larger scale.

2.14 Key points of Section 2

- All minerals in Nigeria, including those in its territorial waters, continental shelf and EEZ, are vested in the Federal Government; petroleum is excluded and governed separately.
- The Mining Cadastre Office is the sole agency for mineral titles, granted on a first-come-first-served basis on a grid of cadastral units of about 0.21 km²; the Mines Inspectorate and Mines Environmental Compliance Departments supervise operations.
- Six titles are available: Reconnaissance Permit, Exploration Licence (200 km², up to 7 years), Small-scale Mining Lease (up to 3 km²), Mining Lease (50 km², up to 25 years), Quarry Lease (5 km²) and Water Use Permit.
- Mining may begin only after an approved EIA, work programme, Community Development Agreement and compensation; an Environmental Protection and Rehabilitation Programme and Fund guarantee rehabilitation and closure.
- Royalties are ad valorem, generally 3% for metals and energy minerals and 5% for industrial minerals and gemstones; fees are charged per cadastral unit and have been revised since 2011.
- Offences, including illegal mining and salting, carry heavy penalties; disputes go to amicable settlement, arbitration under the NIPC Act, or the Federal High Court.

Summary, review questions and glossary

Summary

Topic	Main ideas
Seafloor sulphides: settings and formation	Discovered from the 1960s; found at mid-ocean ridges, back-arc basins and volcanic arcs; seawater convection through hot crust; black smoker chimneys, mounds, stockworks; zone refining
Mineralogy and resources	Pyrite, chalcopyrite, sphalerite, sulphates and silica; metals vary with setting; most deposits small; about 600 Mt in neovolcanic zones
Exploration, mining and environment	Plume detection, AUV mapping, ROV sampling and drilling; Solwara 1 mining system and its failure; vent ecosystems and mining impacts
Law of the Sea	Territorial sea, EEZ, continental shelf and the Area; ISA exploration contracts for sulphides; exploitation regulations not yet adopted
Nigerian mining law: framework and titles	Federal ownership of minerals onshore and offshore; MCO, Inspectorate and Environmental Compliance; six mineral titles; cadastral units; first come, first served
Nigerian mining law: obligations and enforcement	Incentives, royalties and fees; EIA, EPRP and Rehabilitation Fund; Community Development Agreements and compensation; safety; artisanal mining; offences and disputes; sand dredging and offshore minerals

Summary of key equations

Quantity	Equation	Section
Contained metal	$M = T \times g$	1.5
Precious metal (grade in g/t)	$M_{\text{Au}} (\text{g}) = T (\text{t}) \times g (\text{g/t}); 1 \text{ troy oz} = 31.1 \text{ g}$	1.5
Gross in-situ value	$V = \sum_i T g_i P_i$	1.5
Side lengths of a cadastral unit	$a \approx 463 \text{ m (north-south)}, b \approx 463 \cos \varphi \text{ m (east-west)}$	2.5
Number of cadastral units	$N = A/A_{\text{CU}}$ (rounded down to whole units)	2.5
Annual service fee	$F = N \times r$	2.6
Ad valorem royalty	$R = \rho \times Q \times P$	2.6

Here T is tonnage, g grade, P price, A title area, r fee per cadastral unit, ρ royalty rate, Q quantity sold and φ latitude.

Review questions

Part A: Short answers

- Describe the discoveries at the Atlantis II Deep, the Galápagos Rift and the East Pacific Rise at 21° N, and explain their importance.
- Name the four main tectonic settings of seafloor sulphides and give one example of each.

3. Draw and label a diagram of a hydrothermal convection system beneath a mid-ocean ridge.
4. Explain why anhydrite precipitates when seawater is heated, and its role in the growth of chimneys.
5. Describe the internal structure of a mature sulphide mound such as TAG. What is zone refining?
6. How do the metal contents of seafloor sulphides at mid-ocean ridges differ from those in back-arc basins and volcanic arcs? Explain why.
7. Compare seafloor massive sulphides with volcanogenic massive sulphide deposits on land.
8. Why are inactive sulphide deposits more attractive for mining but harder to find than active ones?
9. Describe the three parts of the mining system planned for Solwara 1.
10. List four potential environmental impacts of mining seafloor sulphides and suggest how each could be reduced.
11. Define the territorial sea, the EEZ, the continental shelf and the Area, and state who controls the minerals in each.
12. Who owns the minerals in Nigeria, including those offshore? What minerals are excluded from the Act?
13. Describe the functions of the Mining Cadastre Office, the Mines Inspectorate Department and the Mines Environmental Compliance Department.
14. List the six mineral titles and give the maximum area and duration of each.
15. What must a Mining Lease holder do before starting mine development?
16. What is a Community Development Agreement, and what may it contain?
17. Explain the purpose of the Environmental Protection and Rehabilitation Programme and Fund.
18. What is salting, and how is it punished under the Act?

Part B: Calculations

19. A seafloor deposit contains 2.5 million tonnes of sulphide grading 3.2% Cu, 11% Zn, 6 g/t Au and 120 g/t Ag. Calculate the contained mass of each metal, and the gold in troy ounces.
20. Assuming prices of US\$9,000 per tonne of copper, US\$2,800 per tonne of zinc and US\$2,000 per troy ounce of gold, calculate the gross in-situ value of the copper, zinc and gold in question 19. Why is this value much larger than the value a mining company could actually earn?
21. The Solwara 1 indicated resource contains about 74,200 t of copper. World mine production of copper is about 23 million tonnes per year. What percentage of one year's production does it represent? Comment on the result.
22. An ISA contractor holds 100 blocks of 100 km² for polymetallic sulphides. What is the maximum area it may keep after 8 years and after 10 years?
23. Calculate the area of a cadastral unit at latitude 4.5° N, near the coast of the Niger Delta. How many whole cadastral units can be included in a Quarry Lease of the maximum area?

24. An Exploration Licence of 940 cadastral units is held for its full 7 years. Using the 2011 annual service fees (₦1,000, ₦1,500 and ₦2,000 per unit for years 1 to 3, 4 and 5, and 6 and 7), calculate the total fees.
25. A sand dredging company with a Quarry Lease sells 150,000 m³ of sand in June at ₦4,000 per m³. Calculate the royalty at 5% and state when it must be paid.

Part C: Essays

26. "Seafloor massive sulphides are a real but modest resource." Discuss this statement with reference to the size, grade and distribution of known deposits.
27. Describe the methods used to explore for seafloor sulphide deposits, from the regional to the deposit scale.
28. Discuss the arguments for and against a moratorium on deep-sea mining.
29. Trace the steps by which a company obtains a Mining Lease under the Nigerian Minerals and Mining Act and Regulations, from the first application to the start of production.
30. Assess how well the Nigerian Minerals and Mining Act and Regulations would regulate a proposed project to dredge heavy mineral sands from the continental shelf off the Niger Delta.

Glossary

Term	Meaning
Ad valorem royalty	A royalty charged as a percentage of the value of the mineral
Anhydrite	Calcium sulphate (CaSO ₄), precipitated when seawater is heated above about 150 °C
Area, the	The seabed and subsoil beyond the limits of national jurisdiction, administered by the ISA
Back-arc basin	A basin formed by spreading behind a volcanic arc above a subduction zone
Black smoker	A chimney venting fluid at 350–400 °C, blackened by fine sulphide particles
Cadastral unit	The basic unit of a title area in Nigeria: 15" of latitude by 15" of longitude, about 21 ha
Chemosynthesis	Production of organic matter by bacteria using chemical energy, such as from H ₂ S, instead of light
Common heritage of mankind	The principle that the resources of the Area belong to all humanity
Community Development Agreement	An agreement between a leaseholder and the host community on social and economic benefits
Contained metal	The mass of metal in a deposit: tonnage multiplied by grade
EEZ	Exclusive Economic Zone, up to 200 nautical miles from the baseline
Hydrothermal plume	A cloud of particles and dissolved chemicals spreading from a vent in the water column
Mineral title	A Reconnaissance Permit, Exploration Licence, Small-scale Mining Lease, Mining Lease, Quarry Lease or Water Use Permit
Neovolcanic zone	The narrow axial zone of a spreading centre where new crust is formed

Term	Meaning
Priority Register	The MCO register that records the time of receipt of applications
Riser	The vertical pipe through which ore slurry is lifted to the surface
Salting	Adding minerals to a sample or deposit to mislead investors or buyers
Security minerals	Radioactive minerals with at least 0.05% uranium or thorium
Stockwork	A network of sulphide veins in altered rock beneath a massive sulphide deposit
Surface rent	An annual payment by a lessee to the owner or occupier of the land
VMS deposit	Volcanogenic massive sulphide deposit, the ancient equivalent of seafloor sulphides
Zone refining	Remobilisation of metals within a mound by hot fluids, concentrating Cu in the core and Zn, Au and Ag at the margins

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