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This practical guide is intended for actors in the artisanal mining sector in Southern African Region to enable them to acquire a better knowledge of this sector in the region, as well as good practices at the environmental, health and social levels.

This guide covers 11 English-speaking countries (RSA, Eswatini, Lesotho, Botswana, Zimbabwe, Namibia, Nigeria, Ghana, Sierra Leone, Liberia, and Gambia) and 5 Portuguese speaking countries (Angola, Mozambique, Cabo Verde, Guinea-Bissau, and SaoTome & Principe).

Produced by industry players from each of these countries and experts in the field, this guide covers the following points:

- Regional geological context
- Legislative framework for artisanal mining
- Role of a National Geological Survey
- Organize and develop an artisanal mining site
- Role of women in artisanal mining in West Africa
- Socio-economic, environmental, health and safety issues
- Impacts linked to the use of mercury
- Statements of facts and recommendations for countries in the region

For further information on PanAfGeo please consult https://panafgeo.eurogeosurveys.org

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Artisanal and Small-Scale Mining Handbook for Southern African Region

PanAfGeo

Pan-African Support to Geological Sciences and Technology Africa-EU Partnership

Artisanal and Small-Scale Mining Handbook for Southern African Region

A practical guide

Artisanal and Small-Scale Mining Handbook for Southern African Region

A practical guide

The Pan-African Support to the EuroGeoSurveys-Organisation of Geological Surveys of Africa Partnership, abbreviated as PanAfGeo-2, is a project aimed at training the geoscientific cadres of the Geological Surveys of Africa through the development of an innovative program. This specific training programme, led by geoscience experts from Africa and Europe, includes the acquisition of new knowledge in order to improve the technical level of the trained staff.

The PanAfGeo-2 Project allows trainees to acquire state-of-the-art knowledge and methods and/or participate in study tours in a number of geoscience fields.

This handbook on ”Artisanal and Small-Scale Mining (ASM) in the Southern African Region” is the result of a training session which took place in Maputo, Mozambique from 26 to 30 September 2022, as part of PanAfGeo-2 Work Package C (WP-C) on ASM with participants from 16 countries in Southern African Region.

The PanAfGeo-2 project is co-financed by the European Union (EU) via its Directorate-General for International Cooperation and Development (DG-DEVCO) though the Grant Contract n° DCI/PANAF/2021/423-739.

WP-C is co-financed by the EU via DG-DEVCO, the Geological Survey of Denmark and Greenland (GEUS), Head of WP-C, the Geological Survey of the Portugal (LNEG), and the National Directorate of Geology and Mines, Ministry of Mineral Resources and Energy in Mozambique (DNGM).

GEUS and LNEG, acting as co-editors of this handbook, are solely responsible for the results and conclusions presented, which do not necessarily reflect the position of DG-DEVCO. Nevertheless, each of the authors is individually responsible for the scientific content of his/her chapter.

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All trainees have signed a ”right to image” agreement thus allowing the PanAfGeo-2 Project to use photographs and videos taken during the training session on the PanAfGeo-2 website.

The PanAfGeo Project has been co-funded by the European Union (EU) under Grant Agreement No. DCI/PANAF/2021/423-739.

Editors:	Dr John Tychsen, ASSM Consult ApS/GEUS; Dr Maria João Batista, LNEG; and Dr Jorge Cavalho, LNEG
Text Editor:	Ms. Julie Sophie Hübertz, Freelance/Depict & Deploy
Portuguese and English Translations:	Mr. Nelson Nhamutole, Freelance.
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CONTENT

ABBREVIATIONS

AFDL	Alliance of Democratic Forces for the Liberation of Congo
AI	Artificial Intelligence
AMD	Acid Mine Drainage
AMDC	Africa Minerals Development Centre
AMV	Africa Mining Vision
ASGM	Artisanal and Small-Scale Gold Mining
ASM	Artisanal and Small-Scale Mining
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AU	African Union
BGI	Botswana Geoscience Institute
BGRM	French Geological Survey
CAHRA	Conflict-Affected and High-Risk Areas
CNDP	National Congress for the Defence of the People
CNN	Convolutional Neural Network
DDR	Disarmament, Demobilisation and Reintegration
DG INTPA	Directorate-General for International Partnerships
DG-DEVCO	Directorate-General for International Cooperation and Development
DN	Digital Numbers
DNGM	National Directorate of Geology and Mines, Ministry of Mineral Resources and Energy in Mozambique
DoM	Department of Mines
DRC	Democratic Republic of the Congo
ECC	Environmental Clearance Certificate
EGD	Economic Geology Division
EGS	European Geological Surveys
EHS	Environmental, Health and Safety
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EITI	Extractive Industries Transparency Initiative
EMP	Environmental Management Plan
EMR	Electromagnetic Radiation
EMS	Electromagnetic Spectrum
EPRM	European Partnership for Responsible Minerals
EU	European Union
FARDC	Congolese National Army
FDLR	Forces Démocratiques de Libération du Rwanda
GDP	Gross Domestic Product
GEUS	Geological Survey of Denmark and Greenland
GGSA	Ghana Geological Survey Authority
GIS	Geological Information Systems
GSN	Geological Survey of Namibia
ha	Hectares
ICGLR	International Conference of the Great Lakes Region
IGF	Intergovernmental Forum on Mining Minerals Metals and Sustainable Development

IK	Indigenous Knowledge
INCHR	Independent National Commission on Human Rights
INE	National Institute for Statistic
IPIS	International Peace Information Service
ITD	Intermediate Technology Development
ITRI	International Tin Association
ITSCI	ITRI Tin Supply Chain Initiative
LNEG	Geological Survey of Portugal
Ma	Million Years
MARC	Minerals Ancillary Rights Commission
MC	Mining Claims
MEFT	Ministry of Environment, Forestry, and Tourism
MES	Mining Extension Services
MIREME	Ministry of Mineral Resources and Energy, Mozambique
ML	Machine Learning
MME	Ministry of Mines and Energy
MPRDA	Mineral and Petroleum Resources Development Act
NAP	National Action Plans
NDVI	Normalised Difference Vegetation Index
NEPL	Non-Exclusive Prospecting Licenses
NGO	Non-Governmental Organisation
NGSA	Nigerian Geological Survey Agency
OAGS	Organisation of Geological Services of Africa
OAU	Organisation of African Unity
OECD	Organisation for Economic Cooperation and Development
PanAfGeo-2	Pan-African Support to the EuroGeoSurveys-Organisation of African Geological Surveys Partnership, Phase 2
PCA	Principal Component Analysis
PPE	Personal Protective Equipment
PRA	Participatory Rural Appraisal
RCM	Regional Certification Mechanism
RINR	Regional Initiative Against the Illegal Exploitation of Natural Resources
SADC	Southern African Development Community
SSM	Small-Scale Mining
SSMD	Small-Scale Mining Division
SSMs	Small-Scale Miners
UN	United Nations
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organisation
USD	United States Dollars
WP	Work Packages
WP-C	Work Package C
ZEAs	Artisanal Exploitation Zones

FOREWORDS

Instituto Nacional de Minas, Moçambique

By Dr Elias Xavier Félix Daudi

Mozambique is a board member of the African Union (AU) and participates in all its activities and related organisations. In 2009, Heads of State and Government of the AU adopted the Africa Mining Vision (AMV) to achieve key mineral resource development goals.

Mozambique is also a member of the OAGS and, in this regard, participates in the activities that this organisation promotes, including cooperation with other international geo-scientific organisations. As a result of the geo-scientific cooperation between OAGS and the EGS, in August 2019 the DNGM hosted a seminar in the Tete Province, Mozambique, where technicians from African Portuguese-speaking countries participated in training on environmental management. This training aimed at building capacity in the Geological Surveys of the African continent in matters related to the assessment and management of mineral resources, use and sustainable land development, mitigation of natural risks and environmental protection. This training was co-financed by DG-DEVCO and by a consortium comprising 12 European Geological Surveys. Furthermore, a seminar on ASM in the Southern African Region was held in September 2022 in Maputo, Mozambique under the auspices of the PanAfGeo-2 Project, which is co-organised between DNGM and GEUS, thus representing the continuation of the capacity building activities of the Geological Surveys of Africa.

ASM in Mozambique has potential and relevance for socio-economic development; however, this activity is mostly characterised by high levels of informality and illegality thus resulting in poor knowledge of the real contribution that can be obtained from this activity, in addition to intensive, seasonal work, migration, environmental, social, safety and health degradation. Nonetheless, taking into consideration the challenges of this mining activity, the Government, through Ministry of Mineral Resources and Energy, Mozambique (MIREME)/DNGM, is implementing the Strategy for the Development of Artisanal Mining, approved in 2017, through the creation of mining cooperatives and mining extension services with the objectives to: (i) establish organisational and operational models appropriate for artisanal mining activities; (ii) organise and formalise illegal artisanal operators into associations or cooperatives; (iii) train and strengthen mining associations and cooperatives; (iv) assist technically and scientifically the artisanal miners in mining processes to ensure added value to their products; (v) assist miners in the economic evaluation of mineral products; and (vi) register and control production. Apart from that, the Government of the

Republic of Mozambique, through MIREME and the National Institute for Statistics (INE), in order to support the program for formalisation of mining cooperatives to artisanal mining operators, has carried out for the first time a census of artisanal miners. This census is aimed at providing valuable data and statistical information, which will allow a better and realistic definition of policies and strategies for the support and management of ASM in Mozambique. As a result of these efforts, in 2020, around 1,044 ASM hotspots, legal and illegal, were mapped at the national level against the registered around 100 designated and current areas and 81 mining associations.

All in all, this seminar on ASM in the Southern African Region will greatly contribute to empower participants from different countries with proper skills in regard to ASM and they will later on apply sustainable mining methods in their respective countries.

In addition, this handbook, which is an outcome of the training session, will serve as a guideline for the management of this complex mining activity.

We would therefore like to thank everyone who directly or indirectly contributed in the organisation and success of this seminar.

Dr Elias Xavier Félix Daudi
Instituto Nacional de Minas, Moçambique

EU Delegation to Mozambique

By H.E. Ambassador Antonino Maggiore. Head of the EU Delegation to Mozambique

A quarter of global Gross Domestic Product (GDP) and half the World's population depend in one or the other way on the extractives sector. Africa alone is home to about 30% of the World's mineral reserves and much more is still to be discovered. The challenge for the African continent, like others before, is to ensure that this richness turns into a clean, sustainable industry, which generates economic growth, job creation and results in poverty reduction.

The EU is committed to supporting sustainable development of extractive activities in developing countries worldwide and is a strong advocate of the Extractive Industries Transparency Initiative (EITI) promoting governance and accountability through revenue transparency along mineral, oil and gas value chains. Making these industries profitable is usually the fruit of a long process, where high research and start-up costs are being weighed against potential benefits. Legal angles and questions of sustainability will have to be addressed by government, stakeholders, shareholders and companies involving civil society in a transparent way to ensure that benefits generate true wealth, and not only short-term benefits.

It is also of utmost importance to increase the proportion of responsibly produced minerals from conflict-affected and high-risk areas and to support socially responsible extraction of minerals that contributes to local development. Therefore, the European Commission established the European Partnership for Responsible Minerals (EPRM) together with a selected group of European donors, governments, private companies and Non-Governmental Organisations (NGOs) all willing to materialise real change on the extraction field.

ASM operations continue to grow across sub-Saharan Africa and serve as a source of livelihood to many rural communities. Mozambique is no exception and boasts one of the most dynamic ASM economies in the Southern African Development Community (SADC). The rising value of mineral prices and the increasing difficulty of earning a living from agriculture and other rural activities play a role in explaining the growing interest of this industry. Indeed, there are approximately 100 million artisanal miners globally, of which an estimated 30% are women. The sector represents an important livelihood and income source for poverty affected and under-privileged local populations. It is due to this socio-economic importance for the poor that the ASM subsector is attracting increasing attention from governments, civil society, and development partners.

It is therefore of utmost importance to strengthen the capacities of institutions who are mandated to regulate ASM activities. We need to keep working together to identify the right ingredients of a sustainable strategy for formalising and supporting ASM in Mozambique to improve mining efficiency, generate growth, and create decent jobs for the miners.

The EU co-funded PanAfGeo-1 and PanAfGeo-2 projects have supported training of geo-scientific staff from African Geological Surveys through the development of an innovative training programme. The PanAfGeo-2 project has successfully delivered training to key stakeholders in Mozambique with the aim of strengthening the capacity of regulatory agencies and the civil society actors involved in the ASM sector to assist and manage ASM operators in the country.

This ASM Handbook for Southern African Region is the result of ongoing teamwork between the Organisation of African Geological Survey (OAGS) and the European Geological Surveys (EGS), and we appreciate the effort and work of these organisations in its development. We trust that this handbook will become a useful reference for stakeholders in the mining sector in Mozambique and beyond.

I wish you all an interesting and inspiring reading!

Antonino Maggiore
Ambassador of the European Union to the Republic of Mozambique

ACKNOWLEDGMENTS

By Dr Maria João Batista, LNEG and Dr John Tychsen, GEUS

Under WP-C of the PanAfGeo-2 Project three regional training sessions on ASM were conducted – one in English/Portuguese in Mozambique, one in French in Cameroun, and one in English in Tanzania.

The first regional training session on ASM comprised the participation of 16 country delegations from English- and Portuguese-speaking countries in the Southern African Region, namely Angola, Botswana, Cabo Verde, Eswatini, Gambia, Ghana, Guinea-Bissau, Lesotho, Liberia, Mozambique, Namibia, Nigeria, Sao Tomé & Principé, Sierra Leone, South Africa, and Zimbabwe. In addition to the country delegations, ASM experts from Mozambique, Ghana, and Zimbabwe, Portugal, Denmark, and Belgium also took part in the training session.

This first training session on ASM in Southern Africa Region enabled participants to exchange knowledge and experience on ASM for four days. Each country delegation presented the geographical and geological context of ASM, minerals exploited, national legislative framework, degree of organisation of craftsmen and miners, role of the National Geological Survey, and impacts of ASM sector on environmental, health, and socio-economic issues.

The organisation and development of an ASM site including health, hygiene, safety and environmental issues were addressed by Dr Dennis Shoko and Professor Salvador Mondlane from Zimbabwe and Mozambique, respectively. The socio-economic impacts and the role of women in the ASM sector were addressed by Dr Iracema Maiópuè, Director General, Women's Means of Life Association. Conflicts between ASM operators and criminal entities and the benefit of formalisation as a path toward responsible minerals were presented by Dr. Kenn Matthysen, International Peace Information Service (IPIS). The benefits of using remote sensing as a tool to monitor ASM mining sites and through this support the Government were presented by Dr Abdul-Wadood Moomen, UENR, Ghana.

We would especially like to thank the country delegates for their active engagements during the training session but also for their written contributions to this ASM handbook.

We would also like to thank the ASM experts for contributing to the scientific and technical quality of this handbook, which is considered a milestone and serves as a reference for all stakeholders in ASM in the Southern African Region and beyond.

We would like to personally thank Dr Cândido Acácio Rangeiro, Acting Director of DNGM at MIREME for his warm welcome of us to Maputo, Mozambique and his support and professionalism that contributed significantly to this training session and the edition of this handbook.

Furthermore, we would like to thank Dr Teodoro Cândido Vales, Permanent Secretary of MIREME, H.E. Antonino Maggiore, Ambassador of the EU Delegation to Mozambique, Mr. Daniel Boamah, Ghana National Geological Authority and African Co-lead, Mr. Thomas Roed-Thorsen, CFO of GEUS and Co-Head of the WP-C, Dr Jorge Carvalho, LNEG for their support and presence for the training session and last but not least both Dr Nelson Nhamutole for translating and Ms. Julie Sophie Hübertz for editing this English handbook and Dr Maria Batista for editing the Portuguese handbook.

Dr Maria João Batista
LNEG

Dr John Tychsen
GEUS

INTRODUCTION

By Jean-Claude Guillaneau, Programme Coordinator, PanAfGeo Project and International Institutional Affairs at the General Direction, BRGM

PanAfGeo-2 supports the training of geoscientific staff from 54 African Geological Surveys through the development of an innovative training programme conceived and conducted by 12 EGSs.

PanAfGeo-2 (2021-2024) is a continuation of the well- recognised PanAfGeo-1 (2016-2019), which facilitated 45 training sessions for approximately 1,200 geoscientists from 49 out of the 54 African countries. The PanAfGeo-1 Project had a budget of EUR 10.3 million and was co-funded by the EU, through Directorate-General for International Partnerships (DG INTPA), and a consortium of 12 European Geological Surveys, managed by the French Geological Survey (BRGM).

The PanAfGeo-2 Project allows trainees to acquire a state-of-the-art tool kit and the opportunity to take part in field trips within eight Work Packages (WP): A) Geoscientific Mapping; B) Mineral Resources Assessment; C) ASM; D) Geo-Heritage and Geothermal Energy; E) Geohazards and Environmental Management of Mines; F) Geo-Resources; G) Governance and OAGS/GSOs Institutional Strengthening; and H) Geoinformation Management, Communication and Promotion.

The WP-C is a training programme specifically on ASM to be implemented with participation from 46 African countries. The WP-C is managed by Dr John Tychsen and co-directed by Dr Daniel Boamah of Ghana Geological Survey Authority (GGSA) and the deputy co-lead is Mr. Jules César Yaganza Director of the Geological Survey Department in the Central African Republic.

The objective of WP-C is to train staff of the national geological surveys in subjects related to the ASM sector in order to strengthen their capacity to assist ASM operators and to an understanding of how the knowledge and skills resources of the geological survey authorities can be mobilised more actively in the service of ASM operators to ensure more profitable, efficient, environmentally friendly, safe, and sustainable mining operations in the countries concerned.

In 2021-2024, the WP-C is implementing three regional training sessions. This first took place in Maputo, Mozambique on 26 to 30 September 2022. WP-C has invited trainees from 16 countries from the Southern Africa Region. Among the 16 countries five are Portuguese speaking and 11 English speaking. For the first time, WP-C will provide simultaneous English/Portuguese translation during the training session. This training session is managed jointly by GEUS and LNEG.

The PanAfgeo-1 (2017-2019) programme on ASM completed three country ASM handbooks (Malawi, Ghana, and Zambia) and one regional ASM handbook for eight francophone countries in West Africa. The intention was to extend the learning process, number of beneficiaries and provide a tool to serve as a guide on how to benefit from geological survey involvement in the ASM sector These four ASM handbooks were distributed to participating organisations.

The regional approach in the ASM handbook for the eight countries in Western Africa was very much appreciated by DG INTPA and the Organisation of African Unity (OAU). Therefore, WP-C will produce four regional ASM handbooks covering the remaining 46 African countries. These four Handbooks will be in the English, French, and Portuguese language, respectively.

I know from the feedback that the training session in Maputo, Mozambique was successful and this ASM handbook for the Southern Africa Region will serve as a guide on how to benefit from geological survey involvement in the ASM sector.

For more information on the PanAfGeo project visit http://panafgeo.eurogeosurveys.org/ and/or follow it on Twitter @PanAfGeo.

Jean-Claude Guillaneau
Programme Coordinator, PanAfGeo Project and International Institutional Affairs at the General Direction, BRGM

Milling operation at Tsiquir in Mozambique

ASM SECTOR OF MOZAMBIQUE

By Dr Cândido Acácio Rangeiro, Acting National Director of National Directorate of Geology and Mines, Mozambique

Geographical Context of Mozambique

Demography of Mozambique

ASM is one of the relevant sectors in developing countries for its contribution to income generation for the low-income population. For example, the Intergovernmental Forum on Mining Minerals Metals and Sustainable Development (IGF) estimated that in 2017 nearly 40.5 million people were directly involved in the ASM and 150 million people in 80 countries worldwide relied on this sector. It is estimated that there are close to 9 million ASM operators in Africa and 54 million people relying on the ASM sector.

In SADC, the ASM sector is estimated to contribute up to 5.0% of GDP. In these countries, in which ASM is known as the economic alternative to the practice of agriculture, the number of people engaged in the ASM sector grows exponentially in the periods of severe drought. According to the latest 2017 Census, the Mozambican population is estimated at about 27,909,798 inhabitants with more than 100,000 people directly involved in ASM. In most cases, it is informal and clandestine, with greater incidence in the provinces with high mining potential, namely Manica, Tete, Zambézia, Niassa, Nampula, and Cabo Delgado, respectively. The main products extracted by small-scale explorers are gold, precious and semi-precious stones (emeralds, tourmaline, morganite, and aquamarine), whereas among the less valuable products comprise clays, limestone, building stones, sand, and others.

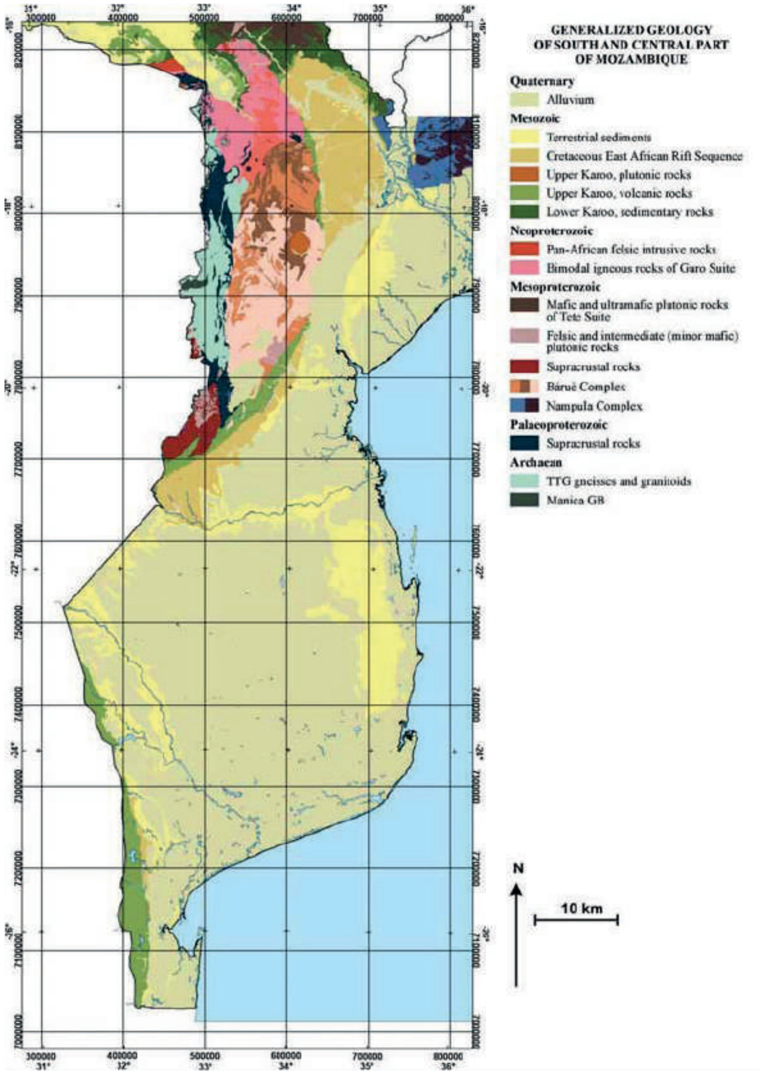
Mozambique's Economy

The informal nature of ASM in Mozambique limits its contribution to the value chain of the mining sector. In fact, the country lacks reliable data on the production and commercialisation of mineral products by the ASM sector.

To remedy this, the Ministry of Mineral Resources and Energy, in coordination with the INE, conducted the first Census of Artisanal Miners of Mozambique in order to obtain the following information: number of artisanal miners in the country, their location, predominant age groups, origins and nationalities, environmental aspects associated with the activity, organisation of the mining communities, and their contribution to local socio-economic development.

Geological Context of Mozambique

FIGURE 1 | GEOLOGICAL MAP OF MOZAMBIQUE



Source: GTK Consortium Geologists, https://www.researchgate.net/figure/Simplified-geology-of-Mozambique-compiled-by-GTK-Consortium-geologists-The-rectangular_fig5_237627148

Brief Overview of the Geology of Mozambique

In Mozambique, given its enormous extension, geological dissimilarities are observed between the north, centre, and south of the country. The north is predominantly Proterozoic in age and the south entirely Phanerozoic, with the central region occupied by archaic, Proterozoic, and Phanerozoic terrains. The Precambrian terrains show a series of regional linear structures delimiting 3 tectonic blocks, a consequence of the collision between the various blocks of Gondwana, with different characteristics: East Gondwana, West Gondwana, and South Gondwana. The east and west blocks are separated by a north-south boundary, and these are separated from the south block respectively by the Lurio Belt and the Sanangoe Shear Zone. The Phanerozoic terrains are subdivided into the Karoo Supergroup and the East African Rift System.

The age of the Karoo Supergroup, divided into Lower (sedimentary) and Upper (sedimentary and igneous), ranges from the Upper Carboniferous to the Lower Jurassic, and is represented in deep intracratonic tectonic depressions as a result of aborted rifts in a break-up phase of Gondwana. This is followed by the opening of the Indian Ocean as a consequence of continental drift and the dispersal of Gondwana, simultaneously with the development of the East African Rift System, which began in the Jurassic and continues to this day, resulting in the development of two huge sedimentary basins, the Mozambique Basin and the Rovuma Basin.

The Archaean formations belong to the Zimbabwe Craton and extend for about 350 km along the border with Zimbabwe, and are assigned an age of >2500 million years. They can be subdivided into granitoid crystalline basement formations and supracrustal greenstone belt formations. The Palaeoproterozoic formations are scattered in three geographical regions of the country extremely distant from each other: (i) in Manica, along the border with Zimbabwe, bordering the Archaic formations; (ii) in Tete, in two isolated patches near Songo and one close to Moatize; and (iii) in the far north-west of Niassa, by Niassa Lake.

The Mesoproterozoic formations constitute the majority of the northern area and a large part of the central area, occurring in the three aforementioned Gondwanan blocks, all of them with intrusive complexes and supracrustal groups. The Neoproterozoic formations, similarly to the Mesoproterozoic, also occur in the three Gondwanan blocks, containing supracrustal groups, various complexes, and the allochthonous Ocua complex of the Lurio belt.

The Phanerozoic is represented by Paleo-, Meso- and Cenozoic formations. The Paleozoic is represented by Cambrian and Ordovician intrusions spread out over the north-east and north-west regions of the country, and by carboniferous and Permian sedimentary formations of the Karoo Supergroup that extends until the Lower Jurassic, where occurs the end-Karoo igneous formations. The Mesozoic (not including the Karoo Supergroup formations mentioned above) and the Cenozoic are made up of sedimentary and igneous formations linked to the East African Rift System.

ASM in Mozambique

In Mozambique, among the main products extracted by artisanal exploiters are gold, precious and semi-precious stones (emeralds, tourmaline, morganite, and aquamarine). In recent years, the activity tended to include other types of minerals and ores, such as tantalite, coal, sand, aggregates (construction stone), clay, and others.

The Legal Framework of ASM in Mozambique

The legal-legal instruments used for the regulation of ASM in Mozambique comprise:

- The Mining Law 20/2014 of 18 August, which establishes the general principles on the rights and obligations related to the use of mineral resources, including mineral water;
- The Decree No. 31/2015 of 31 December, Regulation of the Law and Mines, which establishes the rules for prospecting and exploration of minerals, development, mining, and processing of mineral resources, as well as geological mapping and development of geological, metallurgical and scientific studies;
- The Decree No. 20/2011 of 10 June, Regulation for Marketing of Mineral Products, applicable to national individual and legal persons;
- The Decree No. 26/2004 of 20 August, Environmental Regulation for Mining Activity;
- The Decree No. 25/2015 of 20 November, which approves the Regulation for the commercialization of diamonds, precious metals, and gems; and
- Law No. 20/97 of 1 October, which approves the Environment Law, and establishes the legal bases of the environmental protection regime, prohibiting the production, or deposition in the soil and subsoil of any toxic and polluting substances far above the legally established parameters.

Mining Associations and Cooperatives in Mozambique

Mozambique has a total of 86 Mining Associations and 30 Mining Cooperatives distributed throughout the country.

Institutions Responsible for ASM in Mozambique

Table 1 shows the main institutions involved in the management of ASM in Mozambique and their responsibilities.

TABLE 1 | INSTITUTIONS RESPONSIBLE FOR THE MANAGEMENT OF ASM IN MOZAMBIQUE

Institution	Responsibilities
National Directorate of Geology and Mining	Promote, support, monitor, and control the use of good techniques and the adoption of good practices in artisanal and small-scale mining; • Register and propose the creation or extinction of designated areas for mining; • Promote the formalisation and monitoring of artisanal mining activity;- • Coordinate with local authorities to ensure their participation in the organisation of artisanal mining as well as to strengthen the dissemination of mining legislation and good practices; and • Promote and conduct studies aiming at a deep understanding of the social and economic aspects related to artisanal mining.
National Institute of Mining	Evaluation of the geological and mining potential of the designated areas for the attribution of the mining pass; • Disseminate extraction and mining processing technologies for artisanal and small-scale mining; • Monitor artisanal and small-scale mining activity and ensure its development; • Propose and promote environmentally sustainable mining techniques; • Conduct studies to assess the levels of pollution and contamination of water, soil, and air, among others in areas of influence of mining activities; • Inventory areas degraded by artisanal and small-scale mining and propose measures for their rehabilitation; • Monitor mining activity in coordination with other competent entities.
General Inspectorate of Mineral Resources and Energy	Ensure the control and supervision of compliance with legal provisions, regulations, and standards applicable to mining geological operations, as well as technical standards of safety, hygiene, and environmental protection; • Inspect compliance with plans for mining, closure, and safety, as well as other technical plans prepared for the implementation of geological operations, mining, geotechnical, drainage, and others; • Inspect the quality of materials and equipment used in geological mining activities; • Inspect the transport systems, storage and use of mining equipment, explosives, mineral products as well as mineral processing and beneficiation facilities; • Control the quality and quantities of mined products to determine the taxes established by law in coordination with other institutions; • Draw up notices to demand penalties for contravention of the applicable legislation; • Investigate accidents, incidents, and special events in mining operations; • Inspect the safety systems established in underground and open pit mines and evaluate occupational risks, as well as the established prevention measures; and • Inspect the management systems for protective equipment, testing, operating status, maintenance, storage, certification, and work training in safety matters.
Kimberly Process Management Unit	Management of the technical and administrative procedures for tracking, security, and internal control of diamonds and the marketing of precious metals and gems.
Provincial Services of Infrastructures	Ensure the control, monitoring, and promotion of good practices in artisanal mining at the provincial level.

Source: National Directorate of Geology and Mines, Mozambique

Environmental and Health Problems Related to the Practice of ASM in Mozambique

In Mozambique, environmental problems are widespread among mining operations due to the informal nature of the ASM activities that characterise the country. The main environmental impacts of ASM are:

- Water (surface and underground), air, and soil pollution;
- Deforestation;
- Alteration of the landscape;
- Opening and abandonment of wells and galleries; and
- Soil degradation and erosion.

Pollution of Surface and Underground Water, Air, and Soil

The locations where ASM activities occur are environmentally sensitive and important for the preservation of biodiversity, water resources, landscape, or other natural resources with environmental functions of great importance. Due to the extraction and washing of ore on the banks of rivers and lakes, as has occasionally been observed in the case of gold ore, silting of rivers occurs and consequent deviation of the normal course of the water. This process has also culminated with the contamination of waters by heavy metals resulting from the leaching of solid waste deposited on them.

Deforestation

The frequent excavations carried out for access to the target mineral have resulted in large volumes of vegetation removal followed by deforestation.

Impact on the Landscape

Practically every mining activity implies the suppression of vegetation or impediment to its regeneration. Furthermore, there is also the alteration of the landscape due to the opening and abandonment of excavations, which has resulted in the alteration of the local relief.

Health and Safety Impacts

In Mozambique the informality of the ASM sector affects the health and safety of workers, such as:

- Insufficient technical equipment in the extraction and processing phase of mineral resources;
- Widespread use of substances that are harmful to health and the environment, especially mercury;
- Lack of personal protective equipment or workers are equipped with insufficient material;
- Lack of first aid equipment and qualified first aiders; and
- Unsatisfactory basic hygiene conditions.

Socio-Economic Problems Related to the ASM Sector in Mozambique

The ASM activity in Mozambique has both socio-economic advantages and disadvantages: it is a source of employment in rural areas, serving as a complementary source of income to agriculture or other secondary activities; it discourages rural-urban migration of the population from mining areas and thus contributes to a reduction in rural poverty; but it is difficult to control by the state, due to its unregulated and migratory informal character, low tax contribution, and weak organisation of miners in associations or cooperatives.

The main socio-economic problems resulting from ASM activity in Mozambique are the role of women, children's involvement (child labour), drug and alcohol consumption, prostitution, and conflicts in mining areas.

In the country, depending on the type of mineral extracted, women can assume a major or secondary role in the mining activity.

In gold mining, precious and semi-precious stones, women have been involved in the transport and ore processing activities; whereas in the construction materials mining, women are involved in the entire mining chain (extraction, processing, and commercialisation).

Children also play an important part in the ASM value chain as operators (extraction, transport, and processing of ore) and traders (sale of products and equipment).

In Mozambique, the following denote hazardous activities for women and children with ASM:

- Handling of dangerous products;
- Transporting and loading ore with excessive load;
- Underground (mining) excavations (galleries and shafts);
- Blasting (washing) of minerals;
- Manual crushing; and
- Amalgamation.

The Ministry of Mineral Resources and Energy, in coordination with the Ministry of Labour and Social Security, is developing a National Action Plan to combat the worst forms of child labour to minimise the impact of child labour in ASM, which includes dissemination and awareness-raising on good mining practices.

Underground mining operation named Cleabtec in Mozambique

HOW TO ORGANISE AND DEVELOP AN ASM MINING SITE

By Professor Salvador Mondlane Junior; Eduardo Mondlane University, Geology Department and Geo-Management Services and Consultancy. Lda

Introduction

The definition of ASM is rather controversial; nonetheless its appearance is unique and “when one sees an ASM site, one will immediately recognise it”.

It is our understanding that the ASM definition should encompass a cocktail of aspects of geological, mining, technological, production output, socio economic, environmental, and financial aspects. Literally speaking, ASM encompasses two distinct mining segments: artisanal mining and small-scale mining. The two subsectors may not have anything in common, because in many countries artisanal mining is regarded as the illegal, informal, unregulated mining practised by individual or small group of miners or villagers; while the small-scale mining is regulated, legal and formal and usually governed by the same rules that apply to the large scale mining.

Artisanal mining is that which is characterised by manual labour or zero mechanisation, zero geological knowledge, zero or very low start-up capital, is usually detrimental due to lack of adequate specific policy and regulatory frameworks, is sometimes formal (with precarious mining passes/cards) but mostly informal, not organised (although sometimes organised into associations and mining in designated areas), has a complex and disadvantageous market structure (generally getting less than half of the world mark price due to interdependency with sponsors, land owners and buyers), is highly mobile (they follow the rushes and booms), is precarious, unsafe and unhealthy working conditions, and is marginalised and usually struggling with conflicting land owners and local communities.

Small-scale mining is usually formal (with mining title), semi-mechanised, has limited geological knowledge, low to medium start-up capital, regulated by the Mining Code, required to produce an environmental impact assessment study, and in some countries hijacked by “investors” who produce beyond the allowed output levels, e.g. illegal miners in Ghana.

Background and Context

ASM is typically developed in developing countries by nationals. There are close to 40 million people involved in ASM in 80 countries worldwide, 26-30% of whom are in Africa. Those in ASM mine and process more than 35 different minerals and make a significant contribution to the world production of critical mineral products. For instance, in 2005, 15% of the gold production (400 – 600 t/a) valued at approximately USD 20 billion was undertaken by ASM. ASM activity generates and supports secondary activities/economies of close to 100 million people with the subsector supporting direct and indirect livelihoods of 120 – 150 million people.

In many countries, 70-80% of small-scale miners are informal. Informality brings along damaging socioeconomic, health and environmental impacts, which trap most miners and communities in cycles of poverty and exclude them from legal protection and support (IGF, 2017).

The main commodities mined by ASM in terms of value are gold and diamonds, which are produced by 15 million ASM (for gold only). ASM produces about 10-15% of the world's mined gold, between 15-20% of mined diamonds (AMDC, 2015), approximately 20-25% of tin and tantalum, and around 80% of precious and semi-precious stones (coloured gemstones) (Lucas, 2011 and Villegas et al., 2012).

According to the AMV, between 15-20% of the world's nonfuel minerals, 18% of Africa's gold and almost all African gemstones (except diamonds and some rubies) are produced by ASM, and the activity could greatly contribute to national and local African economies (African Union, 2009).

About 65% of the world's diamond reserves are found in Africa. Madagascar is one of the largest sapphire producers with about 50% of the global supply in 2002. Ruby mining has led to a rush in Mozambique recently, being traded at a high price on the world market.

In Africa it is estimated that around 12 million people are involved in ASM and produce a variety of mineral commodities with prominence in terms of value to gold, diamonds, coltan and coloured gemstones.

In 2011, according to the data provided by Hilson and McQuilken (2014), the number of people dependent on ASM activity in Africa was between four and 12 times the number of ASM operators, but mostly around six times the ASM miner population, e.g. in the Central African Republic, Chad, Ivory Coast and DRC. The Africa Minerals Development Centre (AMDC) considers this a "conservative estimate," citing an important lack of data on ASM as the activity is often informal and mostly operates illegally in several African countries (AMDC, 2015). The research acknowledges that ASM is both complex and highly important for the economies of at least 23 countries in sub-Saharan Africa, especially in rural contexts.

Significant migration of the workforce - within countries and between neighbouring or other countries - is one of aspects that makes it difficult to generate more accurate estimates. Mozambique is presently conducting a census which will inform in detail the proportion of nationals and foreigners involved in the ASM activities.

Policy Analysis

ASM Dimension

Although African countries have benefited from multiple law reviews it was in the 1990s that countries started to incorporate ASM issues in their legislation. Initially the countries had considered ASM as a single sector that encompassed artisanal (mainly illegal and informal) and small-scale mining (the legal part of subsector). Then slowly, governments started to better understand the subsector especially with work carried out by international organisations. The countries thereafter made political attempts to integrate ASM in their poverty reduction strategy papers with some countries distinguishing the artisanal mining from small-scale mining sub-sectors. Lately, the tendency is such that artisanal mining is considered only for the local community and is regarded as a process of empowerment of the locals. Artisanal mining is seen as an income alternative for rural communities mainly dependent on rain fed agriculture. This fact brings other problems related to land use conflict between agriculture and mining, e.g. in the Ivory Coast there is a reduction in coco plantations due to mining.

In our review, with some differences, the mining codes have laid down processes and procedures for licensing ASM. However, the rate of formalisation of ASM is still very low due to lack of mechanisms to reach the miners in their remote mining sites and in some cases due to complex bureaucracy and centralised mechanisms. It was also clear that the licence for Artisanal Miners is still very precarious, valid for one or two years while the Small-Scale Miners the licence is much better in terms of benefits and validity, up to ten years.

Governmental Assistance to ASM

Some countries have been conditioning the assistance to ASM to formalisation. However, the result has been limited despite official formalisation policies and incentives whereby the majority of the 1.5 to 2 million ASM operations continues to operate outside the formal economy in the Democratic Republic of the Congo (DRC).

The governmental assistance to ASM is fundamental for the sustainability of the sector and to be able to bring the sector to implement environmental standards and to adhere to best mining practices. However, this should not be used as a conditionality for formalisation because if two sites operating side by side, one formal and one informal, all efforts being put into the formal site will be meaningless if next to it an informal site continues operating and polluting the environment, for example. Formalisation is a process and should not be regarded as a means for benefiting from governmental assistance, because the governmental assistance may not be sustainable for several reasons. Formalisation needs to live beyond government assistance in order to turn the sector in a sustainable one.

ASM Products Market

Although governments recognise the negative impacts of illicit trade on minerals, very few governments have adopted the framework of the international instruments aiming at control and traceability of the mineral resources. Most of the Mining Codes reviewed mention very softly that licensees should not engage in illicit trade of their products. Few countries, such as Angola, have decided to certify the products from ASM, especially bringing the ASM produced diamonds into the mainstream of Kimberley Process and the Diamond Development Initiative.

The typical market structure of minerals commodities produced by ASM is presented in Figure 2 below.

FIGURE 2 | TYPICAL MARKET STRUCTURE OF MINERAILS COMMODITIES PRODUCED BY ASM

Source: Professor Salvador Mondlane Junior, 2022

The producers are at the start of the value chain and as a result they always get the least of the value of their commodity even in the case when subsidies are introduced in the market structure, such as the case of Ethiopia, where the buying centres receive a 5% premium price on the gold sold to the Commercial Bank of Ethiopia.

Mineral Certification Processes/Frameworks

In Angola the certification of diamonds is done according to the Kimberley Process (decree no. 55/56 of the National Assembly) that includes the Ministry of Geology and Mines and Ministry of Commerce. The Kimberley Process group estimated that the country's 2012 diamond production was worth USD 1.16 billion. The gold mined by ASM is presently commercialised through the licensed gold shops. In Angola, it is forbidden to trade on minerals sourced from unlicensed production sources. This means that informal or unlicensed ASM production cannot be traded in official channels. This has implications for the smuggling of ASM products from Angola and into neighbouring countries.

The market structure of Burkina Faso is similar to the one in Mali where gold is mainly sold to traders and brokers. Occasionally the producers sell directly to the final consumer or even export as long they have an export permit. However, most of the ASM miners sell their production to brokers who sell to the dealers and these to the final consumer. The exporters of gold are charged an export tax of 5%. This export tax, although relatively low when compared to Mali, is still considered high and seems to contribute to gold smuggling to neighbouring countries. In Burkina Faso there are at least 90 licensed buyers in the entire country.

ASM Value Addition
The policies and mining codes reviewed elaborate in a more significant way the need for local value addition and fabrication. They all understand that the “value added” mineral products like jewellery, pottery, and stone carvings, can give a much higher return than the unprocessed mineral alone; but finding a market for these goods can be a major challenge. In all cases, developing skills in marketing and selling is critical to the success of an ASM business.

The specialisation of the ASM mineral value chain can only be possible with proper strategies on research and development that will properly identify the gaps and find the solutions for each segment of the value chain for different categories of minerals, e.g. precious metals, Industrial mineral, base metals, etc.

The reviewed Mining Codes and legislation lay down processes for licensing the processing plants; however, in general they overlook the licensing and formalisation of the artisan that add value to ASM products, such as blacksmiths and others. It is only in Uganda where the Mining Code stipulates that the commissioner grants the goldsmith a license, which is valid for one year.

ASM Technical and Financial Issues
It is recognised that sustainable ASM can only be achieved through some sort of financial and technical assistance.

The technical assistance from governments is very limited due to lack of financial and human resources. However, an initiative that is worth mentioning is the PRECAGEME project in Burkina Faso, which trained miners on fabricating mining equipment.

In Zimbabwe, for several years in the 1990s, a partnership between the National Miners’ Association of Zimbabwe and the ITDG as the implementing agent, ran a multifunction service provider, the Shamva Mining Centre.

Another organisation, which plays a significant role in the technical training of miners is the Artisanal Gold Council, which works with and trains miners in free mercury processing techniques, and has achieved positive results in their countries of intervention including Burkina Faso and Senegal. These techniques, besides protecting the environment, also protect the miners themselves from mercury poisoning.

ASM Financing
The financing of ASM has long been recognised as one of the main constraints to its development. Despite this realisation, most country initiatives have failed to promote the sector from artisanal into small-scale and possibly into middle scale mining.

Most of these schemes have proved unsustainable. The reasons for failure vary from country to country, although they were all unable to manage the financing schemes, to the extent that some countries placed the funds in commercial banks or created dedicated institutions that managed the fund. The reasons for the unsuccessful financing of ASM have emanated from both the demand side and supply side. The demand side reasons include: the inability of miners to produce valid ID, bank account, license or mineral rights, a resource valuation document, or production records that could help to prove that the mine has production capacity.

These factors led to the relaxation of the loan requirements by some countries with funding apportioned to ASM using minimum criteria. The result was that in most cases the miners neither complied with the loan repayment plan nor paid back the loans.

Some countries such as Zimbabwe and Ghana decided to create equipment loans schemes where the miners received only the equipment or equipment hire mechanisms.

In Tanzania, the Government developed microfinance services tailored to the artisanal and small-scale mining sector. Since 2011, efforts to promote linkages between the banks and financial institutions and the ASM sector have been encouraged by the Government and associated to the Government's financial empowerment strategies to support marginalised groups.

Other ways of financing ASM are the joint ventures between finance institutions or mining houses. A successful example is reported from Mozambique, where the Joint Venture between the ASM association of Munhene and a venture capital fund from South Africa has resulted in a 75:25 sharing of the production. This is after deducting the operation costs and investments in the equipment.

Environmental Issues for ASM

All mining codes have clear provisions on the need for preserving the environment. The environmental regulations are rather relaxed for artisanal miners (most cases need to produce an Environmental Management Plan (EMP)), while quite strict for small-scale miners, who are expected to produce in many cases an Environmental Impact Assessment (EIA), e.g. in Zimbabwe, Zambia, Uganda and Ghana. In other cases, they have to produce a simplified EIA, e.g. in Mozambique, Tanzania, or an Environmental Impact Statement (EIS) and EMP together with rehabilitation plan, e.g. in Mali and DRC. The environmental authorities in many countries require that the small-scale miners pay a mandatory environmental bond, which is a percentage of the budget for the first year, e.g. Mozambique, or contribute the Environmental Protection and Rehabilitation Fund, e.g. Nigeria.

The environmental regulations are seen by the ASM sector as one of the biggest impediments for their acquisition of licenses, especially because is very expensive, has complex requirements and very lengthy, e.g. Zimbabwe.

ASM Governance and Transparency

According to the CMV Guidebook: "to ensure effective mineral sector governance, it is essential to have a sound regulatory framework that is grounded in enforceable legal systems, providing for accountability, transparency, human rights and informed administration of the sector which fully acknowledges the rights and needs of mining communities."

African countries have clearly identified the potential underpinning the ASM sector and the transformative capacity of the sector in rural economies. They also recognise the impacts of the sector on the environment, citizens and social fabric. The African governments, under the guidance of the World Bank, reviewed their mining and environmental laws in the 1990s to make them responsive to the dynamics of the mining sector including the under regulated ASM subsector. The mining sector policies, acts and regulations have paved the way for licensing procedures (sometimes supported by Cadastre Systems) and have also decentralised (in most countries) the mining support institutions to the provinces or even to the districts. Ministries responsible of environmental issues and the Ministries of Mines have streamlined the environmental impacts from mining activity including ASM and have in some cases created specific environmental regulations for mining activities, e.g. in Tanzania and Mozambique). The Ministries of Mines have in most case a department responsible for environmental issues in the mining sector.

In general, most countries have legal instruments and structures for managing ASM. However, the enforcement of such instruments and the implementation of appropriate structures, especially at community level still lag behind, mainly due to lack of resources (human, financial and infrastructures) and occasionally lack of political will.

In conclusion, it is important to encourage countries to have structures/institutions dedicated to the management of ASM. It could either be a directorate or a national department. The most critical element is that such an institution must have enough power, authority, and autonomy to implement adequate assistance programmes for ASM. Such institutions need to be decentralised enough to be able to reach and actively involve the affected communities. Given the transformative capacity of the ASM in the rural economies, it is important that governments allocate adequate resources (human, infrastructure and financial) to promote environmentally safe and sustainable ASM.

Governments are encouraged to continue with formalisation, traceability, and certification efforts of ASM products, especially the high value and low volume minerals as a way to reduce the illicit trade and fuelling of political instability in Africa as well as possible money laundering from illegal economic and financial operations.

Policy Implications and Recommendations

Given the scenario of the mining legislation in Africa, to improve the livelihood conditions of ASM communities, there is a general need to review public policy to frame ASM specific issues.

Although some countries have policy statements on gender, these are not implemented. Thus, there is need to cascade down the policy intentions into the Mining Act, and or into specific regulations, procedures, or decrees that will facilitate implementation. This is very important as it would minimise the economic dependency, social exclusion, cultural barriers that impede women's active involvement and benefit from the ASM sub-sector, e.g. in Uganda the Mining Act specifically indicates that "women can be employed in any underground mine" – this reduces the taboos that prevent women from working and supervising activities underground. For this, the Africa Minerals Development Centre (AMDC), in line with implementation of the CMV and its advisory role to the Member States, could assist countries in mainstreaming gender issues in the legislation.

There is an urgent need to understand the specificities of the women's participation in ASM. This requires segregation by commodity as the significant differences between mining aggregates, mining alluvial diamond or mining chromium are known.

To improve women's livelihood and their participation in ASM, there is a need to increase the income generation options for women by developing mechanisms that will capacitate/train women in a range of economic activities that will reduce their vulnerability. This training and support facilitation could either be on ancillary economic activities linked to ASM or if in ASM, this should be targeted towards those activities where women have competitive advantage over their male counterparts. Under such training and education programmes there should be a clear target of improving the technical knowledge and business skills of women in ASM.

It is consensus in African countries that there is a need for value addition of the ASM produced minerals. Subject to further specialised studies, the value addition is one of those activities that women can aggregate comparative advantage, especially because it is usually done in towns and in permanent infrastructures which can be presented to the financial institutions as business enterprises. With adequate coaching, value addition units owned by women would prosper to the level of industry, especially the gemstone cutting and jewellery manufacturing which require an amount of style and taste.

Environmental considerations are an integral part of mining operations. There is a need to create synergies between mineral rights law and policy and those laws and policies that govern environmental management requirements, making specific provisions for the ASM sector and possibly specifically for women. Female ASMs requested that the implementation of the EIA processes should be staged, to accommodate the long period of time it can take to establish a mine.

The access to fair market and adequate technology for ASM has always been problematic; thus, it is recommended that governments create regional integrated mining centres, which would be one-stop shop service providers for ASM – particularly female ASMs. These centres would run gender-responsive extension services for direct field assistance, training programmes, buying facility (which would help to benchmark the price to the producers), community processing facilities, geological services, environmental services, equipment hiring (bulldozers, drilling rigs, jack hammers, etc.). The challenge is to establish a management structure that allows sustainability of the centres without overexploiting the miners. Thus, the centres should not be profit oriented and should charge fair cost recovery price to the beneficiaries. The Government would manage it for several years and after proving that the model works, it would privatise it to a local entrepreneur, who would manage it under the Government's supervision in a tri-party agreement between the operator Government and the miners' association.

At regional and national level, there will be a need to promote and encourage exchange programmes between female miners where they could share experiences and lessons – peer to peer leaning. These activities could be framed in the form of workshops and field visits. These forums could integrate the participants from governments, researchers, practitioners, development organisations with interest on ASM and civil society.

One of the key constraints for the development of a sustainable ASM sub-sector is the lack of financing capital for ASM. It is recommended that innovative and creative financing mechanisms are established at continental and/or at national levels. These would take various forms, e.g. the creation of an ASM Development Bank at continental level which would work with national financial institutions.

The ASM sub-sector needs to be understood as a business by all stakeholders and that as a business it only runs when it makes profit. It is recommended that governments establish Mining Extension Services (MES) that will assist/train ASM in mining and processing techniques, environmental safeguards, records keeping and business skills, marketing and where valid - development of value addition initiatives.

Additional to the training of ASM by the MES, they would also need formal training that would lead to improved productivity and revenue management. These could be organised by the ASM government institutions at central or provincial level. At this level they would also be responsible for the design and production of ASM training material (manuals and pamphlets). The training material would have to be adapted to the local conditions and to the specific commodity, and most importantly should be more graphic than wordy.

At continental and probably at sub-regional levels in Africa, there is a need to develop a strategy for Intermediate Technology Development (ITD) oriented to ASM and research and development geared towards mining and utilization of local mineral resources. This strategy would need to be aligned with the industrialisation strategy of the continent to secure the industrial inputs require for the ITDs. The strategy would also roll out the mechanisms for the establishment of the regional ITD centres based on mineral potential of each region and comparative advantages of the countries.

In line with value addition it is important that a regional strategy is drafted. The strategy would pronounce - at macro level - what comparative advantages are available for the different countries, in line with other initiatives, such as the Integrated Resource Corridors or any other spatial initiatives. For example, some countries have resources, others have gateways to the world market, yet others have affordable electricity. Thus, it would be important to anchor value addition to regional projects rather than national projects and national strategies. This is where the advisory role of the AMDC and the AUC should overlay an umbrella strategy that would advise governments.

Market structures have been identified as one of the weakest links in the development of a sustainable ASM sub-sector, because it contributes to the low income of the miners and perpetuates the poverty cycle that most miners are trapped in. Some governments have intervened substantially on the market structure, e.g. Ethiopia, and managed to regulate the price of gold for ASM miners. The government intervention in the ASM market chain could contribute to formalization, as the buying centres could register the name of the product vendor and ask whether he is a miner or a trader and where the product comes from. In this way, one would at least have the list of miners or ASM players in a specific region. This information would help in the definition of government assistance to ASM.

In previous sections and references, there was discussion on the need to establish national governance structures that would be adequately active at local level and would have enough capacity to reach out the ASM at their sites. The present situation in Africa is such that the Ministry in charge of Mineral Resources have a National Directorate of Mines or Mines and Geology under which a Department of ASM is incorporated.

It is known that there are multiple players in the ASM subsector in Africa. A quick scan has identified the following key players: CSOs, DDI, ARM, AGC, PACT, International Conference on the Great Lakes Region (ICGLR), IGF, Natural Resources Charter, Organisation for Economic Co-operation and Development (OECD), UNIDO, UNDP, UN Woman, International Institute for Environment and Development and others. The agenda of these players might be aligned with national agendas but most likely not aligned with regional and continental agenda (e.g. AMV). The sustainable development of the ASM subsector in Africa requires an integrated multistakeholder approach. In other words, there is need for coordinated intervention which will reduce duplication of efforts and consequent waste of scarce resources. Thus, there is the recommended establishment of a "Mining Engagement Platform in Africa" – multistakeholder partnership, which would coordinate the mining interventions in Africa.

Sluicing at an Artisanal Mining Site in Western Ghana.

MINERAL PROCESSING IN ASM

By Professor Salvador Mondlane Junior; Eduardo Mondlane University, Geology Department and Geo-Management Services and Consultancy. Lda

Introduction

The metals are found in the crust of the earth and sea-bed deposits according to the way they interact with surrounding environment, particularly with oxygen, sulphur, and carbon dioxide. Very few elements occur also in the environment as native form, namely, gold, silver, copper and mercury. The naturally occurring components are known as minerals, most of them termed according to their chemical composition (e.g. galena – lead sulphide, PbS; sphalerite – zinc sulphide, ZnS; cassiterite – tin oxide, SnO2). Of course, there is a complexity suite of combinations of metals that form minerals. Some minerals even share the same chemical composition but have been subjected to different conditions, e.g. graphite and diamond are composed of carbon atoms that have been subjected to different environmental conditions and form different type of crystal.

A combination of different minerals form rocks. The term mineral is also used to include coal, chalk, clay, granite, etc, which in geological sense are rocks.

The metals are usually combined with a variety of minerals to form an ore. Most ores are mixtures of extractable minerals and rocky material considered gangue.

Some ores contain a very small quantity of the economic metal, e.g. gold can be recovered at profit in ores containing only 1 part per million (ppm) of the metal, whereas iron ores containing less than 45% of metal might be considered low grade or even non-economic.

Mineral Processing and Beneficiation

The process by which economically interesting metals are extracted from non-valuable rock material is considered mineral processing. Thus, mineral processing is defined as a procedure of treating crude ores and mineral products to separate the valuable minerals from the waste rock, or gangue (Wills and Napier-Munn, 2006).

In order to recover metal different sequential processes are considered, such as size reduction by grinding or milling up to the size in which the metal can be removed from the ores. Apart from the physical processes of size reduction and milling, some ores require chemical processes where the ore is dissolved and recaptured by adding other compounds of ease separation.

Ores of economic value can be classed as metallic or non-metallic, according to the use of the mineral. Certain minerals may be mined and processed for more than one purpose. For example, bauxite (hydrated aluminium oxide) is used to make aluminium.

Mineral processing, sometimes called ore dressing, mineral dressing or milling follows mining and prepares the ore for extraction of valuable metal in case of metallic ores and produces a commercial end-product of products such as iron ore and coal.

When an operation reduces the size of the ore and separates the valuable portion from the gangue it results in a concentrate, which contains more valuable minerals than the original ore. The gangue is discarded as tailing which contain far less valuable metal than the original ore. In most case, the technology available defines the amount oof the remaining metal in the gangue (Wills and Napier-Munn, 2006).

There are two fundamental operations in mineral processing: 1) the release, or liberation, of the valuable minerals from their waste gangue minerals; 2) and separation of these values from the gangue, the concentration.

Liberation of valuable minerals from the gangue involves crushing, and if necessary, grinding, to such a particle size that the product is a mixture of relatively clean particles of minerals and gangue (Wills and Napier-Munn, 2006).

The most important physical methods, which are used to concentrate ores are (Wills and Napier-Munn, 2006):
1. Separation based on optical and other properties. This is called sorting, which used to be done by hand or specialised machines;
2. Separation based on differences in density between the minerals. Gravity concentration, for example, the differential movement of mineral particles in water due to their different hydraulic properties. The same principle is used for dense medium separation particles sink or float in the dense liquids. This also includes panning for alluvial gold, sluicing, shaking tables and jigs. More complex equipment includes the Kelsey centrifugal jig which is widely used in the recovery of gold, platinum, silver, mercury, and native copper. The Falcon SB concentrator is another spinning fluidised bed batch concentrator used for recovery of free gold;
3. Separation using the different surface properties of the minerals. Froth flotation, which is one of the most important methods of concentration, is done by the attachment of the mineral particles to air bubbles within the agitated pulp;
4. Separation dependent on magnetic properties. Low intensity magnetic separators can be used to concentrate ferromagnetic minerals such as magnetite, while high-intensity separators are used to separate paramagnetic minerals from their gangue. Magnetic separation is an important process in the beneficiation of iron ores; and

5. Separation dependent on electrical conductivity properties. High-tension separation can be used to separate conducting minerals from non-conducting minerals

A combination of the above methods is possible depending on the type of ore.

In summary the physical separation includes crashing, grinding flotation and filtration.

Gold Concentrators
The ASM miners widely recover gold by multiple process, which includes the gravity separators. The coarse gold is concentrated using very simple methods such as panning, sluicing and table jigs. In some small-scale mines equipment, such as the Knelson, Falcon Concentrators.

Mineral beneficiation denotes the successive processes of adding value to raw minerals from their extraction through to the sale of the finished mineral products to consumers.

Beneficiation covers a wide range of varied activities including large-scale and capital-intensive operations like smelting and technologically sophisticated refining as well as labour-intensive activities, such as craft jewellery.

Gold Processing
Gold panning in the rivers of Manica has been known since the times of the Monomotapa Empire. It is the cheapest way of recovering alluvial free coarse gold from placer deposits. It results in environmental impacts when done directly in the rivers, ref. Figure 3. It consists of sifting and turning ore material in the pan while adding water to wash the light minerals. The result is a concentrate of heavy mineral minerals which includes gold, magnetite and other minerals.

The coarse gold is also recovered using locally home-made sluices, ref. Figure 4. The ASMs extract alluvial gold by flowing auriferous sand soil mixed with water (slurry) into an improvised simplistic “sluice” box made from iron metal with several perforations of diameters between 2 and 10mm at the base on one tilted end and supported sideward by planks of wood.

FIGURE 3 | GOLD PANNING IN THE MUNHENE STREAM, MANICA, MOZAMBIQUE

Source: Professor Salvador Mondlane Junior

FIGURE 4 | HOME MADE SLUICES FOR GOLD RECOVERY IN MANICA, MOZAMBIQUE

Source: Professor Salvador Mondlane Junior

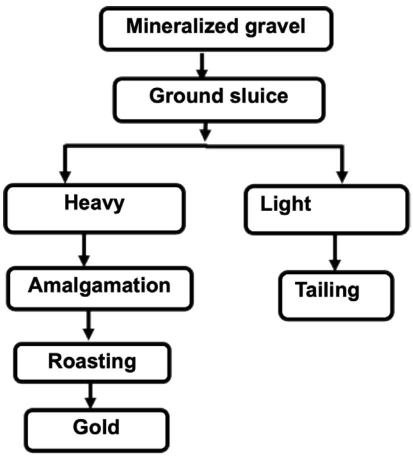
The Figure 5 below shows the gold processing flow chart for the coarse gold. In some countries, the concentrate is amalgamated using mercury and then the sponge gold (mixture of gold and mercury) is roasted, and the mercury evaporates at 60 degrees Celsius and gold bullion is obtained. This bullion might still have some heavy metals and other impurities.

The use of mercury is not recommended in many countries; however, its efficiency and low cost makes it widely popular among the ASM in sub-Saharan countries.

When gold ore consists of hard rock, the above process add few preliminary steps such as crashing r grinding, sieving, and milling as shown in the Figure 6.

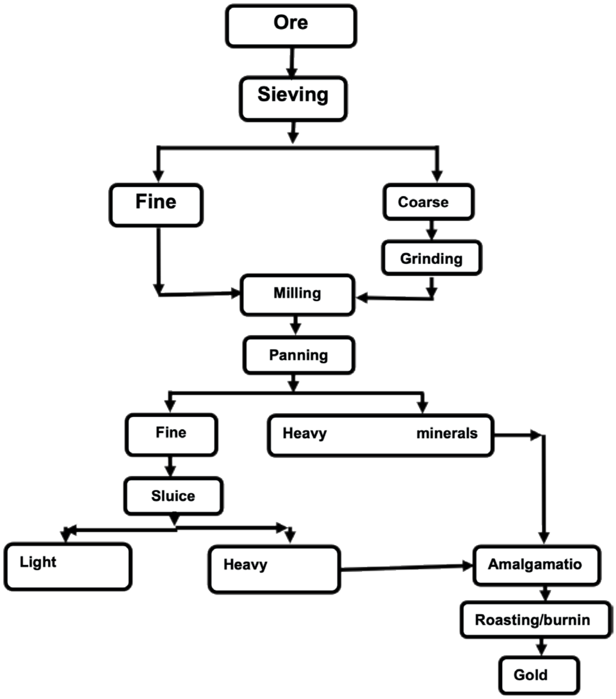
Other gold processing methods include the direct smelting technique – in this process, the melting point of the materials is lowered by adding borax to an extent of reducing the melting point. The major disadvantage of this method is that it requires a lot of energy, something that cannot be achieved with use of firewood, it requires the use of gas tosh or high-temperature ovens.

FIGURE 5 | FLOW CHART OF FREE GOLD PROCESSING (EXAMPLE)



Source: Professor Salvador Mondlane Junior

FIGURE 6 | FLOW CHART OF PRIMARY GOLD PROCESSING (EXAMPLE)



Source: Professor Salvador Mondlane Junior

Mineral Processing Challenges and Opportunities for ASM

The degree of liberation that can be achieved for any particular mineral is typically driven by three factors: i) ore texture, including mineral grain size and mineral associations, ii) the final size of the mineral particles, and iii) the method by which the particles were processed. Different concentration methods employ different types of mechanisms: i) impact, ii) compression, and iii) attrition. Depending on material characteristics of ores, each method is more or less effective at producing different particle size distributions that are suitable for different points in the minerals processing circuit. Therefore, different types of concentration equipment tend to employ one or more of these mechanisms, which serve different functions depending on their circuit placement.

The understanding of the ASM on these factors in their processing methods is very deficient which result in high inefficiency in the mineral processing.

In general, ASM miners concentrate minerals typically by sequentially reduction of ore particles to finer and finer particles sizes, thus achieving greater and greater degrees of mineral liberation.

When finer particle sizes are required, grinding or milling is employed. Milling makes use of a combination of impact, attrition, and shear mechanisms to further reduce the size of ore particles down to micron sized particles. There is a combination of these mechanisms in a mill, but depending on the mill, one or two mechanisms can be dominant. Different types of mills also make use of different grinding media to promote some of these mechanisms. These include ore pebbles, a mixture of steel balls and pebbles, steel balls (Ball mills), and ceramic media (Napier-Munn et al., 1996). In most grinding operations, the grinding media are mixed by rotation of the mill's cylindrical body using motors, with the ore particles being broken up during collision with the grinding media (Wills and Finch, 2016).

Particle size plays a crucial role in mineral processing. The optimum particle size for effective recovery is often dictated by the grain size of the mineral of interest, which informs the processing technique and the process flowsheet. This in general was not clear to the visited sites whether the operators or set ups fully understood the right concepts behind low or high recovery ore processing methods.

Competitive policy and legislative frameworks that support mining and mineral processing Mineral sector's institutional setting e.g. availability of Mineral Processing Research Division in the Department of Mines to support and promote mineral processing and introduction of mineral processing courses in the University is key opportunity for all countries in order to minimise the eventual wastage of deposits by use of inadequate processing technics specially by ASM.

It is key to facilitate collaboration between the Mineral Sector and the training, research, and development institutions to promote the development of adequate mineral processing technologies for use by the ASMs and, development of a robust national mineral processing and mineral value-addition strategy and implementation plan to support ASMs.

There is a need to educate ASM miners through extensionists and promote continuous monitoring in order to increase the performance of ASM.

Women miner at the Osino mining site. Ghana

ENVIRONMENT, HEALTH AND SAFETY CHALLENGES IN ASM IN THE SOUTHERN AFRICAN REGION

By Dr Dennis Shoko. Independent consultant. Zimbabwe

Introduction and Background

ASM is an informal, unregulated, poverty reducing livelihood strategy in developing countries of the global south, including Southern Africa. While individual operations of ASM are small, their collective economic and social impact is significant in many developing countries. ASM has the potential to contribute to more sustainable livelihood strategies, were it not for poor working conditions, accidents and diseases which reduce worker productivity and incomes.

It is estimated that ASM number about 40 million people globally with close to 150 million people depending on the subsector across 80 countries in the global south (IGF, 2017 and Smith et. al., 2016). Over 20% of the global gold production is accounted for by ASM (ASM accounted for 60% of gold production in Zimbabwe in 2021). Over 80% of global sapphire supply and 20% of global diamond supply comes from ASM. About 26% of the world's tantalum production and 25% of global tin production comes from ASM. It is estimated that 40-50% of the ASM workforce in Africa are women and that 70-80% of ASM are informal. It is further estimated that in Sub-Saharan Africa alone, ASM accounts for upwards of USD 2.1 billion worth of mineral production (IGF, 2017; Hinton, 2006; and Hentschel 2002 and 2003).

Despite their glorious production figures, ASM is actually notorious for its deplorable environmental degradation, poor health/living conditions and very low quality of life indicators in addition to almost a total disregard for work place health and safety best practice (Smith, 2016; Bose-O'Reilly et. al., 2004; and Butscher, 2020). Sustainable ASM calls for the equitable mitigation of the subsector's debilitating environmental, health and safety issues. Significant and notable interventions required include formalisation of the subsector as well as training and provision of social services by governments before taxation.

Characterisation of ASM in Southern Africa

Current estimations are that the number of ASM in Southern Africa is nearly 4 million people with about 1.5 million people each in Zimbabwe and Tanzania alone. It is further estimated that up to 20 million people directly or indirectly depend on ASM. ASM is indeed the default livelihood strategy of choice in all Southern African countries. Major pull factors for ASM participation have been largely the decline or stagnation of economies in the region, particularly the agricultural sector, due to a myriad of natural and man-made disasters. Agriculture in Southern Africa has become increasingly burdened by the frequent occurrence of extreme weather conditions due to climate change and in Zimbabwe partly by the haphazard land reform at the turn of the twenty-first century. The rapid growth of gold ASM in Zimbabwe and elsewhere in the region is also attributed to the high and increasing gold price in the last decade and especially in the last two to three years. Besides gold and silver, the other significant minerals produced by ASM are: gemstones (diamonds, emeralds, ruby, sapphire and others); base metals (tantalite, chrome, manganese, iron, lead etc); energy minerals (coal and charcoal); and industrial minerals (limestone, kaolin, salt, dimension stones, talc, gypsum and aggregates), ref. Table 2. As is

TABLE 2 | SOUTHERN AFRICAN COUNTRIES WITH ASM NUMBERS AND MINERALS MINED

Country	**Number of ASM**	**Minerals Mined**	**Annual ASM Production as a proportion of national production**
Angola	150.000	Chrome, manganese, kaolin, gypsum, quartz, phosphates, granite, marble, fluorite, sulphur and talc	Unknown
Botswana	12.000	old soda ash and coal	Unknown
Madagascar	500.000	Gold titanium, nickel, chrome, copper, cobalt, ilmenite, rutile, mica, quartz, salt, graphite, zirconium, gemstones, rare earths, marble	Unknown
Malawi	40.000	Lime, coal, graphite, granite/black granite, aquamarine, tourmaline, rubies, sapphire, rare earths and amethyst.	Lime 12%
Mozambique	100.000	Gold, rubies, sapphire, amethyst, rutile,marbles, titanium, ilmenite, zircon	Gold 100%
Namibia	10.000	Diamonds, copper, gold, lead, tin, lithium, vanadium, cadmium, zinc and salt	Unknown
South Africa	20.000	Gold, diamond, manganese, chromium, beryllium, titanium, coal	Unknown
Tanzania	1.500.000	Gold, lime, salt, aggregates, gypsum, dimension stone, diamond, graphite, soda ash, garnet	Unknown
Zambia	50.000	Gold, silver, aquamarine, amethyst, emerald, tourmaline, coal and industrial minerals	Unknown
Zimbabwe	1.500.000	Gold silver, emerald, amethyst, aquamarine, graphite, gypsum, tantalite, chromium, black granite, limestone, and many others	Gold 40-60%

Source: IGF, 2017; Hruschka and Leoben, 2010 typical of ASM elsewhere globally, the subsector in Southern Africa is largely unregulated, unlicensed, poverty reduction livelihood strategy, commonly undertaken in remote areas with scant social services and infrastructure.

ASM and the Environment in Southern Africa

ASM being a poverty driven, largely informal economic activity, which operates outside the state's legal and policy frameworks, is not bound by any environmental as well as safety and health statutes, practices and policies. Most ASM operations therefore will not subject themselves to EIA processes and certification. Numerous unmitigated environmental risks ranging from land degradation, deforestation, air pollution to water pollution and river siltation are common.

Land degradation is due mainly to the lack of both modern mining techniques and appropriate equipment. ASM operates shallow open pits and underground excavations. Pit excavations target shallow reefs or weathered mineralised rubble while haphazard trenching and scarification usually occurs on old mine dumps and "rush sites". The pits and trenches as well as the shallow shafts are often abandoned without backfilling or fencing-off. The result is "bad-land" presenting physical hazards to the miners themselves, other land users and animals. In due course, these pits and trenches fill up with water, becoming breeding media for malaria and bilharzia vectors. Pillar extraction in old mine workings is a popular undertaking in ASM, and oftentimes results in fall of ground injuries and fatalities. The extraction of pillars also results in ground subsidence and/or collapse, creating further death traps for miners, other land users and animals. Very oftentimes the re-entry into old workings results in carbon monoxide poisoning.

Following a mineral discovery, especially high value precious mineral or gemstones, a mineral "rush- site" is rapidly established as large numbers of ASMs gather at the site. The immediate needs for temporary shelter construction, wood fuel and even shaft support will lead to extensive cutting down of trees around the site. The longer the new settlement subsists, the more severe the extent of deforestation. The aggregate effect of deforestation, haphazard pitting and trenching as well as on-site processing leads to significant loosening of the ground and its exposure to erosion. This in turn provides the feed stock for downstream siltation of rivers and small dams with significant reduction of storage capacities for the respective reservoirs. The reduction in storage of reservoirs has often been blamed for perennial floods as well as disrupting fisheries while degrading freshwater quality. Land use conflicts between miners and farmers have oftentimes been the result, with wildlife depletion and migration as side effects. Where such environmental impacts have affected trans-boundary waterways such as the Congo, Zambezi, Limpopo and Shire rivers, it has had the potential to generate significant strife between and among riparian states (Dreschler, 2001 and Shoko, 2002) Suffice to note that a significant number of wars in history have been fought over the use and abuse of common property waterways and freshwater sources.

ASM, similar to its large-scale counterparts, consumes a lot of water and in some cases, such as gold extraction, use process chemicals, such as mercury, cyanide and various salts and acids. These chemicals and their chemical derivatives are often deleterious to aquatic flora and fauna as well as to humans and animals (domestic and wild). A particular water pollution problem is Acid Mine Drainage (AMD), which is common where the ores are sulphide rich. Sulphur, oxygen and hydrogen react to form a range of acids and usually release poisonous metals, such as cadmium, lead, zinc, copper and nickel among others, into the water. These poisonous heavy metals in turn concentrate in aquatic food chains and ultimately humans and terrestrial animals through mainly the ingestion of carnivorous fish. This, together with pH alteration, can significantly alter both aquatic and terrestrial habitats and therefore biodiversity. Mining processes also alter the water table with serious consequences as both aquatic and terrestrial habitats are altered and/or modified. Sometimes the ASM operations can happen coincidentally on wetlands leading to the destruction of these special and varied habitats whose other special function is to act as a sink for pollutants.

The extensive digging and sometimes dry processing of minerals in ASM result in the generation of significant quantities of dust. Very often the mining activities may require some blasting in the pits, resulting in the generation of both dust and noise. Dust has negative growth and productivity effects on crops and may have harmful effects on human health including serious ailments such as pneumoconiosis or silicosis.

ASM and Occupational Health and Safety Risks in Southern Africa

The bulk of health and safety impacts associated with ASM emanate from unsafe mining pits and underground excavations, lack of Personal Protective Equipment (PPE), lack of safe/clean drinking water and sanitation facilities, low levels of hygiene and poor waste management, ref. Table 3. These conditions in turn trigger mine accidents, spread of communicable diseases and air/water pollution related diseases, sexually transmitted diseases, tuberculosis, acute respiratory infections, malaria and bilharzia, among others.

TABLE 3 | PREVALENCE OF HEALTH AND SAFETY RISKS FOR MINERS, THEIR FAMILIES AND COMMUNITIES

	Health and Safety Risks for Miners	**Health and Safety Risks for Families and Communities**
1	Mercury	Water contamination
2	Rock falls and pit collapse	Mercury
3	Ventilation and Respiratory Diseases	Infectious diseases (AIDS, TB, STDs)
4	Environmental and Community Pathogens: parasitic and blood borne e.g. AIDS, TB	Cyanide exposure
5	Ergonomic stresses	Child labour
6	Lifestyle factor	Gender or domestic violence
7	Noise	Landslides – exacerbated by mining activities
8	Limited exits	Abandoned mines – fall hazards for people and animals
9	Traumatic injuries	Lifestyle factors
10	Lack of safety culture, training and PPE	Conflicts between and among local communities and migrants
11	Temporary living conditions (crowded, unsanitary, conflict and scant services)	
12	Conflicts	

Source: Smith, 2016

Several other less obvious health afflictions, such as lower back pain and hearing loss oftentimes hardly get any meaningful documentation in the ASM due the unavailability of primary health care facilities in ASM communities. The third source of health impacts is exacted by process chemicals, such as mercury, mineral acids and cyanide. Commonly, the extremely poorly planned mining settlements result from "boom" mineral discoveries, have limited and crowded working and accommodation spaces. The result of this scenario is poor water and sanitation services, which expose miners and their families to multiple disease threats and infections of malaria, bilharzia, tuberculosis, cholera and other parasitic and infectious diseases.

The remote and sometimes temporary settlements away from any regulatory enforcement are usually breeding grounds for a number of crimes and vices including alcohol/drug abuse and prostitution, which lead to alcoholism, drug addiction, savage fights and murders, sexually transmitted infections and HIV-AIDS. Working areas, particularly in "boom" ASM settlements are haphazardly put together with little or no planning at all. This makes them particularly prone to all sorts of accidents and deficiencies including rock falls, slippage and roof collapse, accidental ignition of explosives, poor ventilation, lack of knowledge and training and obsolete or poorly maintained equipment. The poverty framed nature of ASM may also mean that they often work without basic PPE like helmets, gumboots, face masks, gloves and ear mufflers etc. The effects of overexertion, restricted working space and inappropriate equipment sometimes also results in injury and lower back pain complications (Hinton, 2003).

There are also numerous health risks arising from the open and careless use of mercury, cyanide, mineral acids and the generation of AMD. Mercury is a persistent nervous system poison with links to kidney failure, loss of vision and more seriously, with sterility in man. Mercury is also capable of affecting the unborn child in a mother to foetus transfer as well as through breast milk (Bose O'Reilly, 2020). All these mercury impacts on human health and the environment have been well documented. Gold ASM is the largest human source of mercury emissions globally. The Global Mercury Project (2002 – 2007) was the largest global, United Nations Industrial Development Organisation (UNIDO) led project aimed at an assessment of the extent of mercury contamination in gold ASM, removal of barriers to the adoption of cleaner technologies, building capacity for policy and regulatory formulation and the crafting of economic mechanisms to minimise mercury pollution (UNEP, 2013). The Global Mercury Partnership, under the United Nations Environment Programme (UNEP), formed in 2005, has the goal of protecting human health and the environment from mercury emissions. The Global Mercury Partnership is also assisting stakeholders in ratifying and implementing the Minamata Convention on Mercury. There is a great momentum toward supporting educational initiatives and implementing programs that promote cleaner processing techniques to reduce the risks of mercury in the ASM sector. Mitigating or removing mercury environmental and health risks for gold ASM communities requires a combination of education and awareness, introduction of cleaner technology and appropriate regulatory reforms. Cyanide is a common gold processing chemical, which is very poisonous and in instances where it has been released into freshwater channels and dams it has resulted in the death of domestic animals and wildlife as well as aquatic flora and fauna. This has in turn resulted in serious miner-farmer conflicts. Cyanide, unlike the persistent mercury, is fortunately biodegradable. Mineral acids and those derived from acid mine drainage significantly reduce soil and water pH, thereby generally reducing or modifying natural soil and aquatic habitats for both animal and plant life. This has the overall effect of reducing biodiversity. A cross sectional study in two gold ASM sites in Zimbabwe to evaluate the internal exposure to arsenic, lead and cadmium indicated that a significant number of the 207 miners sampled from Kadoma exceeded the averages obtained from samples of men of comparable age and weight in both Germany and USA. These results demonstrate that the exposure to toxic heavy metals is relevant for public health in Zimbabwe and likely elsewhere where these heavy metals are released into the environment through ASM activities (Rakete, 2021). There is a gender perspective to health and safety risks in ASM. In the "rush towns" the haphazard settlements can sometimes result in working and living areas overlapping. Oftentimes miners will build their family dwellings at the entrance of mine works in order to protect their mine property while restaurants or feeding areas may combine serving food with amalgam burning and gold buying. There were cases in Kadoma, Zimbabwe where dwelling shelters were more hazardous than the mining and processing sites as the former were sites of amalgam burning, making them mercury hot spots. In the circumstances. women and children will be more exposed to mercury risks than the miners. Furthermore, due to the remote nature of most of these operations, children find themselves with no schools to go to and end up helping with the mining activities to supplement family incomes.

Breaking Barriers to Sustainable Mining in ASM

Most of the environmental, health and safety challenges and risks in ASM can be significantly brought under control, with economic empowerment and formalisation of the otherwise informal ASM. Several governments and non-governmental agencies globally have over the years implemented a range of initiatives and programs to reduce the Environmental, Health and Safety (EHS) impacts of ASM with very limited success. Some of the barriers and interventionist programs and policies by governments and non-governmental agencies are listed in Table 4. Clearly the most critical interventions are those that have to do with formalisation of ASM to bring the activity into mainstream formal businesses so it can be regulated by state environmental, health and occupational safety statutes and pay taxes. The major barriers to formalisation in ASM include low productivity (use of antiquated methods and equipment), poverty, lack of knowledge, lack of government interest and resolve.

TABLE 4 | MAIN ASM CHALLENGES AND SUGGESTED MITIGATION REMEDIES

Challenges	Remedies
Policies/regulatory frameworks neglect ASM	Formalisation required
Illegal ASM, makes it impossible to enforce environmental, health, and safety standards	Formalisation, services and microcredit
Lack of training and support for ASM	Formalisation and training by government and NGOs
Perceived trade-offs between making a living and health and safety standards	Poverty reduction through training and awareness raising
Inadequately trained inspectors to supervise and enforce compliance	Training for Inspectors and formalisation
Lack of access to or cash for materials and equipment	Formalisation and microcredit availed
Inadequate knowledge or awareness of risks	Training and awareness raising after
Resistance to outside intervention from government and NGOs	No clear cut benefits, but taxation. Formalisation with benefits
Veld fires and wildlife poaching	Formalisation and policing

Source: Smith, 2016

In large-scale mining endeavours, the management of the environment, health and safety largely relies on governmental regulation of mining companies, institutionally enforced compliance mechanisms, and company policies and procedures. In contrast, Environmental, Health and Safety (EHS) issues in ASM sector have not been fully addressed by governments or regulatory institutions, in part because ASM activities often take place in remote areas outside the bounds of a state’s legal frameworks. Governments have to take the lead in programs, which help and ease the ASM acquisition of mineral rights, avail training programs for ASM to understand basic reef and ore body geology and mineralogy as well as the standard processing stages of crushing, milling and concentration as well as inventory and book keeping (Veiga, 2006). The build-up to formalisation requires precedents, which include building capacity through local institutional partnerships, encouraging miners to form associations and cooperatives, and encouraging large-scale mines to support capacity building programs for their junior counterparts. Further incentives for formalisation would be in the form of microcredits and improving miner's access to more efficient and cleaner production technology and equipment.

Concluding Remarks

The lack of formalisation is perhaps the single most significant hindrance to sustainable mining within ASM and detracts from efficient production, environmental stewardship, improved occupational health and safety performance and inventory and bookkeeping. Some of the major barriers to ASM formalisation are poverty, lack of mining knowledge as well as top-to-bottom policy prescriptions by governments. Governments need to take centre stage in the organisation and financing of the ASM transformation process with the assistance of donor communities and interested foreign state actors. Once formalised, the ASM operations would be subjected to environmental, health and occupational safety laws. This would in turn mean that at the onset of establishing an ASM operation, an appropriate EIA or environmental management plan would have to be done as a prerequisite to commencement of operations. Several ASM experts and organisations have over the years been advocating for the formalisation of ASM as a way of promoting growth in the subsector and more recently by the Artisanal Gold Council.

Children in Russo, Kaduna State. Nigeria.

REMOTE SENSING IN THE SMALL-SCALE MINING SUB-SECTOR DEVELOPMENT IN SOUTHERN AFRICA

By Dr. Abdul-Wadood Moomen, Department of Sustainable Mineral Resource Development, School of Mines and Built Environment, University of Energy and Natural Resources, Ghana

Introduction

Natural resources are endowments of a country, and a locality, which are exploited to improve the national and local economy. The economies of many countries in the world, particularly in Africa, completely depend on the opportunities offered by natural resources. The trend of dependency on natural resources has not changed since the history of mankind. It has rather been exacerbated by many factors such as rapid population growth, 21st century sophisticated lifestyles and increasing technological advancements (UNEP, 2019). Out of the global stock of natural resources, technological advancement drives an overwhelming demand for mineral resources. For instance, globally, the demand for mineral raw materials is expected to increase in response to the needs for low-carbon society, green hydrogen and renewable energy production. Initially, the dependence was mainly on agro-based raw materials, but this has, in later years, expanded to include extraction of minerals. The increasing global demand for mineral raw materials in conjunction with rising prices for gold and other minerals provide incentives for local people to venture into ASM in most parts of Africa, including southern African states (Busia, 2017). As a result, ASM has become part of the basic livelihood activities and an agent of local economic development in many host local communities in southern Africa.

While there are many benefits derived from mineral resource exploitation by the ASM subsector of the mining industry in Africa, there are fundamental challenges. The challenges still facing the African mining sector include its failure to adequately address problems relating to ASM, provide grants relating to research, development and technological information, and provide current and robust data on mapping relevant mineral resources (AMDC, 2014). Remarkably, most Southern African countries, such as Mozambique, have limited systematic geological mapping, which could expose a greater resource base (AU, 2009 and 2011a).

This lack of new geological information is due to inadequate capacity in the Geological Survey Authorities to perform exploration activities and store these in digital Geological Information Systems (GIS). Inadequate geological knowledge increases the risk for potential investors and does not also allow a comprehensive review of the entire spectrum of mineral production in the country, particularly from the ASM subsector. This challenge can be attributed to lack of technology awareness and capacity on the part of Geological Survey Authorities in southern Africa. With underdeveloped human knowledge, inadequate availability of geodata due to low rates of technology awareness and progress, it is impossible to turn the initial factor endowment into a platform for harnessing the full potential of the ASM subsector to improve rural livelihoods, build successful clusters and diversify economies (AU, 2014).

Much can still be achieved in efforts towards harnessing the potentials of the ASM subsector in Southern Africa if the countries are able to rise to the demand of comprehensive geodata. This requires a variety of information for decision makers, ASM practitioners and other beneficiaries. The possible avenues for all countries to tackle this “knowledge infrastructure” challenge, include:

- Applications of evolving remote sensing: This could be facilitated by higher education institutions through technology partnerships and research with regulatory bodies. Remote sensing is needed for the development of niche technological competencies in monitoring ASM activities and in mineral exploration;
- Increased investments in improving geological and mining information systems (resources “knowledge infrastructure”): Develop a comprehensive knowledge of the country’s mineral endowment with remote sensing. Many studies have shown high returns to the state from investment in basic geological surveys in support of ASM development; and
- Update existing geological data (maps and resource inventories): An essential basis for assessing potential, informing investors and granting exploration permits. Updating and extending these data requires the use of modern exploration technologies, techniques and skills that also need to be regularly updated.

Knowledge about the potential value of a resource in the country gives government and regulatory agencies the capacity to engage even with multinational companies in effective mining contract negotiation. The inadequacy of detailed nationwide geological and mineral information has thus disadvantaged many African countries in their land use planning, strategy for mineral exploitation, and contract negotiations (AU, 2011b). A robust and effective source of gathering this information today is remote sensing technology. Thus, remote sensing, which comprises the science of acquiring, processing, and interpreting images and related data from the interaction between matter and electromagnetic energy, has answers to the challenges that Southern African countries face in ASM management and development. Advances in this technology combined with artificial intelligence and increasing computer processing power have permitted the remote measurement of large areas for mineral resource endowment indicators and handling of otherwise complex data (Booysen et al., 2021).

According to the UN (95th Plenary meeting, 3rd December 1986), the general purpose of remote sensing is to improve natural resource management, environmental protection and land use. Remote sensing techniques allow a detailed mapping and monitoring of ASM activities and the development of high-resolution geomorphic models for identifying resource deposits. Application of remote sensing for mineral exploration uses multi-temporal, multi-source and multi-scale approaches, ensuring cost-efficient, and safe monitoring that benefits both industry and regulatory agencies (Booysen et al., 2021). Through this way, it is less burdening for governments to monitor and demarcate concessions for informal ASM practitioners towards formalisation and regulation of their activities. Formalisation processes of the informal ASM subsector has been topical in regional discussions (UNECA, 2011 and AU, 2009). Monitoring initiatives on mitigating negative impacts of ASM activities often focus on land, water, vegetation and society. However, unlike large-scale mining activities, it can be challenging to obtain reliable information about the location and spatial extent of ASM activities. For this reason, a successful and accurate understanding of ASM activities in the landscape relies on a variety of direct and indirect types of information, provided by a diverse sample of practices. Remote sensing is one of such promising approaches for monitoring the environmental stewardship of the ASM subsector (Li et al., 2015).

Remote sensing technologies collect geographic information about ASM sites, such as measuring surface extent, distribution, accessibility, land use, and tailing waste. However, the applications of simple but efficient remote sensing techniques for monitoring the spatial dimensions of ASM activities in Southern Africa and other developing regions is negligible (Adler Miserendino et al., 2013). Few studies have applied remote sensing tools for monitoring activities of the ASM subsector in the landscape in these regions. These tools are mostly applied in the ASM subsector, principally to: (1) evaluate the amount of land cover change and soil contamination caused by ASM; (2) assess the effects of soil contamination on plant growth due to the presence of mercury; and (3) evaluate the extents of water pollution caused by ASM activities by detecting turbidity changes of river streams. For instance, in their study, Barenblitt et al. (2021) find that between 2014 and 2017 approximately 47,000 ha (2,218 ha) of vegetation were destructed in Ghana by ASM activities at an average rate of ~2,600 ha yr−1. With the aid of remote sensing, the World Database of Protected Areas also found that about 700 ha of protected areas have been disturbed by ASM activities in Latin America and Africa.

Despite the recent availability of Earth Observatory data and the plausibility of remote sensing techniques, there has been limited overall progress and success in evidence on the applications of these technologies for addressing the negative impacts and monitoring of the ASM subsector activities in developing countries. Thus, efforts are required to encourage the adoption of remote sensing to give consistent and effective data based on which discussions on the environmental protection, sustainability and livelihood security of the ASM subsector can be built in developing countries.

The following are some questions to be considered in applications of remote sensing for mineral exploration and in support of ASM development in all African countries:

- How can improved geological knowledge help address the challenges of ASM in the country?
- What are the inhibiting factors to the Geological Survey Authority against discharging their responsibilities of providing geodata for precision and sustainable mining?
- Are geological data and information currently accessible by the ASM practitioners in the respective countries?
- What are the barriers to accessing geological data and information by other interested parties, whether regulatory and development agencies?
- How efficiently would geological data and information be used by government to grant concessions to ASM practitioners?
- Is there an existing mechanism for updating outmoded geological data and information?
- How can remote sensing contribute to the strengthening of geological and mineral information systems in mineral resource-rich Africa?
- Has any country developed a comprehensive knowledge of its mineral endowment, which would enable it to make informed decisions on mineral sector development?
- How current is the data, and how can remote sensing compliment in-situ systems to update this data?
- Is the ASM subsector in the respective country knowledge-driven and internationally competitive?

Any attempt to address the above questions would assist Geological Survey Authorities to meet the following specific objectives:

- Help decision makers appreciate the carrying capacity to resource exploitation and returns;
- Protect areas of defined landscape or nature conservation values from ASM developments;
- Educate, demonstrate, and reassure the public on efforts to harness potentials of ASM;
- Develop a comprehensive mineral information and geodatabase for the respective country: discovering viable resources, based on mineral occurrences, for tender, monitoring and as a marketing window for ASM resource potential;
- Establish spectral signature records for different minerals to provide continuous support in the image-processing of up to-date satellite images for improving existing databases;
- Significantly enhance mineral prospectivity and increase ASM subsector development;
- Reduce the costs burden of in-situ methods of mineral exploration; and

- Formulate strategic plans for sustainable and rational development of the ASM subsector.

In this regard, investing in geological mapping, data collection and geological information system infrastructure is critical for southern African countries. Remote sensing is needed for mapping, monitoring, evaluation, exploration, resource conservation, and contract negotiation purposes, among others.

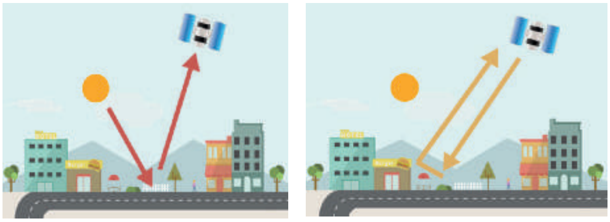
Remote Sensing for Monitoring ASM Activities

According to Lillesand et al. (2015), remote sensing comprises the set of methods scientists and practitioners use to obtain images or record electromagnetic footprints of Earth's surface materials from a distance, process and interpret these images and footprints of the Earth's surface. According to Campbell and Wynne (2011), remote sensing is the method of acquiring information about the features or activities on the surface of the Earth, including water and land, using a source of energy and sensors. RS, thus, is the detection and recording of the Electromagnetic Radiation (EMR) of the Electromagnetic Spectrum (EMS) from target areas in the field of view of a sensor instrument. The EMR could originate directly from separate components of the target area or activity, or reflection of solar energy from them. EMR may also be reflections of energy transmitted to the target area from the sensor itself. Components of the EMR that contain information regarding the illuminated target are known as spectral bands. There are multispectral and hyperspectral bands. These would be discussed later. To acquire information about the Earth's surface, the sensors are placed on a holder, denoted a "platform". Examples of platforms include the stationary tripod for field observations, stationary balloon or mobile aircrafts and spacecrafts. Generally, these examples are grouped into: 1) ground; 2) air; and 3) space borne sensors. The platform is determined by objective, resources, and constraints of the observation mission.

Based on the source of energy used by the sensors in data acquisition, remote sensing can be categorised into two types, known as active and passive remote sensing, respectively, ref. Figure 9. Active remote sensing methods provide their own source of EMR to illuminate a target or landscape. Examples of Active remote sensing include Radar, Lidar, Laser Altimeter and Photographic camera using its flashlight to acquire images. Active sensors mostly work in microwave regions of the EMS, have the ability to penetrate clouds and are not affected by rain. In particular, an Active Sensor sends a wave and measures the backscatter reflected back to it. With this capability of active sensors they have an advantage of accurately mapping ASM activities in rainforest areas, which are otherwise too obscured by clouds and rain. Active remote sensing systems are also capable of providing images in both day and night, under all-weather conditions. This gives them a unique capability to map landforms, vegetation, water, soil, and crop health around ASM sites. Passive remote sensing methods do not have their own source of energy but detect radiated energy or energy naturally reflected from the area being observed. That is, passive sensors measure reflected sunlight emitted from the sun. When the sun shines, Passive Sensors measure this energy. Examples of passive remote sensing include infrared, radiometers, Landsat, ASTER, Sentinel images, and film photography usually employed during fieldwork.

However, photographic cameras are both active and passive sensors. That is during a bright sunny day enough EMR illuminates the targets and reflects to the camera lens. The camera lens simply records the radiant energy illuminated. In that sense, the camera is in a passive mode. Under the circumstances where there is insufficient sunlight to illuminate the target adequately, the camera uses its flashlight to emit energy, illuminate the targets and record the radiation reflected from the targets. This is the process of an active mode, ref. Figure 7.

FIGURE 7 | ACTIVE AND PASSIVE SENSORS



PASSIVE SENSORS ACTIVE SENSOR

Image Credits: RawMatCop

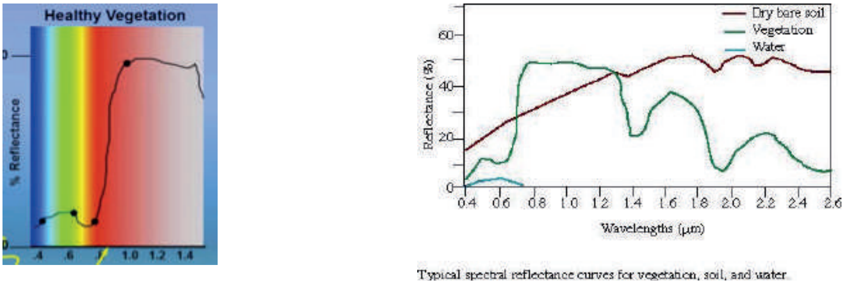
Since the enactment of the Minamata Convention on Mercury in 2013 and its subsequent activation in 2017, Party States are required to develop and implement effective National Action Plans (NAP) showing how they intend to monitor the use of mercury in ASM. In this regard, monitoring of the environment is mostly based on integrated approaches that include analysis of mercury intensity in water bodies and soils using remote sensing. Remote sensing is crucial for monitoring the ASM subsector where mines are often found in the most remote and inaccessible sectors of the country. The evaluation of water pollution relies, instead, on the quantification of water turbidity, which is usually derived using specific multi-band indexes and can be analysed with image-classification techniques (UNODC, 2016). Remote sensing data can be integrated with environmental data to generate more accurate results and better analyse the influence of the mining process on the biota / mercury content in the environment. Water turbidity can be used as a proxy for mercury detection in water if the remote sensing data is combined with in-situ water sample data taken on specific dates that correspond with the available remote sensing data.

In a project run in Colombia (UNODC, 2016), additional data were derived from the results of the remote sensing study such as: 1) the direction of expansion of the mining sites through time; 2) the amount of people being affected by the polluted waters resulting from the mining activity; and 3) the coexistence of illegal cultivations and ASM sites. This could be done by: 1) analysing time-series data on mines size and location; and 2) integrating external GIS data, such as the delimitation of watersheds, gridded population data, and the location of illegal cultivation spots. The identification of mining sites using remote sensing data generally relies on a land cover analysis, which is contingent upon applications of image-classification algorithms to pre-processed multispectral imagery (Barenblitt et al. 2021 and UNODC, 2016). For instance, the location of mining sites from existing datasets or from fieldwork can be used to train supervised classification models. It can also be used to refine the results of the model with the assumption that the absence of a mine in recent high-resolution image[1] implies the absence of mining activities even in the past.

The identification of mining sites using remote sensing data may involve manual inputs, especially in the data preparation and post-classification steps. Manual editing of the results of classification models is generally observed in government and in UN-managed projects as compared to research projects. This observation is common in the post-classification of the workflow in order to best differentiate bare soil land cover type from mines as the two have a similar spectral composition. In some cases, the process of identification of mining sites is completely based on visual identification on aerial photos and satellite imagery from Google Maps and similar providers, or on bands-compositions from multispectral data. The use of remote sensing in monitoring of ASM activities relies heavily on the identification of the spectral signatures of Earth surface materials around the mine site. Surfaces interact with the EMS and in this interaction, every Earth surface material has a unique portion of the spectral bands that it reflects. Vegetation, for instance, looks green because it is mainly the green portion of the EMS that is reflected, ref. Figure 8.

[1] Resolution refers to the smallest unit area an object or detail can be represented in an image. Spatial resolution refers to the size of the smallest possible Earth surface feature that can be detected by a sensor. That is the size of one pixel on the ground. A pixel is that smallest "dot" that makes up an optical satellite image and basically determines how detailed a picture is. High resolution means that pixel sizes are smaller, providing more detail. With high resolution images, small objects can be detected. For example, 30cm resolution satellite imagery can capture details on the ground that are greater than or equal to 30cm by 30cm

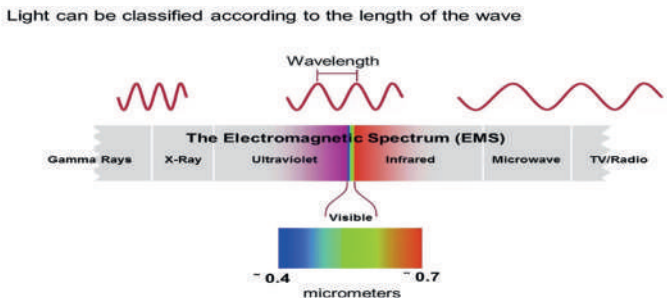
FIGURE 8 | TYPICAL SPECTRAL SIGNATURES OF VEGETATION, SOIL, AND WATER



Source: https://science.nasa.gov/ems/01_intro

Remote sensing was originally not considered as an important tool in mine management and planning. But now, it has emerged as an inevitable methodology to better understand the scale and support the development of the potentials of ASM, especially, image classification for monitoring. Image classification techniques require skills that are currently lacking in the Geological Survey Authorities of most developing countries. The use of non-automated remote sensing steps in monitoring projects, for instance, is a result of: 1) the fact that algorithms for multispectral image classification techniques are generally not automated; and 2) challenges of application scientists with the use of these algorithms.

FIGURE 9 | ELECTROMAGNETIC SPECTRUM ESSENTIAL FOR OPTICAL REMOTE SENSING



Source: https://science.nasa.gov/ems/01_intro

Remote Sensing Techniques for ASM Monitoring

The methods of analysing remote sensing data include spectral, spatial, contextual, pixel-based, object-based, and knowledge-based analysis. Optical remote sensing accounts for the visible, near infrared and short-wave infrared parts of the electromagnetic spectrum as shown in Figure 9.

Optical remote sensing is recorded by sensor systems mounted on navigational platforms, such as satellites. The sensors detect incident radiation reflected from targets on the Earth's surface. As various materials are characterised by their specific reflectance spectra (albedo) the target can be differentiated from their reaction to certain wavelengths bands of the EMS (spectral signature). Thus, based on amount of wavelength bands and spectral properties, optical remote sensing data are classified into multispectral and hyperspectral images. Examples of multispectral images include ASTER, Landsat 4-5 TM; ETM+; Landsat 8 OLI, and Sentinel-2 MSI. Examples of hyperspectral missions are currently being tested, such as PRISMA, or are planned, such as ESA's CHIME and NASA's SBG. Hence, for land use and cover classification for ASM monitoring, currently, multispectral images are commonly used. These data are usually available as pre-processed images, especially from Landsat and Sentinel. However, the availability of pre-processed images varies depending on location and date. Where pre-processed data is not available, the end-user needs to carry out certain corrections on raw data before use. Pre-processing functions involve operations on a raw image which are required prior to processing and extraction of relevant data. These functions are generally grouped as radiometric and geometric corrections (Campbell, 1996).

Radio metric corrections include correcting the raw data for sensor irregularities and removal of unwanted sensor or atmospheric noise. It also involves conversion of the data to ensure accurate representation of emitted or reflected radiation as measured by the sensor. Geometric corrections include correcting for geometric distortions due to the sensor-Earth geometry variations. This also comes with conversion of the raw data to real world coordinates on the Earth's surface. Depending on the techniques adopted for optical image analysis cloud cover can be a hindering factor. Thus, cloud cover and shadow detection are crucial prior to using the imagery, particularly for cases of ASM site detection and monitoring. For instance, the footprints of bare excavated areas have relatively high reflectance but when coupled with water ponds in some areas of ASM activities, cloud and cloud-shadow detection can become challenging. Under such cases, radiometric corrections must be performed on the image. Once atmospheric or radiometric corrections are done, and imagery is analysis-ready, various image processing techniques can then be applied to extract the desired information. Applicable techniques are diverse and include image classification (supervised and unsupervised), image transformation using indices, and feature targeting techniques. Image processing algorithms that are essentially applied are: pixel or object-based techniques, Artificial Intelligence

(AI), such as simulated and annealing classifiers, Machine Learning (ML), artificial neural networks, and fuzzy logic classification systems.

General Approaches to Image Classification

Image classification is the process where each pixel of an image is put into a nominal class. The input for this processing is a multiband image and the output is an image with cells representing thematic codes. The results after an image classification is a vegetation map, land use map or other maps from the grouping of related features. Categories in image classification are defined by the intended use of the output. It can be few or many categories, depending on the purpose of the map and available resources. It is, therefore, important to note that image classification is not a one-size-fit-all method in remote sensing. The choice of classes and techniques is contingent upon but not limited to: 1) the objective of the study; 2) image data accessibility for the area of interest and objectives; and 3) availability of and access to relevant image processing software.

In the past, the commonly used approach to land cover mapping was through a pixel-based image-classification model using machine-learning algorithms. Classical examples of pixel-based algorithms are minimum-distance/nearest neighbour, parallelepiped and maximum likelihood classifiers. These are available on the IDRISI software. Note that a major challenge with the pixel-based image classification methods is that features with similar spectral properties, such as open mines with bare soil and mine ponds with isolated water bodies are easily misclassified. However, this challenge can be addressed using object-based classification approaches, which account for the spatial context.

In object-based image classification, the algorithm starts with segmentation before classification, which is usually done on high resolution images. In segmentation, homogeneity of pixels and spatial contingencies determine image objects delineation and classification. That is, continuous objects and contiguous objects are grouped in the same category. Objects are then classified using visual techniques such as colour, texture, form, and context properties. The standard nearest neighbour classifier and fuzzy membership functions are then used to classify the image. In cases where high level accuracy is required both algorithms can be used in the classification. Under such circumstances, object-based approach is efficient in the classification algorithms in highly homogenous features with a unique shape and topography. The choice of parameters to use in initial segmentation is critical and can dramatically affect the results of the classification algorithm. The major challenge with this approach is its inability to produce high accuracy in case of: 1) non-availability of a near perfect segmentation; and 2) non-availability of a high spatial resolution image. It, however, works well on images with pre-defined boundaries. This means that it is not suitable for classifying highly complex and heterogeneous areas with no clear boundaries.

ML algorithms are generally chosen for image-classification models in remote sensing applications because of their capability to model complex class signatures, accept a variety of input predictor data, without necessarily prior knowledge of the data distribution. ML algorithms operate both supervised and unsupervised learning. On supervised learning, the operator feeds the model with training data. Training data can be obtained by integrating field reconnaissance with local knowledge ("collaborative mapping") and or a visual interpretation of very high-resolution imagery. Unsupervised learning does not require trained data but runs using a smaller portion of the area that should be classified. The model is allowed to run its own iterations on that data without any supervision. Examples of ML algorithms that are mostly used in multispectral image-classification include Random-Forest Classifier, Support Vector Machines, Decision Trees, and Artificial Neural Networks. Recent studies suggest that the Convolutional Neural Network (CNN) has high precision rates on land cover classification with omission and commission errors as low as 8%. However, there is still a limited amount of literature on CNN for land cover mapping since it is still an emerging tool (Gallwey et al., 2020).

Input Data for the Models

Classification models do not often require a wholesome spectral information before they operate. Rather, the most appropriate band selection process is required for enhanced performances of the model in terms of costs and accuracy of the results. For instance, a case study in Southwest Ghana has shown that the Band 5 of Sentinel-2 is the highest contributor to the overall accuracy of land cover classification and delineating mine sites in that part of Ghana (Nyamekye et al., 2021). In some cases, multi-band indexes, such as the Normalised Difference Vegetation Index (NDVI), are used as input data in the models (Nyamekye et al. 2021; Barenblitt et al. 2021). But, when using NDVIs as input data, take note that these can be influenced by environmental factors such as topography, bare soil, atmospheric conditions, vegetation association, rainfall and non-photosynthetic materials. Under these circumstances, the operator may have to use other indexes, such as Soil Adjusted Vegetation Index, Modified Soil Adjusted Vegetation Index and Transformed Soil Adjusted Vegetation Index. To identify mining hotspots along rivers and other waterbodies, the appropriate bands and indexes that could be used include the Modified Normalized Difference Water Index (UNODC, 2016), Band 8A - VRE 4 and Band 3 (Green) of Sentinel-2-A (Nyamekye et al., 2021), bands (4,3,2), (5,6,4) and (6,5,2) of Landsat 8 for distinguishing deep water from shallow water, water from ground, and bare ground from ponds (UNODC, 2016).

Post-Classification Methods to Refine The Models' Results and Change Detection

At the post-classification stage, correlations and similarities in the spectral properties of features that are misinterpreted by the classification model are corrected with automated models or manual operations. For instance, Ibrahim et al. (2020)

used automated proximity analysis on the output data of a model to refine the interpretation of feature classes that were difficult to interpret and the results are robust. In an automated process, “isolated water bodies” that were in proximity to pixels initially classified as “open mines” were reclassified as “mine-ponds”. Also, “open mines” initially classified as “isolated water bodies” were reclassified as “bare-soil”. Pixels that usually experience land cover variation due to seasonal variations can be clustered if typical seasonal change effects on time-series data can be determined. This is done through a sequential pattern analysis on time-series data to detect the high frequency land cover change and associate them with seasonal effects rather than the effects of ASM activities (Ibrahim et al., 2020).

As the spectral signature of bare-soil and open mines is relatively similar, in dry environments like Botswana the detection of illicit ASM or trespassers is usually a challenge. For this reason, a morphological profiling can be used, which can better differentiate mining sites from bare-soil due to its ability to delineate edges effectively on high spatial resolution imagery. Morphological profiling has the ability to isolate bright and dark structures in images. It explores different ranges of spatial domains as well as brightness and darkness contrasts. Hence, it is easy to distinguish non-vegetated from vegetated areas. NDVI could also be used at this stage to reduce the uncertainty over land cover changes after the determination of a threshold that separates seasonal change influence from artificial influence. Manual decisions depend on visual identification of critical features, which are located proximal to the misinterpreted features (UNODC, 2016). The output images of classifications are then used to determine land cover changes in the area of interest through time and calculate the contributions of ASM activities to observed changes. To do this, change detection process is performed over pairs of output images of land cover from a previous year to another.

Defining a Reference Period for Monitoring

As explained by Jenkins (2004), mining issues are localised and cannot be generalised. To address this would require dynamic approaches. Thus, there is no standard reference period for monitoring ASM in all cases around the globe. The most suitable monitoring period depends on local factors, such as the objective of the study, the type of mining activity (e.g., alluvial vs bedrock mines), and other environmental conditions. Nevertheless, the use of remote sensing data, especially, the Data Cube, allows one to analyse the situation in retrospect using one of the available datasets of the area of interest in a given period. This makes it possible to monitor the impacts of a government action towards sustainable ASM over time. That is, observing baseline conditions in the year preceding the action and the year subsequent to the action. This is generally done across a relatively short time period, e.g. every 2 years. Illicit ASM activities are nomadic and sites are created sporadically and abandoned within a period of months. This phenomenon is notably common to alluvial ASM along rivers. Also, vegetation regrowth poses challenges to the detection of abandoned ASM sites after some time. Therefore, frequent or real-time monitoring is recommended, if possible, rather than simply comparing two datasets, which are far from each other with respect to time. As explained earlier, seasonal changes affect spectral signatures of vegetation. To enhance robust monitoring, datasets across different reference times should be selected from the same season (Gallwey et al., 2020).

Depending on the selected source of satellite data, the period for monitoring can be constrained by availability of data. For instance, the first Landsat satellite was launched in 1972. It is impossible to get Landsat data covering any part of Africa in the early periods of the launch. Similarly, the production of Sentinel-2 data only started in 2015. It is, therefore, untenable to monitor land cover changes with Sentinel-2 data in the 1990s. In terms of frequency of image availability in a given place, while Landsat 1–3 repeats the cover cycle of the Earth every 18 days, Landsat 4, 5, 7 and 8 have a coverage cycle of 16 days, and Sentinel-2 images cover the entire globe every 5 days.

Database Development and Monitoring of ASM

Using remote sensing for environmental monitoring can be a complex activity. However, to build a database of ASM, two methods are available: technical and non-technical.

- Technical methods require the use of remote sensing technologies to detect the presence of ASM using bare soils, sediments, and water turbidity; and
- Non-technical methods include participatory community-based monitoring of the ASM activities. These methods are typically more sustainable as they have knowledge transfer and contribution of local communities through active engagement of ASM practitioners.

Time-series multiple-scenes satellite imagery are crucial for monitoring landscape transformations instigated by ASM. Image classification techniques can be employed to delineate distinctive land-cover classes in mine sites for database development. These classes may include affected water in ponds and pits, mining sites and associated excavated soil. With reference to the different kinds of classification methods presented already, variables that can be used to build databases include: 1) spatial dynamics; 2) biogeochemical parameters; and 3) community-based information. Database building using either technical or non-technical or a combination of both methods, planned and executed in a coordinated manner, can establish links between the three variables. To this end, the following protocols may be considered:

- **Identify source of pollution to track the specific location where the ASM is taking place**: Depending on the objective of the monitoring, availability of resources, and accessibility of the area of interest, the most appropriate remote sensing data source should be selected, ref. Table 5. An integrated use of fieldwork, sampling trips and utilising Indigenous Knowledge (IK) during fieldwork helps in image training and data calibration;

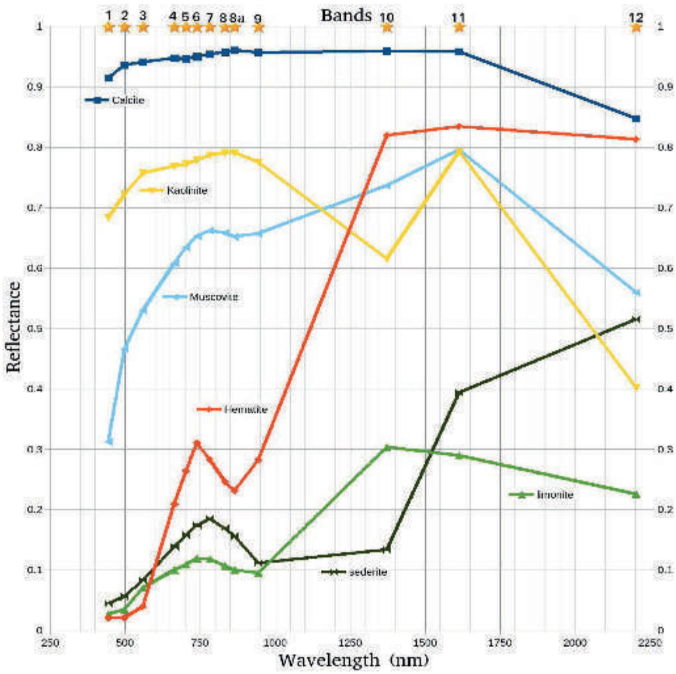
- **If seasonal changes would affect image training and classification, use statistical methods to quantify this phenomenon:** In case of dry environments, like the case of Mozambique, Botswana and Namibia, morphological analysis could be helpful in further separating bare soil from mining sites. This is especially useful in case of bed-rock mines as they are likely to feature a depressed morphology compared to the surroundings. However, its impact is negligible in alluvial mine detection along river burdens and banks;
- **Identify potential contaminants in the case of water and soil:** This entails a basic idea of the physical and chemical properties of environmental and geological features of the area as may be contained in remote sensing. Recognition of the spectral signature of mercury, healthy soils, healthy vegetation, and clear water helps in differentiating between, for example, acidic soils and water on one hand, and mercury contaminated soils and water on the other hand;
- **Conduct laboratory test analysis of water and soils as detected above**: To understand the laboratory results, seek expert opinion or IK, which are good sources for RS training data and results validation. These protocols are suitable for sensing contaminants at ASM sites; and
- **Assess the spatial associations of mining activities to map hotspots of possible chemical contaminations:** This leverages the potentials of the Africa Regional Data Cube for remote sensing data retrieval.

A historical analysis of remote sensing-driven baseline conditions of existing and previous ASM sites would facilitate linking spectral signatures of samples from trees and shrubs to satellite data. For instance, mercury contamination produces a unique colouration in the spectra of vegetation. Using historical data, it is possible to identify abandoned ASM sites. Such sites are mapped as hotspots of chemical pollution due to accumulation of mercury and acid in soils and in both underground and surface waterbodies. Historical images show the baseline conditions of a host region prior to ASM. While current image scenes can provide information for detection of the growth of ASM and its related effects, modelling of the same scenes enhances simulations of future scenarios of ASM. Changes detected from these can enhance awareness of the extents of ASM active operations in near real-time. Thus, a combination of historical and current satellite together with simulation models, such as CNN, provides a strong promise in this perspective.

Remote Sensing for Geological Mapping and Mineral Exploration

Remote sensing is used to identify mineralised areas worthy of further investigation for deposit identification. Remote sensing is applicable for rapidly characterising many of the alteration zones associated with economic deposits. Mineral exploration is a sequential process of information gathering to find ore or mineral deposits in commercially viable concentrations. Exploration is a risky business and can be costly. In order to minimise this risk, it is crucial that you have an accurate process to select an area. Many pure mineral materials can be recognised in remote sensing by the position, depth, and shape of their albedo. To this end, investigations begin with two mutual approaches: 1) Image-based; and 2) field-based approaches. With image-based approach, data should be corrected for effects originating from the sensors, the platforms on which they are deployed, atmospheric characteristics, and geometrical constraints. After calibration, image-based data could be used for mineral exploration in two major ways: 1) mapping geology and the faults and fractures that localize ore deposits; and 2) detecting and mapping hydrothermally altered rocks by their spectral signatures, ref. Figure 10. That is, image-based data can be used to discriminate different lithologic units, trace major structural lineaments, and detect alteration zones and gold sulphide precipitation.

FIGURE 10 | ROCK SPECTRAL SIGNATURES



Source: https://crustal.usgs.gov/speclab/SNTL2.php

Unlike in-situ methods, field-based RS techniques are non-distractive. This includes random field surveys. For field surveys, sampling and data calibration, Participatory Rural Appraisal (PRA) and IK techniques are deployed. A major advantage of PRA and IK methods is that existing and past mineralisation of communities can be inventoried and adequately mapped through informed members and ground truthing (Calinger et al., 2015). However, the method is time consuming and labour-intensive. To address this challenge, the investigator has to: moderate group discussions; clarify the field objectives; and coordinate analysis for proper time and labour management.

Mineral Detection

For mineral detection, image processing steps are the same as those described under monitoring. These include atmospheric and geometric corrections, feature extraction, and image classification. The commonly used image processing methods for mineral detection are spectral enhancement methods, such as the Band Ratio, Band Combination, Principal Component Analysis, Independent Component Analysis, Minimum Noise Fraction, and Decorrelation Stretch, and supervised automatic classification methods, such as the Spectral Angle Mapper, the Support Vector Machine, Random Forest, Matched filter, Maximum Likelihood classifier, Linear Discriminant Analysis, Artificial Neural Networks, and K-Nearest Neighbours. Others include false colour composite, fast Fourier transform, and redundant wavelet transform. It is observed that pixel-based classification can produce accurate alteration mineral and geological maps of different locations (Peyghambari and Zhang, 2021). Mineralisation is often characterised by an induced polarisation and resistivity response. Most ore bodies have good electrical conductivity. These features can be mapped using the above mentioned techniques.

ML algorithms, such as Artificial Neural Networks, Support Vector Machines, and Decision Tree, are employed for analysis and classification of data. Band Radio is a technique in which the Digital Numbers (DN) of a band are divided by the DN of another band. The ratios are based on the peaks and troughs of a reflectance curve. Usually, the band with higher DN is divided by a band with lower DN. This method is useful for identifying certain features or materials that cannot be seen in raw bands. The Principal Component Analysis (PCA) is a multivariate statistical technique used to enhance and separate certain types of spectral signatures from the background. PCA is a widely used method in mineral exploration, especially, for alteration mapping. Generally, PCA is used for iron oxide and hydroxyl mapping. PCA is, generally, not used for enhancing spectral reflectance features of geological materials. Rather, it is used for suppressing irradiance effects that dominate all bands of a multispectral image. Iron, bauxite, copper and gold deposits are commonly hosted by metamorphic units from the Archean to recent times, but mostly in Proterozoic. PCA is found to be useful in mapping these minerals.

With PCA, multispectral remote sensing data, such as Landsat Thematic Mapper and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) can be adopted to extract rock alteration information. Such information in scanty vegetation coverage areas could be detected with ASTER data (Zhao et al., 2021). Optical and radar remote sensing data are fused and used to identify lithological units and geological structures. This is effected using Landsat Enhanced Thematic Mapper Plus and ASTER data. Near-surface structures will be mapped using RADARSAT data. Hill-shading techniques can also be combined with Digital Elevation Models taken from Shuttle Radar Topography Mission to enhance terrain perspectives, extract geomorphological and morphologically defined structures. Applying hyperspectral images, alteration zones are mostly detected by finding alteration mineral assemblages. But interpreting alteration mineral maps is often complicated by surface materials and by minerals not directly associated with alteration. To address this challenge, ASTER, Landsat OLI, Sentinel-2 images and high resolution data could be used.

Hyperspectral remote sensing is capable of capturing spectral properties effectively. The spectrum may be used to invert the mineral composition information and identify it. Minerals and rocks mostly have diagnostic spectral absorption bands in spectral range of 400 – 2,500 nm. Hyperspectral remote sensing can effectively capture these spectral characteristics. The HyMap airborne hyperspectral scanner provides 128 spectral bands between VNIR and SWIR wavelengths (0.45–2.5 μm). It transcends any currently operational orbital multispectral sensor for mineral mapping in exposed areas. HyMap was successfully used in the Warmbad district, South of Namibia, to map rock and alteration mineral. Hyperspectral image mineral spectral classification technologies generally can be divided into two types: the first type refers to the spectral matching method based on similarity measurements between rebuilt spectra and standard spectra; the second type is the pattern recognition method based on parameters of the spectral absorption band. The spectral matching method, represented by spectral angle mapper and support vector machine, is evidenced to have significant advantages in mineral classification (Martin et al., 2015). These should be used for mineral segmentation and signature appraisals.

Sources of Remote Sensing Data Acquisition

Given the nature of ASM, governments require extensive data resources and analysis to monitor and enforce applicable laws and policies. There are two principal sources of primary data for ASM monitoring. These are: 1) image-based; and (2) field-based sources. Image-based primary sources of data include but are not limited to multispectral satellites. Several major sources of multispectral images as are summarised in Table 5. Commercial high resolution and free source multispectral and hyperspectral satellite images are acquired and used to detect, map and analyse hydrothermal alterations and gold mineralisation in the areas of interest. Most data sources require subscriptions fees and others are free to download. Examples of free sources include: United States Geological Survey Earth Explorer, European Space Agency's Copernicus Sentinel Repository, ESRI Open Data Hub, NASA's Socioeconomic Data and Applications Center, UNEP Environmental Data Explorer, Natural Earth, Africa Regional Data Cube, Japanese Aeronautics Exploration Agency, Global Earth Observation System of Systems, and Conservation X Laboratory, and regional governments' databases. The subscription-based data sources include: QuickBird, French SPOT, and IKONOS. These provide high resolution satellite images. Examples of categories of data that can be obtained from both free and commercial data sources include: the Landsat Enhanced Thematic Mapper Plus, ASTER, ASTER-Derived Global Digital Elevation Model, Sentinel-2, Light Detection and Ranging, SPOT-2, China–Brazil Earth Resources Satellite Program, and QuickBird. These require high speed and processing powered computers with sufficient storage space. Both specialised commercial and free software applications for image processing and analysis should be acquired for optimum results.

Landsat ETM+ has a wide observation range and consists of bands which are effective for mineral exploration. They include four Visible-Near Infrared bands, two Short Wave Infrared bands (spatial resolution 30 m), and one Thermal Infrared band (spatial resolution 60 m). Landsat series of remote sensing satellites, e.g., Multispectral Scanner, Thematic Mapper, and ETM+ are used to map hydrothermal altered rocks. ASTER has three optical sensor subsystems with a total of 14 bands, a swath width of 60 km with spatial resolutions of 15, 30, and 90m, respectively. ASTER has been used successfully for mineralisation mapping due to its narrow spectral bands. The data produced mineral maps, which are useful for reconnaissance mineral exploration.

TABLE 5 | SOURCES OF REMOTE SENSING DATA

Database/ Provider	Cost per tile / Km^2	Type of Imagery	Website of Provider	Spacecraft / Data Frequency	Scope
Google Earth	Free Access	High Resolution	https://earth.google.com/web/	Largely from airplanes and satellite. Available 3-4 years.	Global
ESA Sentinel Hub Copernicus Open Access Hub	Free Sentinel-1/2 images.	High/Medium Resolution	https://www.sentinel-hub.com/ https://scihub.copernicus.eu/	Satellite. Every 5 days	Global
NASA/USGS	Free access Licensing for commercial use required	High/Medium Resolution - Landsat, MODIS, and ASTER data Hyperspectral	https://earthexplorer.usgs.gov/	Satellite. Every 7 days. Aerial, and UAV	Global
NOAA	Free Access	GEOS-R and NOAA-20 data. Very low resolution (250m and above)	https://www.nesdis.noaa.gov/content/imagery-and-data	Real-time satellite data. Every 15 minutes	America
Earth on AWS	Free Access	Medium Resolution. Sentinel-2, Landsat-8, GEOS, NOAA, Sentinel-1 and China-Brazil Earth Resources Satellite (CBERS)	https://aws.amazon.com/earth/	Satellite. Every 7 days	Global
Zoom.Earth	Free access for non-commercial applications	Near real-time satellite data and high-resolution archival data	https://zoom.earth/	Every 10 minutes from NOAA GOES and JMA Himawari-8 satellites, and every 15 minutes via EUMETSAT Meteosat satellites	Global
NASA WorldView	Free Access	Low Resolution, open data only	https://worldview.earthdata.nasa.gov/	Near real-time satellite data	Global
NASA Earth Data GIBS	Free Access	Low Resolution, open data only	https://earthdata.nasa.gov/eosdis/science-system-description/eosdis-components/gibs	Available within a few hours after satellite observation	Global
Remote Pixel	Free Access	Landsat 8	https://search.remotepixel.ca/	Satellite. 5-7 days.	Global

Database/ Provider	Cost per tile / Km2	Type of Imagery	Website of Provider	Spacecraft / Data Frequency	Scope
INPE Image Catalogue	Free Access	CBERS-4, alongside U.S., UK, and India's Earth-observing missions: Aqua, Terra, Landsat-8, ResourceSat, Suomi-NPP, DEIMOS, and UK-DMC 2	http://www.dgi.inpe.br/catalogo/	Satellite. 5-7 days	South & Central America Africa
JAXA's Global ALOS 3D World	Free Access	30m Horizontal Resolution; DSM, SRTM HGT	https://www.eorc.jaxa.jp/ALOS/aw3d30/l_map_v2003.htm	Satellite. Every 7 days	Global
VITO Vision	Free Access	Proba-V, Spot-vegetation, Sentinel-2, Metor-AVHRR, Envisat-Meris). Resolution: 100m to 1km	https://vito.be/en	Satellite. 5-7 days	Global
Digital Globe Open Data Program	Free Access	High Resolution	https://www.digitalglobe.com/company/about-us/	Satellite. Daily image capacity of more than three million km^2	Global
Geo-Airbus Defense	$30-40	Very High Resolution, SPOT, Pleiades, RapidEye, TerraSAR-X, 12-meter World DEM	https://www.airbus.com/space/earth-observation.html	Satellite. Daily a nd on demand	Global
SPOT 6/7	$5-8	High Resolution	https://eos.com/find-satellite/spot-6-and-7/	Satellite. Daily. On demand	Global
KOMPSAT-3A	$15-48	Very High Resolution	https://www.satimagingcorp.com/satellite-sensors/kompsat-3a/	Satellite. Daily. On demand	Global
WorldView	$18-52	Very High Resolution	https://www.satimagingcorp.com/satellite-sensors/worldview-3/	Satellite. Daily. On demand	Global
QuickBird	$10-50	Very High Resolution	https://www.satimagingcorp.com/satellite-sensors/quickbird/	Satellite. Daily. On demand	Global
IKONOS	$25-50	Very High Resolution	https://www.satimagingcorp.com/satellite-sensors/ikonos/ikonos-stereo-satellite-images/	Satellite. Daily. On demand	Global

Software Applications for Remote Sensing Data Processing

In order to choose a data product for a given project, a remote sensing data user must be aware of the different products, their applications, and availability of relevant software for data processing. Remote sensing software is a digital processing tool for remote sensing data. The software enables the creation of geographic information from Earth Observatory and airborne sensor data. Numerous software and tools abound for the processing of these data. These include: ERDAS IMAGIN, ENVI, ILWIS, IDRISI, Orfeo ToolBox (OTB), SNAP, Multispec, ArcGIS, and QGIS. Among these, only OTB, SNAP, Multispec, and QGIS are open-source software. But open-source packages in R programming and Python are available. The software is capable of performing many functions including change detection, spectral analysis, and image classification. However, it requires high speed and processing powered computers with sufficient storage space, since this involves handling of large datasets, especially in the case of time-series analysis. Hence, cloud computing has become crucial and includes Google Earth Engine, the Open Data Cube, OpenEO, and Sentinel Hub using Python, R programming, and JavaScript APIs. All of these have their benefits and constraints. Thus, several platforms offer pre-processed satellite data with the possibility to combine multiple images into mosaics. The platforms include Google Earth Engine, Microsoft Planetary Computer, Food and Agriculture Organization and SEPAL.

Conclusions

Remote sensing techniques have unique capabilities and resources for addressing some ASM-related issues. Remote sensing techniques allow a comprehensive understanding of resource potential and extraction, and the environmental impacts of legal and informal ASM operations, especially at local scale. Integrating remote sensing tools when monitoring ASM activities can alert governments and communities of the need to increase security, to create a path towards socially and environmentally responsible ASM, and to move towards safe and environmentally sustainable mining practices. However, the current regulatory and policy frameworks for monitoring activities of the ASM sub-sector in Africa needs reform and there is a need for information for inclusive policymaking and implementation. This includes appropriate extraction of the ore body. A good knowledge base is the backbone to formulate and implement appropriate policy decisions to address the problems associated with ASM in Southern Africa. Using remote sensing technologies with analytical and non-analytical monitoring techniques that integrate remote sensing data, field work/measurements, and knowledge of the local population could be a good starting point.

Since the last decade, most studies have used Landsat data to analyse land cover changes through time, given data availability since 1970s. In recent times, the availability of satellite imagery per region and resolution is growing. Among the freely available data, the Copernicus Sentinel-2 multispectral datasets offer a reasonably high-resolution for the ASM sector. That is 10 to 60m depending on bands but interpolations can be run to increase 20m resolution bands to 10m. Scientists conducting field mapping, use geomorphological and remote sensing techniques to map, monitor, and evaluate mineral deposits, ASM activities and pollution. These methods require transferable expertise to acquire meaningful knowledge in emerging areas. In particular, this Chapter discussed the suitable periods for monitoring ASM activities using remote sensing. This, subject to external variables, is encouraged to be tackled with a case-by-case approach. Remote sensing data allows detailed mapping and monitoring of ASM activities and the development of high-resolution geomorphic models for identifying host resource deposits. High-resolution satellite imagery enables scientists to identify active informal ASM pits, estimate production, and monitor changes in time. Satellite image analysis is integrated with ground-truthing data.

Mining operation in Kaduma State. Nigeria.

Young girls sorting lead/zink in Nahuta, Gombe State. Nigeria.

FROM RESOURCE CURSE TO CONFLICT MINERALS – LESSONS FROM THE DRC

By Ken Matthysen and Lotte Hoex, International Peace Information Service

The DRC, and in particular the eastern part of country, has gone through a turbulent quarter of a century. After several decades of kleptocratic rule by Mobutu Sese Seko, the country suffered two successive wars in 1996 and 1998. The "Second Congo War" officially ended in 2003. Ever since, however, rebel groups continued to emerge and thrive in eastern DRC including in the provinces: Ituri, North- and South Kivu, Maniema and Tanganyika. Insecurity, population displacements and human rights violations are a daily reality for many communities to date.

Mineral exploitation and trade have often been linked to conflict in eastern DRC. The mining sector provides an important source of revenue for several conflict actors, including rebel groups and army units. The picture is however more complex, as armed actors have alternative sources of income, and the mining sector is first and foremost an import source of revenue for hundreds of thousands of households in eastern DRC.

Eastern DRC's (Artisanal) Mining Sector

The DRC holds a wide range of natural resources that are important for its local economy as well as the regional and international market, including minerals (e.g. gold, tin, cobalt and copper), hydropower potential, arable land (and agricultural produce, such as cocoa), immense biodiversity, rainforest, and wood (and charcoal). The stakes are thus high.

Mining of the DRC's mineral resources has a long history, dating back to colonial times. Due to mismanagement and crises on the international mineral market in the 1980s, formal industrial mining declined. The informal artisanal mining sector, on the other hand, rose steadily since Mobutu's liberalisation of the DRC's mining sector in 1982. By the 1990s, eastern DRC's industrial mining had dissolved and mineral exploitation became exclusively artisanal. Ever since, artisanal mining of tin, tantalum, tungsten and gold has become an essential livelihood strategy as well as an important source for the flow of cash into many (remote) communities. It is estimated that more than 500,000 miners may be working in the mines of the eastern DRC, who in turn support a wider community (IPIS/CIFOR, 2012).

The country's artisanal mining sector is largely informal. Only few mining stakeholders are officially registered. It does not necessarily mean that the sector is chaotic. Production mechanisms and trading patterns are in reality quite structured with hundreds of thousands of miners extracting the ores at the mines and local middlemen buying the minerals to transport them to the main trading hubs near the eastern border. The capacity of state services to oversee the artisanal mining sector is however extremely limited. This limited capacity is due to a number of factors including corruption, a lack of trust by mining stakeholders in state representatives, an inability to cover the territory under their responsibility, and a lack of means, personnel, resources and technical knowledge.

"Conflict Minerals" in Eastern DRC

The concept of "conflict minerals" has played an important role in conflict analyses in eastern DRC over the past 20 years. The OECD defines "conflict minerals" as "minerals from Conflict-Affected and High-Risk Areas (CAHRA)" and identifies these areas by "the presence of armed conflict, widespread violence or other risks of harm to people". It further explains that "high-risk areas may include areas of political instability or repression, institutional weakness, insecurity, collapse of civil infrastructure and widespread violence. Such areas are often characterised by widespread human rights abuses and violations of national or international law" (OECD, 2013). The DRC is often perceived as a textbook example of a CAHRA, and the "conflict minerals" phenomenon.

"Conflict minerals" in eastern DRC include tin, tantalum, tungsten (which are mined in the DRC in the form of respectively cassiterite, coltan and wolframite ore) and gold, commonly abbreviated as 3TG. While most of the debate is focused on 3TG, it is important to realise that also some of the other resources mentioned above, such as wood, charcoal, land and fauna have played a role in conflict dynamics and conflict financing.

Anno 2022, the Central Government's lack of control over the artisanal mining sector still offers an opportunity for armed groups as well as state security services to persistently profit from the region's mineral wealth. A high level of informality makes it difficult for the Government to effectively tackle the conflict mineral phenomenon prevalent in the DRC (IPIS, 2013). The question, however, remains to what extent natural resources are the source of conflict – notably a causal relationship - or whether the abundant availability of natural resources rather provide an opportunity for armed actors to finance their ongoing armed struggle?

To answer the latter question, we can confidently say that eastern DRC's mineral wealth plays a significant role in the continuation of insecurity in parts of the country. Revenues from mineral trade have given armed groups the means to operate, have provided off-budget funding to (often poorly paid) state security forces, and have enriched strongmen profiting from insecurity. Nevertheless, mineral wealth is not one of the root-causes of conflict. Their trade however does play a role in funding and fuelling conflicts in the DRC, which further weakens the already fragile governance system (IPIS, 2013).

A brief history of the conflict will reveal the role of minerals in conflict financing, and how it has evolved over time.

Historical Context

From 1996, the DRC suffered two successive wars. The first war ended in 1997 with the toppling of the Mobutu regime by Laurent Kabila's Alliance of Democratic Forces for the Liberation of Congo, supported by the DRC's eastern neighbours Rwanda and Uganda. The second war involved a wide range of Congolese rebel groups and most of DRC's neighbouring countries. As such it was defined as the "First African World War" (Reyntjens, 2009).

Rwanda and Uganda started the First Congo War (1996-1997) for political and security reasons. This included the restoration of security in their border areas with DRC, called "Zaïre" back then. Nevertheless, the war already provided a first taste to Rwandan and Ugandan army officers of the commercial potential of Zaïre's mineral wealth. During the Second Congo War (1998-2003) the economic dimension took on an ever more significant role. President Laurent Kabila accused Rwanda and Uganda of supporting the rebel movement, Rally for Congolese Democracy, in order to strengthen their grip over the DRC's natural resource wealth (Turner 2007, pp. 40, 162–163). The UN Panel of Experts wrote in its final report in 2003: "Illegal exploitation remains one of the main sources of funding for groups involved in perpetuating conflict, … Over the last year, such exploitation has been characterised by intense competition among the various political and military actors as they have sought to maintain, and in some instances expand, their control over territory."

During the Second Congo War, the eastern DRC's mining sector was increasingly subjected to systematic extortion, controlled by mafia-like networks, that exported minerals directly to Rwanda and Uganda.

The Second Congo War officially ended in 2003 with the integration of the warring rebel groups into a Transitional Government. Yet conflict has persisted for a long time in the eastern part of the country, and pockets of insecurity and violence regularly emerge to date. Ever since a huge number of Congolese and foreign armed groups have looked for shelter in the vast territory of eastern DRC. Conflict minerals continued to play an essential role in the financing of these armed groups and consequently the prolongation of the insecurity. So many armed groups have come and disappeared over the past twenty years that it is impossible to discuss all of them. Just now, for example, there are an estimated 120 armed groups in eastern DRC (Kivu Security Tracker, 2021).

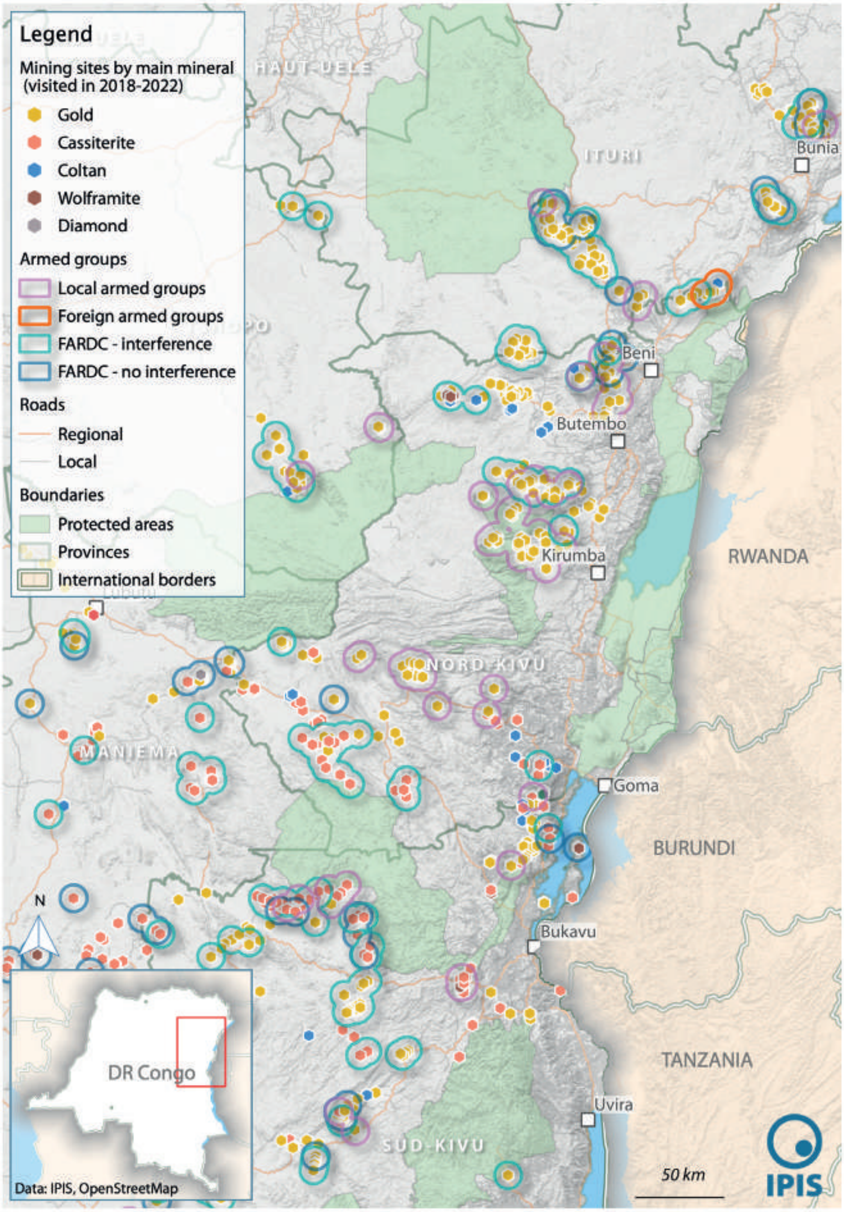
Nevertheless, it is possible to see some evolutions. During the first years after the transition, some sizeable armed groups were involved in intense fighting in the Kivu provinces, including the National Congress for the Defence of the People (CNDP), Forces Démocratiques de Libération du Rwanda (FDLR), the Congolese National Army (FARDC), and the Mai Mai - a plethora of local defence militias (Spittaels S. and Hilgert F, 2008). All of these armed actors profit directly from mining activities in the Kivu provinces. The research institute, International Peace Information Service (IPIS), already assessed in 2009 that armed groups had positions at more than half of the mining sites (Spittaels S. and Hilgert F, 2008).

The security situation has evolved considerably over the past fifteen years. The presence of "foreign" armed groups since the beginning of the century - including FDLR and CNDP - and state fragility in the eastern provinces led to the proliferation of self-defence groups, including more Mai Mai groups, but also Raïa Mutomboki. The importance of foreign armed actors has decreased considerably since 2013, but the plethora of local armed groups tend to stick around (IPIS, 2022).

Analysing the current conflict situation, the Kivu Security Tracker interestingly said: "it is perhaps more important to highlight the inertia of the conflict rather than to speak of new causes or triggers. Much of the violence in the eastern Congo is driven by the need of armed groups, most of whom have existed in their current or previous incarnations for many years, to survive by extracting resources and fighting for their turf" Kivu Security Tracker, 2021). While many of the armed groups in eastern DRC have been established as self-defence groups, over time, illegal predation has become an important reason of existence and at times seems to has supplanted the ideological factor (IPIS, 2022).

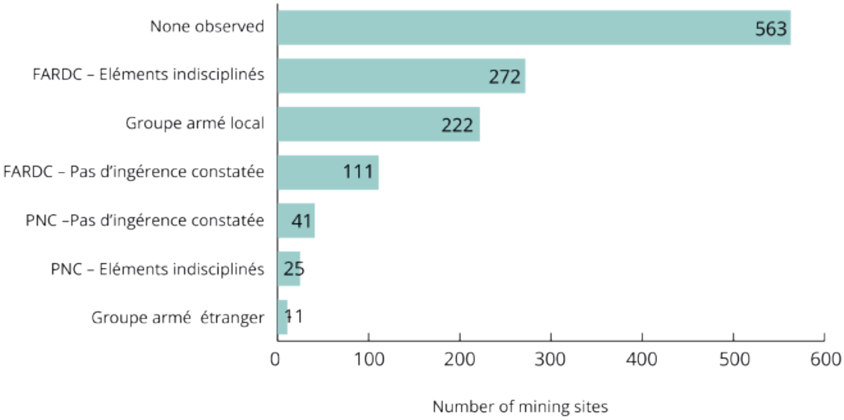
Consequently, the map in Figure 11 shows the extent to which mining sites are affected by the interference of armed men. Of the mining sites visited by IPIS between 2018 and 2022 47% still suffered from the interference of armed men, ref. Figure 12.

FIGURE 11 | INTERFERENCE BY ARMED ACTORS AT MINING SITES IN EASTERN DRC, 2018-2022



Source: IPIS

FIGURE 12 | PRESENCE OF ARMED ACTORS AT MINING SITES IN EASTERN DRC (TOTAL OF 1,069 SITES), 2018-2022



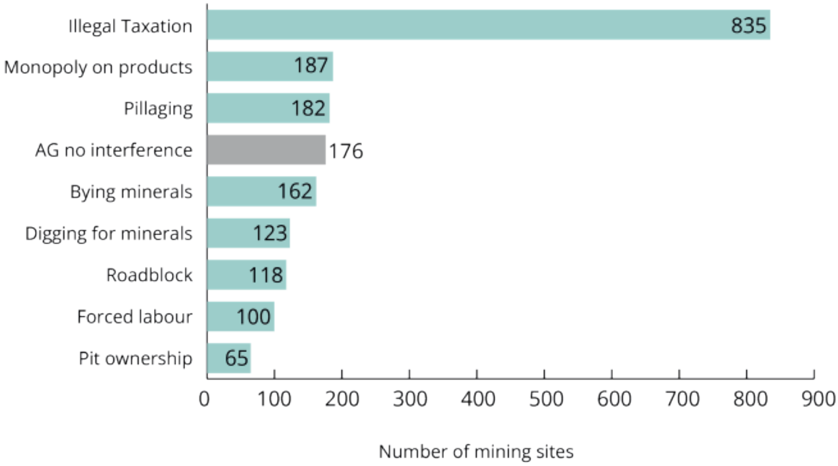
Source: https://ipisresearch-dashboard.shinyapps.io/open_data_app/

Armed Interference in Mining

Large-scale armed conflict over DRC's mineral wealth has decreased significantly over the past twenty years. Nevertheless, the above illustrations show that armed actors are still present at half of the mining sites in eastern DRC. Additionally, at the local level, conflicts over resources are still common. These conflicts regularly result in violence and stakeholders often turn to armed actors (either armed groups, or state security forces) to protect their claim. Additionally, the exploitation of minerals by (foreign) companies in eastern DRC usually leads to social tensions and has spurred armed group activity on multiple occasions.

Nowadays, the armed groups present in the mining sites include especially the wide range of the local self-defence militia. They use several strategies to profit from DRC's mineral wealth. They might exert direct control over a mining site, profiting from it through illegal "taxation" of mineral production or demanding an entrance fee to miners, mineral traders, or any other retail trader. In some cases, armed groups are directly involved in mining itself, their members might be mining themselves, or some of the commanders own their own pits, or they have a monopoly on the commercialisation of the minerals produced, or on some of the consumer goods sold at the mining site, ref. Figure 13. Levels of coercion can also be much more severe however; forced labour is occasionally observed in the eastern DRC. And the threat of violence usually underpins any "taxation". A lot of armed groups do not exercise this level of control, but rather turn to regular pillaging of mining sites (IPIS/CIFOR, 2012).

FIGURE 13 | TYPES OF INTERFERENCE REPORTED IN CASE OF ARMED ACTORS PRESENCE (TOTAL OF 2,288 MINING SITES), 2013 – 2021



Source: IPIS

Rebel groups are not the only armed actors skimming profits off the mining sector. In fact, army soldiers (FARDC) are notorious for the illegal revenue-generating practices that they have developed, including roadblock taxation, racketeering and extortion in natural resources sectors - including charcoal and gold. Additionally, the military increasingly operates as private security guards securing some mining operations. FARDC units are the armed actor that can be observed most often interfering in the mining business, and increasingly so. At a sample of 711 mines visited by IPIS between 2016 and 2018, the main culprits of armed interference were the FARDC. They were responsible for armed interference at 66% of the 'affected' mining sites, 198 out of 265 (IPIS, 2022).

The criminal behaviour and lack of discipline within the FARDC are the results of various factors. A rashly executed integration process of several rebel groups into the national army, the irregular payment of salaries, corruption, the incapacity of the military justice system, and a lack of political will to truly reform the army (IPIS/CIFOR, 2012).

Resource revenues for military people can also partly explain the inertia with regard to armed groups in eastern DRC. Armed group presence provides the legitimacy for an army unit's deployment, which enables them to develop their economic activities, including interference in mining. Multiple examples exist of FARDC and nearby armed groups that coexist and have arrangements with regards to the division of revenues from the local mining business (IPIS, 2022).

Insecurity Beyond Conflict Minerals

In explaining the role of natural resources, and mining in specific, in eastern DRC's conflict dynamics, it is important to underline that the link between "mining" and "conflict" is complex and interlinked with a wide range of other issues. Armed groups do not solely depend on mining as they also have alternative sources of income. Furthermore, the persistence of insecurity in eastern DRC is also the consequence of many other reasons.

Several factors contribute to the "inertia" in the eastern provinces and the survival of all these armed groups. It includes the FARDC's underperformance, failed Disarmament, Demobilisation and Reintegration (DDR)-processes, intercommunity tensions, economic underdevelopment, social dissatisfaction, governance issues and regional dynamics (e.g. refugees).

Armed groups also possess (potentially) alternative sources of income. Some armed groups have developed taxation systems for the entire population in the areas they control, for example via tokens, Jetons, and poll taxes (Kivu Security Tracker, 2021). Most state and non-state armed actors collect taxes at roadblocks on valuable goods transported by road (timber, charcoal, agricultural products, merchandise) as well as on pedestrians and vehicles passing by (Schouten et al., 2017). Another list of such activities exists: kidnapping for ransom, charcoal business, leasing of land, etc.

These observations are of utmost importance as several conflict resolution strategies have narrowly focused on the link between "mining" and "conflict". As such so-called "clean mineral supply chains" have been promoted without a sustainable impact on the security situation.

Conclusion

The DRC is perceived as a textbook example of a "failed state", victim to the "resource curse". It helps to explain how failing natural resources governance has led to corruption, competition for resources and predatory behaviour by strongmen, state agents and others. It has deprived the Congolese population of development and prosperity and created the context for armed groups to survive through extortion.

This analysis however risks to narrow down insecurity in eastern DRC to natural resources and tends to ignore the governance systems that do exist. Consequently, they risk to result in misleading policy advice.

It is very difficult to put one's finger on conflict and insecurity in eastern DRC. Conflict drivers include disputes at the local level, up to national and regional political and economic interests. Several armed groups still prey on local discontent over land conflicts, access to resources and political distrust to legitimise their existence. While on the other hand, regional geopolitical tensions exist over supply chains and support for armed groups.

Mining is not the root cause of the conflict, yet mineral resources do provide the opportunity for the plethora of armed groups to survive. A such minerals are used to consolidate insecurity in eastern DRC.

Both armed groups and state security actors continue to generate revenues from the mining sector. Economic interests seem to have replaced the original political and social causes of many actors. IPIS found that half of the artisanal mining sites in eastern DRC suffer from the interference of men in arms.

Addressing the issue will require long-term, firm engagement from the Government, international partners and local “agents of change” to address governance and corruption in the mining sector and beyond, to launch a credible reform process for the army, and to invest in DDR-processes.

Children playing at the Bandira mining site. Mozambique.

INVOLVEMENT OF WOMEN AND CHILDREN IN ASM IN MOZAMBIQUE

By Dr Iracema Maiópuè, Director General, Women's Means of Life Association, Mozambique

Mozambique is a country that is rich in minerals given that they are present from south to north of the country. In terms of ASM, in the southern region the minerals are primarily used for construction purposes, i.e. stones, sand and clay, whereas in the central and northern region high value minerals, such as gems are also found in addition to minerals used for construction.

Mozambique is still far behind when it comes to the organisation of the mining sector and the involvement of women compared to other countries in the southern African region. In South Africa, for example, women are part of associations and companies, they hold licenses in the mining sector, and they occupy high positions. In Zimbabwe, women are organised in associations, which, among other, help women establish Memorandum of Understanding with big mine concession entities, since the mining sector is still dominated by men; hence, women need to stand strong as one group. Women are encouraged to take a more active stance within both the traditional agricultural sector but also the mining sector. As a result, women in mining is now well known fact with the Zimbabwean Federation of Miners fully recognising women as key participants to help grow the economy by working hard in the mining sector. Malawi is also a country where women are moving upwards within the mining sector. Women who work in mining also do their best to preserve the environment, e.g. they refill the pits and reclaim the land by planting either trees or vegetables. They also encourage male miners to take care of the environment by following their examples.

In Mozambique, however, women still face big challenges within the mining sector primarily due to the lack of organisation and formalisation. Few women have knowledge of the mining sector, the market for minerals, their rights as well as their duties, thus rendering their mining activities non-sustainable.

In Mozambique, women and children are involved in ASM in the following ways:

- Provision of food and housekeeping services at ASM sites;
- Provision of transportation services, i.e. from ASM sites to minerals market;
- Provision of prostitution services at and around ASM sites; and
- Provision of low tier extraction services, e.g. for stones and sand.

Challenges for Women and Children in the ASM Sector in Mozambique

Challenges for women and children in the ASM sector in Mozambique include:

- Lack of support in formalising their mining activity: At present, only four women-led cooperatives within ASM have been formed in the Tete Province with a fifth under formalisation in Inhambane. Formalised cooperatives provide women with marketing information and thereby stronger selling power toward buyers of extracted minerals;
- Lack of proper equipment for the safe extraction of minerals: Access to proper equipment enable women to better both protect the surrounding environment and their own health. At present, few women have access to correct and high-quality mining equipment;
- Lack of training in environmental friendly extraction procedures: Without formalisation of women-led cooperatives, few women are informed and taught about environmental friendly extraction procedures;
- Lack of information and a secure space to facilitate the formalisation of the ASM activity: Usually women have no space for dialogue because they are afraid and forbidden to express themselves in the presence of men. Women need to have the opportunity to be emancipated and to have a platform where they can freely express their concerns and establish proper and formalised networks and cooperatives;
- Lack of information and training on value adding activities: Few women are informed and training in value adding activities that would otherwise enable them to charge a higher price for their minerals;
- Lack of access to proper housing, sanitation, water and energy: Few ASM sites provide for proper housing, sanitation, water and energy thus impacting the health of women and children;
- Uncertainty of income and secrecy of marketing networks: Until 2013, the Fund of Mining Promotion, a government entity, ensured fair and equitable prices for all miners, women and men, but without it especially women are at a disadvantage in obtaining fair and equitable prices for their minerals when standing outside formalised networks;
- Environmental and occupational health and safety risks: Both women and children are often subjected to mercury at or around the ASM sites, which is detrimental to their health;
- Conflict and public insecurity: Women are often victims of violence and sexual abuse by men in and around ASM sites;
- Withdrawal of resources from agricultural production, jeopardizing food production and food security: In hopes of easier and better money from mining, especially rural people tend to abandon agricultural production thus jeopardizing food production and food security;
- Prostitution; and

- Child labour: Too many children are involved in ASM, either directly as workers or indirectly as prostitutes. In Cabo Delgado, at border with Tanzania, families in need of money subject their children to prostitution with Tanzania miners. Children should go to school plus be protected from abuse.

Future of Women in ASM in Mozambique

Women in the ASM sector need to be united and properly informed on how the mining sector works, what are their potentials, rights and duties toward the activity. Mostly women work with no clear strategy. They need to be supported by government authorities in order to establish and operate sustainable mining activities. The fact that the Government of Mozambique will soon release a new survey of the mining sector bodes well the women in the ASM sector, since a strategy for overcoming the current challenges and seizing the opportunities will be development and hopefully implemented. The further development of the ASM sector must be a participatory process where women can vocalise the challenges they face compared to men in order for the governmental authorities to facilitate better options for women, such as access to proper equipment, training, and information on market dynamics and prices.


ASM mining site named Mimosa. Mozambique.

FORMALISATION OF EFFORTS OF THE ASM SECTOR IN DRC

By Ken Matthysen and Lotte Hoex, International Peace Information Service

When effectively monitored and managed, legal and responsible ASM supply chains can promote peace and stability while providing livelihoods and contributing to rural development.

ASM is a legal activity in the DRC. However, many of the legal provisions have never been fully implemented and as such it is often hard for ASM miners to work legally. ASM stakeholders have been used to working in the informal sector for decades. Many state agents recognise the enormous gap between ASM regulation on paper and the reality on the ground and tolerate a lot of the informal activities.

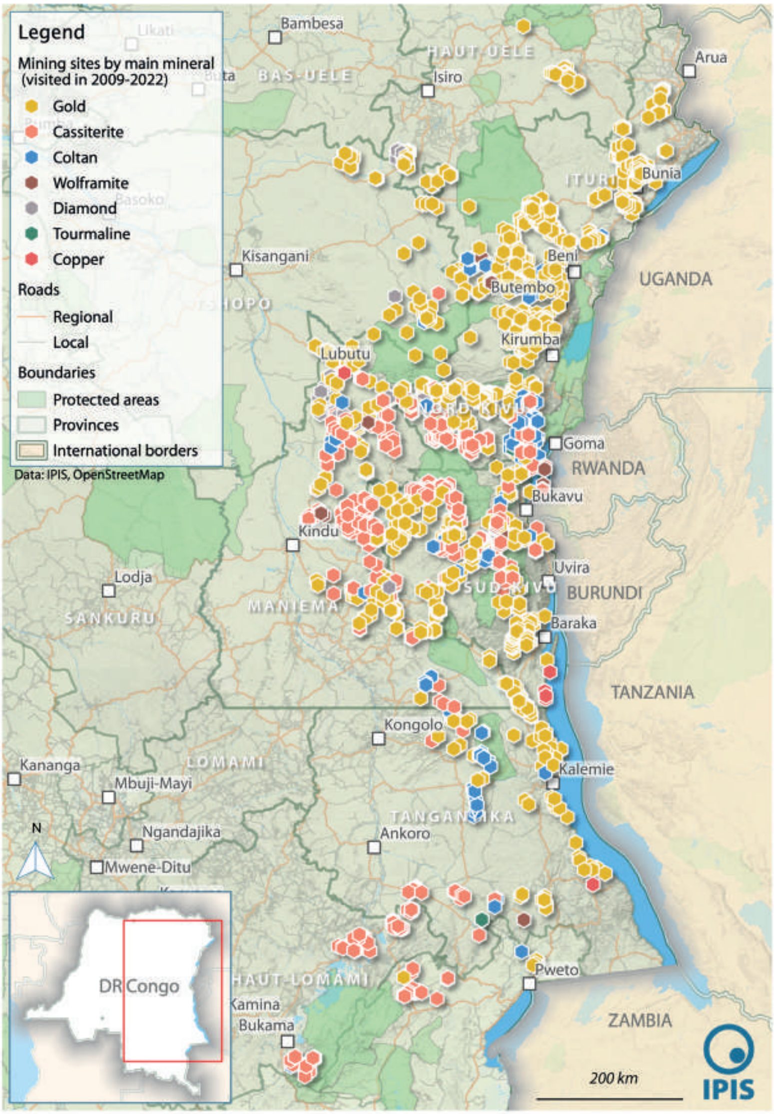
Historical Context DRC

ASM has a long history in the DRC, dating back to colonial times (Fahey, 2008). Cassiterite (tin) and coltan were discovered in the Kivu region in 1910. The tin sector soon fell entirely into the hands of private Belgian companies. The 1960 independence of the Republic of the Congo did not initially appear to have a significant impact as Belgian private companies remained in control of the mining sector. However, 35 years later industrial exploitation of the 3Ts (cassiterite, coltan and tungsten) ceased entirely; the instability of world markets and a failing state were arguably at the root of this collapse (International Alert, 2010). While formal industrial mining declined, the informal ASM sector had been steadily rising since the liberalisation of the DRC's mining sector in 1982 (Vlassenroot and Raeymaekers, 2004). ASM was recognised as a legal activity in the 1980s. By the 1990s eastern DRC's industrial mining had dissolved and mineral exploitation became exclusively artisanal (IPIS(CIFOR, 2012). As of today, large-scale mining investments in eastern DRC continue to be limited (Schütte, 2018).

Since 2009, IPIS has collected data about the on-the-ground situation at mining sites and the trade routes in eastern DRC. Between 2009 and June 2022, IPIS mapped 2,723 mines, employing 376,000 artisanal miners, covering virtually all-relevant mining areas of eastern DRC, ref. Figure 14. Of these mines, 69% were gold mines, 25% cassiterite/ tin mines, 9% coltan/ tantalum and 2,4% wolframite/ tungsten mines (on some mining sites more than one mineral is mined), ref. Figure 15. Today, ASM supports at least 1.7 million people directly and indirectly in eastern DRC.

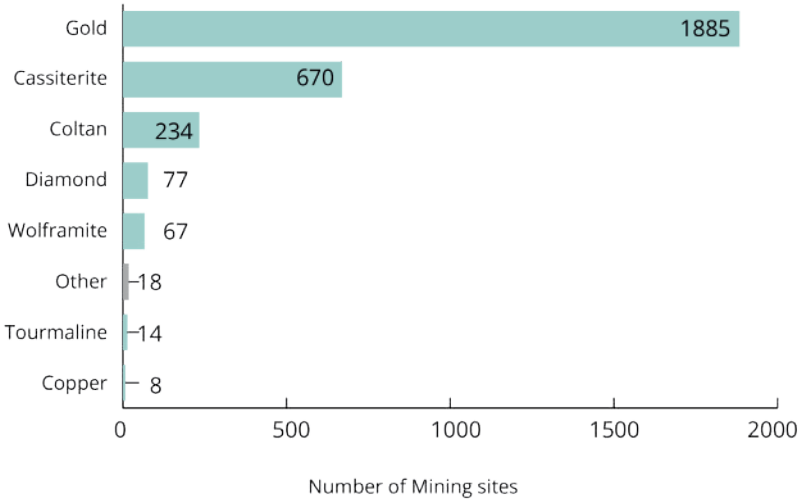
The collected data demonstrates the predominant importance of the gold sector. The DRC is one of the global top-ten ASM gold producers. ASM gold production is mainly focused in eastern DRC but there are also gold mine sites in Kasai and in Congo Central in western DRC. Traditionally, ASM gold production in eastern DRC is primarily done manually, using rudimentary tools such as pickaxes, shovels, crowbars and hammers. Over the past few years, more mechanised tools such as crushing machines and dredges are increasing.

FIGURE 14 I MINING SITES VISITED BY IPIS IN EASTERN DRC. 2009-2022



Source: IPIS

FIGURE 15 | DISTRIBUTION OF ASM MINED MINERALS IN EASTERN DRC, 2009-2022



Source: IPIS

Regulating the ASM Sector in the DRC

The DRC Mining Code (2002) and Mining Regulation (2003) legalised ASM whilst imposing a number of conditions (Loi N° 007/2002): miners need to register and can only exploit in designated zones. Since 2010 a few additional requirements have been established: miners have to be member of a cooperative in order to be entitled to work in the mines (Arrête Ministériel, 2010) and any actor involved in mineral supply chains is obliged to respect OECD due diligence guidelines and the ICGLR Regional Certification Mechanism (Arrête Ministériel, 2012). Moreover, ASM has to take place in ZEAs, delimited upon decree of the Ministry of Mines. ASM activities are reserved to Congolese nationals and are limited in scope and equipment. They are regulated by a code of conduct specifying safety, health and environmental requirements. ASM licenses ('carte d'exploitant artisanal') are to be bought each year. Local mineral traders need to hold a trading license ('carte de négociant') and have to sell their minerals to designated buying houses (the so-called 'comptoirs', or 'entités de traitement'). The latter are the only entities that can officially export artisanal produced minerals.

The mining code was revised in March 2018, but did not affect any of the above-mentioned requirements (Loi N°18/001, 2018).

Government Institutions in the DRC Mining Sector

At the national level, the management of the ASM sector is the responsibility of the Ministry of Mines. The latter is in charge of the creation of Artisanal Exploitation Zones (ZEAs) and regulates the trade of artisanal minerals. Once allocated, mining titles are registered in the national database by the Mining Registry (CAMI).

At the decentralised level, the Provincial Mining Division is in charge of the daily management of the ASM sector, including the granting of miners' and mineral traders' licenses. Technical services also engage with artisanal miners at the local level. SAEMAPE, the Service d'Assistance et d'Encadrement des Mines Artisanales et de Petit Échelle, provides technical support to artisanal miners and cooperatives at the level of the mine. They are supposed to promote safety regulations and the national Mining Code at mining site level.

The Centre for Evaluation, Expertise and Certification (Centre d'Evaluation, d'Expertise et de Certification) is involved in the certification of precious minerals and has the responsibility to implement the Kimberley Process Certification Scheme in the DRC's diamond sector. Finally, the CTCPM (Cellule Technique de Coordination et de Planication Minière) collects data on ASM for statistical purposes and is in charge of developing technical solutions to increase productivity and safety within the sector.

In late 2019, the DRC government created ARECOMS (Autorité de Régulation et du Contrôle des Marchés des Substances Minérales Stratégiques) – a regulatory and market control body for strategic minerals.

Obstacles to Formalisation

Many of the legal provisions outlined above have never been fully implemented. As such, it is often hard for ASM miners to work legally. ASM stakeholders have been used to working in the informal sector for decades. Many state agents recognise the enormous gap between ASM regulation on paper and the reality on the ground. They therefore tolerate a lot of the informal activities, also because they often can benefit from it themselves, for example through informal taxation.

Artisanal Mining Card

Miners often do not hold the official artisanal mining card. IPIS research found that between 2016 and 2018 at 54% of the mines less than 25% of the miners held the miner's card, sites covered by responsible sourcing programmes did not perform any better with regard to card ownership, ref. 711 ASM sites visited by IPIS between 2016 and 2018. Artisanal miners often do not perceive any incentive to purchase the official miner's card, deeming it too expensive, as in practice they get nothing in return for card ownership. Furthermore, working within the formal sector often increases the level of taxation, since op top of the formal taxes it is still hard to avoid informal taxes.

Land Rights and Artisanal Mining Zones
One of the major obstacles to the formalisation of the ASM sector is the difficulty for miners to acquire secure and exclusive mining rights to land. Artisanal exploitation is only permitted in specially designated artisanal mining zones, i.e. ZEAs. There are however very few ZEAs. Moreover, ZEAs have very little security of tenure, as the Government can close such a zone within 60 days if it deems it viable for industrial mining. Furthermore, ZEAs are often located in remote and less mineral-rich areas as the Government designates zones for ASM in areas that are less suited for industrial mining (Singo and Segiun, 2018). Recognising this problem, state services tolerate most informal artisanal mining outside of the ZEAs (Geenen & Radley, 2014). Indeed, less than 2% of the 3,000 mines mapped by IPIS are in a ZEA, while state authorities are present at most of them. Moreover, many of the validated mines are not in ZEAs.

Government Validation
Additionally, only few ASMs have been validated by government inspectors, as required under DRC law. 75% of the 175 3T sites visited by IPIS have not been validated, for gold this is even higher: 96% of the 1,865 gold mines visited by IPIS have not been validated. Without this validation, the miners on these mining sites are considered to be operating illegally and are unable to access legal markets.

Cooperatives
Since 2010, artisanal miners must join a cooperative in order to be eligible to mine (Arrête Ministériel, 2010). The Mining Code has a vision of cooperatives as small production units evolving into business units. Cooperatives are supposed to strengthen the position of the miners vis-à-vis of the other players in the mining sector, such as the state services, landowners, traders, and the export counters, export counters (EURAC, 2017). However, cooperatives in the DRC do not match the criteria of a cooperative as described under international standards. Many miners consider them as yet another "mechanism of state control" imposed on them.

Most cooperatives are top-down organisations, subject to local elite capture. Miners are not involved in the selection of their leaders; they are not aware of their rights to be represented and usually do not participate in cooperative meetings. Cooperatives provide little or no assistance to the miners. They ask for financial contributions from the miners and therefore increase the costs linked to the formal sector. Moreover, participation in cooperatives requires an artisanal mining card, which few miners have. While the majority of the mines has a cooperative in place (74% of the 711 ASM mines visited by IPIS between 2016-2018), at more than 50% of the mines, less than half of the miners are actually members of that cooperative (Matthysen, et. al., 2019). At the mining sites there are often alternative types of organisations, such as associations or comités des creuseurs, that are much more active in defending miners' interests.

Taxation

The informal sector described above is characterised by “legal pluralism”, which is the co-existence of different normative systems, including a statutory land system, customary systems and a variety of informal land governance practices, as well as different norm-producing authorities, including the state (and its services), customary authorities, local communities, economic actors, and increasingly responsible sourcing initiatives coordinated by various international actors (Geenen & Claessens, 2013). Sometimes legal taxes are levied in areas where ASM is not permitted, and as such legitimise illegal exploitation. This is for example also the case in protected areas.

On top of the legal taxes, miners and traders are also taxed illegally. Illegal taxations include payments that have no legal basis, taxes with a legal basis but levied at an illegal rate, and taxes for which people do not get a receipt (Max Impact). Illegal taxation is frequent at mining site level, for example by armed groups and by the national army. The transport of minerals is also systematically subjected to illegal taxation at roadblocks operated by both armed groups and members of the national army. An IPIS/DIIS study from December 2017 identified 798 roadblocks in the Provinces of North and South Kivu alone. The large majority of these roadblocks are used for (illegal) taxation (Schouten, et al., 2017).

Over the last 15 years many observers have referred to the heavy tax burden in the DRC as one of the reasons for artisanal miners and traders not to work in the formal sector. Working in the formal sector often means to be taxed twice, officially and informally.

Specific Challenges in the Gold Sector

The above-described challenges apply to both the gold and 3T ASM sectors. However, there are some specific challenges to the gold sector that are worth mentioning separately. Not only is gold the biggest sector, it is also the most problematic mineral in ASM. It is especially in the ASM gold sector that actors prefer to operate outside the formal sector where they get better prices for their gold.

Estimates put the annual artisanal doré gold production in the DRC at around 15-22 tonnes. In 2017, only 230 kg thereof were officially exported and the 2018 official exports were at a dramatic low of 56 kg. More than 95% (in 2018 even 99%) of the ASM gold leaves the country unrecorded and thus illegally (BGR, 2019). The large majority is smuggled into its neighbouring countries, especially Uganda and Rwanda, from where it is (officially or unofficially) re-exported. In addition, some of the smuggling networks “export” the gold directly from the DRC.

There are several reasons for the high informality of the gold sector. First of all, a disincentive for supply chain actors to enter the formal market is access to credit.

Miners and local traders are both unable (due to their high-risk borrower status) and unwilling (because interest rates from local banks are often higher than their profit margins on gold sales) to access legal forms of credit. As a consequence they pre-finance their mining activities with loans from stakeholders involved in gold smuggling, automatically ending up in the informal gold trade themselves. Secondly, it is suspected that informal traders can offer better prices because they barter the gold for imported goods, which they sell with a large profit. Indeed, gold is not just a mineral commodity but also a financial instrument (Sofola Partners and Better Chain, 2019). Thirdly, criminal networks could be using the gold for money laundering purposes and therefore do not mind paying a higher price than a miner and trader can receive at the formal market.
A fourth explanation of the high informality of the gold sector is that the current "reputation" of Congolese gold negatively affects the willingness of traders to formally export it as such. Furthermore, regardless of whether they want to export legally, there are only limited options to do so as only a very small number of gold mines are certified mines. Finally, compared to 3T minerals, gold can be easily smuggled due to its high value-volume ratio.

(Inter)national Initiatives to Tackle Informality of the ASM Sector

Several national and international initiatives were taken since the late 2000s to tackle informality and mainly to address the issue of "conflict minerals".

ICGLR - Regional Certification Mechanism

In September 2006, the Member States of the International Conference of the Great Lakes Region (ICGLR) signed a Protocol on the Fight against the Regional Exploitation of Natural Resources. This provided the legal basis for the Regional Initiative Against the Illegal Exploitation of Natural Resources (RINR). The first, and most important, tool of the RINR is the Regional Certification Mechanism (RCM) for 3TG. The RCM includes the mine site and mineral export certification criteria, traceability and chain of custody requirements.

In the DRC, RCM certification is carried out by so-called "joint validation teams". These teams include representatives from the government, state agencies, and international partners working in the natural resources sector. The teams assess the security situation at the site and its surroundings, as well as socio-economic risks such as child labour, depth of pits, presence of pregnant women and environmental issues. They classify sites as red, yellow or green depending on their observations. Green and yellow-flagged mines can produce minerals for certified export. Yellow flagged mines have a period of six months to resolve the infractions of one or more of the RCM criteria.

Because only 3TG minerals sourced from validated mines can be legally exported, it is crucial that all eligible ASM mines are validated as soon as possible. However, the validation process in the DRC has often been criticised for its slow implementation. The joint validation teams are a mixture of stakeholders, which makes the validation missions costly and logistically complicated. This is especially problematic for gold. Only 4% of the ASM gold mines visited by IPIS (which do not cover all the gold mines in eastern DRC) have been validated. This implies that only a fraction of the ASM gold can be exported legally.

(Inter)national Regulations

Due diligence is a process that companies or individuals should undertake to ensure that the extraction and trade of mineral ores support peace and development, not conflict. The internationally recognised due diligence standard is the OECD Due Diligence Guidance. It provides detailed recommendations to help companies respect human rights and avoid contributing to conflict through their mineral purchasing decisions and practices. The OECD Guidance is global in scope and applies to all mineral supply chains. The DRC national legislation has integrated the OECD Guidance and hence the obligations for companies, ref. Ministère des Mines, Note Circulaire n. 02/CAB.MIN/MINES/01/2011.

In 2010, Section 1502 of the American Dodd-Frank Act imposed due diligence measures to companies trading on US stock exchanges sourcing gold and 3T minerals from eastern DRC and its nine neighbouring countries. Dodd-Frank 1502 created momentum to increase efforts to address conflict financing from mineral exploitation and trade, and efforts to increase the volume of responsible mineral trade. At the same time, the increased scrutiny on conflict financing had socio-economic consequences as most international mineral traders abstained from sourcing minerals from the DRC in 2010.

In 2017, the European Union passed a new regulation with the objective to stop conflict minerals and metals (3Ts and gold) from being exported to the EU, to stop global and EU smelters and refiners from using conflict minerals and finally to stop mine workers from being abused. The requirements started to apply in January 2021. While the Dodd-Frank 1502 is specifically targeted towards 3TG minerals from the DRC and neighbouring countries, the EU Regulation covers all conflict-affected and high-risk areas.

Mineral Traceability

Traceability initiatives give disclosure of the trade route, from the mine of origin to export. Most responsible sourcing initiatives are a combination of both certification and traceability. The dominant traceability tool for supply chain due diligence in eastern DRC is the International Tin Association's (ITRI) Tin Supply Chain Initiative (ITSCI). ITSCI is an industry led, not-for-profit, multi-stakeholder initiative developed by ITRI. ITSCI covers tin, tantalum and tungsten ores. It has been operational in the DRC since 2010. ITSCI implements traceability by providing labels to Congolese state agents, so that they can tag 3T mineral production at the mine site and along the trade route to verify the origin of the minerals further down the chain. It also implements related activities to monitor the supply chains, including incident reporting, risk management, etc. Besides ITSCI, there are other smaller traceability initiatives such as Better Sourcing Program and the state-led gold traceability system, "Initiative pour la traçabilité de l'or artisanal".

Challenges and Impact of Responsible Sourcing Initiatives

"Responsible sourcing initiatives" include all of the (inter)national initiatives to tackle illegal mining and mineral trade as well as conflict financing in the mining sector. It includes all of the above-mentioned efforts, but also a wide range of other smaller, often donor-funded, initiatives. Generally speaking, all of these initiatives promote a formalised framework for the artisanal sector. However, formalisation risks "dispossessing" artisanal miners to the advantage of local elites and large businesses. For example, the establishment of cooperatives and working through state agents further concentrates control over and access to the sector in the hands of elites. Regular harassment and the collection of illegal taxes by state services responsible for formalisation undermines the position of artisanal miners (EURAC, 2017). Another major challenge of the formalisation initiatives is that costs of due diligence programs are currently not shared between upstream, midstream and downstream actors. Due diligence costs are largely passed on to local miners without any meaningful offsetting compliance premium on prices for the consumers.

Finally, a major challenge of the initiatives is scale. Most of the initiatives only reach a small percentage of artisanal miners. While they do cover a significant part of 3T mining they only include a small fraction of the gold sector, which represents more than 70% of all the 3,124 ASM sites visited by IPIS.

IPIS and others have evaluated the impacts of due diligence programming on mining communities in eastern DRC (PRG et. al., 2020). Due diligence programming entails ongoing monitoring of mineral production and processing to ensure that suppliers respect human rights and avoid contributing to conflict. Combining statistical matching with new data from over 300 3T mines and 1,000 households, the study found that areas with due diligence programs see less interference by the national army and a heightened presence of government regulators compared to households in areas without a due diligence program. This does not necessarily mean that responsible sourcing programmes are the reason for security at mining sites. Often, it is precisely the (pre-existing) absence of armed interference that attracts validation and ITSCI involvement in the first place. Nevertheless, the prospect of being covered by a responsible sourcing initiative could be considered to represent a peace dividend for local stakeholders.

Households in areas with a due diligence program report over 58% more tax collection and service provision by government regulators. Interestingly, they do not report feeling more secure than areas without a due diligence program. Mines in areas with due diligence programs do not have significantly lower rates of child labour nor was there a significant difference in the number of injuries due to accidents. Finally, the study found tentative evidence that households' economic well-being is higher in areas with responsible sourcing initiatives: consumption of food and mobile credit, for example, increase.

Conclusion

Although ASM is a legal activity in the DRC, in reality miners rarely work legally. There is a wide gap between mining legislation and practice. The DRC Mining Code and Regulations impose a number of conditions for ASM, including miner registration, cooperative membership, compliance with international standards and the designation of specific ASM zones. Many of these legal provisions have never been fully implemented, which makes the huge majority of the ASM sector illegal. Artisanal operators often do not perceive any benefits to comply. On the contrary, by working in the informal sector, miners and traders avoid a multitude of legal taxes. Especially in the gold sector, ASM actors prefer to operate outside the formal sector where they get better prices for their gold.

In terms of policy responses, the main challenge is to formalise the ASM sector, especially the gold sector, using it as a driver for local development, while preventing interference by armed groups and criminal networks. Responsible sourcing initiatives in the DRC aim to address this challenge by providing a certification of the origin of minerals and of exploitation conditions. They usually also imply traceability, disclosing the trade route of the minerals, from the mine to their point of export. The Regional Certification Mechanism, ITSCI and others have, to some extent, managed to reduce illegal taxation and armed presence. However, their impact on local development and stabilisation has been limited as these initiatives only reach a small percentage of artisanal miners. While they cover a significant part of 3T mining, they only include a small fraction of the gold sector.

When formalising the market, it is important to provide incentives for the artisanal miners to engage in the process and to remove barriers to include them in a legal framework. Capacity building is another issue requiring significant attention. In order to successfully formalise the artisanal mining sector, the capacity of local state agencies urgently needs to be developed.

Woman collecting water for the household at river near the mining site. Central Ghana.

Artisanal mining operation, north of Tarkwa, Western Ghana.

ASM SECTOR OF ANGOLA

By Jeorgina Domingos A Quimbangala Inácio and Sebastião Malungo Miguel António, Geological Institute of Angola

Geographical Context of Angola

Angola is located on the South Atlantic coast of West Africa, between Namibia and Congo. It also borders the Democratic Republic of Congo and Zambia to the east, with the following geographic coordinates - 12º 30' S, 18º 30' E, with a total area of 1,246,700 km^2.

The country is divided between an arid coastal strip, extending from Namibia to Luanda, a humid interior plateau, a dry savannah in the south and southeast interior, and tropical forest in the north and in Cabinda. The Zambezi River and several tributaries of the Congo River have their origin in Angola. The coastal strip is temperate by the cold Benguela Current. There is a short rainy season, which runs from February to April. Summers are hot and dry. Winters are temperate. The inland highlands have a pleasant climate with a rainy season from November to April, followed by a cooler, dry season from May to October. In general, the altitudes vary, between 1,000 and 2,000 meters. The northern regions and Cabinda have rainfall throughout most of the year.

Demography of Angola

The Angolan population is estimated at 32 million inhabitants according to the most recent data. About 95% of Angolans are Bantu Africans, belonging to a diversity of ethnicities. Among these, the most important are the Ovimbundu, who represent more than a third of the population, followed by the Ambundu with about 25%, and the Bakongo with more than 10%. The Lunda-Côkwe, the Ovambo, the Nyaneka-Nkhumbi, the Ganguela and the Xindonga have a smaller demographic weight. There are still small residual groups of Khoisan (occasionally referred to as Bushmen or Hottentots). Following independence, the Angolan Civil War provoked a veritable rural exodus, so that at the moment, i.e. in 2022, a little more than half of the total population of Angola lives in urban areas. In this context, many Bakongo and Ovimbundu (and much more limited contingents of other groups) settled in cities outside the traditional habitat of their respective ethnicity. As a result of this movement, today there is a very notable ethnic diversity in Luanda (including the adjacent regions), but also in Lubango, while it is relatively more limited in other regions, such as Benguela and Huambo. Overall, the population density is low, with around 15 inhabitants per square kilometre, but extremely unequal: urban areas, which are constantly expanding, are contrasted with large sparsely inhabited areas, particularly in the provinces located to the east and south of the country.

Economy of Angola

Mining in Angola is an activity with great economic potential, ranking second in terms of positive contribution to GDP, as well as in raising revenue for the State through the settlement of taxes of various fiscal natures. Mining is one important pillar of the national economy, important for socio-economic development, since Angola has the largest and most diversified mineral resources both in Africa and in the World. Therefore, it is an essential activity for the progress of the Angolan society, since it plays an important role in the generation of jobs and reconstruction of the country.

Geological Context of Angola

The Geology of Angola consists of depressions or sedimentary basins and the crystalline substrate:

- The peri oceanic sedimentary edge comprises the sedimentary basins of Congo, Kwanza and Namibe, whose ages vary from the Cretaceous to the Quaternary Period. These coastal deposits lie directly on the Precambrian basement, bordered to the east by the African Shield and to the west extending along the continental slope. The east of the country comprises the Congo and Okavango depressions; and
- The Crystalline occupies a vast area, with the shields and the platform, whose rocks present almost exclusively Precambrian ages.

Angola's Tectonic Division

The Angolan sector of the African platform consists of two structural floors; the lower one, which corresponds to the crystalline basement (lithological-structural complexes of the Archaic and early Proterozoic) and the upper one, which is the cover of the platform, constituted by the complexes of the late Proterozoic, Paleozoic, Mesozoic and Cenozoic.

In Angola, the major tectonic-structural elements comprise:

- Punch Protrusions: Shields from Maiombe, Angola, Cassai, Bangwelo, and Horst do Cuanza; and small outcrops of crystalline rocks in the North and Southeast of Angola.
- Structure of the Platform Cover: Late Proterozoic; Western Congo Aulacogen; Riftogenic depression of Lutete; and Congo and Okavango Precambrian Plates, represented by thin unfolded deposits.
- Platform Tectono-Magmatic Activation Zones: Late Rifean with manifestations of basic, acid and alkaline magmatism; Mesozoic with the installation of a great diversity of intrusive rocks of ultrabasic-alkaline, basic and alkaline composition, Kimberlites and carbonatites; and Meso-Cenozoic with intrusion of basaltoids, dolerites, granitic porphyries and rhyolites.

Tectonic Evolution of Angola

1st Basis

The Angolan portion of the African shelf, although stable since the end of the Pan-African cycle, has undergone several stages of cratonisation during the Precambrian, which were well marked either through well-dated folding bands or isotopic rejuvenation of common age at various points of the globe. The Angolan region, which underwent the earliest cratonisation, was the northeast of Angola, forming part of the Cassai Shield. It is currently partially covered by recent sediments. The ages range from 2,915 to 2,500 Ma.

After the Lunda region was cratonized, a large part of Angola moved to the para-platform stage, followed by a very complex evolution. In the south at about 2,200 Ma. the large anorthosite Gabbro complex in southern Angola was installed. In the centre and north the sediments were granitised and cratonised occupying several events to which they were involved without increasing their degree of metamorphism, being able, however, to be isotopic ally rejuvenated.

2nd Stage of Transition

The process by which a given developing region passes from geosyncline to orthoplatform is long and characterised by several intermediate stages. In Angola, this stage began with the deposition of sediments superior to the schist-gresoso series of the Western Congo System. These Molassic sediments are well represented in the Pungo-Andongo region. Also in the Namibe region there are lava rocks that are also evidence of the transition stage.

3rd Stabilisation Stage

At this stage, marked subsidence phenomena begin with the appearance of two large syncyses separated from each other by the Moçâmedes arch. In the north is the Congo syncysis with the tilitic sediments of the Lutõe Series overlaying the crystalline basement. Further in the south, the Kalahari syncysis appears completely to be underlain by the Kalahari sediments. At Cassange, in the Lunda region, Karroo sediments are deposited. Finally, Arco do Zaire and Horst do Cuanza are two structural units that had their evolution during the platform evolution phase.

4th Stage of Reactivation

Once completely consolidated, the platforms can enter this period of reactivation that will give them peculiar characteristics and lead their internal arrangement to a complete structural reorganisation, which results in the reactivation of old faults and arches, mountains in blocks, intense volcanic activity, formation of tectonic basins, implantation of granitic and alkaline cratonic plutonism and important mineralisations.

There are several aspects provided in Angola by the reactivation, highlighting the basic and alkaline magmatism, the tectonic basins, the alkaline granite of Morro Vermelho, and the elevation of the entire coastal region with the consequent formation of abundant conglomerates. The basic magmatism extends across the entire region of Novo Redondo, Moçâmedes, Foz do Cunene and Lunda, whereas the alkaline magmatism is well evidenced by the kimberlitic intrusions of Lunda.

ASM in Angola

In Angola, in principle, there should be no ASM activity due to the measures taken by the executive power to create adequate mechanisms and methods to transform this activity into cooperatives and semi-industrial farms, ref. Presidential Decree No. 85/19, which approves the Regulations for the Semi-Industrial Exploration of Diamonds.

Legislative Framework for the ASM Sector in Angola

An analysis of the mining activities by the existing mining cooperatives in Angola revealed that the achievement of the State's objectives regarding the semi-industrial exploitation of diamonds is more efficient through the creation of small and medium-sized enterprises.

There is a need to reinforce compliance with the Mining Code in mining activities, improve the guarantee and stability of jobs generated by the semi-industrial exploitation of diamonds and their contribution to the generation of income for communities and the State.

Principles of Semi-Industrial Mining

ARTICLE 4 (General Principle)

1. The semi-industrial exploration of diamonds can only be carried out by legal entities duly licensed by the Ministry of Guardianship;
2. The semi-industrial exploration of diamonds is carried out at the risk and expense of the investor, in compliance with the terms of the favourable geological information and negotiation provided for in paragraph 2 of article 97 of the Mining Code; and
3. This activity is also governed by the provisions of the administrative grant instrument, as well as by instructions and technical regulations issued by the Ministry of Mineral Resources and Petroleum and by the supervised entities that act on diamonds, within the scope of their respective competences.

ARTICLE 5 (Principles on Prevention and Suppression of Illegal Activity)
As part of the prevention and suppression of the illegal exploitation of diamonds, the following are fundamental principles applicable to the semi-industrial exploitation of diamonds:

1. Principle of Proactive Prevention;
2. Principle of Risk and Threat Detection; and
3. Principle of Protection of Mining Occurrences.

ARTICLE 6 (Proactive Prevention Principle)

1. The relevant directorates of the Ministry of Mineral Resources and Petroleum (MIREMPET) and the supervised bodies that act on diamonds must carry out studies, collect, process and regularly share data aimed at identifying situations of illegal exploitation of diamonds; and
2. The measures foreseen in the previous number must pay special attention to situations that occur with the participation, directly or indirectly, of foreign citizens or entities promoted or sponsored by them.

ARTICLE 12 of Presidential Decree No. 85/19: Approves the Regulations for the Semi-Industrial Exploration of Diamonds. (Institutional Intervention of the National Concessionaire)

1. Assignment of areas, with the related sketches of location, after negotiation according to the Mining Code.
2. Follow-up of the process until the approval and issuance of the mining title.

ARTICLE 16 (Limit of Areas)

1. The proposed area limit must vary between 50 km2 to 200 km2 (5 000 to 20 000 ha).
2. Exceptionally, any company that presents technical, organizational and financial conditions may be able to request an additional area.

Degree of Organisation of the ASM Sector (Cooperatives)
In Angola there are currently around 188 semi-industrial cooperatives operating in the mining sector, specifically in the exploration of diamonds. These cooperatives are distributed in the different provinces where diamonds are found.

Role of the Geological Service of Angola in Supporting ASM Operators
The Geological Institute of Angola plays a very important role as one of the first State institutions to get in contact with the mining cooperatives, since it is the responsibility of the institute to provide both geological and geophysical information by means of geological maps, small-scale regional maps, as well as large-scale local or detail maps. Furthermore, the institute, through its technical staff, can be useful in

providing technical assistance in prospecting, research and identification of potential areas for mining. Additionally, the institute has technological means through its laboratories fully equipped with apparatus capable of analysing geological materials of various natures.

Environmental and Health Impacts of ASM Activities

Deforestation

Visual degradation from deforestation is one of the main environmental impacts. It is caused by the removal of the cover of the vegetation, the development of the open pit mine, the implementation of infrastructure (housing, offices, etc.) and the disposal of solid and aqueous waste.

Impact on the Landscape

The main and most characteristic impact caused by the mining activity is the one related to the degradation of the landscape. However, even though such detrimental changes and damages to the environment and landscape should not be accepted by society, the mining activities cannot be prevented since they also demanded by that very same society for creation of jobs and thereby income for society. A form of balance must therefore be found between the mining activity and the environment to best protect and restore the environment post-mining activities.

Impact on Health among ASM Operators

ASM operators live day-to-day with risk factors that inevitably endanger their health, such as dust that causes respiratory diseases, inhalation of toxic and chemical substances associated with cancer and, in particular, conditions of vulnerability that leads to the occurrence of accidents at work, which are commonly serious and fatal.

Physical negative impacts on ASM operators include: extreme temperatures, heat, humidity, lighting, noise, vibrations and ergonomic risks, i.e. inappropriate postures and repetitive movements.

Socio-Economic Problems related to the ASM Sector in Angola

The ASM sector in Angola has faced problems related to the lack of investment. This problem is already being sorted out by the executive power through the creation of mechanisms and favourable strategies in order to attract investment in the mining sector. One of the practical examples is the transformation from artisanal exploration to semi-industrial exploration.

The Role of Women

In the Angolan mining sector, women play a key role in the sector's development. In principle, almost or nothing distinguishes the countless tasks performed by men, because they are also performed by women without any constraints. In the mining camps, the presence of several women performing different functions is currently evident, among them, geologists, mining engineers, surveyors, metallurgy engineers, mechanics, electricians, cooks, nurses, wardrobe doctors and, often, are women responsible for marketing the extracted products.

Child Labour

Unfortunately child labour is a reality in Angola. The use of child labour within the mining activity is mainly caused by the lack of basic conditions for survival. This problem is growing more and more due to the numerous difficulties experienced by the Angolan families.

The use of child labour in Angola is for profit as children tend to earn less than adults. However, there is a cultural and historical issue, expressed in old slogans, but still used today, such as: ”child work is little, but almost no one dispenses it, although they are aware of the consequences”.

Families themselves are often the biggest drivers of child labour. For example, in Angola it is very common for a woman to be accompanied by her children during the marketing of minerals. It is a practice that must be vehemently condemned; however, external circumstances forces families to engage in child labour.

Conflicts with Local Farmers and Other Stakeholders

In some areas there are conflicts between miners and farmers, ranchers and other interested parties. Often, in agricultural rural areas, the populations that cultivate them are forced to leave due to mining interests and for various reasons. The main reason has to deal with wrong sketches of location, which are complying with legal procedures, or even others that are invented. This creates conflicts because areas considered uninhabited for mining are in reality inhabited by communities. This results in conflicts that are related to the expropriation of land by farmers or the Government for public interests in rural areas. In addition, farm fences interfere with systems, not only in livestock management for herders, but also for farmers.

Conflicts with Criminal Gangs in the Mining Area

In Angola there are evidence of no conflicts involving criminal gangs in the ASM sector. The impact of criminal gangs or terrorist groups in the ASM sector in Angola is zero.

Two young girls working at a mining site in central Ghana.

ASM SECTOR OF GUINEA-BISSAU

By Vanessa lala Pires and Madiu Tanzigora, Direcao de Geologia e Minas

Guinea-Bissau is located on the West Coast of Africa, bordered on the North by the Republic of Senegal, on the East and South by the Republic of Guinea-Conakry and on the West by the Atlantic Ocean, having an area of 36,125 km² and with almost 1,700,000 inhabitants. In addition to the mainland, the country has a wide area that also has about 88 islands, which form the Bijagós archipelago, with an extensive protected area covered with an incredible diversity of ecosystems, ranging from dense tropical forests to swamps of mangrove. About 26% of the national territory is classified as a protected area (World Bank, 2015a). Its territorial extension is divided into eight regions: Bafatá, Biombo, Bolama, Cacheu, Gabu, Oio, Quinara and Tombali, and the autonomous sector of Bissau, which is the administrative capital.

The society is largely agrarian, almost entirely relying on a single harvest: cashew, as the country is the fifth largest exporter of cashew nuts in the world, and its quality is internationally recognised, being the main source of income for the majority of the population (World Bank, 2015b).

Geology of Guinea-Bissau

The geology of Guinea-Bissau comprises, ref. Figure 16:

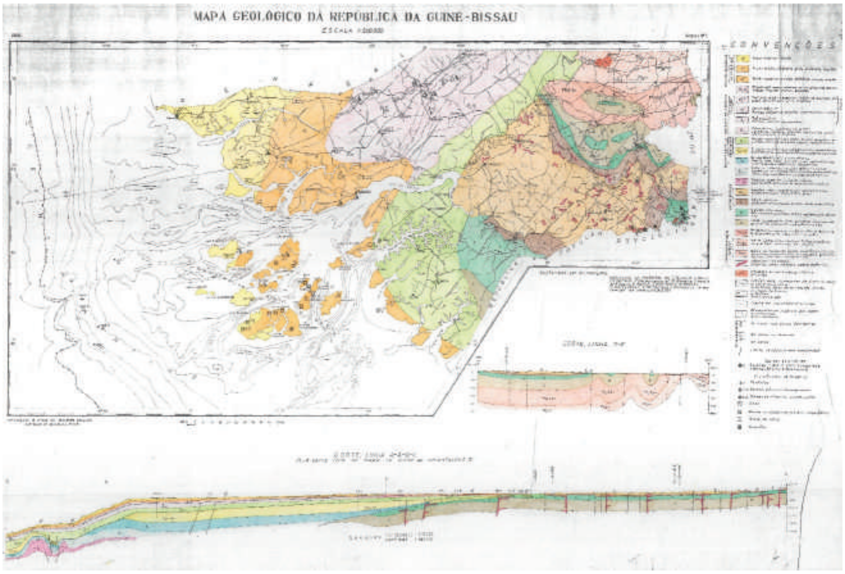
- Thick sediments of the Mesocenozoic Basin, occupying the western half of the country, formed by sedimentary infill in progradation; and
- Paleozoic and Precambric rocks, occurring to the east, generally covered by thin sediments. The oldest units are correlated with known groups in this north-western region of Africa: ″VS″ (Koulountou Group), ″C1″ (Bafatá), ″C2″ or ″Sandstone from Caium″ (Youkoiunkoun), Ordovician (Pita Group), Silurian (Télimélé Group) and Devonian (Bafata Group). The quartzites and sandstones (C2-Sandstone from Caium, Ordovician, Devonian) form, with the Jurassic dolerites, the largest outcrops.

According to the World Bank memorandum, Guinea-Bissau is a country with enormous potential. It is rich in natural resources yet to be explored. Currently, in addition to the phosphate, bauxite and heavy mineral sands deposits, which have already been extensively studied, the prospecting work carried out from 1983 to 1985 by the Portuguese company, S.P.E.-S.A, has shown positive results for gold (>6ppb and >125ppb).

As part of a mapping and prospecting project carried out by BRGM, geochemical anomalies were discovered for copper, lead, zinc and molybdenum in the Gabú region, in the east of the country.

But the only exploitation that is currently undertaken are construction materials (quarries or aggregates), dolerites, Budigor granites, sand-quartzite's and laterites, contributing with 0.4% to the country's GDP from 2015 to 2017 (INE, 2017).

FIGURE 16 | SIMPLIFIED GEOLOGICAL MAP OF GUINEA-BISSAU



Source: Direcao de Geologia e Minas, Guinea-Bissau

ASM in Guinea-Bissau

Guinea-Bissau is not a country with a mining tradition as such. The only large-scale explorations that take place are for construction materials.

However, when it comes to artisanal exploration and small-scale mining, there is a significant activity in the extractive sector, albeit with a strong participation of women and children.

The organisation of the ASM sector in Guinea-Bissau has not made great progress; in fact, the sector in general has no associations, in addition to the

Except for the Association of Guinean Women in the Extractive Industry, created in 2019 with the support of the organisation of Women in Mining of West Africa, which integrates women professionals in geosciences and mine workers of all categories, there are no other formal associations of ASM miners exists.

In 2004, the General Directorate of Geology and Mines carried out a census of artisanal inert explorers in some regions of the country, namely: the autonomous sector of Bissau and the regions of Biombo, Oio, Cacheu, Bafatá and Gabu. As a result, 526 explorers were registered, 4,717 people live from the sale of aggregates, produce 397,725 tons of gravel (total sum of annual production averages), 218,475 tons of sand (total sum of annual production averages), 14,020.5 XOF (average price of the sale of each ton of sand) and 16,086 XOF (average sales price of each ton of gravel) (Tamba, 2014).

According to Article 9, Paragraph C of the Mines and Quarries Code, mining titles, denoted Small Mining Licenses, can be obtained under the following terms and conditions:

After an exploration permit, if the discovered deposit does not have the characteristics or dimension enough for the development of a conventional mine, a small mining exploration permit may be granted by order of the Minister responsible for the mining sector. This license can be granted to any person, natural or legal, national or foreign, but it cannot cover an area greater than 10 ha and is issued for a period of three years, renewable, upon request, and for additional periods of two years, followed by a proof that the exploitable reserves are not sold off, and the holder fulfils his obligations.

According to Article 28 of the Mines and Quarries Code, an application for an Small Mining License must be submitted to the Minister, accompanied by proof of payment of the license fee, and include:

1. A simplified feasibility study;
2. A development plan;
3. An EIA;
4. A site rehabilitation plan; and
5. Name, registered office, registration number, taxpayer number, and mining permit number, if the applicant is a legal person.

According to Article 27 of the Mines and Quarries Code, the holder of a Small Mining License is obliged to start the operations within a maximum period of 60 days from the date of obtaining it, and has to present reports on the progress of the work carried out semi-annually to the Minister.

At the work place during the undertaking of mining operations, licenses or certified copies must be present.

In addition to taxes owed by law, it is mandatory to also pay a production tax, which may be required on a monthly or quarterly basis. The production tax is initially based annual production forecasts but subsequently regulated according to actual production at year end.

The role of the General Directorate of Geology and Mines is to organise and monitor the activities of ASM in Guinea-Bissau, such as organise training and seminars to build national capacity for a better production and sale, and avoid risks, health and environmental damage. However, given misuse of the National Mining Fund, which should be used for above training purposes, there is no follow-up or training anymore.

Environmental and Health Issues related to the ASM Sector in Guinea-Bissau

The ASM sector in Guinea-Bissau is not very developed compared to other countries, but that does not exempt it from environmental and health problems. The situation is even more worrying because the authorities responsible for both, mines and environment, do not follow up on the problems of this activity properly.

Environmental Impacts

In quarrying, a large amount of water is not consumed; hence, there is no great impact on the superficial water resources, i.e. rivers and lakes. However, there is problem of deforestation at mining sites without any replanting post-exploration – and extraction, resulting in a loss of, especially, cashew plantations.

Further, due to the lack of knowledge, the actors in the ASM sector end up exploring in a disorganised way, creating great impacts on the landscapes and without any landscape recovery plan.

Health Impacts

Although there is no official data that report on these health impacts, the amount of dust, both at the time of extraction and upon loading trucks, show the type of health dangers that the workers are exposed . At several times, on dirt roads, not wet periodically, they end up releasing a large amount of dust that is very harmful to the health not only for the workers, but also for those living in the surroundings.

Exploitation is primarily done in an old-fashioned way without using the classic methods of exploitation or respecting elementary safety standards. However, according to the 2004 census, in the entire national territory there were recorded only 7 deaths due to the lack of observance of elementary safety standards for mining.

Socio-Economic Problems Related to the ASM Sector in Guinea-Bissau

The ASM sector in Guinea-Bissau, being an informal activity, ends up bringing socio-economic problems non-negligible because the most vulnerable and target people are women and children.

Gender Issues and Child Labour

Despite the existence of an association of women in the extractive industry, the phenomenon of gender inequality in terms of earnings is notable where women are used frequently as cookers or in activities regarded less important or those that require use of less energy, physical strength, since most of the work is carried out by hand and this is very proportionally with the earnings.

The Guinean law prohibits child labour, but due to lack of control many children are employed in these jobs and used as cheap or free labour. These activities are highly harmful to their health, forcing their withdrawal from school.

Conflicts

Sometime, explorers end up entering cashew gardens (cashew trees) for exploitation and as a result, the pollution from the mining activities create problems for the production of cashews, which is the main source of livelihood for many families which end up in conflicts with the miners. Apart from these conflicts, between farmers and extractive sector stakeholders related to land use conflicts, no involvement of criminal gangs or terrorist groups is known in Guinea-Bissau.

Small marked at Tsiquir mining site. Mozambique

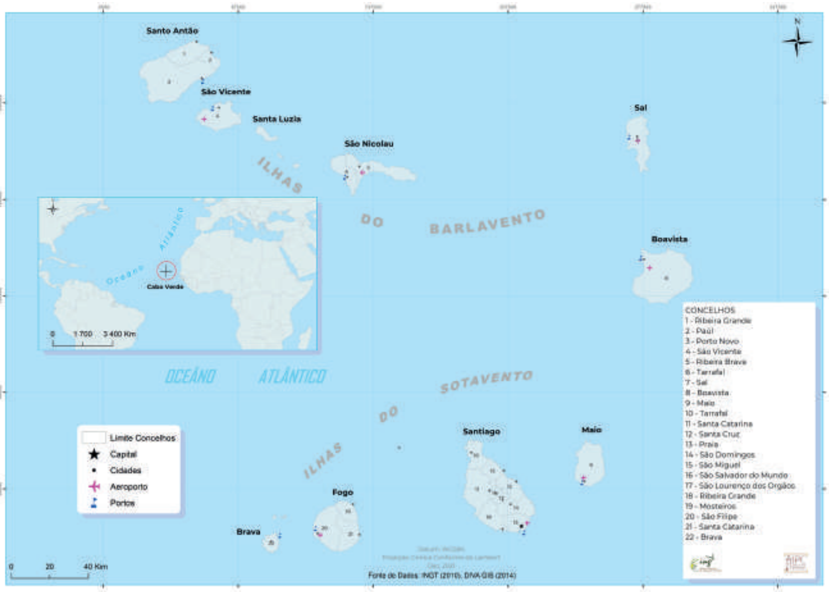
ASM SECTOR OF CAPE VERDE

By Carlos Jorge Carvalho Casimiro and Ineida Pereira Baptista, Instituto Nacional de Gestao do Territorio

Geographic Location, Demographic and Economic Aspects

Cape Verde is an archipelagic country located in the middle of the Atlantic Ocean. The total area of the extension is about 4,033 km2. The archipelago of Cape Verde is made up of 10 islands, one of which is uninhabited. Cape Verde is geographically located in a strategic position, 45 km from Senegal, on the accustomed coast of Africa. Cape Verde is part of a group of Atlantic islands called Macaronesia, highlighting the Açores, Madeira, Selvagens, and the Canarias Islands. Due to the trade winds from the northeast, the island is divided into two groups: The Barlavento islands, located in the north part; and the Sotavento group, located in the South, ref. Figure 17.

FIGURE 17 | LOCATION AND MAP OF CAPE VERDE



Source: Instituto Nacional de Gestao do Territorio, Cabo Verde

The Barlavento group is composed of the islands of St. Antao, S. Vicente, S. Nicolau, and St. Luzia (natural reserve and uninhabited area) in the northern part of the country. In the eastern part of the archipelago, the Barlavento group is formed by the islands of Sal and Boa Vista. The islands that characterise this group are, in turn, composed of different islets, as in the example of the islets Branco and Raso between the islands St. Luzia and S. Nicolau, the islet Pássaros on the island of S. Vicente, the islet Rabo de Junco on the island of Sal and the islets Baluarte and Sal de Rei on the coast of Boa Vista.

The Sotavento group is made of Maio and Santiago islands in the East and northeast and Brava and Fogo Island in the south part of the archipelago. The group is made also of different islets, highlighting St. Maria islet within Santiago Island, the Grande, Rombo, Baixo, Cima, Rei, Luís Carneiro, Sapado, and Areia islets that a very close to Brava Island. Santiago Island is the biggest island, with 991 km2, followed by St. Antao Island with 779 km2 of area. The smallest ones are the Brava and Sal islands with 62.51 km2 and 219.8 km2, respectively.

In 2021, Cape Verde had 505,044 inhabitants, comprising residents, visitors, people without a residence, and others. Nevertheless, among these, 491,337 are residents without a house, where 246,464 are men and 244,873 are women. It is important to highlight that of the total population 65.1% are aged from 15-64, 28% are aged from 0-14 and only 6.7% of the total population are more than 65 years old. Further, Cape Verde is classified as a country made up of young people, where 74,1% of the total population considered live in urban areas and 25.9% in rural areas. These results shows clearly the pressure that exists in the cities, which is characterised by some particularities, since many cities are still located in municipalities with a predominance of a rural lifestyle.

Cape Verde has few geological resources, which, under Articles Nº 1 and 2, of Legislative Decree Nº 14/97 of July 1, are classified as natural resources that exist in the earth, mineral deposits, hydro-mineral resources, geothermal resources, groundwater, hydrocarbon deposits, polymetallic nodules, and underground lands integrated or not in the public domain of the State.

The limitation of these resources contributes to the very low and controlled exploitation of natural resources in Cape Verde and its small contribution to the country's economy is almost invisible, i.e. in 2015 the contribution of the extractive sector to

FIGURE 18 | EVOLUTION OF THE EXTRACTIVE INDUSTRY’S CONTRIBUTION TO CAPE VERDE’S GDP (2007-2015)

Source: INE, 2015

Geological Background of Cape Verde

Simplified Geological Map of Cape Verde

Cape Verde has geological maps/sketches for all the islands of the archipelago, except for the geological sketches of St. Luzia Island, ref. Figure 19.

FIGURE 19 | GEOLOGICAL MAP OF CAPE VERDE

Source: Instituto Nacional de Gestao do Territorio, Cabo Verde

Geological Description of Cape Verde

The Cape Verde islands result from volcanic activities. The archipelago of Cape Verde is notably characterised by anomalies, highlighting the bathymetric, geoid, and gravimetric anomalies that suggest that the volcanism results from a hotspot. This means that in this region there are conditions that favour the formation of magma.

It is important to underline that the causes of the existence of the hotspot are not clearly understood. Some researchers agree with the new seismic tomographic data that suggests the existence of hotspot due to a magmatic plume with a very deep root in the mantle, and others, agree that the root of the magmatic hotspot is very superficial. However, many people agree that the main cause of the volcanic activity of the archipelago is a hotspot called Cape Verde hotspot. Nevertheless, in the other parts of the world where hotspot volcanism also exists, the islands tend to be short-lived, such as those located in the further west part of the Hawaii archipelago; however, the geological history of Cape Verde is different.

On the other hand, in these parts, the islands or the chains of volcanoes tend to align themselves according to the movement of the plates on which they have developed. In Cape Verde, the islands are distributed in a horseshoe shape with an opening to the west. Currently, these two peculiar characteristics are explained by the fact that the speed of rotation of the African plate on which the islands are based is very small in this region.

In Cape Verde, the incipient processes of volcanism, or the beginning of plutonic activity, started about 19 million years ago. Nonetheless, the eruptive activity above the sea level began approximately 16 million years ago in the islands of Sal and Maio (probably also in Boa Vista).

On Sal Island, the eruptive activity extended until about 1 million years ago with interruptions of a few million years. The ages of the main periods of activity are 16, 11.2, 5.4, and 1.1 million years, respectively. On Maio island, the activity was aged between 12 and 7 million years. The rocks and the volcanic activity were discontinuous with interruptions of about 4.6 Ma.

The eruptive activity of St. Nicolau, which began about 6.2 million years ago, was also not continuous and was distributed in four main stages. The first one is from 6.2 - 5.7 Ma, the second was between 4.7 to 2.7, followed by 1.7 - 1 Ma and from 100 to 50 thousand years, respectively. Brava Island is the youngest, the beginning of volcanic activity seems to be about 2.1 million years old and the most recent rocks are about a thousand years old.

Another prominent feature of some islands is the almost permanent elevation. This phenomenon is mainly observed on St. Nicolau, Santiago, and Brava.

The data shows that:
1. Islands with very pronounced age differences and very distant from each other have erupted simultaneously, as is the case of St. Antão and Maio Island; and
2. In many of the islands the eruptive activity has been intermittent with some periods of inactivity, as is the case of the islands of Sal, St. Nicolau, and St. Antao.

Exploitation of Natural Resources in Cape Verde

Main Resources Exploited in Cape Verde

Due to its geological characteristics, Cape Verde's main mineral resource predominantly exploited by miners is rocks. The growing exploitation of inert minerals has generated a strong pressure on the extractive areas in the islands with higher demographic concentration but is also associated with the strong dynamism in the construction of infrastructures and rural engineering. Until the end of the last century, the supply of aggregates market was dominated by spontaneous exploration, which mainly mined gusher, foundation stones, and masonry stones, on the slopes and collected sand and gravel on the beaches and water lines.

This spontaneous exploitation guarantees employment, although precariously, involving a part of the poor population. The incidence of this exploitation of sand and gravel, on beaches and riverbeds, has been harmful to the environment, being legally prohibited by Decree-Law Number 69/97 of November 3. Several studies, produced in the context of conservation of natural resources and environmental protection recommend the urgency of industrial production of inert materials to reduce the incidence of sand exploitation on beaches and riverbeds.

The island of Santiago, a region where more than half the population of the archipelago reside, presents a growing increase in infrastructure, becoming the largest market for the consumption of aggregates. Considering the possibility of the emergence of tourism and the prospects for investment in roads, urbanisation, and real estate construction, greater consumption is expected in the coming years.

In recent decades there has been a large consumption of aggregates without precedent in the history of the islands of the Cape Verde archipelago. Among the possible causes of this increase are:
- Population growth and the consequent demand for housing, infrastructure, equipment, and rapid expansion of urban centres;
- Technological changes in the civil construction sector with the substitution of traditional houses, made of stone and clay, for cement blocks, sand and gravel;
- Increase in urbanised areas and thus infrastructure, namely roads, ports, and airports;
- Rural engineering constructions, mainly, mechanical soil and water protection devices;

- Increase in housing constructions associated with real estate speculation; and
- Promotion of tourism and the consequent construction of accommodation infrastructures.

Legislative Framework for the Sector of Exploitation of Natural Resources in Cape Verde

The legislative framework for the sector presents a lack that urgently needs to be addressed, especially regarding the definition of competencies and the creation of entities whose mission is exclusively to manage geological resources as well as their regulation. However, there are separate pieces of legislation, as listed below, which individually mention and address some issues related to the exploration of the extractive industry sector.

For example, the Basic Law for Environmental Policy, which establishes the basis for the Cape Verdean environmental policy, is guided by the principles of prevention, based on the reduction or elimination of the impacts of this activity on the environment as well as the restoration of negative effects that affect the quality of the environment.

Legislative Decree No. 14/97 specifies in Article 3 that plans, projects, works, and actions that by their nature, size or location, are susceptible to causing significant impact on the environment, the territory, and the quality of life of citizens, are subject to a prior environmental impact assessment process as an essential requirement for the licensing of the work or project. This decree also establishes, in its Article 32, Number 3, that quarrying must be undertaken in a controlled manner so that it cannot cause damage to the environment, namely the deterioration of the landscape and surrounding environment, in such a way than can put the safety of human and property in danger.

Decree-Law no. 27/2020 of March 19 establishes the legal regime for the EIA of public and private projects susceptible to cause impacts on the environment.

Decree-Law No. 56/2014 of October 7 establishes the legal regime for the disclosure and use of natural resources existing in the soil and subsoil, generically referred to as geological resources. Integrated or not in the public domain of the State, except for hydrocarbon occurrences. Under the terms of point 1 of article 6, the establishments of mineral masses take the designation of quarries, and their exploitation is referred to specific legislation creating Decree-Law No. 3/2015 of January 6, as amended by Decree-Law No. 34/2021, which defines the legal framework for the exploitation of mineral masses, comprising their exploitation.
There is also Decree-Law No. 6/2003 - Legal Regime for the Licensing of Inert Exploration and Decree-Law No. 18/2016 - Legal Regime for the Extraction of Inert, also applied in the matter.

Organisation of the Mining Sector into Cooperatives and Associations
The mining sector is characterised by the existence of several duly registered private companies that operate in the area of quarry and aggregate (sand) exploration and by individuals who practice this activity for their own and their family's livelihood. According to the Classifier of Economic Activities, the data about companies, personnel employed in companies, and company turnover recorded between 2011 and 2015, indicates the existence of 15 official companies in the area of extractive industries, 131 people employed in these companies and 347 million Cape Verdean currency (INCV, 2016).

The dynamics of urban growth have allowed the sector to receive greater attention and concern from entities for the impact it causes on the environment, landscape, and the lives of the population in general. However, combining these aspects with the weak structural organisation of the activity by its operators, makes difficult the existence of records of legally formalised cooperatives or associations operating in the sector in Cape Verde.

The Role of the National Institute for Territorial Management
The National Institute for Land Management, in the context of its duties regarding geology in coordination with other entities, has the responsibility to promote the coverage of the national territory through geological mapping; elaboration, promotion, and adoption of national technical standards for spatial planning and urbanism; and production and reproduction of basic and geological cartography. It is also responsible for promoting the development, dissemination, and commercialisation of products and technical information within the scope of spatial planning, urbanism, housing, geodesy, basic and geological cartography, and land registry.

On the other hand, it is observed that in Cape Verde there is no institution with exclusive legal and statutory responsibility of the issues related to geology, thus those issues are addressed in various institutions, such as the Laboratory of Civil Engineering, The National Institute of Meteorology and Geophysics, The University of Cape Verde and the National Directorate of Environment. The latter has the responsibility for the controlling the exploitation of aggregates and quarries, from licensing, through supervision and control of exploitation, approval of environmental impact studies to the cancellation or renewal of exploitation licenses.

Environmental and Health Problems Related to the ASM in Cape Verde

Impacts on Watercourses
First of all, it is important to emphasise that in Cape Verde there are no rivers or lakes. Therefore, the impacts described here happen in streams and seasonal watercourses. The exploration areas located in the creeks have particular landscape characteristics. Through the visual analysis of these landscapes, it can be seen that

it is a unique landscape diversity, generally virgin, with a well-defined and indented water body and a very diverse orography resulting from the natural phenomena and processes, which are the basis of the origin and evolution of the islands (volcanism, erosion, sedimentation).

In the analysis of environmental impacts, the evaluation of the spatial incidence of these extraction sites, regarding their exploitation time, as well as the main threats to the sustainable development of the locality, in case that the mitigating measures are not adopted, it is therefore, emphasised that the most significant negative impacts are consequence from the extraction process.

Deforestation

The vegetation of the Cape Verde islands consists of species introduced by man as well as other vectors, such as birds, sea currents, and winds. Cape Verde's forest areas are extremely vulnerable as a result of persistent drought. Similarly, human pressure on resources has contributed to increased forest vulnerability, despite efforts undertaken by the government for its protection and preservation.
The tree heritage found in the areas of aggregate extraction consists of trees of various species in which Prosopis juliflora (American wattle) and Azidirata indica (Tendente) are dominant species. Other plant species can also be found, such as Amaranthus, Datura, Boerhavia, Echinochloa, Cynodon, Brachiaria, and Prosophis juliflora, the latter a result of forestation campaigns in the post-independence years.

From an ecological point of view, when there are implications for existing forest patches, it is recommended that the activity should be monitored and accompanied by environmental management measures in order to maintain the sustainability of the landscape. Some of these measures involve the implementation of landscape recovery actions in the exploration area. In addition, in other areas, the restoration process happens naturally, because there are species of cyclical life that are born immediately after the rainy season.

Impacts on Landscape

The visual characteristics of the landscape, affected by the extraction and aggregate processing, present a low sensitivity due to the very poor visibility to which the exploration zone is subjected. It might be considered with some reservation that these sites have a reasonable capacity to absorb changes caused by human activities. When they do exist, these visual impacts will be more significant in more larger areas of intervention, in the areas of considerable time of exploration.

It is important to note that the implementation of the Landscape Recovery Plan mitigates many of the identified negative impacts. This will have a great contribution on the reduction of the magnitude of the impacts predicted for the operation.

The Socio-Economic Problems Related to the ASM in Cape Verde

The Role of Women

In Cape Verde, there has been a progress in the involvement of women in the economic, social, and political sectors. However, the participation of women in the informal market is more representative, especially in the exploitation of aggregates for construction, a situation justified by cultural tradition and the peculiar situation of the country. In fact, in Cape Verde women perform a set of domestic activities (cooking, housekeeping, childcare, among others), as well as many other activities to support the direct subsistence of families, such as the practice of agriculture and livestock. In these activities, women are not entitled to remuneration or even social recognition, since they are activities traditionally considered to be female.

In the pyramid of economic, social, and political organisation, the percentage of the female population progressively decreases as one ascends to the highest levels of the hierarchy. It is much easier for men than for women to reach the highest or best-paid positions, even when they are less qualified, either academically or professionally.

However, when women do reach a leadership position it is more often in traditionally female sectors of economic activity, such as education, health, and social action. Most women, due to their low level of education or access to qualified training, do not enter the formal labour market. Therefore, to ensure the subsistence of the family, women participate in multiple activities, including the difficult task of illegal aggregate extraction, which has detrimental implications for the environment.

Child Labour

From the analysis of the available documents, including surveys of people who clandestinely extract the aggregates, it became clear that the riverbanks and coastal strips are increasingly asserting their importance in the economy of the populations, especially female heads of families affected by unemployment and precarious situations.

In addition to the female heads of household, there were also children, the elderly, and some adult men, working in a part-time regime. The children because of school, the elderly because of their health and age, and the adult men for personal reasons. As they get older, physically and psychologically mature, men feel afraid or even ashamed of doing the extractive activity because of the strong exploitation on which they are subjected. Other reason behind this activity is a difficult, dangerous, and low-income task, where the most advantaged group are the truck drivers (men) as they buy the aggregates from those involved in the extractive activity and sell them to the final consumer, thus doubling the price.

Conflicts with Local Farmers and Other Stakeholders

In Cape Verde, conflicts of this nature are very residual, since aggregate exploitation occurs in stream beds and coastal areas, taking into account that both streams and the coastline are State property and classified as public domain. Eventually, because the exploration areas are located closer to some water holes and where traditional and subsistence agriculture is practiced, there might be some conflict of interest because of the water. However, these cases are scarce, because the explorers of these areas are mostly members of the same family.

Conflicts with Criminal Gangs in the Mining Area

This is not the case in Cape Verde, due to the importance and economic value of the existing mining and geological resources.

Impact of Criminal Gangs or Terrorist Groups on the ASM sector

The impact of criminal gangs does not occur in Cape Verde, for the reasons previously described. However, in some uncommon situations, small disagreements between landowners happen when there is an illegal appropriation of their land by ASM operators, truckers, and some larger explorers. Also it can happen when a prohibition of extraction of resources by the state in a certain area, or also when there is too much demand. These situations in in its turn, usually lead to an increase either in the selling price or waiting time for consumers. However, these are not situations that can be compared with conflicts between criminal gangs or terrorist groups, as it is observed in some countries where there are many geological and mining resources of great economic value.

Open pit barite mining in Azara, Nasarawa State. Nigeria.


The owner is inspecting the mining operation, north of Osino in central Ghana.

ASM SECTOR OF SAO TOMÉ AND PRÍNCIPE

By Ana Sofia Ten-jua de Castro and Valdimiro Do Nascimento Will, Direcao de Geologia e Minas

Geographic Location and Social-Economic Characteristics of São Tomé and Príncipe
The Democratic Republic of São Tomé and Príncipe is a state consisting of two small islands and islets. The total territorial extension is about 1,001 km2, with the island of São Tomé and adjacent islets having a total surface area of about 859 km2, whereas the island of Príncipe, including adjacent islets, have a surface area of about 142 km2.

The islands are located in the Gulf of Guinea, at the level of the equator, about 250 km of the northwest coast of Gabon. The climate is of equatorial type, ranging from hot to humid, being the annual average temperatures between 22°C - 30°C. Due to its geographical location, the country is part of the Small Island Developing States.

According to statistical data from the latest General Population and Housing Census, conducted in 2012 by the National Statistics Institute (INE, 2012), the country has a total population of 187,356, where about 61% of the population are young, under the age of 25. However, among these, 51% are women.

The annual population growth rate is estimated at 2.5% and average life expectancy is 65 years. The population density is 187 inhabitants/km^2, with the majority concentrated in the country's capital. The fertility rate is 3.5 births per woman. Príncipe Island is the smallest, with an estimated population of 9,000 in 2020.

According to the Administrative Political Division, São Tomé and Principe is a country made up by six districts and an independent zone called "Região Autonoma do Principe", which has its own administrative entities. The districts of São Tomé and Principe are namely: Água Grande, Cantagalo, Caué, Lembá, Lobata and Mé-Zóchi. Each district is subdivided into cities and towns, and small villages.

The economy is strongly affected by the fragility of the insular nature of the country and by the low capability of absorbing resources, thus causing an enormous dependence of the country on external financial support. For these reasons, São Tomé and Principe is considered a low-income country. A poverty profile study published by the National Statistical Institute in December 2012 estimated that 66.2% live at the poverty line (INE, 2012).

Due to the weak economic growth, the country has experienced over time, several challenges, with emphasis on the rising price of oil, the high cost of transport and communication, lack of infrastructure and skilled and qualified human resources.

To this end, in recent years the search for raw materials of mineral origin has been increasing and in an uncontrolled way.

The Democratic Republic of São Tomé and Príncipe has recently implemented Law 9/2020 - ”Legal Regime of Exploration and Extraction of Inert materials”, published in DR No. 62, of September 22, 2020. This law aims to adopt a Legal Regime for Exploration and Extraction of Inert in the country, defining for this purpose, the conditions under which it is allowed to explore and extract these materials, throughout the National Territory.

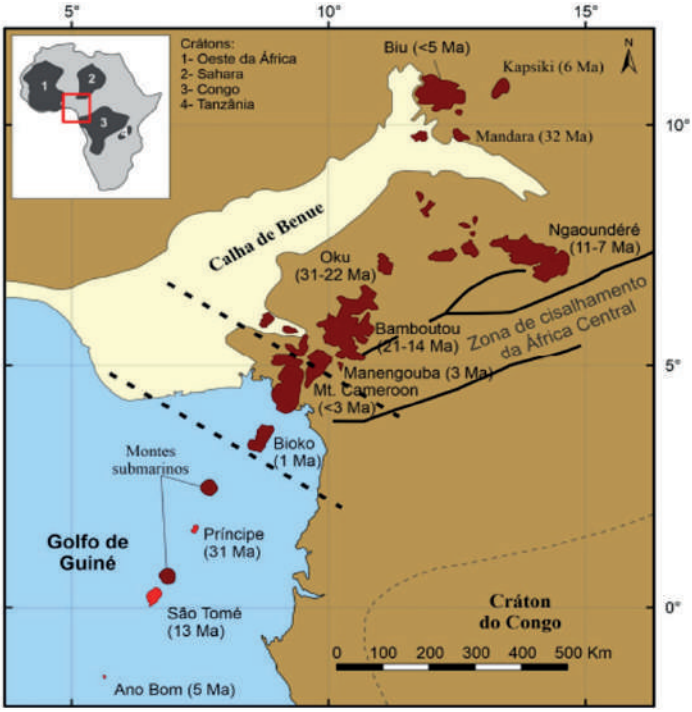
Individuals and legal persons, involved in exploration and extraction, whether temporary, sporadic or permanent, must compensate the State in accordance with the provisions of Law 1/2003 because this is the owner of the natural resources for each cubic meter of aggregate extracted. The amount is normally deposited in the State Treasury, for the country’s economic growth. In cases of infringement in compliance with the law, the holders of a given area of exploitation are subject to sanctions and the payment of fines in the public treasury.

Geologic setting of São Tomé and Principe

From the geological and tectonic point of view, the island of São Tomé is inserted in a Cameroon volcanic alignment, called Cameroon Volcanic Line, which is a gigantic shear zone of alkaline volcanism.

The Cameroon Volcanic Line, ref. Figure 20, is formed by a set of mountain ranges of volcanic origin, extending approximately 1600 km inland from the African continent (SW-NE) from Ano-Bom Island to the Kapsiki Plateau in Cameroon. The line branches off to the north to the Biu Plateau in Nigeria and to the left to the Adamawa Plateau in Cameroon. This volcanic alignment comprises a portion of oceanic and continental lithosphere with an intermediate transition zone between Bioko Island and Mount Cameroon (Caldeira and Munhá, 2003).

FIGURE 20 | CAMEROON VOLCANIC LINE AND ITS MAIN VOLCANIC CENTRES



Source: Lopes, 2022

The geological characterisation of the island of São Tomé was based on the São Tomé Geological Map at scale 1:25 000, ref. Figure 21, and respective Explanatory Note by Munhá et al. (2007). The Geological Map of São Tomé is composed of five sheets, but the sheet 3, which corresponds to the west/central sector defined between Ponta Alemã and Ponta Azeitona on the coast and Águas Belas and Dona Eugénia in the interior, is not published.

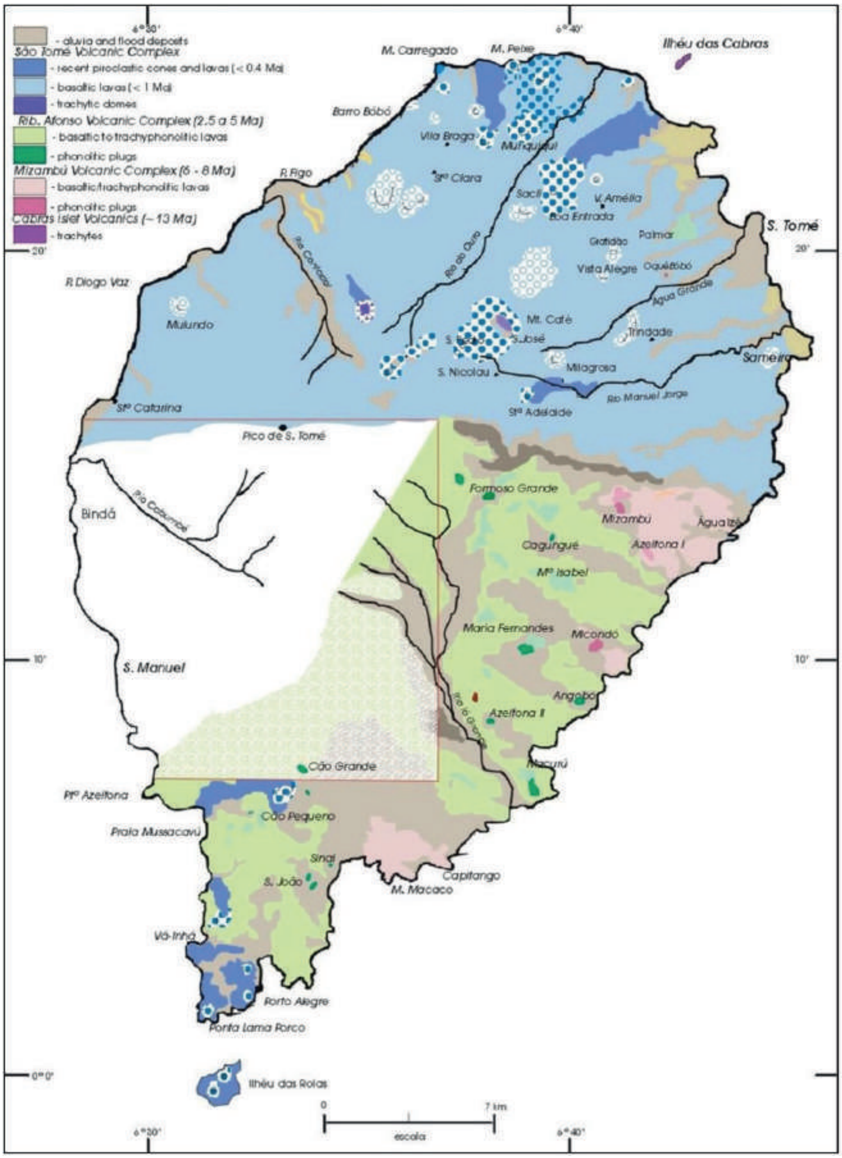
The geological studies developed in São Tomé and the new dating carried out in order to produce the geological map of the island, have allowed the establishment of four volcano-stratigraphic units, namely: Ilhéu das Cabras Volcanic Formation, Mizambú Volcanic Complex, Ribeira Afonso Volcanic Complex and S. Tomé Volcanic Complex (Munhá et al., 2007). The Ilhéu das Cabras Volcanic Formation (13 Ma) is the oldest on the island. It is located to the north east of the island and consists of two trachyte chimneys aligned NE-SW, the earliest building site of São Tomé Island, which resisted erosion due to the massive rock structure (Munhá et al., 2007).

The Mizambú Volcanic Complex (8-6 Ma), represented by two centered volcanoes, includes phonolitic chimneys and tephritic, basaltic and basanitic spills, lahar intercalations, cut by tephritic and trachytic veins. Located in the south of the island, the complex also consists of phonolitic and trachyphonolitic chimneys and subaerial spills, basaltic spills intercalated by lahar deposits, and pyroclastic spills from submarine basalts characterized by pillow lavas (Munhá et al., 2007).

The Volcanic Complex of Ribeira Afonso (5-2.5 Ma) constitutes the south east area of the island. It is represented by central volcanoes with detached phonolitic chimneys and basaltic, trachyte and phonolitic flows. Different types of lithologies occur in this complex, with emphasis on limburgites, alkaline basalts, basanites and tephrites, felsic lava flows of trachytic and phonolitic composition, with columnar disjunction (Fitton and Dunlop, 1985). The São Tomé Volcanic Complex (< 1.5 Ma) in turn represents the youngest volcanic unit, covering mainly the northern region and the extreme south of the island. It is characterized by pyroclastic spills of basaltic to trachyphonolitic composition, interspersed with lahar deposits, originating from a shield volcano (São Tomé peak) (Munhá et al. 2007).

In the far north and northwest, submarine sequences outcrop. The most recent buildings are Hawaiian to strombolian cones and a phreatomagmatic crater with well-preserved shapes. Associated with this volcanic unit are gasified water springs, hydrocarbon exudations, and orthoquartzite enclaves (Munhá et al. 2007).

FIGURE 21 | VULCANO-STRATIGRAPHY OF SÃO TOMÉ ISLAND



Source: Caldeira et al., 2013

ASM in São Tomé and Príncipe

In São Tomé and Príncipe, the main raw materials explored are: Basalt and related materials, Sand, Gravel, Clay and tout venant.
Currently there are a considerable number of companies with national and international capital and investments, which have provisional licenses to extract and explore these resources. These materials are commercialised with the intention of being used in civil construction and Public Works. Among the companies engaged in the extractive industry are ACA-Engenharia e Construções, Samulin Investimento, STP Urbano, JAA Investimento, Socrobrise, Constep, and Constromé.

In addition to the extractive industry companies, there are also so-called clandestine miners and explorers, who also develop activities of aggregate extraction throughout the country.

Legislative framework for the ASM sector in São Tomé and Príncipe

In the context of the current national policy framework for sustainable management of environmental resources and to respond to the indiscriminate exploration and extraction of aggregates, Law 9/2020 of September 22 was approved, which establishes the Legal Regime for Exploration and Extraction of Aggregates throughout the national territory. Nonetheless, violation of the rules set out in Law 9/2020 is liable to generate civil, administrative and criminal liability.

The main highlights are as follows:

- As a rule, inert exploration and extraction is prohibited throughout the country, except in cases expressly provided for by law;
- Special rules are established concerning the extraction of sand and other coastal aggregates for scientific and academic purposes, beach recovery, extraction on private land and in small quantities;
- A specific procedure is established regarding the application and granting of licenses or authorizations for the exploration and extraction of aggregates;
- The Ministry in charge of natural resources, as the competent entity and is responsible for issuing licenses and authorizations;
- The definition and update of the licensing fees should be established by joint order of the Ministers in charge of Finance and Natural Resources, in consultation with the Local Authorities and the Autonomous Region of Príncipe; and
- Those interested in obtaining a license or authorisation must meet and provide proof of compliance with a set of requirements, including specific standards relating to hygiene, occupational safety, environmental protection, and fiscal regularity and absence of debts to the State and Social Security.

There are several other environmental Decrees and Regulations, including:

- Law 11/99 - Conservation of Fauna, Flora and Protected Areas;
- Law No. 10/99 - Environment Basic Law;
- Decree Law 37/99- Environmental Impact Assessment.
- Law No. 9 / 01 - Law on Fisheries and Fishery Resources. Defines the general principles of the policy for the conservation, exploitation and management of fishery resources and aquatic environment;
- Law No. 5/01 - Law of Forests.
- Law 6/06 - Obô from São Tomé Natural Park Law; and
- Law No. 7/06 - Obô from Príncipe Natural Park Law.

Although there is a general and comprehensive legal framework for the environment and efforts have been made in this sector in recent years, there are still significant gaps in terms of technical, material, and financial capacity that limit the effective implementation of legislation and programs for environmental management, monitoring, enforcement, and awareness.

Degree of Organization of the ASM Sector

There is an association of Gravel Miners in the community of Boa Entrada, district of Lobata. A group of young people, who make their living extracting gravel and selling it. It is an unsafe job that has already led to the death of 3 miners.

Role of the National Geological Service in supporting ASM Operators

According to Decree-Law No. 1/2019, the Ministry of Public Works, Infrastructure, Natural Resources is the body of the Central State Administration responsible for designing, executing, coordinating, supervising and evaluating the policy defined and approved by the Government for the fields of public works, natural resources and the environment.

The organic structure of the Ministry of Public Works, Infrastructure and Natural Resources comprises bodies, services and institutions at the service of the State. The Directorate of Geology and Mines is one of the Directorates of the Directorate General of Natural Resources and Energy and is under the authority of the Ministry of Public Works, Infrastructure and Natural Resources.

The role of the Directorate of Geology and Mines in supporting the ASM operators includes:

- To reveal and take advantage of the mineral resources and deposits that exist in the country;
- Promote research studies to improve the exploitation of existing resources;
- Ensure the design of operating licenses;
- Ensure the supervision of the exploitation of quarries and deposits; and
- To promote and develop sustainable activities prepared by the extractive industries.

Environmental and Health Problems related to the ASM Sector in São Tomé and Príncipe

Impacts on Water Resources

São Tomé and Príncipe has a hydrographic network with about 233 identified water courses and a fluvial network with more than 50 rivers. The country has about 2,0 billion m3 of superficial water available per year, which is equivalent to a supply capacity of about 12.000 m3 /year/inhabitant. There are great potentialities in groundwater and some of them, depending on the region where they are stored, present a great index of mineralization, constituting the so-called mineral waters. The main environmental impacts related to water resources in the ASM sector are:

- The raised beach of Micoló, District of Lobata, was the target of sand extraction and exploration. After the extraction, the company did not recover the area, leaving large deep excavations flooded, constituting danger zones for children and also leading to the proliferation of mosquitoes; and
- The contamination of river water in the Cantagalo district by the extraction company is a problem that has worried the local population, who have been appealing to the government for improvements.

Deforestation

The Conservation Areas of São Tomé and Príncipe are defined by Law No. 5/2001 - Forestry Law, as delimited territorial areas, representative of the national natural heritage, destined for the conservation of biodiversity and fragile ecosystems or animal or plant species, and include the following:

- National Parks - territorial spaces that are intended for the preservation of natural ecosystems and representative of the national heritage, some of these areas have been occupied, causing an impact on these territorial sites;
- National Reserves - territorial spaces that are destined to preserve certain species of flora and fauna that are rare, endemic, threatened, or on the verge of extinction or in decline, and also fragile ecosystems;
- Areas of historical and cultural value - territorial spaces that are intended for the preservation of "sacred forests" and other sites of historical importance and cultural use; and
- The impact of deforestation in some areas of the country is a concern of the Directorate of Forests, however, the country has already presented a situation where a company was given a permit for extraction and exploitation of basalt in a place considered a Natural Reserve. This is an impactful scenario, taking into account: the disturbance of terrestrial fauna (borrow areas and quarries) and changes in the landscape (borrow areas, quarries and areas for deposition of surplus materials).

Impact on the Landscape

The exploration and extraction of aggregates in some areas of the country have caused environmental landscape impacts of a great relevance, due to incorrect planning and disrespect for tourist and geoscientific areas. This scenario is considered to be impactful in light of the following:

- The excessive extraction of sand in beaches with great touristic interest and that today are totally degraded, such as at Pigeon and Nazaré beach, respectively, ref. Figure 22 and Figure 23.
- The extraction of basalt and its derivatives in areas very close to buildings , causing noise disturbance, air pollution, and falling if blocks that also cause destruction of buildings, such as, for example, the quarry located in Palmar, district of Água Grande.

FIGURE 22 | COASTAL EROSION AT PIGEON BEACH

Source: Geology and Mines Directorate, 2018

FIGURE 23 | SAND MINING AND ENVIRONMENTAL LANDSCAPE DEGRADATION IN NAZARÉ BEACH

Source: Geology and Mines Directorate, 2018

Impact on Public Health and Artisanal Miners

The public health in São Tomé and Príncipe faces serious problems of structural nature, increased by a context of generalized poverty, lack of basic sanitation structures and potable water.

Inert exploration and extraction as a form of livelihood in some areas of the country has been a worrying factor for the state, given the following damage:

- Job insecurity, especially for illegal extractors, ref. Figure 24;
- Creation of lakes, swamps, and ponds as a source of accumulation of mosquitoes (figures 8 and 9), causing an increase in the malaria index (malaria);
- Increase in infectious diseases caused by pollution of rivers and lakes; and
- Alteration of air quality (dust and particulate emissions from quarries and borrow areas).

FIGURE 24 | ARTISANAL SANDSTONE MINING AT BOA ENTRADA DEPOSITEBEACH

Source: Geology and Mines Directorate, 2020

Socio-Economic Problems related to the ASM sector in São Tomé and Príncipe

Role of Women

In São Tomé and Príncipe, the Geology and Mining Sector is made up of trained technicians of both sexes. Women have always contributed in a very interactive and relevant way in socio-economic issues related to the extraction and exploration sector, as well as in the recovery of the affected areas.

The mining activities in Sao Tome and Principe are often carried out in areas near water courses and these are used by women for their domestic activities, such as: washing clothes and dishes, bathing and irrigation of agricultural land, etc. Despite the importance of these courses, serious situations are often found and recorded, due to non-compliance with standards that ensure the quality of natural resources used by the population.

Child Labour

The country does not resort to child labour, as it is endowed within laws that protect the rights of children. In addition, schools and Non-Governmental Organisations play an important role in educating, informing, and raising awareness about the consequences of child labour and the importance of protecting the environment as a way of safeguarding future generations.

Conflicts with Local Farmers and Other Stakeholders

The Government of São Tomé and Príncipe has designed a National Plan of Territorial Planning and in this regard has been working to safeguard the parameters established on it. Areas suitable for the development of agricultural activities have been identified by the country's Geographic and Cadastral Services, in collaboration with the Ministry of Agriculture.

However, the Directorate of Geology and Mines has often participated as a conflict mediator between the extractive industries and other stakeholders. The main reasons for the conflicts are:

- The invasion of state land by local people for cultivation in an unauthorized area and, in turn, the lack of understanding for the abandonment of the same land;
- The invasion of land by non-legalised small extractors; and
- The negotiation of concession lands that are of great interest for aggregate extraction and exploration.

Conflicts with Criminal Gangs in the Mining Area

São Tomé and Príncipe is a country that presents specific geostrategic and geopolitical conjunctural factors (e.g., economy, culture, religion, politics) as well as its size and insularity, which lead to a passivity regarding the management of conflicts with criminal gangs in the mining areas.

Women in mining. License holder in Bandira in Mozambique

Nahuta lead/zinc mining site in Gombe State. Nigeria.

ASM SECTOR OF NAMIBIA

By Johanna Hendelina Linus and Elkan Aluhe Utoni. Geological Survey of Namibia

Geographical Context of Namibia

Namibia is a developing country in Southern Africa situated along the south Atlantic Ocean. It shares its northern borders with Angola and Zambia, and with Botswana and South Africa to the east and south, respectively, ref. Figure 25. The country has a surface area of 824,269 km2, and it is sparsely populated with a population of about 2.5 million people (National Planning Commission, 2020). It is the second least densely populated country in the world after Mongolia.

Namibia gained its independence in 1990 and has enjoyed peace and political stability since then. The country is the driest in the sub-Saharan Africa, and it is home to the world's oldest desert, the Namib desert. The country's capital city is Windhoek, which is situated in the central highlands. The official language is English, with other main languages being Oshiwambo and Afrikaans. Namibia has good infrastructures, such as roads, railways and port facilities, and it is has been ranked number one country with good roads in Africa (Myles, 2022).

The economy of the country mainly depends on four main sectors: mining, tourism, fisheries, and agriculture. Namibia has been experiencing average annual growth of 4.4% between 1991 and 2015, but the economy slowed down in 2016 and fell into recession in 2017 (World Bank, 2022). Since then, the economy has been struggling to recover.

The country's mining sector is well-developed, with mining contributing 9.1% of the Gross Domestic Product (GDP) in 2021, and it was responsible for 50% of Namibia's overall growth rate in the same year (Chamber of Mines, 2022). The country exports minerals, such as diamonds, copper, uranium, lead, zinc, gold, lithium, semi-precious stones and dimension stones. Globally, Namibia is among the top seven producers of gem-quality diamonds (King, 2022), and in 2021, it was the third largest producer of uranium (World Nuclear Association, 2022).

Geological Context of Namibia

The diverse geology of Namibia encompasses rocks of Archean to Phanerozoic age spanning more than 2,600 million years of Earth history. About half of the surface area of the country is bedrock exposure with the remainder covered by Cenozoic age sediments of the Kalahari and Namib Deserts.

Highly deformed varied metamorphic rocks and associated intrusive rocks, representing the oldest rocks of Archean to Palaeoproterozioc age (ca. 2,600 to 1,600 Ma), are exposed within several metamorphic inliers in the southern, central, and

FIGURE 25 | POLITICAL MAP OF NAMIBIA

Source: www.nationsonline.org

northern parts of the country. These include the volcanic Haib Subgroup and Vioolsdrif Granite Suite along the Orange River, the volcano-sedimentary Khoabendus and Rehoboth Groups in the central parts, as well as the Kunene and Grootfontein Igneous Complexes in the northern parts of the area, ref. Figure 26 (Geological Survey of Namibia, 2011).

The Mesoproterozoic age (1,600 to 1,000 Ma) is represented by the Namaqua Metamorphic Complex in the south, comprising varied metamorphic rocks, and by the volcano-sedimentary Sinclair Supergroup of central Namibia, with associated Mokolian age granites (Geological Survey of Namibia, 2011).

The coastal and intracontinental arms of the late Proterozoic Damara Orogen (ca. 800 to 500 Ma) underlie much of north-western and central Namibia, with stable platform carbonates in the north, and diverse metasedimentary rocks further south. The volcano-sedimentary Gariep Belt along the southwestern coast represents the southern extension of the Damara Orogen. Shallow-marine clastic sediments of the Nama Group covering parts of southern Namibia represent erosional sediments derived from the older Damara and Gariep Belts (Geological Survey of Namibia, 2011).

Sedimentary and volcanic rocks of the Carboniferous to Jurassic Karoo Supergroup occur in several basins in the south-eastern and north-western parts of the country. They are extensively intruded by dolerite sills and dyke swarms that together with basaltic volcanism (Etendeka Plateau) and several post-Karoo intrusive complexes mark the break-up of the Gondwana Supercontinent, and the formation of the South Atlantic Ocean during the Cretaceous (ca. 130 Ma). Currently, the last chapter of Namibia's geological history is represented by the widespread Palaeogene to Recent (<50 Ma) sediments of the Namib and Kalahari Groups (Geological Survey of Namibia, 2011).

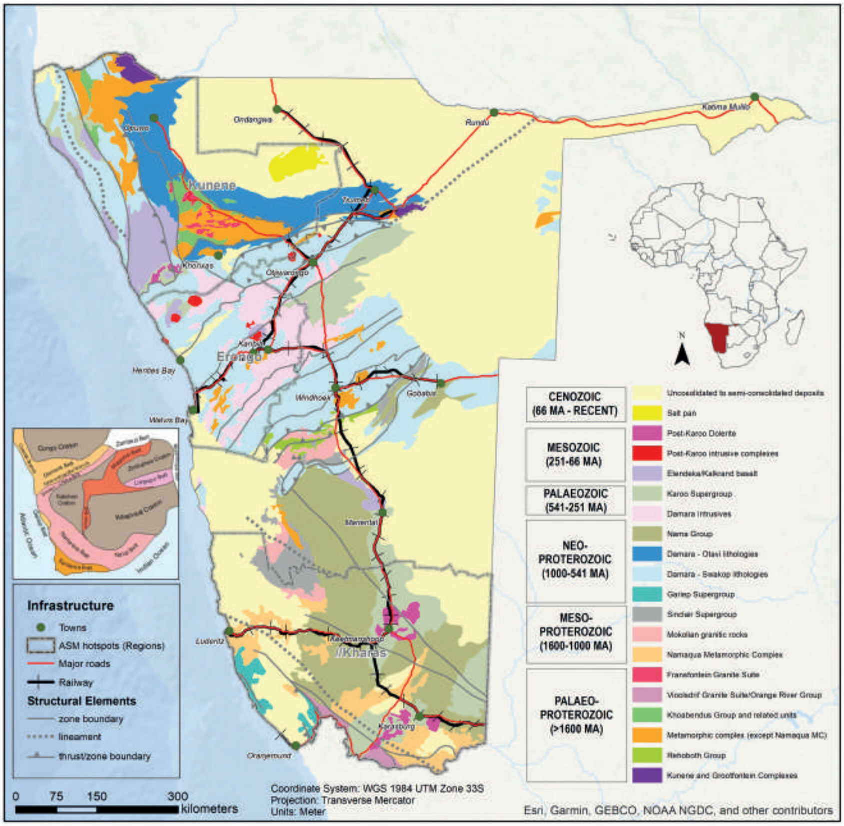
ASM in Namibia

In Namibia, the term Small-Scale Mining (SSM) is used instead of ASM. SSM broadly refers to mining with simple technology or minimal machinery, requiring low financial input. Small-Scale Miners (SSMs) typically exploit small orebodies that are uneconomical for large-scale mining operations. A significant number of unemployed Namibians are involved in the SSM sector. As such, it has the ability to improve local economic development, reduce poverty, and combat urban migration. It is estimated that there are approximately 5,000 SSMs in the country – a significant number for a country, which has a population of just over 2 million people (Priester, 2017).

Types of Substances Exploited by ASM Operators in Namibia

SSMs in Namibia mine different minerals most of which comprise semi-precious stones, collectors' mineral specimens (ref. Figure 27), dimension stones, and base

FIGURE 26 | SIMPLIED GEOLOGICAL MAP OF NAMIBIA



Source: Elkan Aluhe Utoni

metals. Extraction of semi-precious stones constitutes 80% of SSM activities. Semi-precious stones, mined mainly in three regions of Namibia, namely Erongo, //Kharas, and Kunene, include sodalite, varieties of quartz, pietersite, varieties of tourmaline, beryl, and garnet, as well as topaz. Slate used for tiling constitutes the most prominently mined dimension stone, whereas base metals mined are mainly in the form of copper oxides (mainly malachite and chrysocolla). Semi-precious stones and collectors' specimens occur mainly in zones of enriched or hydrothermal alteration zones, pegmatites or miarolic cavities within granites, while other sources include veins, metamorphic rocks, sediments, and other igneous rocks.

FIGURE 27 | COLLECTORS' MINERAL SPECIMEN (AMETHYST)

Source: Johanna Hendelina Linus

SSMs sell their products to international and local buyers including jewellers, traders, collectors and institutions through established relationships, roadside stalls, as well as established crystal markets, the Uiba-Oas Crystal Market near Usakos being the most prominent. The yearly production value of the gemstone and collectors' specimen sector in Namibia at the end consumer level or at export level, considering possible added value, is estimated at USD 8 million (Priester, 2017). Nevertheless, SSMs in Namibia are faced with the challenge of establishing win-win contracts with buyers for their products. In addition, there is minimal value addition currently taking place to manufacture finished products from Namibian gemstones.

Legislative Framework for the ASM Sector in Namibia
SSM activities in Namibia are recognised by law and are regulated by the Minerals (Prospecting and Mining) Act No.33 of 1992 (Minerals Act) and the Minerals Policy of 2003 under the Ministry of Mines and Energy (MME), as well as the Environmental Management Act No.7 of 2007 (Environmental Act) under the Ministry of Environment, Forestry, and Tourism (MEFT).

The Minerals Act makes provision for Non-Exclusive Prospecting Licenses (NEPL) and Mining Claims (MC) to be reserved for Namibians only. The application fee for both the NEPL and the MC is N$ 250 (which is equivalent to USD 16). The NEPL is valid for 12 and is not transferrable or renewable. It is not area specific nor does it give exclusive prospecting rights but it gives the holder the right to look for potential areas before registering the MC. The MC gives exclusive rights to the holder to extract minerals with the purpose of trading. Namibians are allowed to peg up to 10 MCs of 18 ha in one area or in different parts of the country. An MC is valid for three years from the date of registration and it is renewable every two years for an unlimited period.

The Environmental Act stipulates that before an MC can be registered, the holder of an NEPL must complete a questionnaire or enter into an environmental contract with the MEFT in order to obtain an Environmental Clearance Certificate (ECC). The ECC is the prerequisite for granting/registering the MC. The environmental questionnaire includes information on proposed operational methods, anticipated environmental impacts and rehabilitation measures. If the impact is low, then the ECC is granted without any further assessment, but if the impact is high then the MEFT will request the miner to conduct an EIA and produce an EMP. In many cases, SSM operations have low impact and therefore an EIA and EMP are seldom required.

Degree of Organisation of the ASM Sector in Namibia
SSMs with the help of the Small-Scale Mining Division (SSMD) under the MME have formed regional associations within the three main regions where SSM activities are concentrated. These regional associations are: //Kharas Region Small-scale Miners Association; Erongo Region Small-scale Miners Association; and Kunene Small-scale

Miners Association. Below the level of the regional association, in some hotspots, SSMs are organised in local cooperatives/associations. Some of these include: Neu-Schwaben Independent Miners' Association; Xoboxobos Small-scale Miners Co-operative; and Uiba-Oas Small-scale Miners' Cooperative - all situated in the Erongo region. However, not all SSMs are operating under organisations. Due to funding challenges, all three regional associations are currently not operational.

Role of the National Geological Survey and the Mines Departments to Support the ASM Operators in Namibia

The MME has two departments that aid small-scale miners, namely the Department of Geological Survey (Geological Survey of Namibia (GSN)) and Department of Mines.

All successful exploration and mining operations at all scales are based on reliable baseline geological data collected or compiled and disseminated by the Department of Geological Survey. The baseline geological information, obtainable at the GSN at a minimal cost, includes: geological maps and accompanying explanation sheets; custom-made maps based on the client's requirements; and previous exploration and mining data.

Specific enquiries pertaining to mineral potential and geology of the proposed mining area can be discussed with the Economic Geology Division (EGD) and Regional Geoscience Division (mapping), upon appointment, respectively. The EGD is organised under specialised subdivisions focusing on, amongst others, semi-precious stones, base metals, and dimension stones. In addition, the Geochemistry and Laboratory Division offers free analytical services to legally operating SSMs including: sample preparation (cutting, crushing, sieving, polishing, and milling); geochemical analysis using a handheld Niton X-ray fluorescence (XRF) analyser; and mineral identification using the X-ray diffraction technique.

The Department of Mines regulates SSM operations through the SSMD, which has the following responsibilities:

- Providing technical support services to SSMs, especially laboratory sample analysis, free of charge to SSMs with a valid mineral license;
- Facilitating the formation of SSM legal groups/bodies (associations or co-operatives) so that any form of support from government, non-governmental organisations, development partners and financial institutions can be channelled through legal entities;
- Facilitating the formation of regional SSM marketing centres to display and market the products of SSMs;
- Providing training to SSMs on legal procedures of acquiring mineral rights/claims;
- romoting the potential of SSM at exhibitions and conferences;
- Monitoring and evaluating of potential as well as existing SSM projects;

- Liaising with development partners to optimise support to the SSM sector, for instance in environmental governance compliance;
- Assisting SSMs with the pegging of claims; and
- Settling land/farm access disputes.

Environmental and Health Issues Related to ASM Sector in Namibia

In general, there is low environmental risk from the type of mining performed by Namibian SSMs. This is mainly because of the climatic conditions of the country. Apart from the perennial rivers along the northern and southern borders of the country, there are no perennial rivers or lakes inland, and most of the mining activities are taking place in the desert or in poorly vegetated areas, ref. Figure 28. In addition, mining is mainly conducted using hand tools resulting in a moderate to low impact on the landscape. Where machines are used, the larger pits are generally measuring around 15m deep and up to 30m wide. Mining waste management and rehabilitation are neither practiced nor known to the miners. In addition, pits are sometimes periodically worked and reworked after a certain time, therefore backfilling of old mine workings would be counterproductive. Legally, mining is prohibited in national parks and nature reserves, although illegal mining does occur. Pertaining to human health, the impacts are mainly attributed to people living at mining camps, such as household wastes, human excretions, etc. However, no major known diseases are known among miners.

FIGURE 28 | SSM PIT, NAMIBIA

Source: Johanna Hendelina Linus

Socio-Economic Issues Related to ASM Sector in Namibia

Role of Women and Child Labour

It is estimated that women make up about 20% of the SSM sector in Namibia. Although some women are involved in active mining, most play the role of sellers at crystal markets. There are no known incidences of child labour in the Namibian SSM sector. Miners who are working in remote areas send their children to schools in towns or at boarding schools.

Conflicts with Local Farmers and Other Stakeholders

SSMs in Namibia face constant conflicts with farm owners. Some mineral-rich hotspots are located within private farmland thus requiring NEPL-holders to obtain consent from the landowner to peg MCs. Some farm owners regard SSMs as problematic; hence deny them access to the farms. To alleviate this difficulty, the Government of Namibia, through the Minerals (Prospecting and Mining) Act No.33 of 1992, has established a Minerals Ancillary Rights Commission (MARC). The function of MARC is to grant rights to a holder of a NEPL or MC:

- To enter upon land to carry on operations authorised by such license or mining claim on such land;
- To erect or construct accessory works on any land for the purpose of such operations;
- To obtain supply of water or any other substances in connection with such operations;
- To dispose of water or any other substance obtained during such operations; and
- To do anything else necessary to exercise any rights conferred upon him or her by such licence or mining claim.

And who is prevented from carrying on such operations by reasons of:

- The owner of the land in question or any person competent to grant such right in relation refuses to grant such rights or demands terms and conditions of granting access that are unreasonable;
- The owner or competent person to grant such right having conflicting interests; or
- The owner is absent from Namibia or his/her whereabouts are unknown, a minor, or under any disability.

The holder of an NEPL or MC can apply in writing to the MARC to grant any such rights to him or her. Upon receiving the application, the MARC makes an inquiry and hear both parties, the license holder and the landowner, before arriving at the conclusion.

Criminal Gangs and the ASM Sector in Namibia

In Namibia, being a sparsely populated country, incidences of criminal gangs are unknown in the SSM sector as most of the mining areas are in isolated places far from towns and villages. Terrorist attacks at any level are non-existent in the country.

Proper information for the workers at the mining site is important.
Takote Mining Site, outside Tarkwa in Western Ghana.

Deep excavation at the Movuca mining site in Mozambique

ASM SECTOR OF ZIMBABWE

By Admire Charumbira and Diana Mugadza. Zimbabwe Geological Survey

ASM operations in Zimbabwe constitute the illegal panning activities mainly by communities and other groups of youths from other areas. These activities are mainly undertaken along major rivers originating from the greenstone belts. At present, the country does not have a legal framework to support ASM activities.

ASM activities in Zimbabwe date back to the pre-historic Iron Age, long before the colonial era, which marked the beginning of conventional mining and record keeping. Evidence suggests that gold production and trade were vital for the pre-colonial Zimbabwe states of Great Zimbabwe, Khami and Mutapa. Such a long history clearly shows that the ASM sector is not new to Zimbabwe and that it holds great capacity for its economic development.

The following elements have been proposed to constitute the definition of a small-scale miner for the Mines and Minerals Act (MMA) amendments:

"A small-scale miner is an Indigenous Zimbabwean person employing not more than 50 people including contractors on a registered mining location of not more than 40 ha in extent, that produces and or processes no more than 1,200 tonnes of ore per year and with an annual turnover of not more than USD 1,200,000".

In practice, one can distinguish between two broad types of ASM operators in Zimbabwe, namely:

- Registered miners, i.e. those who have registered small claims and gold processing mills with the Ministry of Mines and Mining Development. These are usually individuals, families and companies; and
- Informal, unregistered, or illegal producers, known locally as 'Makorokoza'. These are both full-time, often nomadic artisanal miners targeting auriferous reefs, abandoned mines, old workings and dumps, or rural subsistence farmers engaging in artisanal mining between farming seasons.

ASM activities sustain the livelihood of many people and families in Zimbabwe. Even though the processes involved are arduous and laborious, many people rely on the ASM sector as a panacea to poverty. ASM activities can contribute to:

- Slowing of urban migration;
- Employment opportunities;
- Reduction in poverty; and
- Stimulation of local economic growth.

Key Features of ASM Operations

An ASM operation is often characterised by its key features, which include:

- Minimal machinery or technology used, since ASM operations rely on simple techniques and physical labour;
- Low productivity, since ASM operations often take place in very small or marginal plots. It is limited to surface or alluvial mining, and uses inefficient techniques;
- Lack of adequate safety measures, health care or environmental protections; and
- May be practiced seasonally, e.g. to supplement farm incomes, or temporarily in response to high commodity prices.

ASM activities include excavation of the land and the illegal digging in riverbanks and riverbeds causing land degradation, erosion as well as siltation, and if uncontrolled it has the potential to turn the hazard into an ecological disaster.

FIGURE 29 | WOMEN PANNING FOR GOLD, ZIMBABWE

Source: Admire Charumbira and Diana Mugadza

Several government agencies, which include the Minerals and Border Control Unit, the Environmental Management Agency and the Ministry of Mines Inspectors, monitor and enforce mining and environmental regulations on a daily basis. Such operations have been compromised by informality and remote location of some mining operations, and sometimes lack of resources.

ASM operations in Zimbabwe, similar to many other jurisdictions, contribute to social, environmental and financial challenges, some of which are listed below:

Social Concerns

- Conflicts: In some areas, ASM operations are associated with an influx of people, which creates conflicts with existing formal miners and communities, ref. Figure 30;
- Sexual and Psychological Abuse: Sexual abuse is rampant mainly to women and young girls, who either join the trade or are lured by money for survival. Children around mining sites are exposed to bad language, substance abuse and premature sexual activity resulting in early unwanted pregnancies;
- Sanitation and Basic Health Care: Alcoholism, substance abuse, and communicable diseases often increase due to lack of basic sanitation and health care in the mining areas; and
- Safety: The lack of formality increases workers safety concerns, such as poor ventilation, lack of safety equipment, improper use of chemicals, and use of obsolete equipment. Some sink shaft on incompetent ground, which tends to collapse and many have died to date.

Environmental Concerns

- Environmental Impacts: In most instances, mining activities occur illegally causing land degradation as there are no mine closure procedures and lack of land reclamation requirements, which result in acid mine drainage; and
- Mercury Contamination/Pollution: Use of mercury in the processing of gold (gold amalgamation) without proper control has posed a threat to the health of human, animals and aquatic life. It ends up contaminating water bodies, waterways and soils.

Fiscus Concern

- Tax Evasion: Though efforts to curb leakages are in place, some miners dispose their outputs (gold and other minerals) informally and do not pay taxes or royalties undercutting the viability of legal mining. No proper records of proceedings are maintained.

FIGURE 30 | MACHETE-WIELDING GANG MEMBER, ZIMBABWE

Source: T.Musakwa, Zimbabwe Independent Newspaper

FIGURE 31 | LAND DEGRADATION FOLLOWING ASM OPERATIONS, ABANDONED PIT, ZIMBABWE

Source: S. Shiri

The Role of the Zimbabwe Geological Survey

The Zimbabwe Geological Survey, a department under the Ministry of Mines and Mining Development, was established in 1910. Its mandate is to generate, archive and disseminate geological data for use in various sectors.

Overall functions of the department include:
- Map the geology of the country;
- Generate information on mineral resources potential of the country;
- Provide technical, consultative and advisory services on mining geology and mineral exploration mostly to SSMs;
- Monitor and provide information on mineral exploration and exploitation; and
- Collate and archive national geological data and information.

Since 2014, the Geological Survey has decentralised its extension technical services to the eight provinces of the country. The technical services offered by the Geological Survey are free of charge in order to promote investment and continuous gathering of information on mineral deposits and occurrences.
ASM operations require geological data and technical support services from the Geological Survey. The services listed below are rendered to small- and medium-scale mines:
- Desktop studies;
- Sample/mineral element identification and analysis. Specimens are also analysed through the use of a handheld XRF and laboratory assaying;
- Ground geophysical surveys for mineral exploration. These include Magnetics, Induced Polarization, Electromagnetic, Micro-gravity and radiometric surveys;
- Underground mine evaluations, auditing and monitoring; and
- Free library and museum services.

The Ministry of Mines and Mining Development has technical departments that are there to assist SSMs in the complete mining cycle - from exploration of virgin ground to mineral processing. The services are free of charge and miners are encouraged to utilise the expertise to their advantage. All the departments are decentralised and are in all mining districts of the country. The departments are:
- **Mining Engineering**: This department assists with technical expertise on mining, such as mining methods, safety and environmental issues, inspections, licensing of explosives and their handlers etc. The department has an active mines inspectorate section that is always out in the field monitoring the mining operations. The department also administers the Mining Industry Loan Fund providing mining equipment to ASM operations;
- **Metallurgy**: This department is the official government laboratory and offers analytical services, metallurgical advice on plant establishment, design and efficiency, and mineral dressing. The department's metallurgists are also charged with monitoring duties;

- **Mine Survey:** Although they fall under the Mining Engineering Department, the surveyors carry out work on sitting of structures, waste disposal sites, surface and underground excavations etc.;
- **Institute of Mining Research:** This is an institute based at the University of Zimbabwe, funded by the Ministry of Mines, which offers analytical, mineral economics, geological, environmental and metallurgical services to the mining industry at a cost; and
- **Minerals Marketing Corporation of Zimbabwe:** This is a parastatal that markets all mineral produced in the country except gold and silver. Miners can get useful information on market trends and current prices.

Local buyers ready at a gemstone mining site named Nametile. Mozambique

Excavation aquamarine at Choro Choro mining site in Mozambique

ASM SECTOR OF BOTSWANA

By Vincent Omphemetse Lekula and Kagiso Walter Nnoi, Botswana Geoscience Institute

Geographical Context of Botswana

Demography of Botswana

Botswana is a landlocked country in Southern Africa of 582,000 square kilometres, about the same size as France and Kenya. It shares borders with Zimbabwe, Zambia, Namibia, and South Africa. The estimated population of Botswana is 2,346,179 from the recent 2022 population and housing census. Much of the country is covered by the vast Kalahari Desert and only 5% of the country is considered arable. Botswana has a semi- semi-arid climate (high temperatures and low rainfall). Due to the semi-arid climate, most rivers and streams are non-perennial, therefore Botswana is susceptible to droughts affecting the food security in the country.

Botswana is a relatively flat country with occasional rocky outcrops. The Makgadikgadi pans is the island drainage basin into which several rivers, such as Boteti, Nata and Mosetse flow during the rainy seasons (Talvela et al, 2009). Large areas are reserved as national parks and game reserves. Of notable importance for tourism is the Okavango delta known for its beauty and abundant wildlife. Another area known for its tourism is the Chobe national park which has a huge concentration of large game.

Economy of Botswana

According to Talvela et al (2009) the economy of the country is heavily dependent on mineral resources exploitation as the backbone of the economy. Botswana has numerous minerals like diamonds, copper-nickel, and gold. Botswana is well known for having one of the world's highest economic growth rates since it gained independence in 1966 primarily due to mining contributions. The key drivers of the country's economy are: mining, contributing 42% of GDP; government services, contributing 15% of GDP; restaurants and hotels, contributing 10.5% of GDP; and business and financial services accounting for 9.7% of GDP. The economic growth of the country has been driven by mineral exploitation and export of minerals with the diamond sector contributing most of the sector's output by value. The mining sector took the agricultural sector in terms of economic contribution around the late 1970s.

Lately, there has been a decline in economic growth due to mining sector volatilities (Talvela et al, 2009). This has led to emphasis on economic diversification to ensure that other identified areas can also contribute to the economic environment. Nonetheless, diversification remains a challenge for the country, since the country still relies heavily on the diamond sector, which contributes approximately 75% of exports, 33% of GDP, 3% of total formal sector employment and 50% of government revenue. Agriculture still contributes about 2 %of GDP, driven by beef exports and livestock subsector, makes up roughly 20% of rural income and employment.

Geological Context of Botswana

National Geology

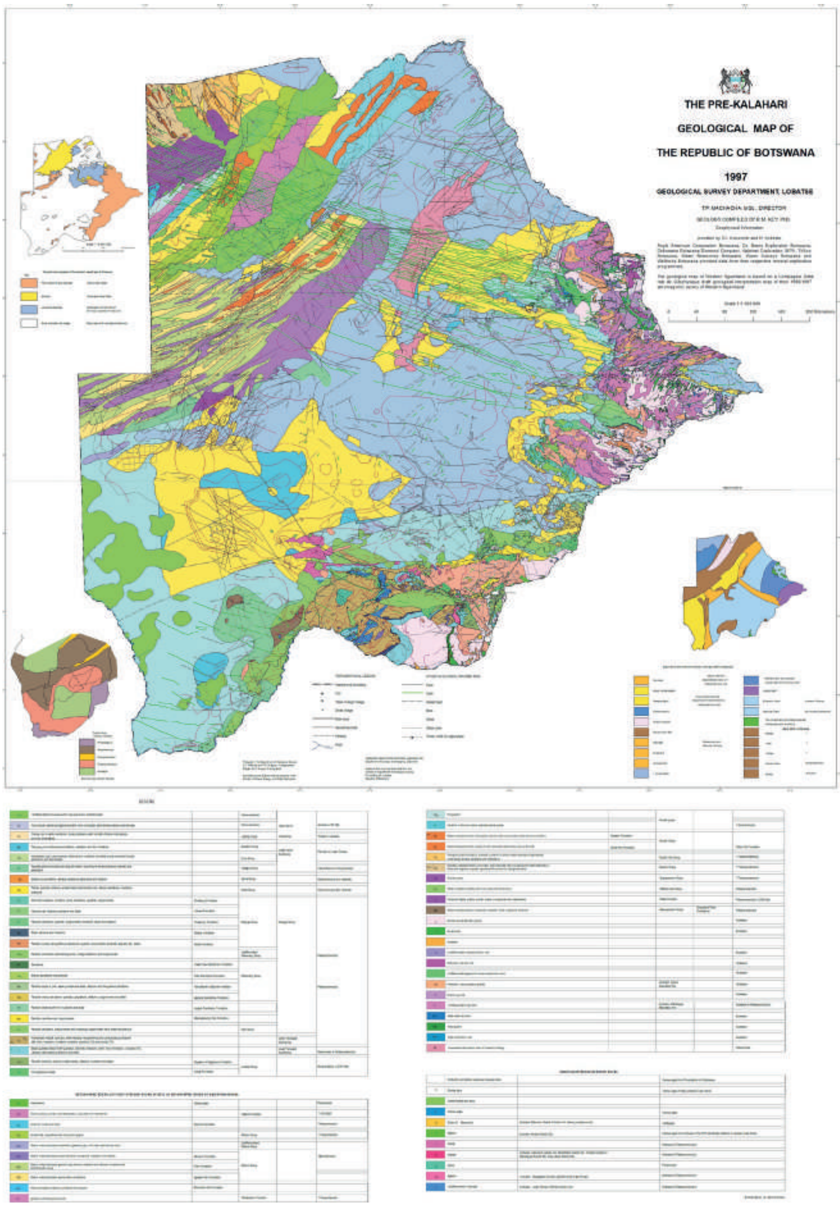
The oldest rocks in Botswana are made up of Archean age basement terranes, which are exposed only in the eastern part of the country (Carney et al, 1994). The geological record spans from the Archaean to recent deposits as shown in Figure 32. Most of the country's geology is hugely impeded by the cover of Kalahari Desert environment limiting exploration. These sequences are subdivided into three main units, namely Kaapvaal Craton, Zimbabwe Craton and the intercratonic domain of the Limpopo mobile belt. These basements are made up of mostly supracrustal lithologies and deformed granitoids. According to Key & Ayres (2000) these terranes are considered lithologically similar but differ in their structural elements and styles and the timing of major thermal events is different. The oldest high grade metamorphic rocks are found in the Kaapvaal craton and the youngest occur in the Limpopo mobile belt, which shows Paleoproterozoic ductile shearing.

The country's geological record contains significant elements of the major tectonic, magmatic, metamorphic, and sedimentary terrains present in the Southern African sub-continent.

There are some minerals, which have been economically exploited since the country's independence in 1966 for development and those that have the economic potential. These minerals are divided according to the host eons:

- Archaean: Gold, silver, copper, nickel, limestone, silica, and sillimanite;
- Proterozoic: Platinum, copper, silver, lead, zinc, asbestos, limestone, mineral pigments, and talc;
- Phanerozoic: Coal, diamond, hydrocarbon, brick earth and limestone.

FIGURE 32 | SIMPLIFIED GEOLOGICAL MAP OF BOTSWANA (PRE-KALAHARI GEOLOGY MAP)



Source: Botswana Geoscience Institute

ASM in Botswana

Substances Exploited by ASM Operators in Botswana

Considerable opportunities for small-scale miners (small capital-intensive operations) exist in the eastern part of the country. Small-scale mines can be defined as operations with low plant investment, have small production rates, less complex operation and are highly labour intensive.

Agates

Agates are known to occur in the North eastern region of the Central District mostly in the Bobonong area along the Motloutse river. Bobonong agates belong to the quartz family showing a variety of chalcedony (microcrystalline quartz) with roughly circular bands of varying colour. The extra fine and colourful banding and patterns on these agates make them unique and sought after by collectors worldwide. According to Gould (1971) these agates occur as blue, pink, banded grey agates, moss agates, rock crystal and jasper. These agates are hosted by amygdaloidal basalt from the 180 Ma Karoo volcanic rocks.

These semi-precious stones have been gathered since 1968. There is no excavation involved during the mining process. Agates are handpicked from the river channels by the local individuals who sell to a licensed dealer. The dealer, who holds a Semi precious Stone Dealers Licence issued by the Department of Mines, tumbles these stones to remove impurities and then sort them based on their colour, size, and texture. Some of these agates are exported and others are used for local jewellery manufacturing and artefacts.

Clay

In Botswana, clay deposits are associated with Karoo sediments of the Ecca group widely spread throughout the country. Currently clay is mined at Makoro and Dipotsana for brick production. Clay deposits are mostly used for brick making and small portions are used in pottery, such as Gabane and Thamaga pottery and other uses, e.g. facial cosmetics.

Aggregates for Roads and Building Construction

There is a significant number of quarries around the country, which produce construction aggregates. These quarries mainly produce fine and coarse aggregates for buildings and road construction.

River Sand

Sand is mined from the rivers for construction purposes. During the past decade demand for river sand has increased drastically due to the construction boom especially in the Southern part of the country. This boom has been caused by the high rate of development in the Greater Gaborone area. These developments need high tonnages of river sand, and consequently there has been illegal mining of the resource complementing the legal mined resource to meet the demand. The illegal mining has a huge negative environmental impact on the river ecosystems and depletion due to unsustainable mining practices. Botswana Geoscience Institute took an initiative to identify and assess suitable rocks for production of manufactured sand. The quarry sites were evaluated to a pre-feasibility stage and tendered out to the public for further development and production to curb river sand shortage problem.

Shales

Botswana has a significant volume of different types of shales of different colours. These shales have good strength and durability for use as flooring material and have been tested as resistant to cracks, scratches, breaks and chips. BGI is assessing these deposits for possible uses like for pavers, floor tiles, roofing tiles and cladding. These slate deposits are currently being mined illegally as pavers by the local communities where they occur.

Legislative Framework for the ASM Sector in Botswana

Legislation

The exploration and exploitation of minerals in Botswana are governed by the Mines and Minerals Act, administered by the Department of Mines - first enacted in 1969, revised in 1976 and 1999, and currently under review. Under prospecting there is prospecting and retention licences, whereas under mining there is mining licence and minerals permit. Other relevant legislation includes the Mines, Quarries, Works, and Machineries Act of 1973, which deals with the health and safety of employees involved in prospecting, mining and quarrying operations, and the Environmental Assessment Act of 2011 that requires environmental impact assessments of prospecting and mining activities.

A prospecting licence is issued for an initial period of 3 years with an option of getting not more than two renewals for a period of 2 years each and the total coming to 7 years. The holder of a prospecting licence may apply for a retention licence in relation to an area and a mineral covered by his licence in the case that the deposit cannot be mined economically at that time after prospecting. A retention licence is issued for an initial period of 3 years with an option for renewal once up to 3 years and a total coming to 6 years.

A mining licence is issued for up to 25 years with a renewal option. A minerals permit is issued for up to 5 years with a renewal option.

At the moment there is no specific legislative framework that deals with ASM operations directly. All the mining activities for both large scale and small-scale operations are regulated by the Mines and Minerals Act of 1999 together with other relevant acts that address particular commodities.

Mines and Mineral Act of 1999

All mining activities in the country are regulated by the Mines and Minerals Act of 1999, which is the main act. The act states that:

- All rights of ownership in minerals are vested in the Republic of Botswana;
- In recognition of the Republic's land tenure system, with regard to tribal land, the tribal leadership ceded mineral rights to the Republic under the Mineral Rights in Tribal Territories act; and
- The Acquisition of Property Act further allows the Government to compulsorily acquire property in the public's interest and land has been so acquired to allow mining with adequate compensation in accordance with the Constitution.

Requirements for a Prospecting and Mining Licence

An applicant, in the case of ASM, should be a citizen of Botswana or a Botswana registered company wholly owned by a Batswana.

An applicant is required to complete Form 1 for a prospecting licence application and show detailed prospecting program, proof of sufficient funds, proof of technical competence and an EMP.

For a mining licence and a minerals permit, an applicant is required to complete and submit the following:

- EIA and EMP approved by the Department of Environmental Affairs;
- Archaeological Impact Assessment clearance from Department of National Museum and Monuments;
- Clearance from Department of Wildlife and National Parks if area is within national park or game reserve;
- Application for mining licence/mineral permit submitted to Department of Mines after fulfilling above requirements;
- Form V for a mining licence; and
- Form VII for a minerals permit.

Degree of Organisation of ASM Sector

Small-scale operations are mostly done by individuals or companies. Currently there are no active cooperatives to run these small-scale operations.

Role of the National Geological Survey to Support the ASM Operators

BGI is mandated to undertake research in the field of geosciences, provide specialised geoscientific services and advice in all matters of geohazards. The institute is also responsible for promoting the search for and exploration of any mineral in Botswana. The institute is a custodian of all geoscience data/ information, which include non-confidential prospecting reports.

The main role of BGI in small-scale operations is the provision of information on mineral deposits to promote exploration and mining of these deposits. BGI is critical for small-scale mining activities by providing basic geological research, compilation of national geo-resource inventory, educating the public in the geology and mineral resources of Botswana and disseminating information on the geology and mineral resources of Botswana.

The institute also assesses some of the deposits up to the pre-feasibility stages to make it easy for these miners as they have limited funds to carry out the risky and expensive exploration. The identified deposits are assessed by technical experts through reviewing historical data, sampling, drilling, sample analysis, interpretation, resource estimation, producing geological and mineral maps and report compilations. Lastly those deposits which are fully assessed are tendered out to the public through the Department of Mines (DoM) for mining.

Environmental and Health Issues Related to the ASM Sector in Botswana

Impact on Waterways

The small-scale operations have an impact on the rivers especially in the case of river sand mining. Some activities are illegal - miners mining sand from the rivers create detrimental gullies within the rivers in the process. The southern part of the country has experienced a construction boom leading to depletion of river sand from the rivers. This has led the Government to exclude these areas from river sand mining although there are still illegal miners stealing river sand at night.

Impact on Deforestation

Deforestation is very minimal as these operations are done over small areas. Clearing of vegetation is done over small areas especially in the case of gravel mining where burrow pits are excavated. The footprint of burrow pits is very small in the country.

Impact on the Landscape

In some cases, mining activities occur illegally causing land degradation as there is no proper mining plan and no rehabilitation is done post mining. This is common for river sand mining whereby sand is mined haphazardly mostly when it is dark to avoid law enforcement officers. The illegal mining has a huge negative environmental impact on the river ecosystems and depletion due to unsustainable mining practices. In the case of licenced activities, the miners are forced to carry out rehabilitation of the sites as it is a requirement under the Mines and Minerals Act.

In the case of gravel mining activities, burrow pits are usually rehabilitated at the end of the operation as most operations are done by companies doing construction, such as national roads. In some cases, some of these burrow pits are reclaimed for other uses, e.g. dams and other recreational places.

Impact on Health among ASM Operators

The health impacts are minimal due to the nature of industrial minerals, which are mostly targeted by small-scale miners. One of the health impacts is dust related diseases due to exposure to dust especially in the quarries. Measures are usually put in place to mitigate health impacts and these operations are visited on a regular basis to check adherence to EMPs in place.

Socio-Economic Issues Related to ASM Sector in Botswana

Role of Women

Women are actively involved in small mining activities especially in the case of clay mining for pottery, collection of agates for reselling, jewellery production and using shales as pavers. Compared to men, women undertake less hard manual labour in small-scale operations.

Child Labour

There are no children involved in small-scale mining activities in the country both in terms of legal and illegal operations.

Conflicts with Local Farmers and Other Stakeholders

In some areas, there is lack of social buy-in from the locals at the project initiations stages due to land use conflicts. Because consultation is one of the requirements according to the act, usually the conflicts are resolved. During consultation stages, the positive impacts of the mining operations are outlined, and the locals agree to operations looking at the economic benefits. Common positive impacts brought about by these small-scale operations include job creations and poverty eradication.

Conflicts with Criminal Gangs in the Mining area

There are no conflicts with criminal gangs in the small-scale mining operations in the country.

Impact of Criminal Gangs or Terrorist Groups ASM Sector

There is no existence of either terrorist groups or criminal gangs in the mining areas.

Small shop at the Nametile mining site. Mozambique

Excavation at Tsiquir in Mozambique

ASM SECTOR OF LESOTHO

By Hareteke Ishmael Khalema and Puseletso Caroline Takalimane, Geological Survey of Lesotho

Geographical Context of Lesotho

Demography of Lesotho

Lesotho lies within the Southern region of the African Continent and covers a total surface area of approximately 30,355 km2 at 29°30'S 28°30'E. The country is surrounded by the Republic of South Africa on all sides with two-thirds of the country's terrain classified as mountainous. Lesotho comprises of four topographical regions: the lowlands, foothills, Senqu valley, and the highlands. The lowest elevation point in the county is 1,400 meters above sea level at the junction of the Makhaleng and Orange (Senqu) rivers, south-west close to the South African boarder. The foothills are at the central part of the country and form a transition zone between then lowlands and the highlands. The elevation in this region ranges from 1,800 meters to 2,200 meters above sea level. In the north east side of the country lies the Senqu river valley at an elevation ranging between 1,400 meters to 1,800 meters above sea level. The highlands, also known as the Drakensberg escarpment, are in the eastern and south eastern part of the country at an elevation ranging between 1,400 meters to 3,482 meters above sea level at Thabana Ntlenyane. The climate in the lowlands is characterised by cold, dry winters and warm summers with occasional rain. The highlands are characterised by cooler summers and cold winters with frequent snows.

The landlocked country has a population of 2,007,201 (2016 Census). From the total population, 34.17% lives in the urban region of the country while 65.83% is located in the rural areas. The sex distribution is 982,133 male and 1,025,068 female, or approximately 96 males for each 100 females (2016 Census). The average inflation rate is estimated at 5% while the average GDP growth rate is 5.8%.

Economy of Lesotho

The mining sector in Lesotho on average has contributed over USD 13,298,608.67 to the country's GDP from 2007 to 2021. An all-time high of USD 22,243,175.62 was achieved in the third quarter of 2008 while the lowest recording was in the second quarter of 2020 at USD 4,742,149.20, ref. Table 6. The export orientated sector declined by 24.7% due to the negative impact of the COVID-19 pandemic. Closure in international markets led to the temporary suspension of mining activities in some of the mines. The GDP from mining in Lesotho has since decreased from USD 11,855,373 in the third quarter of 2021 to USD 9,671,488.50 in the fourth quarter (Lesotho Bureau of Statistics).

TABLE 6 | TRENDS OF CREDIT TO BUSINESS ENTERPRISES (MILLIONS OF MALOTI), 2016-2020

	2016	2017	2018	2019	2020
Agriculture	25,3	17,0	30,3	29,2	47,2
Mining	363,8	284,1	379,7	419,9	359,2
Manufacturing	319,4	252,1	174,1	58,0	29,7
Electricity, gas and water	38,5	41,2	46,2	6,46	2,4
Construction	313,5	284,0	301,8	328,1	321,9
Transport, Storage and Communication	185,7	370,9	349,6	423,7	357,5
Wholsesale, Retail, Hotel & Restaurant	184,7	167,1	261,7	387,5	354,4
NBFIs, Real Estate & Business Services	509,5	522,9	553,2	504,6	530,0
Community, Social& Personal Service	26,4	43,9	0,9	15,0	13,4
Total	**1,966.7**	**1,983.2**	**2,096.6**	**2,172.5**	**2,015.7**

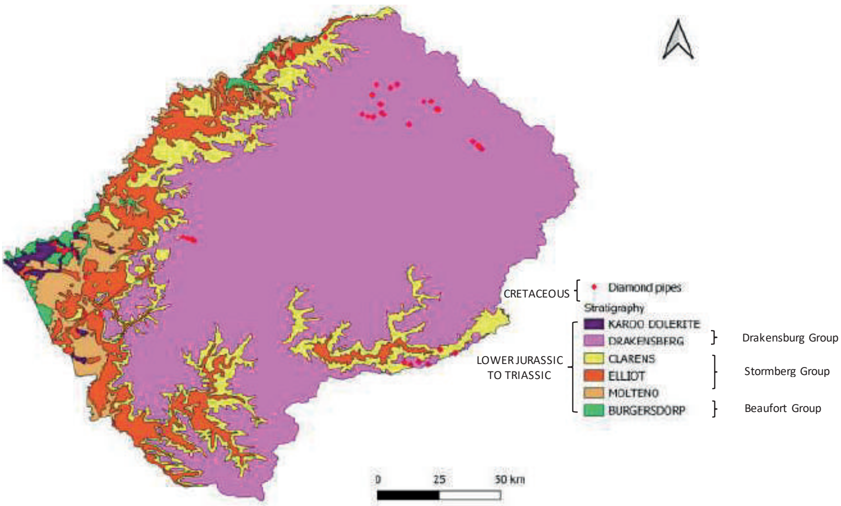
Source: Central Bank of Lesotho, 2020

There is no contribution obtained from the ASM sector towards the revenue collected from the mining sector. This is because ASM is not legalised in the country. The Ministry of Mining is currently in the process of formalising small scale mining and issuing out licenses to diamond diggers.

Geological Context of Lesotho

Simplified Geological Map of Lesotho

FIGURE 33 | SIMPLIFIED GEOLOGICAL MAP OF LESOTHO



Brief Description of National Geology

The rocks exposed in Lesotho consist of a single major division of sedimentary formations of the Karoo Supergroup and basaltic lavas, two different types of igneous intrusions, and younger unconsolidated sediments. The major division, which underlies most of Lesotho, is the Triassic-Jurassic Karoo Supergroup, which comprises of an older conformable terrestrial sedimentary sequence, found in the lowlands, and younger basalt flows found in the highlands. Associated with the lavas are volcanic vents and dolerite dykes and sills. Kimberlite pipes, dykes and blows (dyke enlargements) of cretaceous age are a separate younger intrusive type. Late tertiary to recent unconsolidated sediments (clay, gravel, silt etc.) are found mainly in the lowlands where the material is presently being removed by streams giving rise to narrow steep-sided ravines locally called dongas.

The Karoo Supergroup is lithological divided into the sedimentary Beaufort and Stormberg groups and the volcanic Drakensberg Group. Formational units that are recognised are the Burgersdorp Formation in the Beaufort Group and the Molteno, Elliot and Clarens formations in the Stormberg Group. The Drakensberg Group consists of the Lesotho Formation. The Beaufort Group is only exposed in the upper part of the country although drilling at Mahobong and near Butha Buthe has penetrated into the underlying Ecca Group of the Karoo Supergroup.

The Burgersdorp Formation in Lesotho consists of grey sandstone alternating with buff, green and purple mudstone, with occasional carbonaceous shale with thin coal seams and some ferruginous concretion beds. The Molteno Formation comprises of white grit and sandstone with occasional coaly streaks and plant remains. They alternate with buff and grey mudstone and siltstone while conglomerate beds at the base can found occasionally. The Elliot Formation is characterised by fine to medium grained sandstone becoming red coloured upwards, with occasional coarse beds. The sandstone alternates with buff and red mudstones and siltstones. Phosphatic nodules towards the base and occasional ash beds occur.

The Clarens Formation has massive cream coloured, fine grained sandstone and siltstone with occasional laminated beds. Plant remains and thin coal seams have been found in the upper part (upper facies). Red, fine grained sandstone and siltstone and compact siltstone with nodular cleavage have been noted in this formation along with shaly beds in the lower part (lower facies). Compact and amygdaloidal basalt with several sandstone beds and pillow lavas have been found in the lower part of the Lesotho Formation. Ashy or agglomerate beds occur near the base of the formation. Numerous small explosive vents precede basalt outpouring.

Dolerite sills and dykes are abundant in Lesotho with over 1,000 intrusions recorded (Stockley, 1947). The sills and sheets decrease both in thickness and number from the Beaufort to the Clarens Formation. The dykes and sills were the feeder fissures along which the Drakensberg lava flowed to be poured out on the surface. Alluvial sand and gravel beds and terraces occur along the major rivers. According to Rombouts (1978), dolerite dykes crossing the river channel are the most important factor in gravel genesis. Donga sediments of undefined origin and composed of unconsolidated and pedisedimentary gravels, silts and clays, form a thin cover over the Stormberg strata in the flat lying areas. These sediments are rapidly removed by erosion.

ASM in Lesotho

Substances Exploited by ASM Operators in Lesotho

In Lesotho, diamond mining is the leading industry in the mining sector. Diamond digging by licenced diggers first started at Letšeng-la-terai in 1961. According to Maleka (2007), the remarkable 601 carats Lesotho Brown, which put the country on the word map for large exceptional diamonds, was discovered by diggers. A number of sites have been worked by diggers including Kao, Liqhobong and Hololo, which were later worked by Basutoland Diamonds Ltd until 1967. These sites are located within the northern region of the country.

In 1968, the Government of Lesotho resolved to give exclusive prospecting and mining rights to Lesotho National Development Corporation so that any company willing to enter into mining could do so by entering into an agreement with Lesotho National Development Corporation (Maleleka, 2007). Unfortunately, in 2004 the Government ceased the issuing of small scale mining licences due to its informal and disorganised nature, which often led to injuries of diggers, among other challenges.

Legislative Framework for the ASM Sector in Lesotho

Currently there is no legislation that governs ASM in Lesotho. The Ministry of Mining intends to re-introduce ASM in Lesotho in order to enable participation by Basotho in the Mining Industry. The 2015 Minerals and Mining Policy addresses the ASM and acknowledges the challenges faced in this sector. The policy statement indicates that the Government will work towards recognising and repositioning the ASM sector by transforming it into a value adding, poverty-reducing economic activity. Some of the strategies that would be employed include creating a legal and regulatory framework for enabling and providing for ASM activities. The Government also wishes to transform the informal sector into a well regulated industry and ensure that the ASM activities are limited to Basotho nationals. Furthermore, issues, such as gender equality, mainstreaming HIV/AIDS, sustainable standards of safety, occupational health and environment, would be addressed.

The Ministry of Mining is currently in the process of amending the Mines and Mineral Act of 2005 for it to align with the Mining and Minerals Policy published in 2015.

Degree of Organisation of ASM Sector

There are currently no cooperatives or associations in the ASM sector; however, this is expected to change once the sector has been legalised.

Role of the National Geological Survey to Support the ASM Operators

The Ministry of Mining intends to align itself with the Minerals and Mining Policy 2015 and is working towards legalising the ASM sector. It will make available licences for individual and small-scale Basotho diggers for diamonds. Areas shall be sanctioned solely for development by the ASM sector. The ministry shall seek to facilitate assistance to the diggers in terms of licencing and land use planning, security, site establishment unlocking the ASM potential. The ministry also intends to create a transparent and secure marketing channel locally, while also participating in international route-to-market initiatives. It is imperative that these operations should be responsible, safe and transparent. Through formalisation, the government shall ensure that there are no human rights abuses and negative environmental impact.

Environmental and Health Issues related to the ASM Sector in Lesotho

ASM is not a regulated sector and the operators are not well informed about issues related to the environment, health and safety. Land degradation is one of the leading challenges within ASM. Abandoned trenches and pits dug by miners have been reported to the Ministry of Mining by members from mining communities. These trenches have contributed to soil erosion, scarcity of indigenous plants and destroyed wetlands and grazing land, ref. Figure 34.

FIGURE 34 | ALTERED LANDSCAPE DUE TO ASM DIGGERS

Source: Geological Survey of Lesotho

Diamond panning and sieving in streams and rivers have destabilised the aquatic ecosystem due to water pollution and in some cases affected the flow direction of stream channels, ref. Figure 35. Fish such as trout and yellow fish become scarce due to water pollution.

FIGURE 35 | ABANDONED PIT WITH POLLUTED WATER ALONG A STREAM

Source: Geological Survey of Lesotho

Socio-Economic Issues related to ASM Sector in Lesotho

The impact of ASM on the social and economic lives of people living in mining communities is significant although not well documented. Most of these miners are both men and women, who may work individually or as equal partners. Friend and relatives tend to work together in an effort to improve their livelihood and financial status. There are rare cases where children are involved in ASM activities as they are usually subjected to domestic and agricultural activities. It should also be noted that ASM was illegal in the previous years and therefore parents did not want their children caught in criminal activities. The men focus on the digging and piling of the stream sediments, the women focus on the sieving and panning. Sometimes they take turns in doing each activity. The children may be indirectly involved through ancillary activities, such as delivering food and drinks.

There are no conflicts recorded between the miners and the local farmers or other stakeholders. Instead community members tend to influence each other in partaking in the mining activities. There are no reported terrorist groups or gangs that are associated with the ASM sector although partners tend to have conflicts from time to time on the resources recovered

Meeting with ASM operators at Nametile mining site Mozambique

ASM SECTOR OF ESWATINI

By Sakhiwo Dlamini and Londukuthula Gumede, Geological Survey Department

Geographical Context of Eswatini

Demography of Eswatini

The Kingdom of Eswatini is located in south-eastern Africa. It is a relatively small country, covering 17,300 km2, and it is landlocked by the Republic of Mozambique to the east and the Republic of South Africa on all other sides. The country is mostly mountainous, with tall mountain ranges in the west, and fertile low lying plains towards the east. As such, the country's rivers flow from the west to the east where they spill out into the Indian ocean in the Republic of Mozambique.

The Kingdom of Eswatini experiences a subtropical climate with summer rains and dry winters. About 75% of precipitation falls from October to March, however due to climate change, these patterns deviate from one year to the other. Climatic conditions range from sub-humid and temperate in the Highveld (high altitude) in the west, to semi-arid in the Lowveld (lowlands) in the east. The national long-term average rainfall is 788 mm per year.

The country has a total population of about 1.2 million people (2022) with an estimate of 250,000 living in urban areas (World Population Review 2022). The majority of Eswatini's population is ethnic Swazi, mixed with a number of Zulus and African Caucasians, predominantly of British and Afrikaner origin. Even though the majority of Swazis are farmers and herders, a large proportion works in government, the urban economy and mines in the Republic of South Africa.

Eswatini faces a number of health issues, including HIV/AIDS and tuberculosis. Other infectious diseases include malaria, bacterial diarrhoea and bilharzia.

Economy of Eswatini

In order to diversify the sources of economic development in Eswatini the Government wishes to foster development of a thriving mining industry that will contribute to sustainable economic development. The Government recognises the positive contribution that mining can make as an engine for the economic development of Eswatini by diversifying the export base, widening the tax base, generating skilled employment, creating demand for local goods and services, contributing to infrastructure development, producing raw materials for local usage and acting as a catalyst for wider investment in the economy.

The Government wishes to reverse the decline of the mining industry by attracting new investment in the exploration for and exploitation of mineral resources. Government recognises that to do this it must establish an enabling environment for investors that is based upon modern regulatory arrangements and competitive terms.

Whilst the Government is seeking to encourage investment by mining companies, there is also a need to ensure that mining operations are conducted responsibly. The neglect of the environment and harm to local communities as a result of mining operations is not acceptable. The intention is to ensure that Eswatini is securing the full economic and social benefits which mining development promises.

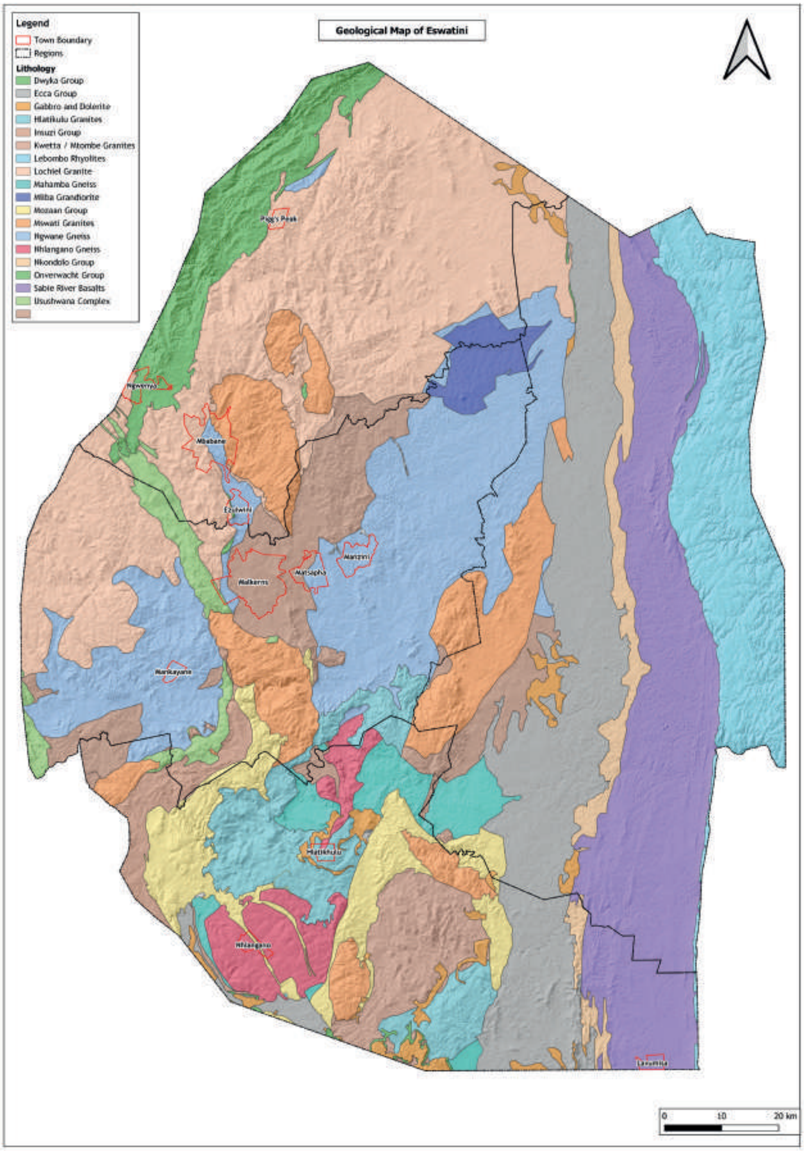
The Government's policies are directed not only at large-scale mining but also at small-scale mining operations, which offer opportunities to support the rural livelihoods of the Swazi nation. Small scale mines need to be assisted in their efforts to operate in an economically and environmentally sustainable manner. The Government recognises its duty to discharge its regulatory responsibilities in an effective, even-handed and co-ordinated way. A process to establish appropriate legal and administrative arrangements and the requisite institutional capacity is in progress. The legal framework being created will ensure that Eswatini's mineral endowment is managed on a sustainable economic, social and environmental basis and that there is an equitable sharing of the financial and developmental benefits of mining between investors and all Swazi stakeholders.

The Geological Survey and Mines Department in the Ministry of Natural Resources of Energy has technical reports and bulletins together with geological maps that are available to the public with the relevant information pertaining to the minerals in the country.

Geological Context of Eswatini

Brief Description of the National Geology

FIGURE 36 | GEOLOGICAL MAP OF ESWATINI



Source: 1:250,000 Geological Map of Eswatini, 1982

For the size of the country, Eswatini is one of the most interesting areas geologically in southern Africa. It lies on the eastern edge of the Kaapvaal craton and since systematic mapping of the country began in 1947, its gneisses, granites and greenstones have been much studied because their mutual relationships are crucial to the understanding of crustal evolution during the Archaean. Until recently, less attention had been paid to the sedimentary and volcanic rocks of the Karoo, which lie on the eastern flank of the craton. The highest ground lies in the west and northwest and from this dissected edge of the Transvaal plateau, the country slopes eastwards to the Lowveld, beyond which lies the impressive west-facing escarpment of the Lubombo Hill.

The Archaean rocks in Eswatini are amongst the oldest known in the world dating back to at least 3,000 Ma. Basic and acid volcanic rocks of the Onverwacht series were extruded into an unstable basin and were succeeded by a succession of politic sediments with subordinate lavas (the Fig-tree series). Following a period of folding, coarser sediments were deposited, now represented by the Moodies series. Intrusive into all these preceding rock-types are the basic and ultrabasic intrusive of the Jamestown Complex. After the intrusion of the Jamestown, the area in common with wide areas in the Republic of South Africa was subjected to intensive deformation. At depth, the sediments, volcanics and intrusives were transformed into gneisses of appropriate composition while granite magma was generated. As the paroxysms of the orogeny became less violent, granite was intruded into the upper crustal levels, there to consolidate as the various granites seen today. In addition to the metamorphic changes at depth, the rocks in the upper levels were folded, broken and sheared. Finally, tension cracks developed, along which dykes of the diabase were subsequently intruded.

During the period of the quiescence and relative stability which ensued, the great mountain chains were eroded down to their roots. No records remain of this lengthy period until frigid conditions heralded the start of the Karoo period. This period witnessed a gradual increase in temperature resulting in the development of lush and verdant vegetation. Semi-desert conditions prevailed towards the close of the Karoo period during which time many species of reptile were common. The Karroo period was brought to a close by a great outburst of volcanic activity. The sediments and volcanics deposited during the Karroo period were tilted gently eastwards and preserved mainly the bushveld region of Eswatini.

Once again Eswatini passed through another period of erosion and peneplanation which is still continuing to this day (Hunter et. al., 1991).

ASM in Eswatini

Substances Exploited by the ASM Operators in Eswatini

The ASM sector in Eswatini is mainly exploiting building/construction materials, such as: gravel – mined or not mined at barrow pits; river sand; plaster sand; quarried stone; and slate stones.

It is a relatively new sector and must be adequately regulated, as such the Government of Eswatini has embarked on a project to train existing and aspiring small-scale miners. The educational exercises deal with themes including licensing, environment, health and safety, finance, taxation, reporting and labour laws. There is, however, a need to mention that with the rise in demand of precious stones and metals, such as green chert and gold, illegal mining activities have expanded to areas with such mineral deposits.

Legislative Framework for the ASM Sector in Eswatini

The small scale mining operations are guided by law enforcement as per the Mining Act of 2005, distinguishing small-scale mining as follows:

- A prospecting or mining operation or a proposed prospecting or mining operation shall be classified as a small-scale operation for the purposes of this Act if:
  - In the case of prospecting operations, the proposed prospecting area does not exceed 5 km^2
  - In the case of mining operations, the proposed mining area does not exceed 0.05 km^2

- Notwithstanding above paragraph, a prospecting or mining operation may also be classified as a small-scale operation for the purposes of this Act if:
  - In the case of mining operations, the actual or estimated annual extraction of minerals or material bearing minerals does not or will not exceed 25,000 cubic metres; or,
  - The proposed prospecting or mining operations do not or will not employ specialised prospecting or mining technologies; or,
  - The proposed prospecting or mining operations, do not or will not involve substantial expenditure.

Mineral rights that may be granted in respect of small-scale operations include:

- A prospecting permit; or
- A mining permit.

Mineral rights relating to small-scale operations shall not be granted to an applicant that is not:

- In the case of an individual, a citizen of Eswatini; or
- In the case of a body corporate, a body corporate in which citizens of Eswatini hold a simple majority of the beneficial ownership of the body.

A 'citizen of Eswatini' means a citizen by descent as provided under section 41 of the Constitution of Swaziland Act, 2005.

Degree of Organisation of ASM Sector

The ASM sector has solid structural organisation with regards to the construction industry, which is not the case for the extraction of precious metals. Precious metals can only be legally extracted by large-scale miners who use dedicated machinery.

Role of the National Geological Survey to Support the ASM Operators

The Government of the Kingdom of Eswatini realised that ASM operations may provide additional or alternative rural livelihoods opportunities for Swazi Citizens. The Government intervened in a way so that some minerals and mineral deposits or occurrences are reserved exclusively to be exploited by indigenous Swazi Citizens. The obligation for the ASM sector to exploit the minerals in an economically and environmentally sustainable manner is an obligation that is enforced by the Geological Survey, Minerals and Mines Department.

Environmental and Health Issues related to the ASM Sector in Eswatini

Impact on Waterways

When it comes to gold mining and the refining processes not much has changed with ASM for hundreds of years, even millennia. The basic practice is still panning or sluicing of placer sands yields gold mixed with other materials. Chunks of rock are broken with hammers in preparation for further crushing in ball mills. Liquid mercury provides a simple way to concentrate gold from a larger volume of finely crushed rock or sediments. The disposal of processed rock and sediments containing residual mercury or volatilization from heating of the amalgam releases mercury to the atmosphere, soils, and aquatic systems. This creates enormous and persistent environmental and health impacts. The water problems caused by these activities persist down to Mozambique, breaching the water treaty that was signed between South Africa, Mozambique and Eswatini (Tripartite Interim Agreement between the Republic of Mozambique, the Republic of South Africa and the Kingdom of Swaziland for Co-operation on the protection and sustainable utilisation of the water resources of the Incomati and Maputo watercourses 2000).

Deforestation

Deforestation in the country has been attributed to a national crisis. This term is used to describe the act of destroying indigenous plantations in Eswatini. Even though it is widespread, deforestation seldom coincides with ASM. Rather, the increase in deforestation has been associated with the unrelenting demand for indigenous plants for medicinal purposes and the harvesting of trees for firewood. Where ASM activity occurs, the minerals sought after are oftentimes bare or free of thick natural vegetation.

Impact on the Landscape

ASM has devastating impacts on the environment, such as burning of bushes, the use of harmful chemicals and over-stripping of overburden. It is the latter that seems to be the most problematic as it promotes soil erosion which is destructive to the landscape, ref. Figure 37. The driving factor is the demand for material used in construction, which are but not limited to; river sand, plaster sand and crushed stones. When these materials are extracted, the soil is left baren with cavities, which is eventually affected by natural elements. Not only does this cause soil erosion, but soil degradation and desertification.t

FIGURE 37 | EXCAVATION AREA, POST MINING ACTIVITIES

Source: Londukuthula, Gumede, 2022

Impact on Health among ASM Operators

There are serious health effects associated with ASM, known in general but not in detail. The data problem with ASM extends to health impacts because such mining activities are often illegal and located in remote, sometimes violent or conflict areas. Health hazards are often categorised as chemical, mechanical and psychosocial hazards.

Chemical Hazards

Miners are susceptible to inhaling, absorbing and ingesting chemicals throughout the mining process (Schwartz, Lee et Darrah 2021). The most common chemical exposures in artisanal small-scale gold mining are mercury, cyanide and chemicals contained in dust and gases. Mercury is used in artisanal small-scale gold mining to form gold amalgam, releasing the highest concentration of elemental mercury vapour during the heating process. Inhalation can directly affect the lung, causing airway irritation, chemical pneumonitis, and pulmonary oedema, high inhalation exposure can cause respiratory failure and death. Chemicals contained in dust include Silica found in the ore mined in gold. Silica dust particles are small and can be readily inhaled and deposited in the pulmonary tree, causing progressive scarring and tuberculosis even when exposure has stopped. Gases including carbon monoxide, methane, oxides of nitrogen and sulphur dioxide tend to be problematic in artisanal small-scale gold mining as a result of petrol and diesel operated machinery in inadequately ventilated environments, causing lethal poisoning.

FIGURE 38 | AN ABANDONED MINE WHERE INDIGENOUS MINERS ILLEGALLY WORK FROM TIME TO TIME

Source: Buyani Fakudze, 2022

Mechanical Hazards
Miners experience fatigue and chronic injuries from carrying heavy loads on their backs over long distances and bending over awkward positions inside the small mining tunnels. Physical traumatic injuries experienced by the miners include fractures, eye injuries, impalements and burns as a result of rock falls, explosions and the inappropriate or unsafe use of equipment. The processes of hammering, crushing and milling subjects the miners to high levels of noise that are above the limits to prevent loss of hearing. They also cause stress, heart diseases and hypertension.

Psychosocial Hazards
ASM is usually practised in communities struck by poverty, making it impossible for them to afford healthy foods. Bread and water running in the nearby streams is usually the only food miners have, then in a few cases usually after scoring big they indulge in mealie meals and tinned foods. The abuse of drugs and alcohol are seen as a way to cope with the difficult situations faced by the miners. Marijuana is one of the main drugs as it is easily accessible in those areas, since many illegal plantations are found around the country.

Socio-Economic Issues related to ASM Sector in Eswatini

Role of Women

In the Kingdom, women are not so physically involved in the mining sector, only few are even in the professional circles. The culture views women as fragile who cannot be subjected to difficult tasks, whereas men are seen to have an internal drive to acquire a source of living, so as to make an impression and gain favour amongst the females. Some males work to feed their women and children yet some just for popularity amongst the women, especially in drinking taverns.

Child Labour

Children are not yet involved in the mining of precious minerals in the country, but they are in the mining of building materials. Young boys especially are used in loading sands and building stones in trucks.

Conflicts with Local Farmers and Other Stakeholders

In recent years, the country has seen a growth in illegal mining activities, which now include the precious minerals. Poverty, desperation and the possession of mining expertise are the pushing factors to these activities. These illegal miners, or indigenous miners as we prefer to call them, often have had work experience from mines in neighbouring South Africa. Their knowledge of; mining operations, mineral occurrences, basic geology and abandoned shafts encourages them to seek means of making a living through this illegal trade in our borders. The Barberton Greenstone Belt, which is located along the north-eastern boundary of the country, is endowed with mineral occurrences such as gold, iron, green chert and asbestos, the latter being abandoned because of its hazardous effects. The miners, equipped with various tools and sometimes weapons (fire arms), trespass to mine these minerals only to be sold in the black market, where they are exposed to all sorts of dangerous situations by criminal gangs or organised crime. Many times, these miners are intercepted by game rangers and policemen in various locations in the country, of which they are sometimes found with not only their lot, but illegal firearms as well. When interrogated as to why they possess arms, their response is self-defence from people who may want to steal their lot; from local residents, criminal gangs and even potential clients who are untrustworthy.

FIGURE 39 | EXTRACTED GREEN CHERT, A MATTRESS AND THE SACS IN WHICH THE ROCKS ARE TRANSPORTED

Source: Londukuthula, Gumede, 2022

Conflict with Criminal Gangs in the Mining Area

Even with the Mining Act in place illegal mining activities are conducted even for the building material minerals, conflicts arise among illegal miners and those that have permits. Such conflicts are usually settled when residents of that area are assumed to be obligated to mine without permits as they are residents of that area, when the legal miners also assume it is only them who are to mine.

In recent years, the country has seen a growth in illegal mining activities, which now include the precious minerals. Poverty and desperation is pushing miners to risk their lives, health and safety in abandoned shafts and in not yet functional mines. The chance to strike it rich drives the miners, who are often armed to defend their illegal claims. The green stone belt, lying in the north eastern part of the country, which is also along the border lines between the kingdom and South Africa. Locals that have worked in mines before and South Africans are working together in the illegal practices of mining minerals.

The north-eastern mountains of the country have been home to illegal miners throughout all the seasons of the year. There are serious health effects associated with ASM, which are known in general but not in detail. The data problem with ASM extends to health impacts because such mining is often illegal and located in remote areas. During the summer rains they find shelter under the forest trees and in winter they make fires to survive the very cold mountains. Chemical exposure is the major class of hazard. With gold, the latter stages in processing can lead to the inhalation of elemental mercury and exposure to a variety of harmful mineral dusts. There is a long list of severe health effects associated with airways and lungs, neural and behavioural problems, and other body systems. Other exposures involve cyanide used in secondary processing and toxic gases. Hazardous working conditions involve mining in deep tunnels where oxygen levels can be dangerously low; mining in conditions with high risk of landslides; and ferrying excessively heavy loads.

Impact of Criminal Gangs or Terrorist Groups ASM Sector

In recent years, the country has seen a growth in illegal mining activities, which now include the precious minerals. Poverty, desperation and the possession of mining expertise are the pushing factors to these activities. These illegal miners, or indigenous miners as we prefer to call them, often have had work experience from mines in neighbouring South Africa. Their knowledge of; mining operations, mineral occurrences, basic geology and abandoned shafts encourages them to seek means of making a living through this illegal trade in our borders. The Barberton Greenstone Belt, which is located along the north-eastern boundary of the country, is endowed with mineral occurrences such as gold, iron, green chert and asbestos, the latter being abandoned because of its hazardous effects. The miners, equipped with various tools and sometimes weapons (fire arms), trespass to mine these minerals only to be sold in the black market, where they are exposed to all sorts of dangerous situations by criminal gangs or organised crime. Many times, these miners are intercepted by game rangers and policemen in various locations in the country, of which they are sometimes found with not only their lot, but illegal firearms as well. When interrogated as to why they possess arms, their response is self-defence from people who may want to steal their lot; from local residents, criminal gangs and even potential clients who are untrustworthy.

Conclusion

The ASM sector and policies are sufficiently developed to sustain the construction industry, but his is not the case for precious minerals. There is great potential to improve the livelihoods of the general population if policies and frameworks would be put in place, which would accommodate the extraction and processing of precious minerals using artisanal methods. With the Government of Eswatini being keen on stimulating the economy through the mining sector, there is reason to believe that amendments to the current mining policy will be implemented, thus providing an enabling environment for investment, research and development, as well as an improved standard of living for the general population.

Barite mining operation in Azara, Nazarawa State. Nigeria.

Diatomite mining in Alamgafi, Tobe State. Nigeria.

ASM SECTOR OF NIGERIA

By Abegunde, Toluwase and Abdulraheem, Muhammed Babatunde,
Nigerian Geological Survey Agency

Geographical Context of Nigeria

Demography of Nigeria

Nigeria lies on the west coast of Africa between latitudes 4º16' and 13º53' north and longitudes 2º40' and 14º41' east. It occupies approximately 923,768 km^2 of land stretching from the Gulf of Guinea on the Atlantic coast in the south to the fringes of the Sahara Desert in the north. The territorial boundaries are defined by the republic of Niger and Chad in the north, the Republic of Cameroon on the east, and the Republic of Benin on the west. Nigeria is the most populated country in Africa, with approximately 216 million people in an area of 923,768 km^2, and the seventh largest population in the world. The country's 2006 Population and Housing Census placed the country's population at 140,431,790. According to the 2017 revision of the world's population prospect the total population of Nigeria was estimated at 185,989,640 in 2016, compared to only 37,860,000 in 1950. Nigeria's population is equivalent to 2.64% of the total world population. According to Census Bureau of the United States, the population of Nigeria will surpass that of the United States in 2047, when the population of Nigeria will reach 379.25 million.

Economy of Nigeria

Nigeria began to explore and exploit her natural mineral resources in 1902. In its prime the solid minerals sector was one of the largest producers of tin and coal as well as a producer of a considerable 1.4 tons of gold annually. Nigeria is enriched with several types of minerals including marble, gypsum, lithium, silver, granite, gold, gemstones, bentonite, iron ore and talc. The extractive industry in Nigeria has always been a viable greenfield, but the sector is now getting the attention it deserves through the recent interventions by the Federal government to the solid minerals sector, specifically the National Integrated Mineral Exploration Project, championed by the Nigerian Geological Survey Agency (NGSA) and the digitisation of the license administration in the Mining Cadastral Office. Although the sector only contributes about 0.3% of the GDP due to the influence of its vast oil resources, it has now been fully recognised as a key source of economic development and diversification of the revenue streams of the country. The Nigerian oil and gas sector has played a central role in the Nigerian economy. The revenue realised from the Nigerian petroleum industry has been the country's fiscal mainstay and remains a major source of revenue. The reality of the recent downward trend in oil prices and its impact on the revenue and foreign reserves of the country however means that it has never been more vital for Nigeria to protect herself by diversifying her revenue streams.

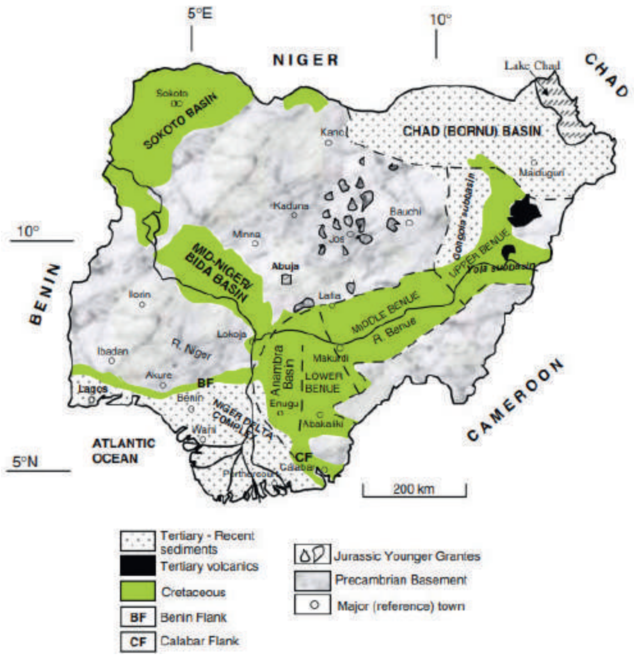
According to the 2021 records of the National Bureau of Statistics, the mining sector's contribution was N5.37 trillion to the GDP. In this sector there are four subsectors, which include: crude petroleum and natural gas, coal mining, metal ores, and quarrying and other minerals. The crude petroleum and natural gas have a higher contribution of N5.24 trillion; the coal mining subsector contributed N7.71 billion; the metal ores subsector contributed N8.33 billion, while the quarrying and other minerals contributed N111.09 billion. It is however indisputable that the solid mineral sector is under-performing and plagued with issues ranging from inadequate infrastructure to illegal artisanal mining and community challenges. These issues stifle potential by deterring potential investors whose resources are essential to the revitalisation of the sector. 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 derived from ASM.

Geological Context of Nigeria

Geology of Nigeria

The basement complex is one of the three major litho-petrological components that make up the geology of Nigeria, ref. Figure 40. The Nigerian basement complex forms a part of the Pan-African mobile belt and lies between the West African and Congo Cratons and south of the Tuareg Shield (Black, 1980). It is intruded by the Mesozoic calc-alkaline ring complexes (Younger Granites) of the Jos Plateau and is unconformably overlain by Cretaceous and younger sediments. The Nigerian Basement Complex was affected by the 600 Ma Pan-African orogeny and it occupies the reactivated region which resulted from plate collision between the passive continental margin of the West African craton and the active Pharusian continental margin (Burke and Dewey, 1972; Dada, 2006). The basement rocks are believed to be the results of at least four major orogenic cycles of deformation, metamorphism and remobilization corresponding to the Liberian (2,700 Ma), the Eburnean (2,000 Ma), the Kibaran (1,100 Ma), and the Pan-African cycles (600 Ma).

FIGURE 40 | GENERALISED GEOLOGICAL MAP OF NIGERIA



Source: Obaje, 2009

The Mesozoic Younger Granite ring complexes of Nigeria form part of a wider province of alkaline anorogenic magmatism. They occur in a zone 200 km wide and 1,600 km long extending from northern Niger to south central Nigeria. Rb/Sr whole rock dating indicates that the oldest complex of Adrar Bous in the north of Niger is Ordovician in age, with progressively younger ages southwards. The most southerly ring complex of Afu is Late Jurassic in age (Bowden et al., 1976). Aeromagnetic anomalies suggest that a series of buried NE–SW lineaments of incipient rifts controlled the disposition of the individual complexes (Ajakaiye, 1983).

Basaltic lava plateaus, trachyte plugs and domes, large central volcanoes and small basalt cinder cones with thin flows are all found among the more southerly manifestations of Cenozoic volcanism in West Africa (Wright, 1985). This province also includes the remarkable offshore continuation of the Cameroon volcanic line, the four islands situated in the Gulf of Guinea itself. Areas of basement doming include the Jos Plateau, southeast of the Benue Trough, with probably still greater uplifts; and the Adamawa Highlands further east, where lavas of the Ngaoundere Plateau overlie the Ngaoundere fault zone, which was reactivated in the Cretaceous.

Nigeria has six sedimentary basins, which are identified as Dahomey Basin, the Illumeden Basin, the Chad Basin, the Benue Trough Complex, the Mid-Niger (Bida/Nupe) Basin and the Niger Delta Basin comprises of sediment fill of Cretaceous to Tertiary ages. Out of all these basins, only Bida basin is not shared with neighbouring countries.

ASM 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 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. ASM in Nigeria employed about 0.5 million as of 2015 (Oramah et al., 2015) and in 2021 over 2 million. These miners' and mining communities' contribution to societal development is vital. There are over 2,000 ASM sites identified in the country; the Ministry of Mines and Steel Development has registered more than 1,000 mining cooperatives with each having over 10 members. The major metallic and precious minerals currently exploited in Nigeria by the ASM are gold, tantalum ore (tantalite), lead, zinc, copper ores and Cassiterite (metallic minerals), while the non-metallic minerals (industrial) are Barite, Bentonite, Gypsum, Diatomite, Kaolin, Calcium carbonate, Dimension stone and Gemstones. ASM is a livelihood strategy adopted primarily in rural areas and it is usually poverty driven.

Minerals extracted by ASM operators are usually informal; 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, such as the World Bank, have been working assiduously to formalise the ASM sector in Nigeria.

The Legislative Framework for the ASM Sector in Nigeria

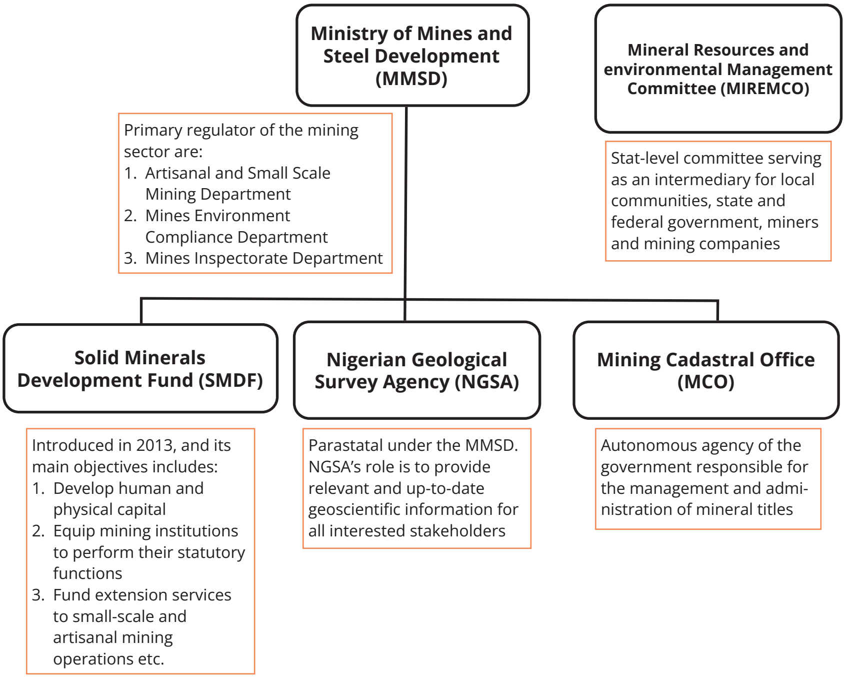
The Mining Legislation of Nigeria makes up the rules and procedures needed to fulfil the goals and objectives of the Mineral Policy of Nigeria. These laws and regulations try to be investor friendly while recognising the limited technical capabilities and financial difficulties of ASM operators in Nigeria.

The Minerals and Mining Act No. 20 of 2007 is the principal legislation that regulates the Nigerian mining sector. The Act vests the control, regulation and ownership of all mineral resources in the Federal Government of Nigeria.

The Nigerian Minerals and Mining Regulations of 2011 are intended to establish a more coordinated and accountable solid minerals sector in the country and to stamp out the discretionary grant of minerals title. The regulations were issued to set out the rules, procedures and processes for the acquisition of mineral titles, and to give effect to the Minerals and Mining Act No. 20 of 200.

The Nigerian Minerals and Metal Policy of 2008 restructured the Ministry of Mines and Steel Development and established the Mining Cadastre Office, the Mines Inspectorate Department, Artisanal and Small-Scale Mining Department, and the Mines Environmental Compliance Department, ref. Figure 41.

FIGURE 41 | INSTITUTIONAL FRAMEWORK FOR MINING NIGERIA



Source: Afolayan et. al., 2021

Degree of Organisation in the ASM sector

In the last couple of years, the Federal Government has made efforts to organise ASM from an individual or family holding into a formal sector through mining co-operatives and associations. This effort has yielded results as a good percentage of mining activities in Nigeria come from ASM. Despite the difficulty in gathering data on the activities of this subsector, the number has been increasing exponentially every year.

In Nigeria, mining cooperatives and associations must be registered with the Ministry of Mines and Steel Development and the Artisanal and Small-Scale Mining Department. Cooperatives in Nigeria, operate using principles like voluntary and open meetings, member economic participation, and so on. Membership associations are either voluntary or in some States seen locally as a prerequisite to working in the industry. Where mining associations exist, a financial contribution may or may not be required. It is solely dependent upon the individual association and their membership criteria. At state level, there may be a mineral/mining association, e.g. Cross River Barite and Bentonite Producers Association or Edo Sand Producers Association in the South. Associations provide a voice for the specific mineral and group of producers that are member of that association. Some associations were active in a number of states, determined by presence of a common mineral, e.g. barite.

Roles of the Nigerian Geological Survey Agency to Support the ASM Operators

It is very important that the ASM operators understand the geological processes and the environment in which the minerals were formed. This may help the miners to discover further deposits and understand the geologic process of each mineral.

NGSA is responsible for providing the country's geoscientific information for wealth creation. NGSA provides the baseline geological data, such as the Regional Geological maps, Geochemical Maps of parts or the entire country on various scales as may be applicable e.g.; 1:50,000, 1:100,000, 1:1,000,000. These maps have been used by the artisans to locate suitable lithologies for their commodity of interest.

NGSA also provides mineral testing centres to help in determination of mineral grades for the ASM operators to ensure that they are paid the right value for the minerals they mine.

NGSA also provide airborne magnetic data that helps in identifying structures that serves as conduits for some of the minerals being sought for by the artisanal and small-scale miners. This helps because most of the materials mined by ASM operators occur at or near the Earth's surface.

NGSA's bulletins are readily available for any investor including the ASM operators to gain knowledge of the geology and mineral occurrences in Nigeria.

Environmental and Health Issues related to the ASM Sector in Nigeria

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 is to mitigate such risks by engaging relevant mining communities and groups through information and education and at the same time use the legal and regulatory frameworks and make direct agreements with the mining operator to establish appropriate environmental performance as well as acceptable working conditions. Major mining accidents occur due to the use of crude and sharp tools by ASM operators to extract minerals.

Common environmental impacts associated with mining include: deforestation, destruction of landforms and soil erosion, water pollution, air pollution, destruction of natural habitats and so on.

Impact on Waterways and Rivers

Several ASM operations require a substantial amount of water for extraction purposes, such as sieving ore to remove precious and semiprecious stones and gold. The need for substantial quantities of water often leads ASM operators to relocate this part of their processing to rivers. When ASM operators remove large amounts of overburden, the area becomes 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, which may clog the streams. Heavy metal contamination due to mining and mineral processing (washing) has become one of the most silent but significant environmental side effects (Adamu et. al., 2014 and 2015). Studies in the literature have reported on acidification and acid mine drainage associated with the mining of coal, gold and other minerals containing pyrite and galena (Adewumi et. al. 2020).

Impact on the Landscape

During prospecting and exploration for mineral deposits, trenches and ditches are dug to trace the ore-bearing structures. The next step in ASM is to dig down to the ore to test whether it can be mined with a profit. This often requires removal of large amounts of overburden. Only few of the ASM operators consider where they dump the overburden. They merely dump it where it is easiest for them. Due to ASM operations a large farmland area may within short time be littered with exploration pits and trenches making the fields useless for farming purposes. 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. An absolute minimum requirement from the environmental authorities is that the miners fence off active as well as abandoned pits and trenches.

Deforestation
There will be some impact of ASM communities on the nearby forests, but not much more than if the same people held other jobs. ASM operators, however, who utilise wood to support their pits may cause significant deforestation. The amethyst miner, for example, does underground work with small tunnels from pit to pit. The purpose of this is to increase recovery without digging too many new pits. Unfortunately, the tunnels are rarely supported and often cave in, causing fatal consequences. Miners could prevent such fatalities if they learned how to support walls and roofs in tunnels and steep sides in deep excavations. Deforestation can be a serious problem if not handled correctly.

Impact on Health among ASM Operators
Mining is one of the world's most dangerous occupations. Over the years, many mining associated accidents have occurred in various parts of the world, often with significant loss of life (Amponsah et al, 2016). Mining accidents and fatalities among the ASM operators occur in the process of mining metals, minerals, and energy materials. Thousands of miners die from these mining accidents each year, especially in coal and hard rock mining.

Research has shown that enacting an act and introducing laws or policies to drive Nigeria's mining sector can strengthen the regulatory frameworks (Ango et al., 2019 and Akper et. al., 2020). However, there were no prior works on health, mine safety, and mining hazard prevention procedures until March 2016, when the Nigerian Government acknowledged mercury and lead health risks. Mining accidents are not limited to chemical hazards. It also includes every form of harm against the miners, mining communities, and resources located within the mining environment. This set of rules is mandatory and must be enforced by every player within the mining and mineral business (Heffron, 2020)

Socio-Economic Issues related to ASM Sector in Nigeria

Role of Women
In Nigeria, women make up a large percentage of the workforce and are involved in many aspects of an ASM activity including associated ancillary activities. Women involved in ASM have had varying degrees of success, e.g., there are few females owned mine sites. The work that most women undertake on an ASM site is generally unskilled, flexible in terms of employment, paid on a daily or weekly basis (see figure 5) and therefore does not require any academic or practical experience. 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 participating in the decision-making process. Therefore, this limits their ability to access the potential benefits that ASM might bring, this is common in northern Nigeria.

Child Labour
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. 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 a means by which children, or their families earn the money for school fees.

Conflicts with Local Farmers and Other Stakeholders
There have been reports of conflicts between miners and local farmers in Nigeria, due to adverse effect of ASM on farmlands and water sources. There may also be a shared understanding of the need to engage in ASM, and this may help to prevent conflict in some communities.

An estimated 70% of mining in the northwest region occurs illegally and is carried out by local populations. The mining of large untapped mineral deposits in the area, especially gold which has strategic importance and economic value, has been at the root of community violence since 2014.

Impact of Criminal Gangs or Terrorist Groups ASM Sector
Illegal mining in Nigeria reveals fundamental social, institutional, and structural problems. It reveals the prevalent socio-economic problems in the region, including inadequate responses to poverty and inefficient service delivery mechanisms by the state. Those who sponsor illegal mining utilize youth as labour because they have limited income generation opportunities. This is harmful to the development of the country. Terrorism and banditry financing is happening in Zamfara state and other parts of the country. Minerals like gold are being illegally sold to fund terrorism and banditry. Additionally, some of the ASM operators have been kidnapped by some bandits in some regions, especially in Zamfara State, Kaduna State, and some other part of the country. Majority of the kidnapped ASM operators are freed by paying a huge ransom, while some are killed by the bandits.

Children carrying water for the household, collected at or from a river near the mining site, central Ghana.

ASM SECTOR OF GHANA

By Selma Tahiru and Ebenezer Atule, Ghana National Geological Authority

Geographical Context of Ghana

Demography of Ghana

Ghana is situated in the western part of Africa. Its bordering countries are the Ivory Coast to the west, Burkina Faso to the north, and Togo to the east. It is bounded by the Atlantic Ocean to the south. Ghana covers an area of 238,535 km2, spanning diverse biomes that range from coastal savannahs to tropical rain forests. With about 31 million people, Ghana is the second-most populous country in West Africa, after Nigeria. Apart from the Capital city, Accra, other major cities in Ghana are Kumasi, Tamale, and Sekonidi -Takoradi.

According to the 2021 population census, there are 30,832,019 people in Ghana, out of which 50.7% is female and 49.3% male representing 15.6 and 15.2 million people, respectively. Greater Accra has the highest population with 5,446,237 people followed by the Ashanti with 5,432,485 people.

Ghana has more than seventy ethnic groups, each with its own distinct language. Languages that belong to the same ethnic group are usually mutually intelligible. English is the official language whereas Akan is the most widely spoken. Major ethnic groups in Ghana include the Akan at 47.5% of the population, the Mole-Dagbon at 16.6%, the Ewe at 13.9%, the Ga-Dangme at 7.4%, the Gurma at 5.7%, the Guan at 3.7%, the Grusi at 2.5%, the Kusaasi at 1.2%, and the Konkomba people at 3.5%.

Economy of Ghana

Ghana is well endowed with substantial mineral resources, the major ones being gold, diamonds, manganese and bauxite. Gold is the predominant mineral produced in the country, accounting for over 90% of all mineral revenues annually over the past two decades. Most Ghanaian mining production was state owned, but since the Economic Recovery Program entered by the Provisional National Defence Council Government in 1983, Ghana has attracted foreign investments and pushed towards privatisation and state divestiture. Today, Ghana is Africa's largest gold producer, overtaking South Africa for the top spot in 2019.

Mineral rights are granted to private parties giving them the right to mine the minerals in the ground. However, the Government of Ghana is entitled to 10% free carried interest in the rights and obligations of the mineral operations but does not make any financial contribution. The Government can however obtain further participation in mineral operations upon agreement with the holder. In 2012 alone, six mining laws and regulations were passed. These policy revisions have proven successful. In 2013, over 50% of Foreign Direct Investment in Ghana was related to the mining sector. The mining sector contributed significantly to Ghana's overall export and tax revenues: 37% of export revenues were attributable to mining and the sector was responsible for 19% of all direct tax payments in Ghana. This clearly indicates the significant importance of mining in Ghana, which is also reflected in mining's contribution to GDP (i.e. 1.7%) and direct employment (i.e. 1.1% of the Ghanaian labour force).

The Government of Ghana is increasingly focusing on regulating and promoting small-scale mining and strengthening the collection, transparency and management of mineral revenues. The ASM sector plays a very significant role in the socio-economic development of the country. It, without doubt, contributes significantly towards foreign exchange earnings, generates both direct and indirect employment for many people in many parts of the country and hence is a recognisably important component in Government's poverty reduction strategies.

Geological Context of Ghana

Ghana falls mostly within the West African Craton which stabilised in the early Proterozoic (2000 Ma) during the Eburnean Orogeny. About two-thirds of Ghana is dominated by Paleoproterozoic Birimian rocks consisting of six volcanic belts, ref. Figure 42. The remaining one-third is made up of post-Birimian rocks. Geologically, Ghana can be divided into several distinct geological systems, namely:

1. **Birimian System:** Rocks of the Birimian System underlie most of southern, western and northern Ghana. They host most of the gold and diamond deposits in the country. Kesse (1985) gives an overview of the ideas about the Birimian up through the early 1980s. The Birimian consists of metamorphosed volcanic and sedimentary rocks which form belts of volcanic rock separated by broad "basins" of sedimentary rocks. The rock types present in the Birimian sedimentary rocks are greywackes with turbidite features, phyllites, slates, schists, weakly metamorphosed tuffs and sandstones. Some of the phyllites contain pyrite, and finely divided carbonaceous matter is present in most of them. The Birimian volcanic succession consists of lava flows and dyke rocks of basaltic and andesitic composition. Most of these rocks have now been metamorphosed to hornblende actinolite-schists, calcareous chlorite schists and amphibolites (the greenstones). The Birimian rocks are generally tightly and isoclinally folded; they are also commonly sheared and fractured.

2. **The Tarkwaian System:** A distinctive sequence of clastic sedimentary rocks occurs in elongate troughs developed on top of the Birimian System within the Ashanti, Bui, and Bole-Navrongo Belts. These rocks host important paleoplacer gold deposits and are known as the Tarkwa System. Kesse (1985) and Hirdes and Leube (1989) summarised the literature on the Tarkwaian up through the mid-1980's. In the Ashanti Belt, the Tarkwaaian is made up of four units. The

lowest unit, the Kawere Group, consists of matrix supported, large pebble conglomerate dominated. The Kawere is overlain by the Banket Series which consists of mature, quartzite, breccia and conglomerate composed in part of well sorted quartz pebble conglomerate beds known as "reefs" that host the gold mineralisation. The Banket is overlain by the Tarkwa Phyllite which consists of a transition sequence from sandstone to chloritic and sericitic phyllite. The uppermost unit is the Huni Sandstone; sandstone and quartzite with interbeds of phyllite. In the Bui Belt, Tarkwaian rocks are folded into a regional syncline with a steep northeast trending normal fault parallel to the fold axis. Along the northwest margin of the belt the Tarkwaian rocks are strongly tectonised and overturned. The Tarkwaian in the Kibi-Winneba Belt has been less well studied but appears also to be a northeast trending overturned syncline.

3. **Birimian Granitoids and Associated Intrusives:** Four main types of granitoids are recognised in the Birimian of Ghana. They include Winneba, Cape Coast, Dixcove and Bongo granitoids (Kesse, 1985). The latter three have been recently termed "Basin", "Belt" and "K-rich" granitoids. (Leube et al., 1990 and Hirdes et al., 1993). The Cape Coast and Dixcove type granitoids are widespread in Ghana, the Winneba type is limited to small areas near Winneba, and the Bongo type crops out in the Bole-Navrongo Belt and in the Banso area.

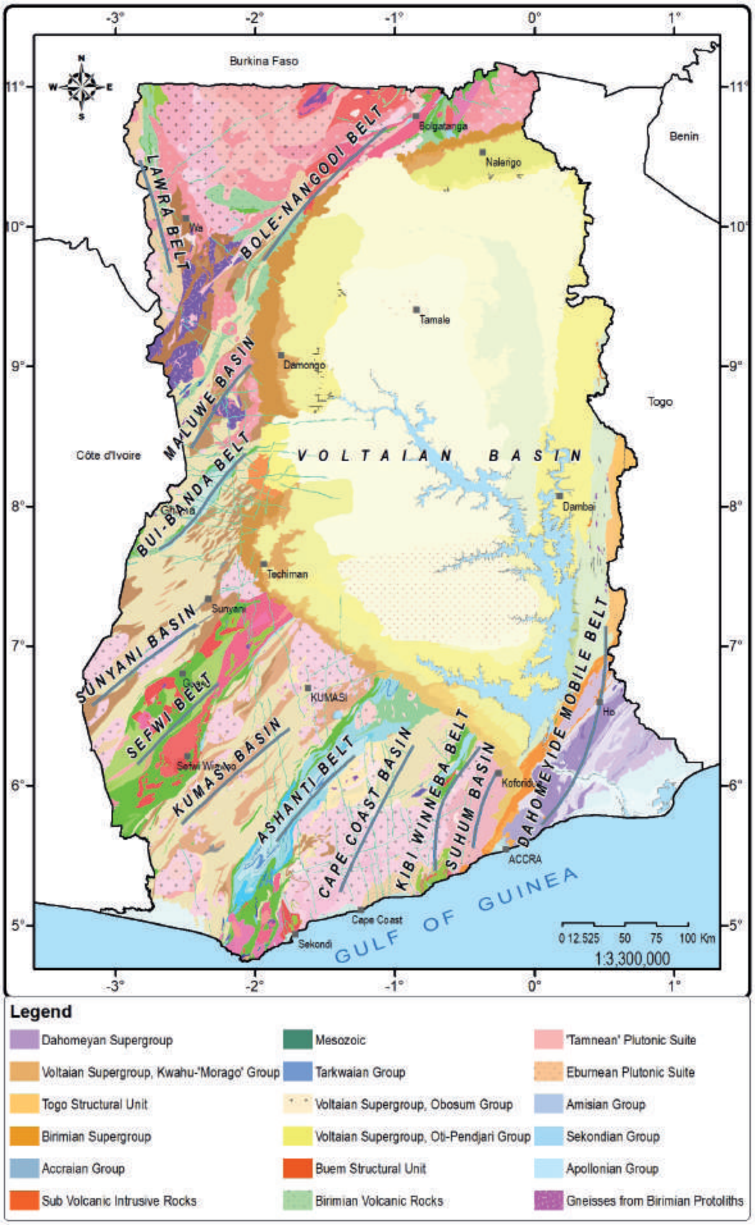
4. **The Voltaian Basin:** The Voltaian strata are nearly horizontal beds of sandstones, shales, mudstones and conglomerates thought to be of late Precambrian to Paleozoic age. In most places, the flat lying Voltaian strata overlie the Birimian rocks with a marked angular unconformity. Junner and Hirst (1946) subdivided the Voltaian sediments on the bases of lithology and field relationships into Lower, Middle and Upper units. The Lower Voltaian sediments represent a marine transgression-regression cycle on the craton, whereas the Middle Voltaian records a glacial event followed by prolonged marine incursion and subsidence of the basin. The Upper Voltaian, otherwise known as the Obosum Formation, is thickest and coarsest in the southeast. The conglomerates contain pebbles of granite and other igneous rocks as well as quartzite fragments.

5. **The Dahomeyan System:** The Dahomeyan System is a part of the second major tectono-stratigraphic terrane in Ghana; it underlies eastern and south-eastern Ghana. The Dahomeyan is the easternmost rock group in Ghana and differs significantly from other rocks in Ghana in that it is composed of high-grade metamorphic rocks. The system consists of four lithologic belts of granitic and mafic gneiss. The mafic gneisses are relatively uniform oligoclase, andesine, hornblende, salite and garnet gneisses of igneous parentage and generally tholeiitic composition. The granite gneisses interlayer with the mafic gneiss and are believed to be metamorphosed volcaniclastic and sedimentary rocks. A distin-

ctive, but normal, lithology in the Dahomeyan is the “Kpong Conglomerate”, a calcareous rock which has been interpreted to be a carbonatite (Mani, 1978).

6. **The Togo and Buem Formations:** The second major lithologic group which makes up the eastern Ghana terrane is the Togo Belt comprising the Buem and Togo Series. The Togo series consist of strongly tectonised phyllite, quartzite and serpentinite (Kesse, 1985). The contacts between the Togo and Dahomeyan to the east and the Buem to the west are thrust faults. West of the Togo Range is a belt of volcanic and sedimentary rocks known as the Buem series.

FIGURE 42 | GEOLOGY OF GHANA



Source: Ghana National Geological Authority

ASM in Ghana

ASM is a collective term referring to low-tech, labour-intensive mineral processing and extraction (Hilson and Pardie, 2006). Though there is no exact definition for ASM in Ghana, the term is used almost exclusively to refer to licensed operations based on a concession not exceeding 25 acres, along with several other pre-qualifications legislated by the Minerals and Mining Act, 2006 (Act 703).

Formal ASM operations have the requisite licences and permits required by law, and conform to regulations, policies and management practices.

Informal ASM operations, on the other hand, do not have the requisite licences and permits required by law, but have a 'social licence to operate' from the local community, or other local actors who do not have power vested by the State to award mineral rights and concessions.

Substances Exploited by ASM Operators in Ghana

The major substances being exploited by ASM operators in Ghana are: Gold, Diamond, Brown Clays, Kaolins, Clam Shells and Jasper.

Legislative Framework for the ASM Sector in Ghana

The Small-scale Gold Mining Law of 1989 regulates registration activity, granting of gold-mining licences to individuals, groups and registered cooperatives, licensing of buyers, and the establishment of district centres to support applicants.

The Precious Minerals Marketing Corporation Law of 1989 changed the Diamond Marketing Corporation into the Precious Minerals Marketing Corporation (PMMC) and authorised it to buy and sell gold and diamond.

The Minerals Commission Act of 1993 established the Minerals Commission as a corporate body and defined its functions and powers.

The Minerals and Mining Act of 2006 Act revised and consolidated mining and mineral law. The Act empowers the Minister, after consulting the Minerals Commission, to designate areas for ASM operations. The Act repeals the Minerals and Mining Act of 1986 and the Small Scale Gold Mining Law of 1989 among others and incorporates existing laws and regulations on the sale of mercury and minerals, use of explosives, requirement for environmental permits, etc.

The Minerals and Mining Amendment Bill of 2014 (Mineral Development Fund Bill) amended the Minerals and Mining Act of 2006. First, to enable the Minister of Lands and Natural Resources to prescribe the rate of royalty payments (formerly fixed at 5%), and second, to enable the confiscation of equipment used in illegal artisanal and small-scale mining operations.

The Role of Ghana Geological Survey Authority to Support ASM Operators
The Ghana Geological Survey Authority operates under the new Ghana Geological Survey Authority Act of 2016. The Act was enacted to replace the Survey Act of 1962, which established Geological Survey Department.

The Act mandates the Ghana Geological Survey Authority to:

- Promote the exploration and exploitation of the natural resources of the country. In the pursuit of this mandate, various samples (rocks, stream and soil) are collected and examined for their economic mineral content;
- Organise training courses and seminars in basic geology; surveying, mineral processing, environmental management and reclamation for artisanal and small-scale miners to enable them improve the ore recovery with less damaging impact on environment and health;
- Provide geo-scientific data and information to artisanal and small-scale miners;
- Conduct geological investigation of blocked out areas for artisanal and small-scale miners;
- Hold regular Geology clinic as a platform for educating the artisanal and small-scale miners of the different mineral resources of the country; and
- Encourage small-scale miners to use newly developed local technologies, for example, "Sika Bukyia" (gold smelting gas stove) to reduce the use of mercury and cyanide in gold recovery.

Environmental and Health Issues related to the ASM Sector in Ghana

Impact on Waterways

Gold mine tailings block the passage of waterways, such as rivers and lakes, and sometimes lead the source of water to dry up entirely especially in the dry season. Gold mining is a major polluter of both surface and underground water and it does not become safer with time without proper remediation or treatments. The most important source of water pollution in mining communities are from mine tailings flowing into water bodies either by failures (accidents) or lack of standard practice in operations. The use of chemicals, such as mercury, to extract gold pollute the water body and make it unsafe for drinking. Natural disasters such as floods, seismic impacts, landslides may cause tailing management facilities to break thereby allowing mine tailings to get into water bodies and the environment.

Deforestation

In many areas where ASM activities take place, large tracts of land are stripped of vegetation cover including forest reserve in order to get access to ore material that is mined. This exposes the land surface directly to rainfall leading to erosion, loss of water due to severe evapotranspiration. Fauna and flora are also affected as some are dislodged from their habitats, destroyed or lost by as a result of removal of vegetation. Soil nutrients, elements and microbes essential for growth of plants and animals are also affected.

Impact on Landscape

ASM generally destroys the physical features of the land, such as forests, water bodies and aquatic life. This creates a whole inconveniences and extreme environmental degradation.

Impact on Health among ASM in Ghana

The health impact on ASM operators in Ghana are enormous including; lack of clean water for domestic use, such as drinking, cooking, bathing and washing of clothes. Many ASM operators also struggle with diseases, such as respiratory diseases and skin rashes, etc. when they use polluted water. Mostly, the work of ASM contaminates the aquatic life which go a long way to contaminate protein food obtained from these sources of water: rivers, streams, lakes, which get polluted by ASM activities.

Socio-Economic Issues related to ASM Sector in Ghana

ASM operations in Ghana are rated as being more lucrative. While the question on the lucrative nature of ASM remains a debate amongst academics, the socio-economic tragedies of ASM operations dominate the literature (Hilson and Pardie 2006). ASM has been practiced in Ghana as far back as the 4th century. The Small-Scale Mining Law of 1989 (Provisional National Defence Council Law) and the Minerals and Mining Act of 2006 limit ASM to Ghanaians (Crawford and Botchwey, 2016). The aim of this limitation is to provide Ghanaian citizens with a source of livelihood. However, most artisanal and small-scale miners find it difficult to register and obtain licenses before operating.

Role of Women

It is important to highlight the particular pressures felt by women in ASM, who are often more disadvantaged than men. At sites, women are ever-present, most visibly engaged in work as ore haulers and washers, and as service providers (supplying food, clothing, water and light mine supplies). Most often women, who engage in ASM are intimidated and sexually harassed by the men. Sometimes the only way for them to even secure a position in the ASM is to offer their bodies.

Child Labour

The effects ASM impose on mining communities in Ghana are significantly higher than the impacts. A lot of children are exploited for ASM activities. Adults are often replaced with child labour because they are cheap and docile. This exposes the children to serious hazards and illness. The rate of child labour in ASM is very alarming and therefore there is an urgent need to find measures to curtail the socio-economic effects such school dropout and teenage pregnancy in the mining communities and the Ghana as a whole.

Conflicts with Local Farmers and Other Stakeholders

ASM activities come with some negative socio-economic and environmental effects. In another related study, Bagh et al. (2016) reported a scuffle that ensued between smallholder farmers and artisanal miners in the district. This can manifest itself in many forms, from community unrest due to the dispossession of ancestral land and the awarding of extensive concessions to large-scale mining, to localised violence over access to and the control of land, resources and gold (Crawford and Botchwey, 2016). These scuffles sometimes lead to serious conflict which in turn affects the activities of the farmer.

Impact of Criminal Gangs in the Mining Area

The ASM sector also serves as breeding grounds for criminal activities which most often endanger the safety and the peace of the people in the community. Places of ASM activities aggravate robbery and chaos in the community because of the huge money involved in such activities. In some communities, farmers are not even willing to go to their various farms to work because of the fear of being attacked or robbed.


ASD mining operation at Bandira in Mozambique

ASM SECTOR OF LIBERIA

By Tanyenoh Jlateh and Ben S. Toejaeh, Liberian Geological Survey. Ministry of Mines and Energy, Liberia

Geographical Context of Liberia

Demography of Liberia

Liberia, officially the Republic of Liberia, is a country on the West African coast. It is bordered by Sierra Leone to its northwest, Guinea to its north, Ivory Coast to its east, and the Atlantic Ocean to its south and southwest. It has a population of around 5 million and covers an area of 111,369 km2. English is the official language, but over 20 indigenous languages are spoken, reflecting the country's ethnic and cultural diversity. The country's capital and largest city is Monrovia.

Liberia was the first African republic to proclaim its independence and is Africa's first and oldest modern republic. It was among the few African countries to maintain its sovereignty during the Scramble for Africa. During World War II, Liberia supported the United States war effort against Germany, and in turn received considerable American investment in infrastructure, which aided the country's wealth and development. President William Tubman encouraged economic and political changes that heightened the country's prosperity and international profile; Liberia was a founding member of the League of Nations, United Nations, and the Organisation of African Unity.

Economy of Liberia

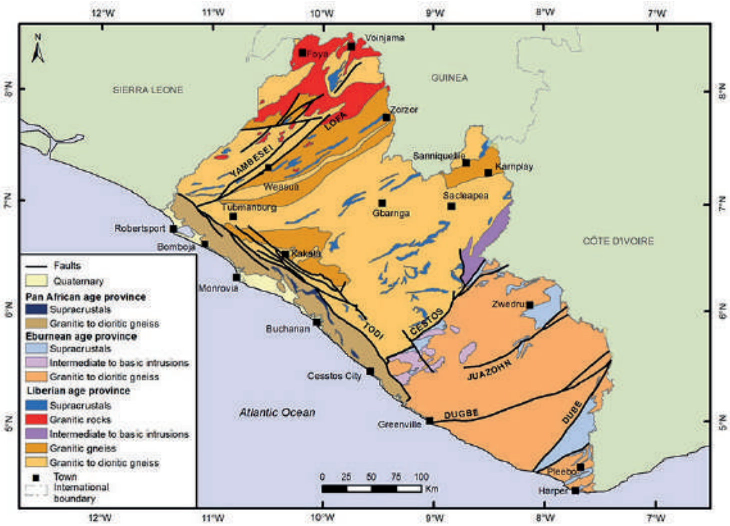
The mining industry of Liberia has witnessed a revival after the civil war which ended in 2003. Gold, diamonds, and iron ore form the core minerals of the mining sector with a new Mineral Development Policy and Mining Code being put in place to attract foreign investments. In 2013, the mineral sector accounted for 11% of GDP in the country and the World Bank projected a further increase in the sector by 2017.

The mining sector is considered the prime mover for the economic growth of the country and its exploitation has to be appropriately balanced with sustainable environmental preservation of its rich biodiversity. Apart from iron ore extractions, cement, diamond, gold, and petroleum resources have also been given due importance to enrich the economy of the country.

Geological Context of Liberia

Simplified geological Map of Liberia

FIGURE 43 | GEOLOGICAL MAP OF LIBERIA



Source: Liberian Geological Survey

Brief Description of National Geology

Liberia is underlain by the Man Shield, which comprises two major areas of Archaean and Palaeoproterozoic rocks. The Archaean basement which is of Liberian Age Provence (2.5–3.0 Ga) and extends across Central and Western Liberia, is characterised by a granite-greenstone association that is dominated by granitoid gneisses and migmatites, which are infolded with supracrustal metavolcanic and metasedimentary rocks and intruded by a younger igneous complex. The supracrustal rocks form discontinuous narrow, elongate 'schist belts'. The metamorphic grade is generally amphibolite facies with greenschist facies dominating the schist belts.

The boundary between Archaean and Palaeoproterozoic-aged rocks (is the Eburnean-Age Province, 1.8–2.5 Ga) is not well defined in eastern Liberia but is generally considered to lie along the north-east-trending Cestos Shear Zone. The south-eastern part of this province in Liberia, extending west from Côte d'Ivoire to Greenville, consists of tightly folded paragneiss, migmatite, and amphibolite. The north-western part of the province, to the north of Greenville, has similar lithologies and geophysical characteristics, but younger isotopic ages.

An extensive Palaeoproterozoic volcano-sedimentary sequence, the Birimian Supergroup, surrounds the Archaean basement of the Man Craton along its northern and eastern margins. The supracrustal rocks are surrounded by a regionally extensive granitoid complex. Although the genetic relationship between the Birimian sequence elsewhere in west Africa and the Eburnean-age province of Liberia is unclear, they are widely considered to be equivalent.

Rocks of Pan African age (approximately 550 Ma) underlie an elongate, fault-bounded zone along much of Liberia's coastline. They comprise metasedimentary and mafic meta-igneous rocks, containing granitic bodies and subordinate noritic intrusions. Phanerozoic rocks in Liberia include extensive north-west-trending Jurassic-age dolerite dykes, minor Palaeozoic and Cretaceous sandstones, and unconsolidated Quaternary deposits.

Multiple phases of deformation are present in the Precambrian rocks. The structural trend of the rocks in the Liberian and Eburnean-age provinces is principally north-east, whereas that of the Pan African-province is mainly north-west. Several major north-east-trending faults in eastern Liberia are extensions of regional structures, which extend into Côte d'Ivoire and include the economically important Cestos, Dugbe, Dube, and Juazohn shear zones. The Lofa River Shear Zone in northwest Liberia also trends northeast.

The northwest-trending Todi Shear Zone marks the boundary of the Pan African province and comprises a series of southwest-dipping faults associated with intense zones of mylonite. The extensive Archaean and Proterozoic terranes that are present in Liberia are highly prospective for many metals and industrial minerals, but an understanding of the detailed geology is poorly known.

ASM in Liberia

Substances Exploited by ASM Operators in Liberia

Two categories of licenses that are issued to ASM operators: Artisanal Miners are considered Class C license holders while the Small-Scale Miners are consider Class B license holders.

Substances exploited by ASM operators are gold, and diamond notwithstanding some of the small-scale miners are engaged in the exploitation of barite, corundum, rock quarry, river sand, coltan, and heavy beach sand minerals.

Legislative Framework for the ASM Sector

The legislative framework for the ASM sector is coined after the ASM Road Map that was developed in 2016 and reaffirmed in 2018. It contains eight thematic sections namely:

1. Decentralisation of MME Governance Structures;
2. Improvement of Accessibility to AM Licenses;
3. Tracking and Reporting of Mineral Production and Sale;
4. Piloting mining cooperatives;
5. Spatial mapping of artisanal mines in Liberia;
6. Improvement of ASM Environment Management Practices;
7. Enhancement of ASM Health, Safety, and Security Practices; and
8. Demonstration of Social Responsibility.

Role of the National Geological Survey to Support the ASM Operators

The role of the Liberian Geological Survey is to help the ASM operators prospect or explore to delineate the primary deposits from the secondary ones. The reason is to identify working areas for ASM operators and avoid the exploration companies and license companies overlapping the secondary deposits that should be mined by ASM operators. Secondly, when delineated and prospected properly, the Liberian Geological Survey will be able to establish the confidence levels of these secondary deposits by knowing the infare, or probable resource level of these secondary deposits. But due to the Ministry's low budgetary allotment, the Liberian Geological Survey cannot support the ASM operators as of now.

Environmental and Health Issues related to the ASM Sector in Liberia

Impact on Waterways

ASM activities can cause a serious environmental problem when done badly. Some of the environmental problems are direct results of mining, others are caused indirectly. The most common and important environmental problems relate to water pollution as a result from ASM activities, which affect most of the creeks, streams, and rivers where the mines are operated. Water availability and quality are a big problem in Liberia, and all the major river basins are badly polluted, often from ASM activities. Mining activities can pollute rivers, streams, and creeks, spoil drinking water, and kill fish, affecting most of the nearby communities in these ASM mines.

Deforestation

ASM may impact or even destroy land that may be used for other purposes. ASM activities across Liberia also lead to the clearing of forests and also to excessive hunting of wild animals for bush meat. Damage to the environment also occurs when miners cut down trees for cooking, building houses, or when they clear an area to dig for gold or diamond and leave the holes uncovered- with no backfilling at some sites. Forests are crucial for maintaining healthy ecosystems, supporting biodiversity, capturing greenhouse gases, regulating local and worldwide climates, etc.

Impact on the Landscape
Communities have the right to make decisions on how their land is used. This is why the Government needs to consult with communities when making decisions about land, forest, or mining activities. Communities have rules regarding how land is acquired and used. It is unfair and wrong to conduct mining activities on land that belongs to communities without their prior approval. Doing so may result in conflict and violence.

Therefore, the Ministry assigned Mining Agents to each Mining District. Artisanal miners should get the approval of the communities before using their land for any purpose. Artisanal and other miners must also avoid mining one of the Protected Areas and Proposed Protected Areas.

At some mining sites, some information is or has been provided about how to take care of the environment. For example, the MME agents assigned to various mining districts across Liberia inform miners that they must backfill through the “dig hole, cover hole” practice. This practice is ongoing in some mining places. However, in some places, no backfilling takes place.

Socio-Economic Issues related to the ASM Sector in Liberia

Role of Women

Women often perform tasks in the ASM sector, including crushing, washing, and sorting. They are also involved in providing goods (for example food and drink) and services (for example transporting dirt and water, cleaning, and doing laundry) in the mining camps. In some mining areas, women have leadership roles in cooperatives, and there are examples of women serving as mining agents, mine chairpersons, financiers, and traders. However, women often face challenges in finding safe opportunities where they are not exploited, and some women may have very limited awareness of their rights. Women may face a lot of discrimination due to cultural beliefs and norms.

Often, women are given lower status tasks in ASM – jobs that are physically difficult but pay less than those done by male counterparts. Further, because of differences in access to credit, women may have limited ability to purchase the necessary equipment to mine, while many of them lack awareness of their rights and the value of the minerals they mine.

There is also a risk of gender-based violence in and around mine sites and a lack of proper sanitation facilities and childcare options can limit women’s participation in the sector. In some mining areas, women become the victims of trafficking, forced labour, and sexual exploitation.

Mining work can create health risks for the whole family, including women. And where men have control over radios, women can have a hard time getting information (such as on health risks or training) and cannot participate in public awareness activities. Some cultural taboos also stop women from going to mining places when menstruating.

The MME wants an ASM sector where women's rights are fully respected. The MME, therefore, encourages all actors involved in ASM (miners, local authorities, etc) to implement and enforce the existing laws that protect women's rights. Everyone needs to know that women are entitled to the same rights and freedoms as men according to Liberian law. Therefore, the ASM community should make sure to uphold the rights of women. People making decisions in the ASM sector should ensure that women have access to working tools and equipment just like men do. Women's role in the ASM sector must be controlled by the women themselves and not by men. Furthermore, it is not acceptable to stop a woman from working because she is menstruating.

Children

Children below 18 are not allowed to work in the mining area within Liberia, whether underground or on the surface. Children may not either be used for operating a machine for lifting or moving objects. The Liberian Law says that this is wrong. So, when children work in mining sites, responsible adults can be prosecuted.

The Independent National Commission on Human Rights (INCHR) is the government office that is responsible for the need to address human rights abuses and violations in Liberia – and that mandate includes working to improve the often bad working conditions in ASM. The INCHR, therefore, wants to improve the working conditions within ASM overall, including human rights-related risks and issues.

The INCHR is working with other government authorities to make sure that ASM practices are regulated in a manner that causes less negative impacts on the environment, human health, safety, and social well-being. The UNCHR encourages miners and other stakeholders to respect the laws regarding human rights. This includes a no to forced labour, no to child labour, no to the use of minerals that harm the environment and human health, and respect for the rights of women and children. The INCHR wants miners and other ASM actors to be aware that people who are responsible for violations of human rights can be punished under the Laws of Liberia.

Sluicing at a small artisanal mining site, north of Tarkwa in Western Ghana.

Miners coming up from a underground section of the Takote Mine outside Tarkwa in Western Ghana.

ASM SECTOR OF SIERRA LEONE

By Joseph E.W Jackson and Nancy M. Tucker, National Minerals Agency, Directorate of Geological Survey

Geographical Context of Sierra Leone

Demography of Sierra Leone

Sierra Leone is a West African country along the Atlantic Ocean, bordering Liberia and Guinea. The country is divided into four quadrants: Guinean mangroves (swamps along the coastline), forested hills, plateaus high above sea level, and mountains in the east. Sierra Leone has its government divided into executive, legislative, and judicial branches. The country itself is divided into four first-order administrative division, three provinces and one area (Western Area). These are sub-divided into 16 district at second-order level. The country is further broken down into 149 chiefdoms, small local units of government.

Sierra Leone has 16 different ethnic groups, each with a different language. The largest ethnic group is the Temne (35%) who live in Northern Sierra Leone, followed by the Mende (31%) who mostly live in the South-Eastern Sierra Leone. The third-largest ethnic group is the Limba (8%), who live in Northern Sierra Leone. The fourth group are the Fula (7%), who are descendants of Fulani migrant settlers from the 17th and 18th century who came from Guinea. Other major ethnic groups include the Mandingo (2%), who are descended from Guinea traders; the Kono (5%), who are also descended from Guinea migrants; and the Krio (2%) people, who are descendants of freed African American, West Indian and Liberated African slaves and make up 3% of the population. Smaller ethnic groups include the Kuranko, who arrived in the area around 1600; the Loko (2%), who are native to Sierra Leone; the Kissi, and the Sherbro.

There is no official religious affiliation in Sierra Leone, but nearly everyone living there is either Muslim or Christian. About 78% of the population are Muslims, while Christians make up 21% of the population. Religious violence is rare, and Sierra Leone is known as one of the world's most religiously tolerant nations, with Christians and Muslims regularly working together peacefully. Any civil disputes in the country were never religiously motivated.

Sierra Leone's population increased more than threefold between 1960 and 2020, from 2.3 million in 1960 to 8.0 million in mid-2020, mostly through high fertility rates and longer life expectancy for both males and females (also because of rapidly improving child and infant mortality figures). After 1972, population growth figures have always been higher than 2.0%, with the exception of the troubled period between 1989 and 2000. In the years 1992-1995 there was even a period of population decline as a result of the civil war, the killing of people and refugee migration to other countries. In 1987 and during the recovery years between 2001 and 2006 population growth figures have been higher than 3% per year. Currently, the average growth rate is around 2.1 percent per year.

Total fertility was around 6.0 live-born children per woman in 1960; it first increased to 6.7 between 1985 and 1990, and then started to diminish relatively fast, with currently 4.3 births per average woman in Sierra Leone during her lifetime. As a result of these demographic developments Sierra Leone has a skewed population pyramid, with more young people than adults and elderly people. The median age changed from 21.0 years old in 1960, to 17.7 years old in 1995-2000, and currently 19.4 years old. Urbanisation is on the increase, and the urbanisation rate has reached 43% in 2020.

The provisional results of the 2021 Mid-Term census recently released by Statistics-Sierra Leone have raised eyebrows among Sierra Leoneans. According to the provisional results of the 2021 Mid-Term, population in Sierra Leone has increased by only 449,528 - from 7,092,113 to 7,541,641 between 2015 and 2021.

Economy of Sierra Leone

The economy of Sierra Leone is that of a least developed country with a gross GDP of approximately USD 1.9 billion in 2009. Since the end of the Sierra Leone Civil War in 2002 the economy is gradually recovering with a GDP growth rate between 4 and 7%. In 2008 its GDP in public Private Partnership ranked between 147th (World Bank) and 153rd (CIA) largest in the world.

Mining has been the mainstay of the economy since independence and the government has remained heavily dependent on mineral resources over the years. Mining contributed 0.7% to GDP, constituted 65% of export earnings, and 3% to employment in 2018. The Government established the National Mineral Agency under the Ministry of Mines and Mineral Resources in 2012 with a mandate to implement clear policies and regulations, enhance transparency and accountability and ensure mineral resources support economic and social development. Sierra Leone became a member of the Kimberley Process in 2003 to protect the legitimate trade in rough diamonds, and in 2007 enacted the Diamond Cutting and Polishing Act to issue licenses entitling the holder to buy, deal in, export, import as well as cut, polish, crush and set diamonds for trade. In 2006, Sierra Leone joined the Extractive Industry Transparency Initiative to improve governance and revenue management in the extractive sector. Consequently, the country is heavily reliant upon foreign aid. Agriculture is also an important part of the economy, accounting for 58% of the country's GDP, and employing 80% of the people living there. Rice is Sierra Leone's most common export.

Sierra Leone has achieved commendable economic growth rates in the post-war period that peaked at 20.7% in 2013 with the launching of the government's Agenda for Prosperity 2013-18. The continued double-digit GDP growth resulted from resumption in iron ore production combined with government investment in infrastructure as well as buoyant activities in agriculture, tourism and services. The impressive growth rates were, however, disrupted by the twin-shocks of:

- unprecedented decline in international iron ore prices starting in late 2013; and
- the outbreak of Ebola Virus Disease (EVD) in 2014, together culminating in GDP contraction of 21.1% in 2015.

Prior to the Ebola epidemic, mining, primarily iron ore, accounted for 15% of GDP and about 80% of merchandise exports. However, the sector has exhibited significant volatility in recent years, with iron ore output declining to almost zero in 2018–20. Thus, while growth averaged 4.2% over the past decade, it has fluctuated widely (by 10.3 from the mean, two-thirds of the time).

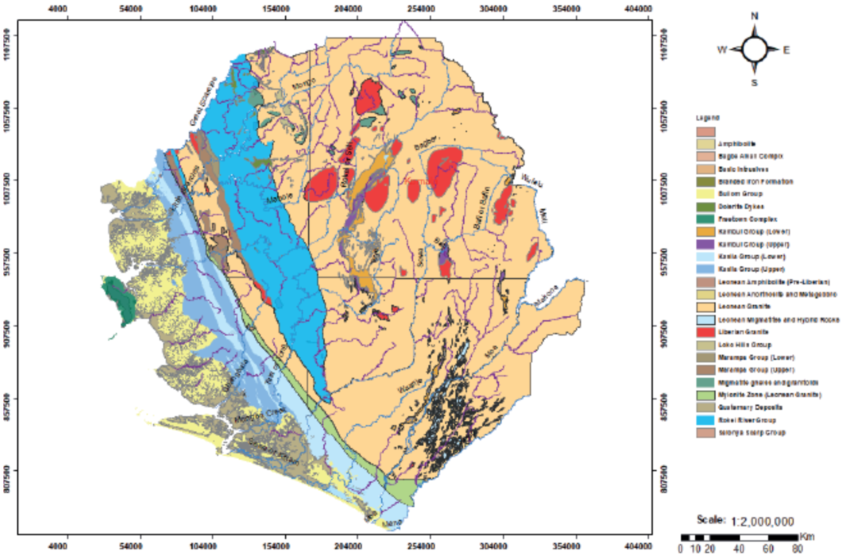
The authorities have struggled to restore macroeconomic stability and fiscal balances since the Ebola shock. Since 2014, the budget deficit has exceeded 5.5% of GDP, due to low domestic revenue mobilization (average of 12.6% of GDP) and expenditure overruns (average of 22.0% of GDP). Sierra Leone is at high risk of debt distress, with debt dynamics partly affected by increased reliance on expensive domestic borrowing. The ratio of interest payments to domestic revenue was estimated at 19.8 percent in 2020. Inflation has remained elevated, largely in double digits, raising concerns for food security. Economic growth has translated into modest per capita income gains because of rapid population growth (averaging 2.1% per annum). Poverty (measured using the international poverty line of USD 1.9 per day, 2011 PPP) fell by 11.7% over the last decade to 43% in 2018. Since three-quarters of the poor live in rural areas, poverty among subsistence farmers remains a major challenge.

Despite the Ebola epidemic and the shutdown of most iron ore mining in 2015, Sierra Leone recorded average annual GDP growth of 5.2% in the period 2012–2016. Agriculture is Sierra Leone's main sector, accounting for almost 60% of GDP in 2016, and recorded average annual growth of 3.3% from 2012 to 2016. Industry accounted for 12.4% of GDP in 2016 and is dominated by mining and quarrying, which alone contributed 5.8% of GDP. Iron ore mining resumed in 2016 and led to an overall growth of mining of almost 50% in 2016. In 2014, when iron ore mining was in full swing, mining made up more than 18% of GDP. This shows the sector's huge potential for future growth. Nonetheless, it is important to note that this growth depends on global commodity prices in the steel sector. Bauxite, diamonds, gold, ilmenite and rutile mining have also been drivers of growth in the sector.

Geological Context of Sierra Leone

Simplified Geological Map of Sierra Leone

FIGURE 44 | GEOLOGICAL MAP OF SIERRA LEONE



Source: Directorate of Geological Survey, Sierra Leone

Brief Description of National Geology

Sierra Leone is a resource-rich country, with extensive known and potential mineral and petroleum resources. However, knowledge about the geology of the country is limited, with very little modern data in the public domain, and this hinders sustainable development of these resources for the national good. The lack of data is now being addressed by the Extractive Industries Technical Assistance Programme Phase 2, which is funded by the World Bank, and which aims to deliver a national airborne geophysical survey and subsequent geological mapping of the country.

Below summarises the state of knowledge on each of the major lithostratigraphic units currently identified within Sierra Leone, working broadly from youngest to oldest.

- **Bullom Group:** the youngest recognised stratigraphic group in the country, and comprises poorly consolidated Cenozoic sediments which outcrop along the coastal strip of Sierra Leone. It rests unconformably on the older rocks of the Kasila Group and the Freetown Complex;

- **Kimberlite:** Mesozoic kimberlites are exposed in the area around Koidu in eastern Sierra Leone. This area contains three kimberlite pipes up to 300 m across and a swarm of kimberlite dykes, typically running ENE-WSW and <5m wide. A second swarm of kimberlite dyke, with ENE-WSW trend, occurs in the Tongo area;
- **Doleritic Dykes:** Mesozoic dolerite-gabbro dykes, formed during the opening of the Atlantic in this region, are mapped in great detail in the Gola Forests area in the SE of the country, but have not been mapped elsewhere;
- **The Freetown Layered Complex and other intrusive complexes:** The Freetown Complex is a moderately well-exposed mafic layered igneous complex forming the mountains on which the city of Freetown is built. It has been studied in some detail by a number of authors, both for its igneous history and for its potential for platinum-group of metals;
- About 35 km ESE of Freetown, at Songo Town, small outcrops of the nepheline- 7 rich rock ijolite have been identified and shown to form a small intrusive stock;
- In the Gola Forest, the Bagbe Complex is a larger igneous intrusion comprising alkaline granitic and syenitic lithologies. These alkaline intrusive rocks have the potential for resources of critical metals such as the rare earth elements and niobium;
- **The Saionia Scarp Group:** this Group is in northern Sierra Leone, and is a sedimentary succession that rests unconformably upon the underlying Rokel River Group and Archaean Basement. It has been divided into two formations: the lower Moria Formation and the upper Waterfall Formation. The Waterfall Formation contains sedimentary rocks considered to be of glacial origin, and of late Ordovician age;
- **The Rokel River Group:** this Group is a volcano sedimentary succession, metamorphosed to low grade, and is relatively well-exposed in the northern part of its outcrop, chiefly in river exposures. It has been divided into 4 formations namely Taia Formation, Kasewe Hill Formation, Teye Formation and the Tabe-Makani Formation. It rests unconformably upon the Marampa Group and the basement gneisses;
- The Rokel River Group: This consists of conglomerates, sandstones, greywackes and waved sediments with volcanics. The above series of rocks are succeeded eastwards by the bulk of Basement, a migmatitic area with granites, oriented granites, gneisses, amphibolite etc. This area includes the four Schist belts - Sula Mountain/Kangari Hills, Nimini Hills, Gori Hills and the Kambui Hills. These greenstone belts (Schist-belts) contain metamorphic sediments, volcanics and ultrabasics;
- **The Marampa Group:** this is a Neoproterozoic, volcano sedimentary succession which crops out in a discontinuous strip along the eastern side of the Rokel River Basin. This group is divided into two formations: a lower Matoto Formation, including mafic volcanics and ultramafic units; and an upper Rokotolon

Formation dominated by metasedimentary rocks. The Rokotolon Formation was further divided into three Members, namely Massaboin Member, Masimera Member, and Mabla Member;

- **The Kasila Group:** this is a NW-SE trending strip of highly deformed and metamorphosed amphibolite to granulite facies metasedimentary and meta-igneous rocks of Palaeoproterozoic age. It forms the westernmost part of Sierra Leone's basement, and was likely accreted to the margin of the West African Craton during the Pan-African Orogeny, at the end of the Neoproterozoic. Its western contact is entirely covered by Bullom Group sediments, and its eastern contact is recorded as a mylonite zone, several km in width. The Kasila Group is divided into two successions, the Magbele and Tapr, and it represents the source rock for Sierra Leone's bauxite and rutile resources, as well as being an area with potential for other metallic mineralisation; and
- **The Archaean Basement:** Archaean basement gneisses underlie much of eastern Sierra Leone, and also crop out to the west of the younger Rokel River and Marampa groups. The western strip of exposure has been termed the Kenema Assemblage; it is likely to be continuous to lie beneath the overlying Rokel River and Marampa groups. The Archaean basement comprises three broad units: the basement gneisses, the supracrustal belts, and the late-tectonic granitoids. Previous work had proposed that two major cycles of Archaean crustal formation could be recognised (the Leonian and Liberian) on the basis of structural relationships observed in the field.

ASM in Sierra Leone

ASM in Sierra Leone plays a vital role in the extraction of the country's mineral resources. It is estimated that over 80% of Sierra Leone's diamonds are extracted by artisanal miners and that the sector provided approximately 4.5% of GDP in 2007, providing livelihoods for approximately 150,000 individuals, nearly 3% of the total population.

Artisanal and Small-Scale Gold Mining (ASGM) constitutes 37% of the global anthropogenic atmospheric mercury emissions to the environment. The Minamata Convention on Mercury is a global treaty to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds. Sierra Leone ratified the Convention on 1 November 2016.

With support from the United Nations Institute for Training and Research, the Environmental Protection Agency is currently developing a National Action Plan for reducing mercury use in the ASGM sector. This project is implement by UN Environment and funded by the Global Environment Facility.

Substances Exploited by ASM Operators in Sierra Leone

Currently, the only known places where mercury is used among artisanal miners

are Kumaru and Baomahun. Based on the gold production in those locations, it can be estimated that 4,000 artisanal miners are annually consuming 156 kg of mercury in average. Mercury use in small-scale mining is more difficult to estimate, and urgently requires further research. However, based on secondary sources, it can be reported that mercury amalgamation appears to be practiced to some extent.
Both in Kumaru and in Baomahun, miners add mercury to the pan containing sand-like ore concentrate. They do this because they do not believe gold can be recovered otherwise, or because they believe the recovery would be lower if mercury were not used. Both of these beliefs might well be true, due to the rudimentary and arbitrary concentration methods applied. As toxic as mercury is, it is an undeniable fact that it is also very effective at capturing gold in typical artisanal mining site conditions.

Currently, most of the miners seem to be entirely unaware of the amalgamation method. Furthermore, it makes sense that mercury use is not more prevalent in Sierra Leone because most of the gold deposits available for artisanal miners are alluvial in nature and host gold in the form of sands or nuggets. This already liberated gold can most of the time be recovered with the present rudimentary gravity concentration methods by sluicing and panning. In addition to this, mercury is also fairly expensive in Sierra Leone (Le3,500/g or 0.5 USD/g) 97 in comparison to miners' modest daily earnings. Nevertheless, in view of the mobile nature of artisanal mining in Sierra Leone and declining gold deposits, the situation might change in the future and the use of mercury must be addressed pre-emptively before its use becomes more widespread.

Legislative Framework for the ASM Sector in Sierra Leone

The Government's drive is to improve integrity in the mining sector and ensure the country maximises gains from its mineral resource endowments. It established the National Minerals Agency in 2012 and the Environment Protection Agency in 2008, enacted the Mines and Minerals Act of 2009, and the Public Financial Management Act of 2016, and the Extractive Industries Revenue Act of 2018 to improve transparency and accountability in the minerals sector. In 2018, the Government approved the Sierra Leone Minerals Policy, the Artisanal Mining Policy, and the Geodata Policy, and currently awaits the interpreted report of a geophysical survey that collected data in 2019 on the type, quantity, and location of minerals in the country.

In Sierra Leone, the current legal framework guiding the exploration, production, marketing, and regulation of solid minerals is contained in the Mines and Minerals Act (2009). The Ministry of Mines and Mineral Resources administers the Act, which provides for the consolidation and amendment of the law on mines and minerals. With respect to ASM, the Mines and Minerals Act of 2009 draws a clear distinction between artisanal and small-scale mining operations. The holder of an Artisanal Mining License must be a Sierra Leonean national and shall have exclusive rights to carry out exploration and mining operations in licensed areas that do not exceed half a hectare. The Director of Mines issues these licenses and regulates the mining and marketing of precious minerals produced under these licenses through the Precious Minerals Trading Department, formerly, Government Gold and Diamond Office. A scheme for artisanal licenses, the Alluvial Diamond Mining Scheme, has been in existence since 1956 and has been a major source of employment for unskilled labour and also a major source of revenue for Sierra Leoneans. The holder of a Small-Scale Mining License, on the other hand, has exclusive rights to carry out exploration and mining operations in licensed areas that are not less than 1 hectare and not more than 100 hectares. The validity of a Small-Scale Mining License does not exceed three years and may be renewed for further periods not exceeding three years at a time (Mines and Minerals Act of 2009).

The Mines and Minerals Act, 2009, and the National Minerals Agency Act, 2012, are the principal legislative instruments regulating the Sierra Leone mining sector. The 2012 Act establishes the National Minerals Agency as the key institution responsible for regulating the mining sector. Its mandate includes the promotion of the development of the minerals sector by:

- effectively managing the administration and regulation of mineral rights and minerals trading in Sierra Leone; and
- providing technical and other support to the mineral sector including geological survey and data collection activities.

Artisanal Mining Policy of Sierra Leone of 2018 sets out a clear framework for guiding actions leading to the improvement of artisanal mining sector governance and management, improve sustainable artisanal mining practices, enhance environmental protection, community and occupational health and safety safeguards, ensure that miners get a fair deal for their winnings; and strengthen linkages between artisanal mining and other sectors of the economy.

Degree of Organisation of ASM Sector

Most of the people involved in artisanal mining are organized in what are locally referred to as 'gangs': small groups of 4-10 people, while others chose to work individually. In a case where someone is in possession of a license, the number of miners typically exceeded the prescribed number of 50 labourers per license. Most license holders, community chiefs and paramount chiefs allow this because "these people need a living". The license holders are typically community leaders, chiefdom leaders and businessmen, and they may also be the leader of mining gangs. Gangs usually operate in one pit, although in some cases, a big gang splits the workers over two pits. In an alluvial mine site, gangs typically include 5-6 people consisting of several 'diggers' who dig most of the gravel with shovels; washers who wash the ore in sluice boxes; a panner who pans the concentrate; and one 'gang leader', 'boss' or 'manager'. In some cases, this 'boss' is involved in the work, and in other cases, he or she only supervises the work and motivates and supports the workers. The gang leader may also appoint one of the labourers as a 'team leader' who is responsible for overseeing the work in the gang leader's absence. As such, there is substantial social mobility in the artisanal mining sector because labourers can get positions such as a 'team leader' and after gaining experience and accumulating capital they may start their own mining gang or become a (typically unlicensed) gold trader.

In a hard rock mine site, gangs are usually bigger as this type of mining is harder and also includes the tasks of crushing the ore and transporting it from deep in the pits to the surface. Within a gang, labourers often work on a rotational basis so that diggers start washing and vice-versa, or that one person takes a break and another person takes of this person's work. This is especially the case in the hard rock mines where the work is physically more demanding than in alluvial mines, but where labourers may rotate so that the gang can work even 24 hours per day, 6 days in a week.

However, there is a clear separation in sex. Whereas the digging work is exclusively done by men as this work is typically very demanding, panning is typically (but not always) done by women who are traditionally viewed as 'panning experts'. The washing activities are carried out by both men and women. The gang is usually established by the gang leader who gathers labourers to work for him or her, or by an external 'supporter' who supports the gang leader and his/her gang financially.

The gang leader or supporter motivate people to work for them by offering food, and in some cases cigarettes and alcohol. The supporters are in most cases unlicensed gold traders, in some cases the artisanal mining license owners, in some cases the gang leaders, and in other cases local or external businessmen. Gangs operating in the same area coordinate to some extent. For example, when one gang's water pump breaks down, they may borrow from another gang, and gangs may come together sometimes to discuss collective concerns, often with the involvement of the community chief and/or license holder (which may sometimes be the same person).

Role of the National Geological Survey to Support the ASM Operators

The Directorate of the Geological Survey is mainly responsible for the following;

- Collection, storage and management of the country's geo-science information, which improve understanding of Sierra Leone's mineral potentials;
- In terms of ASM, the directorate provides geo-science information and technical guidance to ASM operators who often times operate blindly without any geo-science data;
- Responsible for facilitating and overseeing exploration activities in the country, ensuring that reconnaissance and exploration companies conduct their activities in a responsible manner and in compliance with the country's mining laws;

- Among other things, the Directorate plays a leading role in promoting and facilitating the effective and efficient management and the development of mineral resources; and
- The Directorate is mandated to carry out investigations and inspections necessary to ensure compliance with the provisions of the mining laws, and advise holders of mineral rights on proper and safe mining methods.

Environmental and Health Issues related to the ASM Sector in Sierra Leone

Impact on Waterways

Mining can deplete surface and groundwater supplies. Groundwater withdrawals may damage or destroy streamside habitat many miles from the actual mine. ASM activities contaminate water resources, particularly streams, rivers and lakes. The issue of water contamination is applicable to all forms of ASM in Sierra Leone. This is mainly caused by the runoff of mining waste from tailings which are poorly managed, if at all. For example, in Baomahun, mining waste and tailings including mercury, is washed down to the valley during excessive rains in the wet season. Even where no chemicals are used, water quality is affected.

Moreover, in many places it will be observed that sediments that are released to the water, changed colour and the turbidity of the water increased. Sediment plumes can impact rivers for many miles downstream and may also affect estuaries and coral reefs. Massive amounts of sediment are released into waterways from alluvial mining, that are negatively affecting freshwater fish populations. The situation in Sierra Leone, places like Yengema, Kono District and Makong, there are many such abandoned sites that had become artificial lakes containing water with high levels of chemical residuals. Thus reducing the amount of light available to the river habitats. This is likely to adversely affect aquatic life and biological diversity in river ecosystems.

Water bodies, the source of drinking water for many rural households in mining areas are at risk of contamination due to ASM activities. Water quality therefore remains a topical issue for policymakers and researchers.

Three water pollution sources can occur from mining, namely:

- Acid Mine Drainage/Acid Rock Drainage: When mined materials (tailings, waste rock, and heap and dump leach materials, etc.) are excavated and exposed to oxygen and water, acid can form. The acid formed dissolves metals and other contaminants from mined materials to form a solution that is acidic, high in sulphate and metals. Acid drainage and contaminant leaching is the most important source of water quality impacts related to metallic ore mining;
- Erosion and Sedimentation: Due to the large area of land disturbed by mining operations because vegetation is stripped and trees are cut down, erosion can

be a major concern at hard rock mining sites. Erosion control is necessary from the beginning of operations through to the completion. The soil is washed into water bodies which increases the turbidity of the water; and

- Pollution by Processing Chemicals: Mercury is commonly used in the amalgamation of gold although it is very toxic. The concentration of mercury varies considerably, even within a specific ore deposit. For example, 10 tons of mercury are potentially released to the environment, if the mercury content in gold ore is 10 mg/ kg, and one million tons of ore is processed at a particular time. This is a major source of mercury and therefore needs to be controlled.

Mining and its related operations not only consume a great deal of water, but often impact the immediate hydrological system and also influence water quality. The sources of water in these communities, included boreholes, wells, public taps, nearby streams, and rainwater. Mining activities have resulted in a severe water shortage in the mining communities. Majority, (66.7%), of the residents within the vicinity of Octea Mining Limited in Kono, reported that mining exploration had limited the access of communities to safe and adequate water, thus causing water scarcity compared to 61.7% of the respondents in Lunsar and 56.7% of the inhabitants' in Rutile. Regarding the impacts of water pollution on mining communities, majority (68%) of them stated that water contamination induced by mining operations contributes to a lack of water for drinking and other domestic uses, 18% suggested that it contributes to waterborne diseases, 8% suggested that it leads to the extinction of aquatic organisms such as fish, amphibians, crabs, etc. while 6% stated lack of water for irrigation purposes. According to the participants, this was due to the drying up of water bodies serving as primary water sources for domestic and agricultural uses.

Deforestation

Illegal and unregulated ASM is some of the leading cause of deforestation in Sierra Leone. And the preparation of ASM mine sites requires the removal of plants and trees, which are typically not replanted after the mining ends contributing to deforestation. Moreover, the removal of trees, and with their roots, increases soil erosion and undermines slope stability, which could lead to landslides. Soil erosion caused by deforestation, has also caused the shrinking of swamps through siltation. These issues are particularly pressing as significant ASM activity has been reported to take place in Sierra Leone's national protected areas, such as the Gola Rainforest.

The study has shown that artisanal gold mining is carried out in inland valley swamps that are used for rotational subsistence agriculture (i.e. rice cultivation and as well as vegetable gardening). The uncontrolled digging and turning over of top soil that is rich in plant nutrients by miners caused destruction of land beyond economic and technical reclamation and thus makes land unfit or unfavourable for agricultural use. Since agricultural productivity is closely linked to environmental factors including soil quality and water availability, provisioning services such as food (security) can be threatened or compromised by mining-related factors such as loss of agricultural land; water pollution; water supply. This may result to change in the surface hydrology.

Impact on the Landscape
ASM operators typically require consent from land owners to access and use land for mining purposes. However, considerable illicit AM operations persist. In some cases, miners mine without license from the National Mineral Agency (NMA) but with acquiesce from traditional authorities and or legal or beneficial land owners. Although incorrect, surface rent payments may in some instances be used to address land access and use concerns. In both legal and illegal scenarios, rules for compensation of land access and use in unclear. A critical community issue is Government's issuance of exploration licenses on existing artisanal mining areas. The law clearly prohibits the overlapping of artisanal and small-scale mining license areas atop one another unless a clear permission from a holder is given. In fact, implementation of overlapping restrictions is less formal and artisanal mining is overlapping other license areas without permission. Throughout AM operations, land disputes revolving around access, use, remediation, and payments occur. Grievance resolution mechanisms are generally undefined in which case relatively ad hoc (impromptu) and locally-driven resolutions emerge which are most times ineffective.

Damage and destruction to forest environments lead to habitat loss, biodiversity loss, erosion, topsoil loss, and water pollution. Such negative externalities dilute the nutrient rich soil upon which farmers depend, and abandoned pits leave land unproductive for economic activities.

Impact on Health among ASM Operators
ASGM communities in Sierra Leone face significant health problems, resulting from the limited availability of basic health infrastructure, including proper sanitation and clean water, as well as protective equipment such as gloves, helmets and masks. Besides this, the housing conditions are typically bad in ASM areas, as most houses have only a plastic roof covered with grass. Pregnant women, lactating mothers and under-five year old are consistently listed as vulnerable groups. The following health conditions below are frequently affecting the ASM workers in the mining areas such as: Malaria, Diarrhoea and vomiting, Intestinal worms among children, Skin infections, Sexually Transmitted Diseases, Acute Respiratory Infection, including acute pneumonia, Gastric issues.

Moreover, among alluvial AGM miners who spend extended amounts of time in the water, cold, fever, coughing, skin rashes and skin aches are frequent symptoms; but dysentery and pneumonia occur to a lesser extent. Health issues arise from the contamination of water sources and the degradation of lands by mining pits which are routinely left behind after the mining activities end. And the neglected mining pits serve as a breeding ground for mosquitoes in rural areas of Sierra Leone. The mosquitoes spread malaria, especially among the people living, working or playing close to the open pits, streams and rivers. The other 'minor' health complaints that miners frequently deal with include back pain and muscle aches resulting from their demanding physical work.

Socio-Economic Issues related to ASM Sector in Sierra Leone

Role of Women

Women have a special role in Sierra Leone's ASM sector. The sector draws women because it requires virtually no formal education or skills, and little or no capital. Women perform a range of tasks in the sector, including crushing, washing, panning, sieving, and sorting. Women are also active in the provision of goods (e.g., food and drink, artisanal equipment, and cell phones) and services (e.g., transporting dirt and water, cleaning, and doing laundry) in mining areas. Women are also assuming leadership roles in mining cooperatives and women's mining advocacy networks, and there are examples of women serving as negotiators, mine managers, financiers, and traders. This is an important attribute for women as traditional caregivers for their families. The majority of women involved in ASM are single mothers, whose husbands/man have either passed away or have abandoned them. They carry most of the responsibilities in their household, and many of them are involved in agricultural activities as well as mining. In more productive gold mines, women make up to 15% of the workforce, focusing on the final concentration of the ore by panning. However, when recognizing that the universal gold panning, present in countless rivers and streams, is almost exclusively carried out by women, it can be estimated that women make almost half (47%) of the entire ASM population in Sierra Leone.

Most women in Sierra Leone's ASM sector work on an individual basis, panning in the river, and sometimes in groups where they wash and pan ore. Women face gender-specific challenges in the sector. They face more difficulty in joining mining groups which are dominated and ruled by men, unless their husband, a relative or a close friend is part of the group and invites her. They cannot access hard rock mining sites as they are often not allowed to go up in the hills as a result of superstitious beliefs and security concerns. In addition, women face difficulty in accessing land due to historical gender norms and due to their difficulty in accessing finance. This is related to women's market access, since it is often the gold buyers that invest in ASGM operations. However, given that women are often excluded from mining groups, it is less viable for gold buyers to invest in women's operations as their production is lower. Consequently, women rarely have fixed buyers, and sell to whoever wants to buy, often at lower prices. Finally, women face difficulties in improving their positions in the supply chain (e.g. becoming a gang leader or gold trader) because of prevailing gender norms and limited market knowledge, and low levels of education (e.g. most of them don't know how to handle a simple calculator to determine gold prices). Despite these challenges, many women still chose to pursue a livelihood in

ASM, because they believe that it is an activity that is economically more viable than other options and is directly available. While some women want to stay in the sector on the long term, combining it with agriculture and other activities, most of them pursue this livelihood with the aim of eventually raising enough capital to pursue other activities such as starting a small business.

Child Labour

With regards to the role of child labour in the ASM sector, Sierra Leone is a Party to the 'UN Convention on the Rights of the Child'. In Sierra Leone, children play an integral role in contributing to the survival of the household, both economically and in terms of ensuring food security. Indeed, 51.3% of children aged 5-14 years are working, 67% attend school and 43% combine work and school (Bureau of National Labour Affairs, 2016). However, they seem to have a limited role in the domestic artisanal mining sector. In the majority of mine sites, children, if present, were mainly selling foodstuffs to artisanal miners and accompanying their mothers while they were working. For instance, in Dalakuru, children go to school during the day but after school they join their mothers who are panning along the river and play with each other. In only a handful of mine sites were a few children seen to be engaged in ASGM activity. In those sites where children were observed to be engaged in ASM activity, they were mostly involved in helping their parents by performing tasks such as carrying water, washing ore and panning concentrate. For example, in Masumbiri, two children between the ages of 6-10 years were observed filling a pan with gravel together on the surface of a mine site. When asked why they were doing this, the children shared that they do this out of school hours to make some cash to be able to pay for their school's lunches, and to earn additional cash for helping their parents to pay their school fees. As opposed to the situation in other countries in the region, no children were observed in hard rock sites or deep mining pits, and no children were observed to be involved in treating mercury. Still, children's presence and in some cases involvement in alluvial AM sites exposes them to several health threats.

Conflicts with Local Farmers and Other Stakeholders

The ASM sector is often cited as a factor that sparks conflicts. In Sierra Leone, less tension arises (due to the farmer-miner structure of the two operations observed), it was obvious that there was fierce competition between artisanal miners and smallholder farmers for swamp lands, which contain fertile soil suitable for farming and also for mineral exploitation. Many stakeholders hold the view that swamp lands should be ring fenced for rice and vegetable cultivation. So far, policies and legislation have failed to address these emerging land use issues.

Marketing challenges as they have limited means to transport their produce to suburban areas where demand and prices are higher. The sector also has negative impacts on agriculture. Since many miners do not rehabilitate the land after mining activities have ended, farmers cannot use this land for farming anymore, and in some cases, farmers have taken it upon themselves to recover the land.

Moreover, surface gold deposits are declining and artisanal miners now have to dig deeper to extract ore from rich gold deposits, which decreases the earnings they earn relative to the efforts they put into extraction and processing activities. On top of this, while most community leaders and Paramount Chiefs appreciate the sector's contribution to local job creation, there is a sense of frustration that the sector, since it is largely informal and controlled by foreign buyers, does not realize its full development potential in their communities.

Conflict with Criminal Gangs in the Mining Area

AM operation in Sierra Leone is speedily becoming a common ground for criminals, fugitives, the less educated and unemployed individuals within the country and its environ. The minerals sought for usually attract people from all works of life in search for a quick fix to get rich. This usually leads to people sorting and arranging themselves to form gangs and alliances. These alliances are usually motivated by religious, political, and sociological means.

As we know, the mining environment attract people from a wide range of discipline, values and upbringing and is never void of prostitution, drugs and lawlessness. This lead to constant internal strife with local artisanal miners and sometimes with the law apparatus like the police and the local authority. This conflicts usually result to abusive languages, fighting, stabbing, murder, kidnaping, rape, and other vices.

Impact of Criminal Gangs or Terrorist Groups ASM Sector

The criminal character of many activities within ASM also represents another huge impediment. Illegal ASM is often tied to powerful individuals with vested interests. Illegal mining is the easiest and most profitable way to launder money. In addition, the exploitation of natural resources is a lucrative source of financing for transnational criminal organizations, terrorist organizations, and insurgent groups. The trade and export of ASM production is an effective vehicle for money laundering, transfer pricing and tax evasion. The minerals are used to hide the origin of the dirty funds or to transfer large sums of money outside the formal banking system.

ASM formalization necessitates engaging and collaborating with law enforcement or diplomats to address organized crime and vested political interests. Most fraud and the root causes of smuggling are shared with officials to speed up action to address criminality. This helps to address criminality deeply embedded in economies, making them less attractive environments for outside transnational criminal organizations.

Domestic criminal groups are for the most part composed of Sierra Leonean nationals who cooperate with foreign nationals on occasion. This type of criminal gang is mostly involved in the trafficking of drugs, arms, timber and illegal diamonds. Citizens and organized criminal groups are involved in illicit smuggling activities in Sierra Leone from abroad, currently; mafia-style criminal groups in the form of organized gangs with known names, colours and symbols are operating in Sierra Leone.

Mining an alluvial deposit at the Stone Gold Mining site central Ghana.

A 3-step sluice used at mining site, North of Osino in central Ghana.

ASM SECTOR OF THE GAMBIA

By Lamin Kanteh, Senior Geologist, Geological Department of Gambia

Geographical Context of The Gambia

Demography of the Gambia

The Gambia is a small West African country, bounded by Senegal, with a narrow Atlantic coastline. Its known for its diverse ecosystems around the Central River Gambia.

Abundant wildlife in its Kiang West National Park and Bao Bolong Wetland Reserve includes monkeys, leopard, hippos, hyenas, and rare birds. The capital is Banjul with a population of 2.4 million people.

Economy of The Gambia

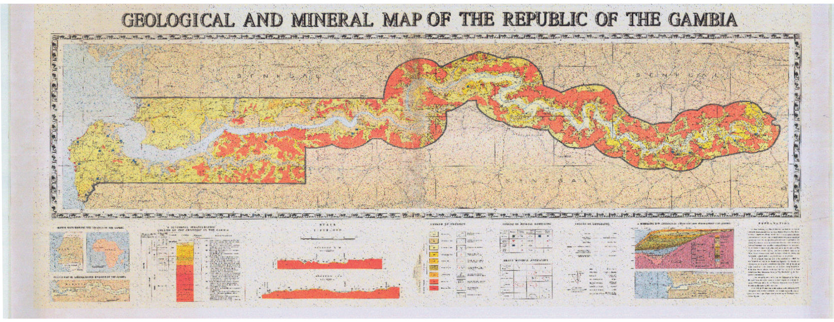
GDP of The Gambia is expected to reach 2.10 USD billion by the end of 2022 according to trading economic. ASM sector contributed immensely in the Gambia economy by creating employment opportunities for Gambians and non-Gambians.

Production of construction materials, such as sand and gravel, this materials propel high demand on cement, rods, paints, tiles which inject high tax to economy.

Geological Context of The Gambia

Geological Map of The Gambia

FIGURE 45 | GEOLOGICAL MAP OF THE GAMBIA



Source: Geological Department, Gambia

Brief Description of National Geology

The Gambia is located at the centre of Mauritania-Senegal-Gambia-Guinea (Bissau) and Guinea (Conakry) basin In which mainly Meso-Cenozoic strata have been deposited. In The Gambia only the Cenozoic strata are exposed.
The communication of The Gambia convenient, the two nearly west-east highways parallel to The River Gambia run from west to east of the country and the river is very important for transport.

There are short south-north roads passing through major towns such as Farafenni connecting ferries along the river.

The Gambia belongs to tropical grassland and has no high mountains throughout. The elevation differences between the east and west is small, with east being slightly higher (maximum elevation being 60m). The River Gambia begin to become wider from Jappeni reaching 12 km in width at segment from Lamin Bolong to Buniadu Bolong but narrowing 4 km between Banjul and Barra at the river mouth. The sea water intrudes to the Bird islands along the river with the actual intrusion degree changing with difference season of each year. The river channels in the upper reaches is relatively deeply dissected and that in the lower reaches exhibit the character of estuary in Jappeni to Bansang in the middle segment, there are many topographically low transitional zones 2-4 km wide and 5-10 km long forming river island. On the two sides of the river from the seaside to the bird island in a swamp area about 5km wide where dense mangroves are present. The mangroves become sparse and later gradually disappear in the eastward. Between Kuntaur and Bansang there some high lands 5-10m in height on the two river banks, with occasional mounds or cliffs 5-20m height in eastward from Bansang, there lots of cliffs that are about 20-40m high on the two banks. Between the cliffs and highlands are some swamps which are 5x2 km in size topographically low and full of cover grown grass and shrubs, representing the old streams channels.

ASM in The Gambia

Substances Exploited by ASM Operators in The Gambia

The Gambia is underexplored therefore it is yet to discover precious minerals, such as diamond, platinum, copper etc.

The mining sector, thought to be in its early development stages, is based on industrials minerals, such as ilmenite, rutile, zircon, silica sand, kaolinitic and plastic clay, cockle shell, ironstone and other construction materials.

Legislative Framework for ASM Sector in The Gambia

The Mine and Quarries Act of 2005 is the legal document for administration of mineral resources of The Gambia. This Act defines minerals and lays out the procedures and requirements for the exploration, exploitation and exportation of these minerals. Mining

Degree of Organisation of ASM Sector in The Gambia
The constitution of The Gambia allowed free association and cooperation, which means that there are associations within The Gambia mining sector.

Role of the National Geological Survey to Support ASM Operators
The Geological Department is mandated by the Government to carry out geological survey and administer the Mine and Quarries Act. The Department initiates, promotes, implements and evaluates all geo-scientific programs pertaining to mineral exploration and development in the country.

Administering the Mine and Quarries Act involves processing and issuing permits and licenses for prospecting, mining and quarrying operations including that of the ASM sector. The regulatory functions of the Geological Department also includes monitoring and supervising mining and quarrying activities, which enable direct interaction with ASM sector.

Environmental and Health Issues related to ASM Sector

Impact on Waterways
The Gambia is not yet a mining country; however, the water runoff from quarry sites is worrying for the future of the country.

Deforestation
Destruction of natural habitats and losses of animal species.

Impact on Landscape
Destruction of arable land, soil erosion and sediment due to excavation.

Impact of Health among ASM Operators
The health risk is high in case of outbreak and communicable diseases.

Socio-Economic Issues related to ASM Sector

Role of Women
The Gambia is witnessing an increasing number of women undertaking, often risky, work in the ASM sector. The Geological Department helps women to register with the Association of Gambia Women in Mining.

Child Labour
The Gambia is not experiencing child labour in the national ASM sector.

Conflict with Local Farmers and Other Stakeholders

To obtain a quarrying license/permit in the Gambia, one is required to consult with the local community surrounding the ASM site and complete a consent land use form. This ensures minimal confrontation with local farmers and stakeholders.

Conflict with Criminal Gangs at the Mining Sites

The Gambia is not into gold and diamond mining; hence, The Gambia is not exposed to criminal gangs.

Impact of Criminal Gangs and Terrorist Groups in ASM Sector

The ASM sector in The Gambia is not subject to terrorist groups.

Sluicing operation at Stone Gold mining site. Ghana

Gold remaining after the mercury is evaporated. Tachwa mining site. Ghana

ASM SECTOR OF SOUTH AFRICA AND THE ROLE OF THE COUNCIL FOR GEOSCIENCE

By T. Mudau and S.P Gcasamba, Geoscientists, Council for Geoscience

In South Africa, ASM is defined as a "mining activity employing less than 50 people, and has an annual turnover of less than R10 million with fixed and moveable assets of less than R15 million. It is estimated that the ASM sector employs between 10,000 and 30,000 people (Mutemeri & Petersen, 2002; Hoadley & Limpitlaw, 2004; Buxton, 2013). These figures include both the legal and informal ASM sector. The Department of Mineral Resources has been the leading agent in the development of the ASM sector in South Africa in collaboration with other key role-players in the sector. ASM operations in South Africa are not restricted to specific mineral commodities. ASM operators are allowed to exploit any type of mineral as long as it is within the required provisions of the mining license. Minerals exploited by ASM operators range from precious minerals and metals to industrial minerals and construction materials.

According to the Department of Mineral Resources (2011), most ASM operations exploit industrial minerals, such as sand, slate, clay, sandstone, dolerites and granites. Prospective ASM operators must apply for and be granted a right under the Mineral and Petroleum Resources Development Act (MPRDA) before commencing any prospecting or mining activities. The ASM sector in South Africa became an item on the national agenda after the country had a change in Government in 1994 (Ledwaba, 2017). The ASM sector was developed to eradicate injustices of the previous Government by promoting social and economic growth for previously disadvantaged South Africans as part of the Reconstruction and Development Program (Mkubukeli & Tengeh 2015).

Legal and Regulatory Framework of the ASM sector

All mining activities in South Africa, including that of the ASM sector, are regulated and recognised under the Mineral and Petroleum Resources Development Act 28 of 2002 supported by:

- National Environmental Management Act 108 of 1997 (NEMA 108 of 1997);
- Mine Health and Safety Act 29 of 1996;
- National Environmental Management: Air Quality Act, 2004 (Act 39 of 2004);
- National Water Act 36 of 1998 (NWA 36 of 1998);
- Explosives Act, 2003; and
- National Business Amendment Act, 2003.

Section 3 of the MPRDA 28 of 2002 provides for the State to be custodian of all mineral resources for the benefit of South Africans. The State therefore, through the Department of Mineral Resources, may grant mineral rights as contemplated in the

Act. Section 27 (1) (a)(b) of the MPRDA 2002 makes provisions for ASM operators to mine under a mining permit on an extent not exceeding 1.5 hectares with no depth restrictions for 2 years. There is no depth restriction for ASM operations; however, granting of the mining permit is subject to the applicant meeting the requirements of the act. ASM operators are required to meet requirements with respect to an EMP and consultation with the landowner/occupier and affected parties as contemplated in section 27 (5)(a)(b). Applications for a mineral right can be done at the office of the Regional Manager in whose region the land is situated as contemplated in section 27 (2)(a). It can take more than six months to obtain a mining permit.

Challenges of the ASM Sector in South Africa

The ASM sector in South Africa, similar to other developing countries, is faced with many challenges owing to the complexities in mineral regulation of the country. The challenges of ASM operations range from access to capital, access to markets, lack of technical and business skills, access to appropriate technologies and skills, and health and safety issues. Often these challenges are drivers of illegal ASM operations.

Access to Financial Assistance

Mining, no matter large or small, is a risky business given the great level of uncertainty. As a result of this, most financial institutions do not offer any financial assistance to ASM operators. ASM operations have always depended on Government and related organisations to provide channels for funding. There are very few institutions that offer financial support to miners, but these include a few development agencies. The Eastern Cape Development Corporation (ECDC) assists with the development of business plans and feasibility studies required to obtain funding, and the Small Enterprise Finance Agency (SEFA) provides loans to small and medium-sized businesses, from R50 000 to the maximum R5 million. However, providing the collateral to secure these loans prevents many miners from accessing them.

Legislative Requirements

According to MPRDA and NEMA, ASM operators are required to meet requirements with respect to EMP authorisation, consultation with the landowner/occupier and affected parties, financial provision for land rehabilitation, and proof of technical ability. All these requirements carry substantial costs, which often require the service of professional consultants. The application process for rights is also tedious and time-consuming – it can take more than six months to obtain a mining permit. In addition, applications are completed online, disadvantaging those in rural areas without access to computers or the Internet. These barriers have forced the majority of miners to operate outside the legal framework.

Availability of Markets

Access to markets is a major challenge for most ASM operations; this is because most of these operations are located in remote areas. The majority of ASM operators lack marketing skills and knowledge to identify and compete in major markets. Most operations rely on word of mouth advertising and referrals. The majority of the operations depend largely on surrounding communities as their principal markets. The provisions of the mining permit also present barriers even to those that managed to acquire them. The size, extent and total duration of mining permits limit growth in the sub-sector. Most ASM operations find themselves in a situation where they cannot secure funding because the payback period does not make sense, whereby they fail to secure long-term market contracts because they can only operate for a few years, and they fail to invest back into their businesses because there are few growth prospects.

Lack of Technology and Skills

Most ASM activities rely on manual labour and basic tools for mining and processing. The majority of operations depend on manual labour and the use of basic tools such as pick and shovel (Ledwaba, 2017). Most miners do not have a formal education; the lack of skills in the sector is still a major concern. Low-level skills have resulted in poor practices, inefficient mining techniques, poor working conditions, and lack of compliance with and understanding of Government regulation, poor adherence to mine health and safety requirements, and damaging environmental impact.

Role of the Council for Geoscience

The main objectives underlying the establishment of the Council for Geoscience (CGS) are to develop and publish world-class geoscience knowledge products and to render geoscience-related services to the South African public and industry. The mandate of the CGS, as defined in the Geoscience Act 100 of 1993 includes:

- The systematic reconnaissance and documentation of the geology of the earth's surface and continental crust, including all offshore areas within the territorial boundaries of South Africa;
- The compilation of all geoscience data and information, particularly the geological, geophysical, geochemical and engineering-geological data in the form of maps and documents, which are placed in the public domain;
- The collection and curation of all geoscience data and knowledge on South Africa in the National Geoscience Repository; and
- The rendering of geoscience knowledge services and advice to the State to enable informed and scientifically based decisions on the use of the earth's surface and the earth's resources within the territory of South Africa.

The main role of the CGS in ASM operations is the promotion and provision of access to information on minerals deposits amenable to small-scale mining through provision of technical expertise; geoscience information produced; and through conducting geological investigations for mineral occurrence that can be possible for development by small-scale mining initiatives. Technical support/services to ASM operations include: mineral potential investigations; review of available historical data (geological and borehole data); geological and mineral maps; geological reports; mineral resources estimation; compilation of documents for license/rights application; and analytical work.

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