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This practical guide is intended for actors in the artisanal mining sector in Eastern and Northern Africa 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 15 English-speaking countries (Egypt, Eritrea, Ethiopia, Kenya, Libya, Malawi, Mauritius, Rwanda, Seychelles, Somalia, Sudan, South Sudan, Tanzania, Uganda and Zambia).*

*Produced by governmental entities from each of these countries and experts in the field, this guide covers the following points:*

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

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Artisanal and Small-ScaleMining Handbook for Central, North and Eastern Africa

PanAfGeo

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

# Artisanal and Small-Scale Mining Handbook for Central, North and Eastern Africa

## *A practical guide*

Egypt | Eritrea | Ethiopia | Kenya | Libya | Malawi | Mauritius | Rwanda

Seychelles | Somalia | Sudan | South Sudan | Tanzania | Uganda | Zambia

# Artisanal and Small-Scale Mining Handbook for Central, North and Eastern Africa

*A practical guide*

The Pan-African support from European Geological Surveys through EuroGeoSurveys (EGS) to African Geological Surveys through Organization of African Geological Surveys (OAGS) 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 program, led by geoscience experts from Africa and Europe, includes the acquisition of new knowledge to improve the technical level of the trained staff in OAGS member organisation.

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 English Speaking Eastern and Northern African Regions” is the result of a training session which took place in Dar es Salaam, Tanzania from 13 to 16 November 2023, as part of PanAfGeo-2 Work Package C (WP-C) on ASM with participants from 16 countries from the Eastern and Northern African Regions.

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|---|---|
| Editors: | Dr John Tychsen, ASSM Consult ApS (jtassm@gmail.com) |
| Text Editor: | Ms. Julie Sophie Hübertz, Freelance/Depict & Deploy |
| Layout and DTP: | Graphic Studio, GEUS |
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10 Oester Voldgade, DK-1350 Copenhagen, Denmark
Mail: geus@geus.dk
Web: www.geus.dk
Phone: +45 38 14 20 00

# CONTENT

**ABBREVIATIONS** ... **14**
**FOREWORDS** ... **16**
EU Delegation to Tanzania ... 16
African Minerals and Geosciences Centre ... 18
**ACKNOWLEDGMENTS** ... **20**
**INTRODUCTION** ... **22**
**ASM SECTOR OF TANZANIA** ... **25**
Geographical Context of Tanzania ... 25
Demography of Tanzania ... 25
Economy of Tanzania ... 25
Geological Context of Tanzania ... 25
Simplified Geological Map of Tanzania ... 25
Brief Description of the National Geology ... 25
ASM in Tanzania ... 28
What substances are exploited by ASM operators in Tanzania? ... 28
The Legislative Framework for the ASM Sector in Tanzania ... 28
Degree of Organisation of ASM Sector ... 30
Role of the National Geological Survey to Support the ASM Operators ... 31
Environmental and Health Issues Related to the ASM Sector in Tanzania ... 32
Impact on Waterways ... 32
Impact on Deforestation ... 32
Impact on the Landscape ... 32
Impact on Health Among ASM Operators ... 33
Socio-Economic Issues Related to the ASM Sector in Tanzania ... 33
Role of Women ... 33
Role of Child Labour ... 33
Conflicts with Local Farmers and Other Stakeholders ... 33
Conflicts with Criminal Gangs in the Mining Area ... 34
**ASM SECTOR OF KENYA** ... **37**
Geography, Demography and Economy of Kenya ... 37
Geology of Kenya ... 38
Archaean (Nyanzian and Kavirondian) ... 38
Proterozoic (Mozambique Belt and Bukoban) ... 38
Palaeozoic/Mesozoic Sediments ... 39
Tertiary/Quaternary Volcanics and Sediments ... 39
Pleistocene to Recent soils, Alluvial Beach Sands ... 40
ASM in Kenya ... 42
Introduction and Commodities ... 42
Legislative Framework for the ASM Sector ... 42
Degree of Organisation of the ASM Sector ... 43
Role of the National Geological Survey to Support the ASM Operators ... 44

Challenges Faced by ASM Operators ....................45
Environmental and Health Issues Related to the ASM Sector in Kenya....................47
Impact on Water Ways ....................47
Impact on Deforestation....................47
Impact on the Landscape....................48
Impact on Health among ASM Operators....................48
Socio-Economic Issues Related to the ASM Sector in Kenya....................49
Role of Women....................49
Role of Child Labour ....................49
Conflicts with Local Farmers and Other Stakeholders....................49
Conflicts with Criminal Gangs in the Mining Area ....................50
**SOCIAL, HEALTH AND SAFETY ISSUES RELATED TO THE ASM SECTOR ....................53**
Overview of the Social, Health and Safety Issues ....................54
Social Issues....................54
Health Issues ....................55
Safety Issues....................56
Conclusion ....................59
**HOW TO ORGANISE AND DEVELOP AN ASM MINING SITE ....................61**
Introduction....................61
Background and Context ....................61
Policy Analysis ....................63
ASM Dimension....................63
Governmental Assistance to ASM....................63
ASM Products Markets....................64
Mineral Certification Processes/Frameworks....................64
ASM Value Addition ....................65
ASM Technical and Financial Issues....................65
ASM Financing....................66
Environmental Issues for ASM ....................66
ASM Governance and Transparency ....................67
Policy Implications and Recommendations....................68
**FROM RESOURCE CURSE TO CONFLICT**
**MINERALS – LESSONS FROM THE DRC....................73**
Eastern DRC's (Artisanal) Mining Sector....................73
"Conflict Minerals" in Eastern DRC....................74
Historical Context ....................75
Armed Interference in Mining....................78
Insecurity Beyond Conflict Minerals....................80
Conclusion ....................80
**MINERAL PROCESSING IN ASM ....................83**
Introduction....................83
Mineral Processing and Beneficiation....................83
Gold Concentrators ....................85

Gold Processing ....85
Mineral Processing Challenges and Opportunities for ASM ....89
**ASM SECTOR OF ETHIOPIA ....93**
Geographical Context of Ethiopia ....93
Demography of Ethiopia ....93
Economy of Ethiopia....93
Geological context of Ethiopia....95
Simplified Geological Map of Ethiopia....95
Brief Description of National Geology ....96
ASM in Ethiopia ....98
Substances Exploited by ASM Operators in Ethiopia ....98
Legislative Framework for the ASM Sector in Ethiopia ....100
Degree of Organisation of the ASM Sector ....101
Role of the National Geological Survey to Support the ASM Operators ....101
Environmental and Health Issues Related to the ASM Sector in Ethiopia ....101
Impact on Water Ways ....102
Impact on Deforestation ....102
Impact on the Landscape....102
Impact on Health among ASM Operators....102
Socio-Economic Issues Related to ASM Sector in Ethiopia ....102
Role of Women....102
Role of Child Labour ....103
Conflicts with Local Farmers and Other Stakeholders....103
Conflicts with Criminal Gangs in the Mining Area ....103
Conclusion and Recommendations ....103
**ASM SECTOR OF SUDAN ....107**
Summary of Geology....107
Stratigraphy and Tectonics ....110
Economic Mineral Deposits ....111
Artisanal Mining in Sudan ....112
Governmental and Legal Framework of Mining ....114
Governmental Bodies and Sub-bodies ....114
The Central Bank of Sudan ....115
Local Authorities ....115
Legal Frameworks Mining....116
Licensees' and Contractors' Statutory Duties....117
Women and Children Involved in Mining....118
The Environmental Impacts of Artisanal (Traditional) Gold Mining....119
**ASM SECTOR OF EGYPT ....123**
Geographical Context of Egypt....123
Demography of Egypt....123
Economy of Egypt ....124
Geological Context of Egypt....124

Simplified Geological Map of Egypt ....124
Brief Description of National Geology ....125
ASM in Egypt ....126
Environmental and Health Issues Related to the ASM Sector in Egypt ....127
Socio-Economic Issues Related to ASM Sector in Egypt ....128
Role of Women ....128
Role of Child Labour ....128
Conflicts with Local Farmers and Other Stakeholders ....129
Conflicts with Criminal Gangs in the Mining Area ....129
**ASM SECTOR OF SOUTH SUDAN ....131**
Brief Description of National Geology ....132
Basement Complex ....132
Igneous Intrusions ....132
Tertiary Volcanics ....133
Umm Ruwaba Formation ....133
Structure ....133
ASM in South Sudan ....133
Substances Exploited by ASM Operators ....133
Legislative Framework ....134
Degree of Organisation of ASM Sector ....135
Role of Geological Survey of South Sudan to Support the ASM Operators ....135
Environmental and Health Issues Related to ASM in South Sudan ....135
Impact on Water Ways ....135
Impact on Deforestation ....135
Impact on Landscape ....136
Impact on Health Among ASM Operators ....136
Socioeconomic Issues Related to ASM in South Sudan ....137
Role of Women ....137
Role of child Labour ....138
Conflicts with Local Farmers and Other Stakeholders ....138
Conflicts with Criminal Gangs in the Mining Area ....139
Impact of Criminal Gangs or Terrorist Groups on the ASM Sector ....139
**ASM SECTOR OF SOMALILAND ....141**
Geographical Context of Somaliland ....141
Demography of Somaliland ....141
Economy of Somaliland ....141
Geological Contexts of Somaliland ....143
Geological Map of Somaliland ....143
Brief Description of National Geology ....143
ASM in Somaliland ....144
Minerals Exploited by ASM Operators in Somaliland ....144
Legislative Framework for the ASM Sector in Somaliland ....145
Degree of Organisation of the ASM Sector ....145

Role of the National Geological Survey to Support the ASM Operators ....145
Environmental and Health Issues Related to the ASM Sector in Somaliland ....146
Impact on Waterways ....146
Impact on Deforestation ....146
Impact on the Landscape ....146
Impact on Health Among ASM Operators ....147
Socio-Economic Issues Related to ASM Sector in Somaliland ....147
Role of Women ....147
Role of Child Labour ....148
Conflicts with Local Farmers and Other Stakeholders ....148
**FORMALISATION OF EFFORTS OF THE ASM SECTOR IN DRC ....151**
Historical Context of ASM in DRC ....151
Regulating the ASM Sector in the DRC ....153
Government Institutions in the DRC Mining Sector ....154
Obstacles to Formalisation ....154
Artisanal Mining Card ....154
Land Rights and Artisanal Mining Zones ....155
Cooperatives ....155
Taxation155
Specific Challenges in the Gold Sector ....156
(Inter)national Initiatives to Tackle Informality of the ASM Sector ....157
ICGLR - Regional Certification Mechanism ....157
(Inter)national Due Diligence Requirements ....158
Mineral Traceability ....159
Challenges and Impact of Responsible Sourcing Initiatives ....159
Conclusion ....160
**APPLICATIONS OF REMOTE SENSING, GIS, AND GEOPHYSICS FOR GROUNDWATER MAPPING ....163**
Groundwater and Mapping ....163
Linking Remote Sensing to Groundwater ....163
Remote Sensing Data Sources ....164
Methods and Mapping Procedures ....166
Variables in Groundwater Mapping ....166
Lithology (Geology) ....167
Topographic Wetness Index ....167
Lineament Density ....168
Groundwater Recharge ....168
Land-Use and Land-Cover ....169
Drainage Density ....169
Soil 169
Multi-Criteria Decision Analysis and Analytical Hierarchy Process ....169
GIS Overlay Analysis for Groundwater Mapping ....170
Field Validation and Ground Truthing ....171

Geophysics for Imaging the Unseen....173
Summarising Remarks....173
**INVOLVEMENT OF WOMEN AND**
**CHILDREN IN THE ASM SECTOR IN EASTERN AND NOTHERN AFRICA REGION....177**
Support for Women in ASM....178
Child Labour in ASM....180
Addressing Child Labour Issues....181
**ASM SECTOR OF ZAMBIA....183**
The Role and Work of the Ministry of Mines and Minerals
Development....184
Legislative Framework....184
Geology 184
Challenges of ASM in Zambia....187
Degradation of the Environment....187
Lack of Formalisation....187
Development and Acceleration of Development Minerals....188
**ASM SECTOR OF MALAWI....193**
Geographical Context of Malawi....193
Demography of Malawi....193
Economy of Malawi....193
Brief Regional Geology....193
Brief Local Geological Context of Malawi....195
ASM in Malawi....196
Substances Exploited by ASM Operators in Malawi....196
Legislative Framework for the ASM sector in Malawi....197
Degree of Organisation of ASM Sector....198
Role of the Malawi Geological Survey to Support the ASM Operators....199
Environmental and Health Issues Related to the ASM Sector in Malawi....199
Impact on Waterways....199
Impact on the Landscape....202
Impact on Health Among ASM Operators....204
Socio-Economic Issues Related to the ASM Sector in Malawi....204
Role of Women....204
Role of Child Labour....205
Conflicts with Local Farmers and Other Stakeholders....206
Conflicts with Criminal Gangs in the Mining Area....206
**MINERAL EXTRACTION SECTOR OF**
**THE SEYCHELLES....209**
Geographical context of the Seychelles....209
Demography of the Seychelles....209
Economy of the Seychelles....210
Geological context of the Seychelles....211
Simplified Geological Map of the Seychelles....211

Brief Description of National Geology....212
Mineral Extraction in the Seychelles....213
What Commodities are Exploited in the Seychelles....213
Legislative Framework for the Mineral Extraction Sector in the Seychelles....214
Role of the PetroSeychelles in the Mineral Extraction Sector....214
Environmental Issues Related to the Mineral Extraction Sector in the Seychelles....215
Impact on Waterways....215
Impact on Deforestation....216
Impact on the Landscape....216
Socio-Economic Issues Related to Mineral Extraction in the Seychelles....218
Role of Women....218
Conflicts with Local Farmers and Other Stakeholders....218
**MINERAL RESOURCE EXTRACTION OF MAURITIUS....221**
Geographical and Socio-Economic Context of Mauritius....221
Geographical Context of Mauritius....221
Demography of Mauritius....223
Economy of Mauritius....224
Contribution of the Mining Sector in Mauritius....224
Geological Context of Mauritius....225
Mineral Extraction in Mauritius....227
Coral Sand Extraction from the Lagoon....227
Inland Sand Mining....228
Mining Basalt Rocks....229
Policy and Legislative Framework for Mineral extraction in Mauritius....229
Technical Advisory Committee on Mineral Resource Sites....230
Policies of the Outline Planning Scheme....231
Environment Protection Act....233
Quarry Operations....234
Environmental Impacts Related to the Rock Quarry Activities in Mauritius....236
Land Degradation and Disruption of Landform....236
Emission of Dust and Particles....237
Noise and Vibration....237
Traffic Generation....237
Contamination of Water Resources....237
Solid Wastes....238
Destruction of Habitats....238
Challenges....238
Illegal Quarry....238
Competing Land Uses in Potential Mineral Resource Sites....240
Conclusion....240
**ASM SECTOR OF UGANDA.... 243**
Geographical Context of Uganda....243

Demography of Uganda....243
Economy of Uganda ....243
Geological Context of Uganda....245
Simplified Geological Map of Uganda ....245
Brief Description of National Geology....245
ASM in Uganda....246
Substances Exploited by ASM Operators in Uganda....246
Legislative Framework for the ASM Sector in Uganda ....247
Degree of Organisation of ASM Sector ....247
Role of the Geological Survey and Mines Department of Uganda to Support the ASM Operators .. 247
Environmental and Health Issues Related to the ASM Sector in Uganda....249
Impact on Waterways ....249
Impact on Deforestation....249
Impact on the Landscape....249
Impact on Health Among ASM Operators ....250
Socio-Economic Issues Related to ASM Sector in Uganda....250
Role of Women....250
Role of Child Labour ....251
Conflicts with Local Farmers and Other Stakeholders....252
Conflicts with Criminal Gangs in the Mining Area ....252
**ASM SECTOR OF RWANDA....255**
Geographical Context of Rwanda ....255
Demography of Rwanda ....255
Economy of Rwanda....255
Geological Context of Rwanda ....256
Simplified Geological Map of Rwanda....256
Brief Description of National Geology....256
ASM in Rwanda ....258
Substances Exploited by ASM Operators in Rwanda ....258
Legislative Framework for the ASM Sector in Rwanda....258
Degree of Organisation of ASM Sector ....258
Role of the Rwanda Mines Petroleum and Gas Board to Support the ASM Operators....259
Environmental and Health Issues Related to the ASM Sector in Rwanda ....259
Impact on Waterways ....259
Impact on Deforestation....259
Impact on the Landscape....260
Impact on Health Among ASM Operators ....260
Socio-Economic Issues Related to ASM Sector in Rwanda ....261
Role of Women....261
Role of Child Labour ....263
Conflicts with Local Farmers and Other Stakeholders....263

**MINING SECTOR OF LIBYA........265**
Introduction........265
Geology of Libya........265
Geological Exploration by the Industrial Research Centre........266
Regional Mapping Program........267
Prospecting and Exploration Work........267
Detailed Geological Studies........268
Primary Raw Materials and Metallic Minerals........268
Metallic Raw Materials in Libya........268
Non-Metallic Raw Materials in Libya........269
Results and Conclusion........274
**ASM SECTOR OF ERITREA........277**
Demography of Eritrea........278
Economy of Eritrea........278
Geological Context of Eritrea........278
Simplified Geological Map of Eritrea........278
Brief Description of National Geology........279
ASM in Eritrea........279
Substances Exploited by ASM Operators in Eritrea........279
Legislative Framework for the ASM Sector in Eritrea........281
Role of the National Geological Survey to Support the ASM Operators........283
Environmental and Health Issues Related to the ASM Sector in Eritrea........283
Impact on Waterways........283
Impact on Deforestation........283
Impact on Health Among ASM Operators........283
Socio-Economic Issues Related to ASM Sector in Eritrea........283
Role of Women........283
Role of Child Labour........283
Conflicts with Local Farmers and Other Stakeholders........284
Conflicts with Criminal Gangs in the Mining Area........284
**THE ROAD LESS MINED: CO-EXISTENCE OF ENVIRONMENTAL SUSTAINABILITY AND ASM IN EAST AFRICA........287**
Background........287
East Africa's ASM Context........287
Environmental and Health Issues Related to the ASM Sector in East Africa........291
Socioeconomic Issues Related to ASM Sector in East Africa........292
Conclusion........294
**BENEFITS OF USING GEOPHYSICAL EQUIPMENT IN NATIONAL GEOLOGICAL SURVEYS........297**
Background........297
Mineral Exploration........297
The Mineral Sector........297
Geophysical Exploration Methods........297
Geophysical Data Acquisition........298

Magnetic Mineral Exploration Methods....298
Gravity Mineral Exploration Methods....299
Radiometric Mineral Exploration Methods....302
Electromagnetic Mineral Exploration Methods....303
Benefits of Using Geophysical Equipment at National Geological Surveys....305
Case Studies from Malawi, Australia, and India....306
Conclusion....309
**LARGE- AND SMALL-SCALE MINING – LESSONS LEARNED....311**
Introduction....311
Scale 312
People, Decision-Making and Time....313
ASGM in the Akobo area, Ethiopia....315
LSM at Segele Mine, Akobo area, Ethiopia....319
Lessons 322
**SYNOPSIS FOR GROUP WORK....325**
Introduction....325
Group A....326
Challenges in Establishing and Developing an ASM Operation....326
Group B 328
Challenges in Formalising ASM Operations....329
Conflict minerals and Challenges with Armed Actors Profiting from ASM Supply Chains....330
Group C 331
Geophysical Methods Used by National Geological Survey and their Benefits....331
Challenges for a Geological Survey Involved in National Groundwater Mapping....332
Group D 333
Environmental Challenges Related to ASM....333
Opportunities and Challenges for ASM and LSM to Co-exist....334
**REFERENCES....337**

# ABBREVIATIONS

| | |
|---|---|
| AHP | Analytical Hierarchy Process |
| AMDC | Africa Minerals Development Centre |
| AMGC | African Minerals and Geosciences Centre |
| AMV | Africa Mining Vision |
| ASGM | Artisanal and Small-Scale Gold Mining |
| ASM | Artisanal and Small-Scale Mining |
| BRGM | French Geological Survey |
| CAHRA | Conflict-Affected and High-Risk Areas |
| CI | Consistency Index |
| CNDP | National Congress for the Defence of the People |
| CSR | Corporate Social Responsibility |
| DEM | Digital Elevation Models |
| DG INTPA | Directorate-General for International Partnerships |
| DG-DEVCO | Directorate-General for International Cooperation and Development |
| DRC | Democratic Republic of the Congo |
| EEZ | Exclusive Economic Zone |
| EGS | EuroGeoSurveys |
| EIA | Environmental Impact Assessment |
| EIS | Environmental Impact Statement |
| EM | Electromagnetic |
| EMP | Environmental Management Plan |
| EMRA | Egyptian Mineral Resource Authority |
| ESA | European Space Agency |
| ESRI | Environmental Systems Research Institute |
| 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 | Geographic Information System |
| GNI | Gross National Income |
| GRAS | Geological Research Authority of Sudan |
| GSD | Geological Survey Department |
| GST | Geological Survey of Tanzania |
| IPIS | International Peace Information Service |
| IRC | Industrial Research Centre |
| ITA | International Tin Association |
| ITD | Intermediate Technology Development |
| ITSCI | International Tin Association’s Tin Supply Chain Initiative |
| KAB | Karagwe-Ankole Belt |
| LiDAR | Light Detection and Ranging |
| LSM | Large Scale Mining |
| MASMA | Malawi Artisanal and Small-scale Mining Association |
| MES | Mining Extension Services |

| | |
|---|---|
| MHILT | Ministry of Habitat, Infrastructure and Land Transport |
| MMMD | Ministry of Mines and Minerals Development |
| MSM | Medium-Scale Mining |
| NGOs | Non-Governmental Organisations |
| NST | National Strategies for Transformation |
| OAGS | Organization of African Geological Surveys |
| OAU | Organization of African Unity |
| OECD | Organisation for Economic Co-operation and Development |
| PPE | Personal Protective Equipment |
| RADAR | Radio Detection and Ranging |
| RCM | Regional Certification Mechanism |
| RI | Random Consistency Index |
| SCA | Specific Contributing Area |
| SMRC | Shalateen for Mineral Resources Company |
| TAC | Technical Advisory Committee |
| UN | United Nations |
| UNIDO | United Nations Industrial Development Organization |
| USD | United States Dollar |
| WP | Work Packages |
| WP-C | Work Package C |
| ZEA | Artisanal Exploitation Zones |

# FOREWORDS

## EU Delegation to Tanzania

*By Christine Grau, Ambassador, EU Delegation to the United Republic of Tanzania and to the East African Community*

The extraction of minerals from the earth has been undertaken for centuries, if not millennia. For Europe, the mining industry was one of the most critical industries, shaping its economies. More than a century ago, Europe accounted for about 40% of the global mining output.

Today, the mining industry and in particular critical minerals sector are gaining increased importance in the context of green and digital transitions globally. Both sectors can play a crucial role in transforming African economics, presenting many opportunities for socio economic development. But they are also associated with various environmental and social risks, which should be mitigated. Given the importance for employment and livelihood generation for the economy, countries are making efforts to support and regulate these activities.

Within the mining sector, ASM - usually a labour-intensive, less mechanised exploitation of mineral resources - provides an important contribution to the employment and livelihoods dimension of the economy, particular in the rural areas. It is estimated that in Tanzania around 1.5 million people are associated economically with ASM, of which about 25% are women. ASM contributed around TZS 271 billion in royalties, representing 40% of all royalties in the 2022/23 fiscal year. Globally, it is estimated that ASM contributes up to about 15-20% to the overall mining production.

The Government of Tanzania has made a commendable effort over the years to regulate the activities. Amongst others, it has developed microfinance services tailored to the artisanal and small-scale mining sector and efforts are ongoing to enhance linkages with financial institutions. The Government offers equipment for hire/purchase, training and skills enhancement and sharing available geological data to ASM. In each region, Minerals Markets have been established to fight smuggling. Tanzania is amongst the pilot Fairtrade countries within East Africa, to support sustainable development of ASM communities. And last but not least, the Government is promoting value addition of mineral products by reducing the royalty to 1% if the miner adds value, otherwise it remains at 5%. These are all important steps.

Nevertheless, challenges exist regarding environmental impacts and protection of human rights. The use of mercury for gold extraction is not banned in all countries and it continues to be applied in the ASM sector, posing challenges to the health and environment. The inhalation of mercury can cause neurological problems, and nearby communicates suffer from water and soil contamination.

The European Union (EU) takes great interest in promoting sustainable ASM techniques, which would preserve the environment, protect human rights, and safeguard the health and safety of those concerned, with a focus on preventing child and women labour exploitation, gender equality and community development. The promotion of safe and sustainable ASM is important to increase and safeguard employment and job creation in the mining sector.

In particular, the EU has established the European Partnership for Responsible Minerals with the objective to increase the proportion of responsibly produced minerals and to support socially responsible extraction of minerals that contributes to local development. The aim of this support is to enable more mines to comply with the standards required under the OECD Due Diligence Guidance.

In this regard, we are happy to support the PanAfGeo Project to strengthen ASM in its contribution to sustainable socio-economic development in the respective countries and in particular to increase knowledge of African Geological Surveys, so that they can better support, improve and control the conditions in local artisan communities. With the EU's contribution to the PanAfGeo Project's Phase1 and 2, the Project has supported the sustainable management of geological resources in Africa and strengthened the EU-African partnership in geosciences, through training of geoscientific staff from African Geological Surveys. The PanAfGeo Project also provides opportunities for dialogue and networking between all participants, trainees and trainers, Europeans and Africans, building relationships at individual, national and continental levels.

This resulting ASM Handbook for the Eastern and Northern African Region aims to increase the African-owned geological knowledge and skills for sustainable mineral exploitation, related infrastructures, and prevention and mitigation measures. We appreciate the work of each author in contributing to this collection of articles and trust that you, the reader, will find inspiration, assurance, and guidance from this wealth of shared knowledge. I wish you all a fruitful reading.

*Christine Grau*
*Ambassador*

## African Minerals and Geosciences Centre

*By Ibrahim Shaddad, Director General of the African Minerals and Geosciences Centre (AMGC)*

ASM refers to mining with minimal or no mechanisation often within the informal sector. ASM also constitutes a vital source of mineral resources and geological materials production in the World. It ranges from informal individual miners earning a subsistence livelihood to more formal and regulated small-scale entities producing minerals commercially. It is estimated that in Africa ASM provides a livelihood for 10-12 million men, women, and children with an additional 50-70 million people depending on the sector indirectly; however, growth in ASM numbers is expected to continue in line with the increase in the population and limitations in new job opportunities.

Nevertheless, ASM operations often lack legal status, environmental safeguards, health and safety measures, and economic security for miners. ASM miners labour under outdated and difficult working conditions and live in extreme poverty, often receiving less than the retail price of the valuables they extract. A lack of internal controls leads to disconnected and often illegal mines and prevents miners from acquiring the licenses required to operate within the law, the equipment necessary to increase their gains, and the assets needed to diversify their livelihoods. Over the years, this has caused damages to the environment, mining accidents and other issues affecting the communities, leading to a pressing need to enhance the quality of life for miners working in this sector.

Therefore, the African Minerals and Geosciences Centre (AMGC) has partnered on multiple occasions with the PanAfGeo Project to support training of geoscientific staff from African Geological Surveys aiming at improving and reinforcing the skills of African geoscientists. Under this exceptional Project, AMGC has hosted African and European experts and helped to train geoscientists from different English-speaking African Countries aiming at improving the governance and sustainable use of African mineral resources and related infrastructures. During the training sessions geoscientists from National Geological Surveys have been introduced to key subjects related to the ASM sector, have got opportunities to discuss their future roles in the ASM sector and provided input on how African Geological Surveys can handle issues facing the ASM sector in Africa.

On the other hand, AMGC, as a member of the advisory board comprising Euro-GeoSurveys (EGS), the Organisation of African Geological Surveys (OAGS) and the PanAfGeo-2 Project, will always participate in the activities that this organisation promotes, including cooperation with national and international scientific organisations on capacity building and formalisation of the ASM sector so that it continues to grow positively.

Under these circumstances AMGC is confident that this ASM Handbook has come at the right time to serve as a guideline for the management of this complex mining activity and as a valuable guide and resource book to all ASM stakeholders. Subsequently, AMGC urges all stakeholders to make use of this ASM Handbook and thanks everyone who directly or indirectly contributed in the organisation and success of these training sessions.

*Ibrahim Shaddad*
*AMGC*

# ACKNOWLEDGMENTS

*By Editor Dr John Tychsen, ASSM Consult/GEUS*


Under WP-C of the PanAfGeo-2 Project three regional training sessions on ASM have been conducted – one in English/Portuguese in Maputo, Mozambique, one in French in Douala, Cameroun, and this one in English in Dar es Salaam, Tanzania. During the PanAfGeo-1 Project, a training session in French in Dakar, Senegal was also conducted. This is the first time a set of handbooks has been produced with contribution from all 54 countries in Africa.

This final regional training session on ASM in Tanzania comprised the participation of 15 country delegations from English speaking countries from the Eastern and Northern African Regions, namely Libya, Egypt, Sudan, South Sudan, Eritrea, Somalia, Ethiopia, Kenya, Tanzania, Uganda, Malawi, Zambia, Rwanda, Mauritius, and Seychelles. In addition to the country delegations, ASM experts from Kenya, Malawi, Tanzania, Ethiopia, Belgium, Sweden, and Denmark also took part in the training.

This training session on ASM 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 organization of craftsmen and miners, role of the National Geological Survey, and impacts of ASM sector on environmental, health, and socio-economic issues. 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

The organisation and development of an ASM site and the mineral processing techniques were addressed by Professor Salvador Mondlane from Mozambique. The environmental issues related to ASM was covered by Mrs. Mecktilder Mbajo Mchomvu Tanzania Women in Mining & Mineral Industry. The socio-economic impacts and the role of women in the ASM sector were addressed by Mrs. Monica Gichuhi from Kenya. Conflicts between ASM operators and criminal entities and the benefit of formalization as a path toward responsible minerals were presented by Mr. Elard Selestine Mawala. International Peace Information Service (IPIS). The relationship and potential conflicts between Large Scale Mining (LSM) and ASM were discussed by Dr. Mattias Fackel from Ethiopia/Sweden. The benefits of using remote sensing as a tool to monitor ASM mining sites and through this support the Government were presented by Mr. Hassan Steven Mdala from Malawi. Applications of remote sensing, GIS, and geophysics for groundwater mapping by Dr Tadele Dagne Ewunetu from Ethiopia.

We would also like to thank the co-trainers for contributing to the scientific and technical quality of this ASM Handbook, which is considered a milestone and serves as a reference for all stakeholders in ASM in the Eastern and Northern African Regions and beyond.

We would like to thank Director General Ibrahim Shaddad and his team of Bashiri Juma, Mr. Alex Mkama Rumazi.and Chales Buteta at AMGC for assistance with contact to Immigration in Tanzania and preparing letters of Invitation to the participants.

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*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-recognized 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 program 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 and Deputy co-lead Mrs. Enatfenta Gebre, CEO for Energy Minerals and Chemicals R&D, Ministry of Mines, Ethiopia.

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. The first one 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. The second one was in Douala, Cameroun for 15 French speaking countries from the Central and

Northern African Regions and the third one was in Dar es Salaam for 15 English speaking countries from the Eastern and Northern African Regions.

The PanAfGeo-1 (2017-2019) program 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. All four ASM handbooks have been 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 , the Organization of African Unity (OAU) and the Organisation of African Geological Surveys (OAGS). 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. This is the first time a set of handbooks has been produced with contribution from all 54 countries in Africa.

I know from the feedback that the latest training session in Dar es Salaam, Tanzania in November 2023 was successful and that this ASM handbook for the English speaking Eastern and Northern African Regions 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*
*BRGM*

ASM mining in Tanzania

# ASM SECTOR OF TANZANIA

*By John D. Kalimenze, Melania A. Nyimbo, Getty Massawe, and Nyambita Ibrahim*

## Geographical Context of Tanzania

### Demography of Tanzania

Tanzania is geographically located in the East African Region bordered by Kenya and Uganda to the North; Rwanda, Burundi, and the Democratic Republic of Congo to the West; Zambia, Malawi, and Mozambique to the South; and the Indian Ocean to the entire East side. It covers an area of 947,303 $km^2$ with well-known wilderness areas. Demographic features of the population of Tanzania include population density, ethnicity, education level, the health of the populace, economic status, religious affiliations, and other aspects of the population. According to the 2022 census, the total population size in Tanzania is 61,741,120 (males 30,053,130 and females 31,687,990).

### Economy of Tanzania

The Tanzanian mining sector has been improving from the early 2000s to date following the increase in the number of stakeholders who are involved both directly and indirectly in the sector. Mining has therefore contributed to the development of other sectors such as banking, financial services, transport, logistics, among others. Mining also contributes to development of host communities and the public at large through the implementation of Corporate Social Responsibility (CSR) programmes. The contribution of the mining sector to the national economy has increased from 6.7% in 2021 to 9.1% in 2023. The Government plans to have this sector contribute more than 10% of GDP by 2025. Besides a few major companies, this sector contains several medium-scale companies and a cluster of small-scale mining companies and artisans. The mining industry in Tanzania is highly important since it accounts for a significant share of the country's export revenues.

## Geological Context of Tanzania

### Simplified Geological Map of Tanzania

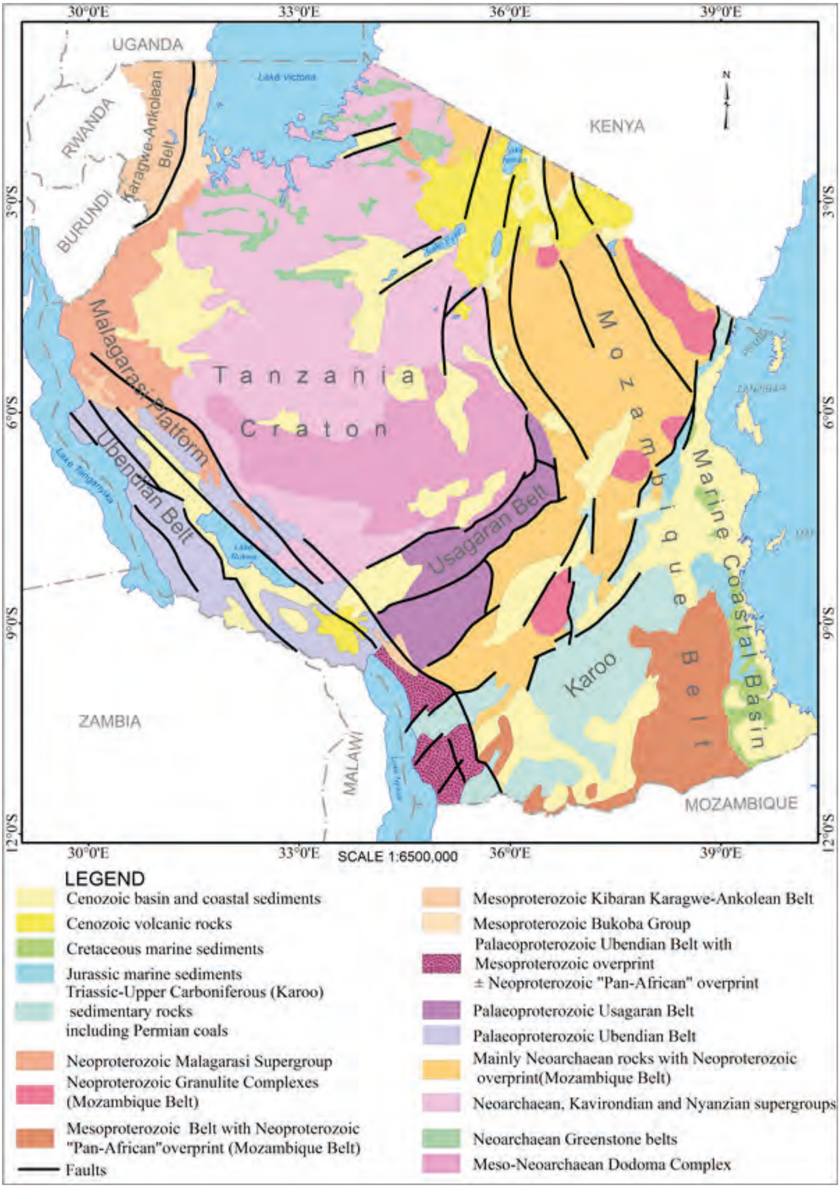
Tanzania is blessed to have a well-known geological setting endowed with substantial reserves of mineral resources classified into five groups: (i) metallic minerals group (this includes gold, iron ore, nickel, copper, cobalt, and silver), (ii) gemstone groups (this includes diamond, tanzanite, ruby, garnets), (iii) industrial minerals group (limestone, soda ash, gypsum, salt, and phosphate), (iv) energy-generating minerals (like coal and uranium) and (v) construction minerals (like gravel, sand, and dimension stones), ref. Figure 1.

### Brief Description of the National Geology

The geology of Tanzania began to form during Precambrian in the Archean and Proterozoic eons - in some cases more than 2.5 billion years ago. The Igneous and metamorphic crystalline basement rock forms the Archean Tanzania Craton, which is surrounded by the Proterozoic Ubendian belt, Mozambique Belt and Karagwe-Ankole Belt, ref. Figure 1. The massive Karoo Supergroup was deposited during the Palaeozoic and Mesozoic era. Within the past 100 million years, Tanzania has experienced marine sedimentary rock deposition along the coast and rift formation inland, which has produced large rift lakes. Tanzania is endowed with almost all lithostratigraphic unit from Archean to Recent include:

a) Archean Tanzania Craton (Au, Ag, Cu, Diamond);
b) Paleoproterozoic Mobile Belts (2.5 to 1.6 Ga years) Ubendian and Usagaran Belts;
c) Mesoproterozoic Karagwe Ankolean Belt (1.6 to 1.0 Ga years) (Ni, Co, Fe, PGE, Sn, Nb and W);
d) Neoproterozoic Mozambique Belt (1.0 to 0.54 Ga years) (gemstones: tanzanite, garnets, ruby, sapphire, spinel, emerald, tourmaline, graphite, REE, Nb, Ta, industrial minerals (feldspar, quartz);
e) Neoproterozoic Malagarasi Supergroup known for Cu; and
f) Phanerozoic geology (0.54 Ga to present) rich in coal, geothermal energy, helium gas, uranium, natural gas, salts, REE, bauxite, limestone, kaolin, calcite, dolomite etc.

FIGURE 1 | GEOLOGY MAP OF TANZANIA




Source: Geological Survey of Tanzania, 2015

## ASM in Tanzania

ASM is the activity of extracting and processing minerals and gemstones with high labour intensity and low levels of investments, technology, and mechanisation. In Tanzania, the term small-scale mining is often reserved for licensed operations, while artisanal mining refers to activities that are not covered by a proper license. The mining sector in Tanzania involves both LSM, medium-scale mining, and ASM operations. ASM in Tanzania often involves local miners using basic methods to extract near-surface deposits in an informal, low investment and labour-intensive operation, alongside the use of informal marketing channels. About two-thirds of Tanzanian ASM involves gold extraction; other minerals mainly include gemstones (including diamonds), industrial minerals, and metallic ores, such as copper. Recently, some are mining nickel, iron and involved in lithium prospection.

ASM tends to be carried out by people who have no basic formal mining training and no access to formal credit facilities, e.g. commercial bank loans. The sector still has considerable potential to reduce poverty, and according to national statistics, ASM communities fare better in terms of poverty levels than other communities. In addition to being a source of wealth creation, asset accumulation, and investment; ASM has the potential to increase people's livelihood security and reduce their vulnerability.

**What substances are exploited by ASM operators in Tanzania?**

Tanzania's geological setting favours deposition of metallic, gemstones and fuel minerals throughout the country; nevertheless, the majority of ASM operators are engaged in mining and trading of the following minerals:

a) Metallic minerals such as gold, iron, silver, copper, lithium and tin;
b) Gemstone minerals such as diamonds, tanzanite, ruby, garnet, emerald and sapphire;
c) Industrial minerals such as kaolin, sand, aggregate, gypsum, bentonite, salt and lime;
d) Building materials such as stone, aggregate and sand; and
e) Energy minerals such as coal.

**The Legislative Framework for the ASM Sector in Tanzania**

Mining activities in the country are governed by laws, policies, and regulations that have been changed or modified depending on the environment of investments. However, the ASM sector in the country is mostly governed by the Mining Act of 1998 and the Mining Policy of 1997 with their subsequent modification.

*Tanzania Mineral Policy of 2009*

The policy aimed at supporting and promoting the development of the ASM sector so that it can contribute significantly to the national economy. The policy also intended to transform and upgrade small-scale mining into organised and modernised mining; engaging stakeholders, such as financial service providers to enable ASM to access capital, market, geological and technical services; and ensure ASM operates while protecting the natural environment. To achieve its objectives, the policy recognised ASM within the legal framework, providing support services to ASM, establishment of mineral markets and engaging ASM and stakeholders in all matters to facilitate smooth and safe operation while complying to rules, regulations, and laws.

*The National Environmental Policy of 1997*
The policy aimed at achieving sustainable development through the rational use of national resources and incorporating measures in any development activities to safeguard the environment.

*The Mining Act of 2010 (and as amended in 2017)*
The Mining Act is the principal piece of legislation for the management of all mining activities in the country. It has provisions for the issuance of mineral rights for ASM, i.e., provisions for application, grant, renewal, conversion, and the allocation of rights in areas dedicated to ASM. The act also provides the rights for the provision of processing, smelting, and refining licenses, and provides for licenses in minerals.

*The Environmental Management Act of 2004*
This is the act that regulates environmental management in Tanzania. The act requires the mineral rights holder to conduct a baseline environmental investigation and social study before commencement of mining activities. The report should outline the conditions of human settlements, burial sites, cultural heritage sites, water, vegetation, and animals prior and the mitigation plans for the possible effect after mining operations in their licensed areas.

*The Occupational Health and Safety Act of 2003*
This act regulates the health and safety of all industries including mines which is also regulated by the Mining Act of 2010. Although ASM is also expected to abide by some of the provisions of these regulations, there is no specific occupational, health and safety legislation for ASM growth.

*Mineral Right Regulation of 2018*
This Regulations replace the Mining (Mineral Rights) Regulations of 2010. Regulations are set to monitor and control all procedures and respective activities related to mineral right holders. According to the Regulations, application for a mineral right shall be made to the Mining Commission (the Commission) in a prescribed form. The Mining Commission is established as a body corporate and is vested with functions that include supervising and regulating the sector, issuing, cancelling, and renewing mineral rights, and resolving any disputes arising out of mining activities.

**Degree of Organisation of ASM Sector**

In Tanzania, associations within the mining sector are also actively involved in various ways and have the potential to provide support to miners and influence change for better policy and practice. Tanzanian ASM associations include but are not limited to: Tanzania Chamber of Minerals and Energy; Federation of Miners' Associations of Tanzania; Regional Miners' Associations; Tanzania Women Miners' Association; Tanzania Mineral Dealers' Association; Women in Mining Association; Tanzania Salt Producers' Association; HakiArdhi; and HakiMadini. These associations have been established for the reasons outlined below:

a) **Tanzania Chamber of Minerals and Energy**: In collaboration with the Ministry of Minerals and other relevant agencies, aims to develop a code of conduct for their members to ensure compliance with relevant legislation, and to provide a platform for ASM participants to have a voice and air their views during negotiations with the Government, changing of policies and laws, etc.
b) **Federation of Miners' Associations of Tanzania**: Conducts awareness campaigns amongst ASM and ensure all participants in the sub-sector are members of the relevant organisation.
c) **Regional Miners' Associations**: Established to bring together miners working with different mineral commodities and provide a platform for the development of organised operations. The establishment of these associations was intended to provide channels through which assistance from the Government and other interested parties would be passed.
d) **Tanzania Women Miners Association**: Formed with the aim of facilitating women miners to organise and access the required financial, technical, and marketing services to enable them to carry out mining activities that are both economically viable and environmentally sustainable; and thereby raise the standard of living of female miners and their families.
e) **Tanzania Mineral Dealers' Association**: Established to give opinions and recommendation to government in relation to the strengthening and promotion of activities of purchase or sale of minerals in foreign countries in order to increase the contribution of the mining sector in the national level. It is also responsible in motivating members to cooperate in the purchase of Gold and Gems to prevent smuggling.
f) **Women in Mining Association**: Established to minimise the gender gap by promoting and advocating the participation, representation, leadership, and inclusive empowerment of women in the mining sector in Tanzania.
g) **Tanzania Salt Producers' Association**: Aimed at ensuring that all salts produced in the country and especially those of small-scale producers are mixed with mineral salt at the appropriate level in special facilities. It is also collaborating with the Government to improve policies that will enable salt

producers in the country to increase the production and consumption of quality and with rich mineral salts.

h) **HakiArdhi**: Established as the Land Rights Research and Resources Institute to predict a socially just and equitable land tenure system in which all groups in the society and especially the rural based small producers are guaranteed security of tenure, access and ownership to land and other means of their livelihood. It also promotes and ensures realisation of the rights to land.

i) **HakiMadini**: Focuses on strengthening voices, connecting various stakeholders for collective engagement, and working together to protect the rights of artisanal and small-scale miners and mining affected communities, ensuring transparency and accountability, and that Tanzanians benefit from a pro-poor mining sector. It also aimed at advancing the rights of marginalised communities through policy reforms, development projects, research and education while directly engaging policymakers, artisanal and small-scale miners, and mining-affected communities and positively impacting the livelihoods, health and wellbeing of the communities including women and non-mining land users.

**Role of the National Geological Survey to Support the ASM Operators**

The GST is mandated to carry out geoscientific investigations and to store and disseminate geoscientific data and information to the Government and other stakeholders. Based on its mandated tasks, GST plays a major role in the growth and promotion of mineral/mining investments in the country particularly to ASM. In recent years, GST has played the following roles in ASM:

a) Provision of cheap and credible geoscientific data and information;
b) Provision of training on mineral prospecting and exploration to ASM;
c) Provision of technical services to ASM on geology, mining, and mineral processing;
d) Carrying exploration program on ASM demarcated areas to define mineral resources;
e) Dissemination of flyers, booklets, and books showing potential areas for ASM;
f) Provision of laboratory services for ASM at affordable fees; and
g) Provision of training on environmental and health issues related to the ASM sector in Tanzania.

FIGURE 2 | ASM PIT, TANZANIA

Source: John Kalimenze, 2016

## Environmental and Health Issues Related to the ASM Sector in Tanzania

### Impact on Waterways

Some of ASM operations are conducted in nearby water bodies. For instance, the mining of sand and alluvial gold is done in river channels. These operations not only pollute water in a river stream but also result in the collapse of river channels leading to the siltation of downstream dams, swamps, and gullies in river channels.

### Impact on Deforestation

ASM depends on timbers and poles to support hanging walls during mining activities. The boom in mining operations in recent years has been directly proportional to the demand for logs and timber for mining activities that resulted in increased illegal harvest of forests in mining sites and nearby forests. Furthermore, the importation of logs from other areas affects local vegetation by introducing new species of plants and pests that result in unhealthy vegetation in mining areas.

### Impact on the Landscape

ASM prefers open pit mining rather than underground mining in their operation to recover minerals because it is cheaper. However, after the completion of mining activities, pits are not backfilled thereby rendering a once arable farming land unsuitable for other economic activities, such as agriculture or livestock keeping. Similarly, the rock damps and tailing accumulated after mining operation create artificial hills that may be a source of rapid movement of water resulting in erosion, reduced beauty of the area, and seepage of toxic elements into the water table or nearby streams.

**Impact on Health Among ASM Operators**

The nature of an ASM operation poses major health effects to workers, laborers, and nearby communities. In most ASM mining areas there is poor observation of health and safety measures which results in the death of workers due to the collapse of hanging walls or pits during the rainy season; exposure to rock dust/fumes and dangerous gases such as sulphur during mining operations; reduced/loss of hearing from noises and high-rate transmission of sexually transmitted diseases due to unsafe sex and prostitution in mining camps.

## Socio-Economic Issues Related to the ASM Sector in Tanzania

**Role of Women**

In Tanzania, women are playing an important role in ASM operations and value-adding activities. The Mining Policy of 2009 has been the major driver in women's engagement in mining activities by encouraging owning mineral rights, provision of training and workshop to women groups, and provision of lapidary training and tools to women at the Geology Institute based in Arusha, Tanzania. Generally, in ASM women are involved in crushing ores, washing concentrates, cleanliness of surroundings, provision of food and accommodation in mining camps, small businesses and mineral brokers, and value addition activities for gemstones to make cabochons, earrings, and related decorations.

**Role of Child Labour**

The Tanzania Mineral Policy 2009 prohibits child labour in mining activities through policy objective number 6, both in terms of legal and illegal operations but rather encourage and promote women's participation in mining activities and strengthen enforcement of laws and regulations against child labour in mining activities.

**Conflicts with Local Farmers and Other Stakeholders**

Land and mining conflicts are regulated by the Mining and Land Acts together with the Mining Disputes Resolution of 2021 where the power of handling disputes between persons engaging in prospecting or mining operations was bestowed to the Executive Secretary of the Mining Commission or by an officer delegated by the Executive Secretary. Common conflicts between ASM operators and farmers occur during the mine rush whereby the process of land acquisition for mining by ASM is not done. Furthermore, the conflict between ASM and LSM operators occurs when

ASM operators invade the mineral right of the LSM operators during the exploration stage or when LSM operators apply for and are granted a license to an area where ASM operators are conducting mining activities without a license.

**Conflicts with Criminal Gangs in the Mining Area**
There are no criminal gangs operating in ASM areas in the country. All ASM operations are done under the supervision of the local security team under the Village Executive Officer and Police officers stationed at the mining sites.

ASM in Asoca in Ethiopias


Mining village in Zambia

# ASM SECTOR OF KENYA

*By Sarah Jepkoech Bungei, Chief Superintending Geologist, John Kirasesa Iugalia, Chief Superintending Geologist and Edward Olali Omito, Chief Superintending Geologist, Manager Voi Gemstone Centre Department of Geological Survey and Geo-information Management*

## Geography, Demography and Economy of Kenya

Kenya is found within the Eastern Africa Region and occupies an approximate area of 580,367 km$^2$. It borders Tanzania to the south, Somalia to the east, Ethiopia to the north, South Sudan to the northwest and Uganda to the west. The country boasts a wide range of geographical features. The western area hosts Lake Victoria and Mt. Elgon, which are found along the border of Kenya and Uganda. The Kakamega Forest is also located in this region. The Kenyan Rift Valley cuts through north-western area and stretches down to the southeast. The floor of the rift valley is also home to several lakes with varying sizes. The lakes are namely, Turkana, Baringo, Bogoria, Nakuru, Elementaita, Magadi, Natron, and Naivasha. Lake Turkana is the largest lake in Kenya with an approximate size of 6,400 km$^2$. Towards the western part of Kenya, on the flanks of the rift valley, lays the mountain ranges of Abedares, Mau and Chereng'ani with the highest point being Mt. Kenya, having an altitude of 5,197 m. The northern and vast sections of eastern Kenya are plains which are generally arid and semi-arid. Kenya is also a coastal country as it borders the Indian Ocean to the southeast with a coastline of about 536 km.

As per the Kenya National Bureau of Statistics report on the countrywide Population and Housing census conducted in 2019, Kenya has a population of 47.6 million. Of the 47.6 million citizens, 23.6 million are male and 24 million are female. Additionally, the largest population group is between the ages of 15-64 accounting for over 50% of the population. Population density is high in the urban areas with Nairobi, the capital, registering the highest population of 4.3 million. The report further notes that the growth rate was at 2%, the life expectancy stood at 67 years, net migration rate at 0.19 migrants/1,000 population and the fertility rate at 3.29 children.

According to the World Bank data of 2021, Kenya's Gross Domestic Product (GDP) is US$ 110.35 billion, which is 0.05% of the global economy. Kenya Institute for Public Policy Research and Analysis 2022 Report indicates that the service sector contributes slightly over 50% to the economy, agriculture up to 20% and the industrial sector taking up 16% of the share. Revenues from mining and quarrying activities account for less than 1% of the GDP. A report from the Alliance for Responsible Mining estimates that ASM gold mining contributes about US$ 224 Million to the country's economy. The Ministry of Petroleum and Mining also estimates that Kenya's entire mining sector produces more than 34 tonnes of gold per year. ASM operations accounts for 2% of Kenya's total export earnings but have a potential of 4-10% (Kenya National Bureau of Statistics, 2019).

The Government aims to increase the mining sector's contribution to the GDP. In 2015, the mining sector's share already reached 0.8% and, the Government now aims for 10% by 2030 through value addition and the implementation of the Mining and Minerals Policy of 2016. A 20-year vision policy for mining and minerals combined with the new Mining Act outlines a long-term mining strategy for Kenya.

## Geology of Kenya

The geology of Kenya can be classified into five broad categories, the main distinction being the nature of rocks and the age of formation. The oldest rocks in Kenya were formed during the Achaean while the youngest rocks are superficial sediments that are Recent in age. The geological formations have grouped the rock as follows (Opiyo Akech et. al, 2013), ref. Figure 3 below:

**Archaean (Nyanzian and Kavirondian)**

These rocks are constrained to the western part of Kenya and are believed to be the supracrustal oldest rocks in the country. The rocks are believed to have formed 3,000 million years ago and are broadly divided into: a) Nyanzian Super Group; and b) Kavirondo Super Group. Archaean rocks of Kenya are a northern extension of the Tanzanian Shield of greenstone rocks.

a) **Nyanzian Rocks**: These rocks are primarily meta-volcanics consisting of lavas any pyroclastic with minor sediments and banded iron formations. The volcaniclastics and mafic volcanics have been studied to be older and are overlain by an Upper Nyanzian system that is dominated by the ultramafic, mafic and felsic volcanics; and
b) **Kavirondian Rocks**: These rocks rest unconformably over the Nyanzian Package. Kavirondian rocks can be described as meta-sedimentary rocks of protoliths from clastic sediments. They consist of polymictic conglomerates, sandstones, grit, sandstones and greywackes. The greenstones belts are intruded by felsic and intermediate plutonic rocks that are 2650-2640 million years ago (Henckel et al, 2016). Both the Nyanzian and Kavirondian Subgroups are folded with east-westerly trends.

**Proterozoic (Mozambique Belt and Bukoban)**

*Mozambique Belt*

The belt is among the many regional orogeny belts in Africa and extends from Ethiopia through along the Eastern border of Africa to Kenya and Tanzania. The Mozambique belt is made of highly metamorphosed rocks that are 500-1,000 million years in age. The rocks occur in both east and west of the Rift Valley. The rocks are mainly high grade reworked or reactivated basement. The belt itself shows a general N-S structural trend (Nyamai et al., 2004). The rocks include gneisses, schists, migmatites, amphibolites, marbles and intrusions.

*Bukoban Series*

Also referred to as the Kisii series, which is a system found in western Kenya neighbouring the Nyanzian System. The Kisii group is a volcano-sedimentary series that sits on the granitised Victorian sequences of the Tanzanian Craton. The volcanic and sedimentary formation is interlayered with the volcanic rocks consisting of sub aquatic Kisii basalts, Ikonge rhyolitic ignimbrite and the volcaniclastic beds. The sedimentary rocks on the other hand are siltstone and local conglomerate, minor cinerite and chert (Pinna et. al., 2000).

**Palaeozoic/Mesozoic Sediments**

Palaeozoic and Mesozoic formation are found near the coast and in northern Kenya. The historical geology of the sediments in Kenya is related to the evolution, faulting and succeeding formation of the rift valley in the Mesozoic Era (Pepper and Everhart, 1963). It is hypothesized that the break-up of the rift was accompanied by the formation of an intracratonic basin which was filled by Permo-Triassic clastic deposits of the Duruma Group. The Duruma group was followed by the deposition of the Jurrassic rocks. The Duruma group that is composed of sandstones is similar to the Karoo System of the Southern Africa. A breakdown of the local formation includes Mazeras Sandstones, Maji ya Chumvi siltsones, Kambe Limestones, Taru Grit, Kibiongoni beds and the Jurassic shale.

**Tertiary/Quaternary Volcanics and Sediments**

*Tertiary/Quaternary Volcanics (TQV)*

Volcanic rocks of the TV/QV are distributed along and within the floor of the East Africa Rift system. The rocks extend to distances of up to 200 km on both the east and west of the Rift Valley in Kenya (King et. al., 1972). These rocks vary greatly in composition, mode of extrusion and form of volcanic accumulations. The rocks are Miocene in age to the present day. The oldest igneous rocks are of lower Miocene and comprise the eroded lavas and pyroclastic piles of South Nyanza. In the Central towards the south there is emplacement of a plateau phonolite. Volcanic centres that are responsible for the formation of Mt. Kenya and Mt. Kilimanjaro can be characterised as giant phonolite-trachyte or basalt-phonolite-trachyte. The vast basalt fields observed in Samburu are a result of fissure eruptions.

*Tertiary/Quaternary Sediments (TQS)*

The sediments are encountered at the northern sector around the Rift Valley, eastern sides of Kenya toward the coast. Within the Rift the TQS formations normally occur at the base of volcanic successions intercalated with them or in tectonic troughs. The tectonic evolution of the Rift valley formed numerous basins in which lacustrine, fluvial and aeolian sediments were deposited. The sediments are largely without fossil traces but of interest are the middle Pleistocene-Lacustrine-Olorgesaillie lakebeds that contain diatomite, mammalian fossils and artefacts.

Along the coast, the beds were deposited from Miocene to Pliocene. They include conglomerates, limestones, marls, mottled clays, red sands.

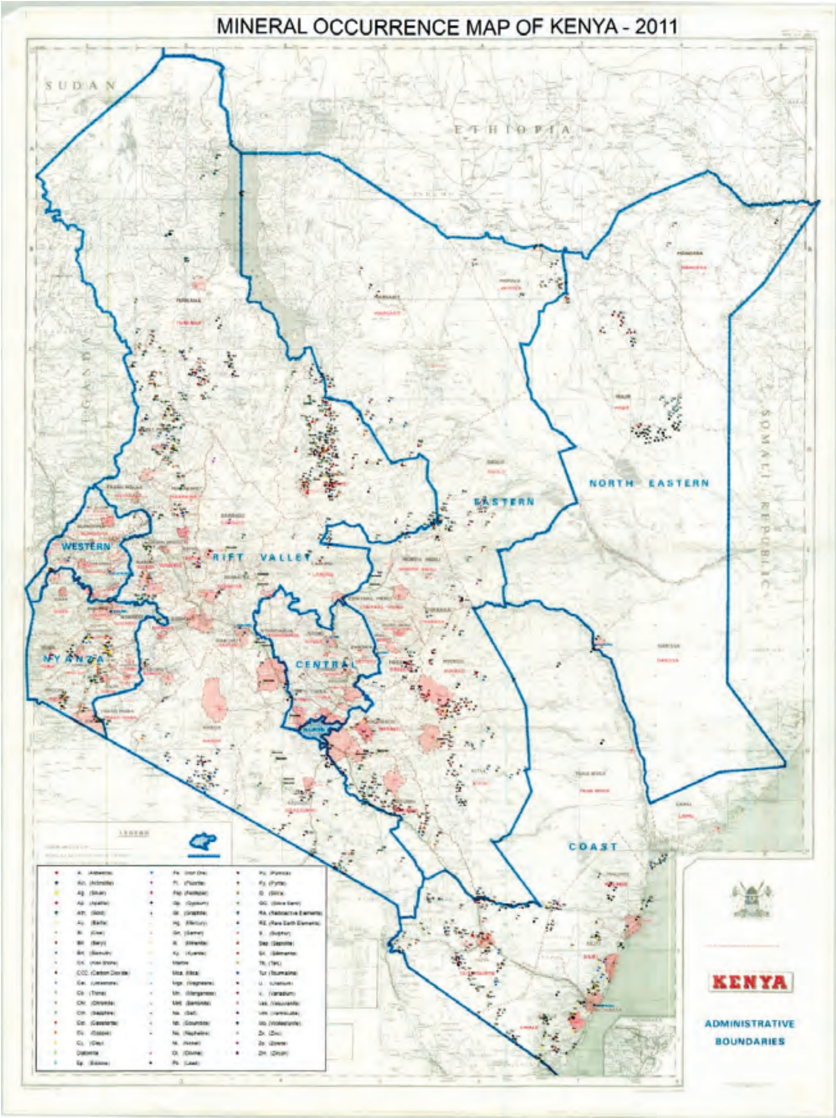
**Pleistocene to Recent soils, Alluvial Beach Sands**
Red volcanic soils, which overlie the TQVs, are well drained and rich in nutrients for agricultural use. Alluvial soils on the other hand are found in flood plains, valleys, and mouths of large water bodies. Beach sands along the coast are deposited from the marine transgression and regression activities.

Table 1 below provides insights on mineralisation.

TABLE 1 | MINERALISATION

| Geology | Mineralisation |
|---|---|
| The Nyanzian Shield (Nyanzian and Kavirondian) | ▪ Metallic Mineralisation of base and precious metals occur.<br>▪ Gold, copper, and silver have been mined.<br>▪ Potential for ferrous and non-ferrous metals. |
| Mozambigue Belt | ▪ Kyanite, Corundum, Graphite, Wollastonite, mantle, asbestos, fluorspar, magnesite, kaolin, variety of gemstones are found.<br>▪ Minerals found are associated with basic and granite rocks. |
| Paleozoic and Mesozoic Formations | ▪ Rocks in this formation are sources and hosts for limestone, gypsum, clays, manganese, and construction materials.<br>▪ Base metal mineralisation, lead-zinc-barite and copper are known to occur in the sedimentary basin along the coast belt.<br>▪ Heavy mineral sand also occurs along the coast beach sands that host deposits of titanium that is mined now by base titanium company. |
| Tertiary and Quaternary volcanic | ▪ Hosts a variety of minerals and construction materials.<br>▪ Have deposits of clay and evaporates, soda ash, diatomite, and natural carbon dioxide, kurkar and gypsum.<br>▪ Gem quality rubies have been discovered as well. |
| Tertiary and Quaternary Sediments | ▪ Hosts a variety of minerals, such as manganese, coal, and iron. |

FIGURE 3 | GEOLOGICAL MAP OF KENYA




Source: Department of Geological Survey and Geo-information Management, Kenya

## ASM in Kenya

### Introduction and Commodities

ASM refers to mining by individuals, groups, families or cooperatives with minimal or no mechanisation, often in the informal sector of the market (Hentschel et. al., 2003). Owing to its informality there is no accurate statistics on the number of ASM miners that operate in Kenya. Furthermore, the miners at times delve into other sources of income depending on the season or mining dynamics. However, Sebastian Pennes, an associate at Levin Sources, points out that the ASM sector and associated activities directly employ 140,000 Kenyans and support 800,000 more. Solidaridad, an international Civil Society, confirms that the ASM sector is a means of livelihood to roughly 250,000 miners in gold mining alone with women making up 40% of the total. ASM activities are mainly panning of gold, gemstone mining, winning of sand, gravel, clay and quarrying of construction material.

Different minerals are mined in different parts of the country by ASM operators as shown in Table 2 below.

TABLE 2 | LOCATION OF TYPES OF MINERALS MINED, KENYA

| Regions | Counties | Minerals |
|---|---|---|
| Eastern | Mbeere, Tharaka Nithi,kitui | Gemstones, industrial minerals, and construction materials. |
| Coast | Taita Taveta ,Kilifi, Lamu Tana River Kwale | Gemstones, salt, construction materials, and industrial minerals |
| Western | Kakamega,Vihiga | Gold and industrial minerals |
| Nyanza | Migori,kisii,Nyamira | Gold, industrial minerals, soapstone, and construction materials |
| Rift valley | Transmara, Nandi, Turkana,,Narok, Naivasha, Nakuru, Baringo Kajiado,Samburu and Marakwet etc. | Gold, gemstones industrial minerals, and construction materials |
| Northeastern | Moyale, Garissa,and Marsabit | Gypsum, gemstones, and construction materials. |
| Nairobi and Central | Most counties | Construction materials |

### Legislative Framework for the ASM Sector

Mining in Kenya is governed substantively by the Mining Act of 2016 and its regulations. The act gives direction on how minerals are to be prospected, mined, processed, refined, treated, and transported, and provides regulations on mining dealings.

According to the Mining Act of 2016, every mineral in its natural state in, under or upon land, in or under a lake stream or water courses, exclusive economic zone and an area covered by territorial sea throughout the republic is vested in the national government in trust for the people of Kenya.

According to Section 6, Part A of the Mining Act of 2016, a person shall not search for, prospect or mine any mineral, mineral deposit, or tailings in Kenya unless that person has been granted a permit or licence in accordance with the Mining Act of 2016.

Section 93 of Mining Act of 2016 calls for the establishment of Mining Committees in the counties where ASM activities take place. These Mining Committees will be responsible for granting, renewing and revoking artisanal mining permits.

Environmental legislations, as stipulated by the Environmental Management Act of 1999, 2003 and 2017, also require partakers of ASM sites to conduct Environmental Impact Assessments (EIAs) before any mining activities begin and do rehabilitation of the mining sites after mining activities are concluded. ASM working areas like all other work setting within the Republic of Kenya are controlled by laws that require the miners not to employ minors, maintain safety by wearing of protective equipment and ensuring the working condition as well as the routine pose no threats on the health of the miners. However, these set of laws are not adhered to as required.

The ASM Sector in Kenya is now regulated by the following legislation:

a) Mining Act of 2016
b) Environmental Management Act of 1999, 2003 and 2017
c) Employment Act of 2007
d) Occupational Safety and Health Act of 2007
e) Explosives Act No. 115
f) Land Act of 2016

**Degree of Organisation of the ASM Sector**

The ASM sector in Kenya can be at best defined as slightly organised. Albeit its existence even before the independence of the state, ASM stakeholders have shied away from mainstreaming the sector. The ASM operators have local onsite groups that coordinate the day-to-day tasks, and many a times are engaged in table banking. In isolated cases the ASM operators have formed cooperatives at the county level, one such group is the Migori County Artisanal Miners Cooperative that has been reclaiming old and abandoned mines as a means of ecosystem restoration. However, the ASM operators lack national robust unions that can represent them at a national or regional stage. Lobby groups and humanitarian non-governmental organisations (NGOs) have in the recent past advocated for better working conditions for them and continuously run programmes that impact them positively particularly on the risks involved in mining. The State Department for Mining is also pushing for the establishment of the ASM Mining Committees that will better address the issues in the sub-sector.

**Role of the National Geological Survey to Support the ASM Operators**
The State Department for mining has been operating under an old mining policy. There was a need to develop a new regulatory framework that could address several issues within the mining sector. The Mining Act of 2016 was developed and became a law and it is now in the process of implementation. Formalisation of ASM operators is one of the issues that were expected to be addressed by this policy; however, the law could not operate without guidelines. It has taken several years to develop regulatory guidelines including that of ASM. Some guidelines have been enacted but specific ASM guidelines are yet to be enacted as a law.
The Department of Mining comprises 2 directorates - each with its own function when it comes to supporting the ASM: a) Geological Surveys and Geo-formation Management; and b) Mines.

The role and activities of the Department for Mining comprise:

a) Facilitating credit through cooperative savings, banks, and private arrangements of equipment leasing and government-supported concession lending;
b) Implementing the Mining Act of 2016 by which a few piloted ASM Mining Committees have been established in counties where concentration of ASM activities especially mining gold and gemstones are known to occur. This has enabled access for acquiring minerals rights because such Mining Committees are responsible for granting, renewing and revoking artisanal mining permits;
c) Establishing an online mining cadastre system to enable management of mining concessions and allocation of mineral rights;
d) Carrying out sensitisation and awareness of regulatory framework and sustainable mining procedures;
e) Delineating and setting aside areas for ASM activities;
f) Undertaking systematic geological mapping and structural mapping of the whole country to describe the onshore and offshore geological conditions;
g) Assessing and providing information on mineral wealth of the country using detailed investigation;
h) Providing quantitative and qualitative analysis of rocks, mineral ores, precious and semi-precious metals, and assay for gold etc.;
i) Undertaking of arbitration of mining disputes;
j) Provisioning of mining techniques and services, monitoring of mine health, safety and environment;
k) Certification of commercial explosives; and
l) Assessing and monitoring mine and quarry buffer zones.

**Challenges Faced by ASM Operators**

ASM operators face a lot of challenges such as:

a) Most of the ASM operators lack the necessary skills to help them in mining of gemstones; hence, they waste a lot of time and money before they strike good production;
b) They also lack equipment, which will make their work easy. They mostly use hand tools like chisels, hammer, and crowbar, which are difficult to use and also are time consuming;
c) Since most of the ASM operators are not well-organised, they mine in environments which are not safe, e.g. they dig tunnels which are very small, lack support structures hence prone to collapse at any time;
d) There is a general security problem in the mining zone. Most of the ASM operators are youths, who used to be mine employees in particular mines. They are laid off and since they cannot find work in other mines why they end up being illegal miner, named "zururas", who roam the whole mining zone stealing from miners and making the zone to be insecure;
e) Since the mining zone is isolated, there is danger of criminals from other areas coming to hide in the mining zone. This has greatly contributed to insecurity problem in these zones;
f) Marketing is a big problem to the ASM operators. This is because they are exploited by middlemen "brokers" who buy their gemstones at very low prices. This is because the ASM operators do not have direct contact with those who buy the gemstones. This makes the mineral brokers who do not even know how to mine to benefit at the expense of the ASM operators;
g) There is a problem with explosives use at the mining zone. Only established miners can access legally obtained explosives. ASM operators cannot access the explosives because most of them are not licensed and do not have qualified or experienced blasters. They end up smuggling explosives from Tanzania. The explosives in Kenya are also very expensive, so the ASM operators opt for the cheap alternative explosive from Tanzania, which is smuggled to Kenya;
h) The mining zone borders Tanzania - a stretch of almost 70 km, which is porous, since it is mostly in areas within National parks, e.g. Tsavo West in Kenya and Mkomazi in Tanzania. The porous border has encouraged smuggling of gemstones especially from Kenya by Tanzanians illegal dealers. They come to Kenya on motor bikes to buy gemstones and escape back to Tanzania without paying the necessary taxes. This is coupled by the fact that they deal with miners, who are not licensed back here in Kenya;
i) Mining is done mostly by men. Women have not fully engaged in mining significantly. There only exists one miners' group for women and they are not even active now;

j) The health of the ASM operators is also waning as most of them live in very dilapidated housing with some actually sleeping in polythene tents despite the fact that the area has wild animals;
k) There is also a social problem of alcohol and drug abuse among the ASM operators. Most of them spend the little money they get from mining on alcohol and drugs and do no meaningful development elsewhere. They end up living the rest of their lives in dilapidated conditions at the mining zone;
l) Some ASM operators have abandoned their families and have spent many years in the mining zones;
m) There is also lack of proper medical facilities in the mining zones;
n) The ASM operators lack a proper place where they can add value to their gemstones; and
o) The ASM operators also do not have access to gemmology laboratories where they can identify the gemstones they are producing to help them getting the right markets for the gemstones.

The above challenges necessitated the establishment of the Voi Gemstone Centre. The Centre was constructed primarily to achieve the following:

a) The gemstone centre will enhance value addition for gemstones before they are exposed to the international market. This will increase the competitiveness of the gemstones internationally and thus enhance the revenue base of the Government;
b) Since the gemstone centre will bring players in the gemstone industry in a one-shop premise, regulation will be made much easier thereby increasing efficiency;
c) Having a gemmology laboratory at the centre will ensure that no gemstone is not accounted for. Now, the miners have sold some gemstones for what they are not and at cheaper prices, and these gemstones eventually get higher prices when they leave the country and are properly identified;
d) Having a gemstone business conducted in one place is secure and conducive. This will enhance the security of the business and attract international dealers, who are particularly careful about security issues;
e) Since the lapidary section of the centre has facilities for jewellery making, most tourists coming to Tsavo National Park will be attracted to the centre to buy jewellery made from gemstones as finished products and thus boost foreign exchange;
f) The gemstone centre has created jobs for many youths and women who are engaged in cutting, polishing, and faceting of the gemstones and in jewellery-making;
g) Increase revenue collection by regularising the gemstone trade;
h) Provision of market opportunities to the ASM operators by providing a pool of international buyers accessible to the miners and dealers;

i) Marketing of Kenyan gemstones online through online forums;
j) Provision of booths at the centre where dealers can rent and conduct their trade in a safe and conducive environment;
k) Provision of safe deposit boxes to the dealers and miners for safe keeping of their gemstones;
l) Conduct periodic gemstones exhibitions and open-air markets to market Kenyan gemstones;
m) Provide storage of credible data and information on the gemstone industry; and
n) Provide training and extension services to dealers, small scale and artisanal miners on matters concerning gemstone mining and trading.

## Environmental and Health Issues Related to the ASM Sector in Kenya

### Impact on Water Ways

Uncontrolled mining has grave effects on the general hydrological cycle. The degradation is either of the water quality or quantity. In Kenya, sand harvesting in some counties is usually carried out in rivers and along riverbanks and along the roads. This interferes with the natural water flow and destroys the natural ecosystem. Excessive misuse of mercury, which if discharged into rivers and water courses, stay in suspension for long distances. This accumulates in tissue of some species of fish, which later affects the people consuming fish in the food chain. It is also discharged into ponds which are later let out into processing plants, such as leaching plants, which use cyanide to extract gold for the ore. The effluent form of the leaching plant is disposed into lower grounds, which then flow into rivers and lakes causing water contamination. Animals have been reported to die upon consuming water contaminated with cyanide. In areas where underground mining is practiced, ground water has been contaminated by the materials used by the miners.

### Impact on Deforestation

In the central and eastern regions of Kenya, quarrying is conducted on a relatively moderate scale. The quarries produce dimension stone and building aggregate that serves the area's booming construction industry. The area also bears natural vegetation including indigenous species of trees. The clearing of bushes and cutting down of trees is at times unavoidably to pave way for ASM activities and as a result the ground is left bare without vegetation cover making it vulnerable to soil erosion, land degradation, climate change, destruction of wildlife habitat, imbalance of water, local rainfall pattern change, sedimentation, etc. The local rainfall patterns will eventually have ripple effects on national patterns, then regional and finally global. Underground mines rely on timber products to support the walls and the foot. The timber is obtained from forests. The demand for wood in ASM has led to deforestation.

**Impact on the Landscape**

In all parts of the country where ASM and quarrying are undertaken, the original landscape has been severely destroyed. The open pits, quarries, shafts are often poorly designed and low-tech and little planning is employed in their operations. Mine owners in most cases rarely engage subject matter experts and neglect the existing laws that control land use. Weak enforcement of pertinent legislation has worsened the issue. Most ASM operators do not carry out EIAs, as required by the Environmental Management Act of 1999, 2003 and 2017, before carrying out their mining activities. This makes it difficult to monitor and evaluate their activities. An EIA report normally contains an Environmental Management Plan (EMP) that spells out the mitigation measures, which should be carried out to address the negative impacts on land brought about by mining. The environmental expert can give one or two proposals to guide the quarry owner on mitigating the negative effects of the mining activities. The disused mines are never rehabilitated causing a lot of damage to landscape. As a consequence, in sections of the country where locals are living out of mining, abandoned pits, mounds of debris and artificial fissures are a common occurrence. The open pits which are not backfilled after mining pose danger to nearby homesteads because most of the time during rainy season water collects in these pits acting as breeding places for mosquitoes, which transmit malaria diseases. Also, children, who are tempted to swim in this stagnant end up drowning in them or contract water borne diseases like cholera. Deep pits left unfilled pose danger to animals and people. Lack of solid waste management system causes alteration of soil profile.

**Impact on Health among ASM Operators**

In Kenya ASM can be categorised as a high health risk venture. ASM operators, support staff and the general populace residing within the vicinities of mines are exposed to life threatening situations. Due to the poor infrastructural designs in underground mines, the mines at times collapse causing serious injuries or fatalities. A local newspaper, the Nation, in February 2023 reported that at least 60 people have died in mining sites in four counties over the past six-year period. Lack or limited personal protective gear coupled with faulty machines have also caused serious injuries and maimed several ore handlers. Suffocation in the underground mines is also a serious challenge and respiratory disorders amongst miners that have been in mines for longer periods is also common. A report by the Aga Khan University in 2019 reveals that women living or working around mines are exposed to waterborne diseases due to contaminated stagnant water on the pits. Women around these areas are at high risk of contracting HIV and STIs (Mwakumanya et. al., 2017). Noise pollution and chemical exposure from pollutants trace elements pose occupational and inadvertent health risks to the extent that has not been well elucidated in Africa (Ondayo et. al., 2023). Physical deformities and musculoskeletal disorders occur to people, who have been engaged in mining for prolonged periods.

## Socio-Economic Issues Related to the ASM Sector in Kenya

### Role of Women

There are women who own mines as ASM miners and have employed both men and women in these mines, especially in gemstone mining areas. Women are also employed in small scale gold mining areas and their major roles are crushing of gold ore minerals stones to sizes that can be milled using a ball mill and sluicing (gravity separation of gold) and amalgamation. On the other hand, women have ventured into mining by use of jembes and oars they dig on shallow gold rich veins and carry out the processing by themselves. Crushing stones to make ballast/aggregate. Sorting and washing different grades in iron ore and manganese mining areas.

FIGURE 4 | WOMEN SLUCING GOLD, ASM GOLD MINES IN KENENE MINES IN KERICHO COUNTY

Source: Sarah Bungei. Chief Superintending Geologist

### Role of Child Labour

Child labour has reduced in recent years in ASM mining due to a combination of heightened attention by regulators, such as the Ministry of Education and local administrations.

### Conflicts with Local Farmers and Other Stakeholders

The issues of land in Kenya have always brought in a lot of conflicts between miners, landowners and other stakeholders. According to the Mining Act of 2016, the land status can either be private, public or community owned. According to the regulatory framework in the case of private status, a written landowner consent of a registered owner is a requirement for one to apply for any mineral right. In the case of a community status, consent should be sought by an authority obligated by law relating to administration and management of community. In this case an interested miner and community shall enter into legally binding agreement. In most cases conflicts occur when the land is community or public.

ASM miners took advantage of limited relevant regulatory framework where mining is done without environmental impacts assessment. This has made it hard to follow up on mine closure and restoration of the environment. There are no designated areas for ASM and thus mining is done on lands for farming and grazing purposes. This can be dangerous to both animals and human because of pits left unclaimed and poor waste disposal management.

**Conflicts with Criminal Gangs in the Mining Area**
Although ASM is an income generating activity benefiting many low income and vulnerable groups, the sector is faced with challenges of conmen, exploitation by middlemen and smuggling. Gold is smuggled to Uganda and here thus evading royalty payment to the Government of Kenya. Gemstones, mined in Taita Taveta and Kwale Counties, are smuggled through porous borders to Tanzania and other neighbouring countries. Due to lack of knowledge on precious and semi-precious minerals, traders have been conned by gem-like materials, which are either glass or synthetic materials. Due to the remoteness of these mining areas and an unavailability of secure/safe storage rooms, poor infrastructure, and lack of communication on precious and semi-precious minerals, criminals take advantage and steal from vulnerable groups of miners.

ASM in Hetsatsec. Ethiopia

Mining site in Tanzania

# SOCIAL, HEALTH AND SAFETY ISSUES RELATED TO THE ASM SECTOR

*By Ms. Monica Gichuhi, Kenya*

Mine collapses, hundreds are injured, and several deaths reported. These are the typical headlines in newspapers and social media platform that characterise ASM activities in many African countries. This negative publicity continues to propagate what many associate with ASM activities as highly unsafe, mainly informal or in some instances illegal. Despite the recognised risks, ASM is an integral part of an overall livelihood strategy for many households worldwide, and there is a growing consensus that ASM is mostly poverty driven (Aryee et al., 2003).

ASM is a critical poverty reduction strategy for millions of people around the world; however, it is notoriously dangerous (Smith et. al., 2016). Nonetheless, ASM provides many benefits to rural communities: it can be a source of identity and cultural belonging, it provides employment and cash for families, which can help alleviate poverty, and it often results in increased participation in schooling and other business activities (Lole, 2005). ASM activities may also reduce the negative impacts of rural/urban migration (Hinton, 2006).

Several countries in Eastern and Northern Africa have reviewed their legislations to guide formalisation of the ASM sector. Formalisation is often presented as a key strategy for increasing the sustainability of ASM activities, creating benefits for communities, and minimising negative environmental and human impacts (Maconachie and Hilson, 2011). Some of the laws have introduced a sub-category in licensing specific for the ASM sector with reduced requirements to make it simpler for miners to get legalised and comply to basic environment, health, and safety provisions. The laws mainly require ASM to work within designated areas and observe basic mine health and safety measures. The responsibility is upon the regulator to enforce these provisions through vigilant inspection of numerous ASM sites, spread out across vast rural areas and involving a significant number of casual labourers. Government agencies charged with these roles often have challenges of limited resources in ensuring effective oversight of ASM sites.

This chapter seeks to highlight the social, health and safety challenges in the ASM subsector and the risks they pose to the miners and the communities around them. It also evaluates why enforcement of these provisions has been an uphill task for most governments and what would be some nuanced ways of increasing compliance through incentives to the miners. Finally, it rallies stakeholders around a call for action on how collectively ASM miners can be supported through engagement and not criminalisation of their activities to safeguard their health and safety in the mines.

## Overview of the Social, Health and Safety Issues

ASM is one of the world's most dangerous occupations. The World Bank estimates that 100 million children, women and men work in ASM worldwide, mostly in remote rural areas of low-income and lower-middle-income countries. These miners often work under extreme conditions, the communities where they and their families live are heavily polluted, and ASM is responsible for high, but preventable rates of disease, injury, and premature deaths.

Identifying and understanding the risks people encounter in their everyday lives and how they understand and attempt to mitigate these risks, is an essential step in addressing risk in a way that contributes to more sustainable rural livelihoods globally (Smith et. al.,2016).

### Social Issues

ASM activities are mainly conducted in rural areas on community or family land. ASM miners tend to be locals in the area with some number of migrant casual labourers, who have either been hired to bring expertise or have migrated to seek fortunes when there is a boom. These diverse groups of people working together in an informal setup result in various social challenges for both the men and women engaged in these activities.

While ASM has the potential to contribute to more sustainable livelihood strategies, poor working conditions, accidents, and diseases can reduce worker productivity and income for dependents, burdening families and communities. ASM miners are usually engaged in heavy and precarious manual labour and frequently utilise rudimentary or unsafe mining and mineral processing techniques. In addition, the impacts of ASM activities often extend beyond the miners themselves to their families and communities, who are exposed to environmental pollution and hazards either through their participation in various parts of the mining commodity value chain or because of their residential proximity to mining activities (Maier et. al., 2014).

Diversion and siltation of water sources affect all surrounding and downstream communities too. Also, due to the migratory nature of ASM, miners and mineral transporters can spread illnesses and diseases, particularly if they engage in promiscuous sexual behaviour. Child and youth labour is prevalent in many mines and these young people are particularly prone to physical and psychological damage. ASM work often takes place in remote areas where access to health care, schools, basic sanitation, or other social services is minimal at best (Vingård and Elgstrand, 2013). In addition, mining camps are areas where prostitution and drug use are common, exposing miners and communities to increased risks of HIV/AIDS and other sexually transmitted diseases (Ballard and Banks, 2003; Hentschel et. al., 2003).

Communities bear the brunt of ASM operations taking place in their environment, neighbourhoods, and homesteads.

**Health Issues**

Mines workers in the ASM sites are continuously exposed to high health risks. However, the migratory nature of ASM activities as well as the workers, poses a challenge in enforcing environment, health and safety. This situation is worsened by the fact that ASM is a largely informal activity where adherence to labour laws and safety management measures are often not taken into consideration.

ASM miners are exposed to multiple toxic hazards as they go about extraction and processing different minerals that they extract, most notably mercury, lead, cyanide, arsenic, cadmium, and cobalt. The main mineral mined by ASM in the Eastern and Northern African Region is gold thereby making mercury usage the single most pressing issue impacting health and safety of the miners, the mining communities, and the environment. ASM gold mining is the largest human source of mercury emissions, contributing around 35% of total anthropogenic emissions globally (UNEP, 2013).

*Mercury*

Mercury exposure occurs mainly in gold mining, where milled ore is mixed with mercury to form an amalgam, and the amalgam is then vaporized and produces highly toxic mercury vapor. Mercury, once taken in, is accumulated into the human body and attacks the central nervous system resulting in numbness and unsteadiness in the legs and hands, awkward movements, tiredness, ringing in the ears, narrowing of the field of vision, loss of hearing, slurred speech, loss of sense of smell and taste and forgetfulness. Mercury poisoning may lead to a disease known as Minamata. Minamata disease was first detected in 1956 in Minamata, Japan.

Many gold miners show symptoms of a chronic inorganic mercury vapor intoxication, which can also be found in affected communities.

Since the early 1990s, the reduction or elimination of mercury in AS gold mining has been a focal point of several international initiatives. The Global Mercury Project launched in 2002 by the United Nations Industrial Development Organization (UNIDO) was formed to assess the extent of mercury contamination in AS gold mining areas of the world, remove barriers to the adoption of cleaner technologies, and build capacity for the development of policy, regulatory, and economic mechanisms to minimise mercury pollution (Spiegel and Veiga, 2005; Veiga and Baker, 2004).

*Cyanide*

Cyanide exposure is another very serious hazard of gold mining and occurs when cyanide is used as an alternative to mercury in the separation of gold from ore. Cyanide adversely affects respiratory and cardiovascular health and is known to adversely affect the central nervous system.

*Lead*
Lead, arsenic, and cadmium exposure occurs in mines where lead, arsenic, cadmium, gold, and other metals occur together in the mineral ore. Lead is a neurotoxic substance, negatively affecting the pre- and post-natal cognitive development. Lead is a human carcinogenic substance. Lead exposure in ASM causes severe clinical symptoms, such as anaemia, abdominal pains, seizures, encephalopathy up to increased mortality. Arsenic is a carcinogenic substance which causes dermatological, pulmonary, and cardiovascular and skeletal health.

*Cobalt*
Cobalt exposure occurs in cobalt mining. Exposure to cobalt can cause negative effects to the pulmonary, haematological, endocrine, and nervous system.

The above exposures have multiple adverse health outcomes, including serious social implications on miners and the mining communities.

Workers in ASM sites also suffer from various other health issues including exposure to colossal amounts of dust and noise. Sustained noise exposure mainly from dynamites and heavy machinery, such as ball mills, can lead to hearing loss, as well as cognitive and behavioural disabilities. Labor at these sites is also physical, heavy, and repetitive, which can result in musculoskeletal injuries. The temporary nature of some of the sites also means that the sanitation facilities are lacking or are heavily stretched. Most sites lack clean drinking water, properly constructed latrines and overall poor sanitation leading to gastrointestinal diseases.

**Safety Issues**
ASM is highly dangerous work associated with multiple occupational and environmental hazards. In most mines little consideration is given to health and safety. Most ASM sites utilise rudimentary equipment and crude methods which are likely to increase the severity of occupational exposure to physical and chemical hazards (Smith et. al., 2016).

Miners are exposed to a myriad of safety risks at ASM sites that lead to serious injuries and fatalities. Due to the informality of the sector, most of these incidences do not get reported; hence, lack of comprehensive data on the frequency. Some of these risks include:

- **Collapse of pits, shafts and tunnels**. This is due to poor construction or lack of reinforcement. Miners especially in artisanal sites cannot afford the costs of timbering the shafts or using other alternatives to secure the pits. Most of these sites are also temporary; hence, do not warrant much investment in safety measures. Other risks to the pits, shafts and tunnels that result in massive loss of lives are landslides, flooding, and lack of ventilation;

- **Lack of Personal Protective Equipment (PPE)**. Some miners blame this on the prohibitive costs of some of the relevant PPE gear required to safely conduct their work. Others complain of the discomfort of protective gear inside some of the poorly ventilated shafts that become unbearable in the conditions underground. There is also a general lack of appreciation and understanding of the importance of PPE among most of the ASM labourers and also how to use it;
- **Using inappropriate or poorly maintained equipment** that leads to injuries or production of dangerous fumes underground from equipment using heavy diesel fuels that are poorly maintained.
- **Fatal falls resulting** in injuries since most sites have not invested in any safety precautions like metals railings or support mechanisms to use when going into or out of the pits or when hoisting ore, which is often carried manually from the shafts to the surface; and
- **Injuries from poor usage and handling of explosives**. Explosives used for blasting in ASM sites are sometimes illegally acquired hence miners cannot seek the assistance of an experienced professional to ensure safe use.

A summary of the main occupational hazards in ASM sites and proposed preventative and control measures is listed in Table 3 below:

TABLE 3 | HAZARDS AND PREVENTATIVE AND CONTROL MEASURES

| Type of Hazard | Preventative and Control measures |
|---|---|
| Dust | PPEs (i.e. masks)<br>Water spraying<br>Use of wet drilling techniques |
| Rock falling | Securing entrance to the shafts<br>PPEs (helmets)<br>Introduction of safety chambers |
| Harmful fumes | PPEs<br>Sufficient Ventilations<br>Monitoring air quality<br>Use of appropriate and maintenance of equipment<br>Use of appropriate technology (e.g. retort) |
| Noise | PPEs (ear plugs) |
| Ventilation issues | Mechanised ventilation<br>Natural ventilation |
| Lighting | Use of headlamps<br>Use of low voltage solar powered lighting system<br>Use of portable electric lamp |
| Roof failure | Timbering, Grouting, Pillars |
| Vibrations | PPEs (leather gloves, safety goggles)<br>Suppression at source<br>Vibration dampers<br>Blast design |
| Underground water and flooding | Dewatering/pumping out water around working area<br>Draining water into a sump |
| Heat stress | Provisions for drinking water<br>Ventilation |
| Sanitation | Provide adequate sanitation facilities on the surface. |
| Conveyance (ore hoisting) | Routine inspection and maintenance<br>Use of steel ladder<br>Use of steps |
| Occupational Injury | Use of appropriate PPEs<br>First aid kits<br>Training and awareness |
| Waste Rock/soil | Dispose of exhausted workings<br>Siting of waste rock stockpiles<br>Reasonable height and slope of stockpiles<br>May be used as construction material |

Source: Draft Guidelines for Health, Safety and Environment in ASM, Kenya, OSHA, 2007

## Conclusion

The influential Global Report on Artisanal and Small-scale Mining produced by the Mining, Minerals, and Sustainable Development Project (MMSD) proposed a number of reasons for increased health and safety risks in the ASM sector. These include: 1) A lack of economic resources; 2) A lack of or non-application of safety regulations; 3) A general unawareness of health and safety risks; 4) Illiteracy; 5) A lack of training; 6) Inadequate equipment; and 6) The remote location in which many ASM activities take place (Hentschel et al., 2003).

The above stated reasons show there is need for interventions from various stakeholders to assist in not only advocating for the formalisation of the ASM sector but also training of miners and the ASM casual labourers on the social, health and safety risks of their work.

Governments should put in place frameworks and mechanisms for safeguarding the health and safety of ASM operators. This should include availing resources for training, site inspections and supervisions of areas with intensive ASM activities. They should also try to make available public services, such as security, dispensaries and safe drinking water to miners and communities around ASM operations. This would help treating some of the health issues and fatalities and mitigating the diseases brought about by poor sanitation.

Finally, a rallying call to purchasers of minerals in the supply chain to promote responsible sourcing practises by performing due diligence on the source of their minerals. Insisting that minerals sourced from ASM sites should demonstrate adherence to basic environment, health, and safety safeguards. Mid- and down-stream stakeholders can also partner in purchasing or donating safety and protective equipment to ASM operators in some of the sites where they source their minerals. This would incentive the miners to do their best to implement some basic health and safety measures to secure their workplace.

Mining site in Tanzania

# HOW TO ORGANISE AND DEVELOP AN ASM MINING SITE

*By Professor Salvador Mondlane Junior; Eduardo Mondlane University, Geology Department and Geo-Management Services and Constancy, 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 Africa Mining Vision (AMV), between 15-20% of the world's non-fuel minerals, 18% of Africa's gold and almost all African gemstones (except diamonds and some rubies) are produced by the ASM sector, which indicates that this sector greatly contributes to both 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 the Democratic Republic of the Congo (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 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 Markets**

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 reviewed Mining Codes 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. In Mozambique it is only lately that the Unity for Management of the Kimberly (UGPK) was empowered with capacity to bring the production from ASM, especially gold into a traceable revenue stream to an extent that the gold produced by ASM has rose to kg in 2020, 800 Kg in 2021, and record figure of 1264 Kg in 2022

The typical market structure of minerals commodities produced by ASM is presented in Figure 5 below.

FIGURE 5 | 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 PROCAGEME 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 operational 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 EMP), while quite strict for small-scale miners, who are expected to produce in many cases an 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 the 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 to 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 it is very expensive, has complex requirements and is a very lengthy process, 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 lags 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 African Union Commission 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 multi-stakeholder 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” – multi-stakeholder partnership, which would coordinate the mining interventions in Africa.

ASM mining in Tanzania

# 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 provides 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 does however 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). 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. 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 different armed groups in eastern DRC (Kivu Security Tracker, 2021).

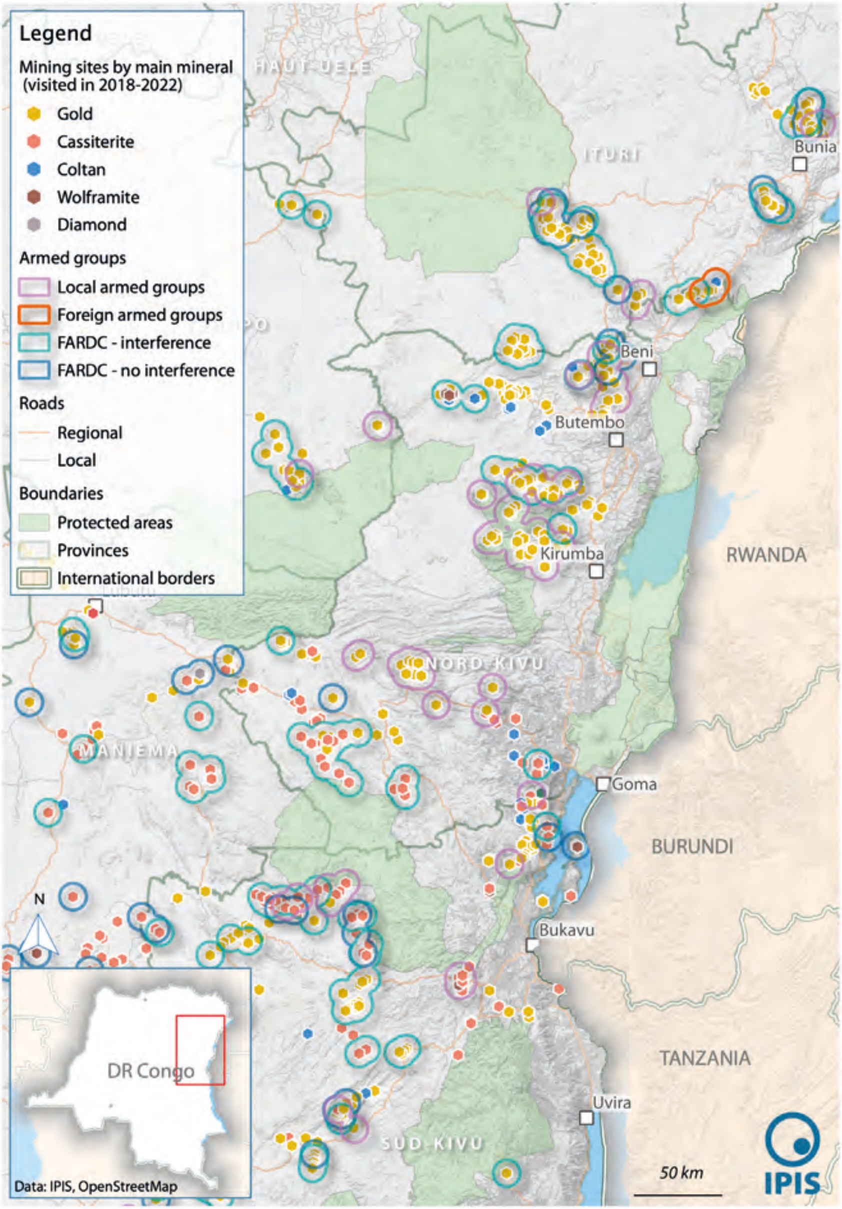
Nevertheless, it is possible to see some evolutions. During the first years after the transition, some sizeable armed groups were involved in intense fighting in the Kivu provinces, including the National Congress for the Defence of the People (CNDP), Forces Démocratiques de Libération du Rwanda (FDLR), the Congolese National Army (FARDC), and the Mai Mai - a plethora of local defence militias (Spittaels S. and Hilgert F, 2008). All these armed actors profited 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 artisanal and small-scale mining sites in eastern DRC (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 tends 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). Since early 2022, the regional dimension of conflict in eastern DRC gained in importance once again, with the revival of M23. In response to this development, several of the local armed groups formed new alliances to resist M23. Illegal profiting from mineral persisted unabated in the meantime.

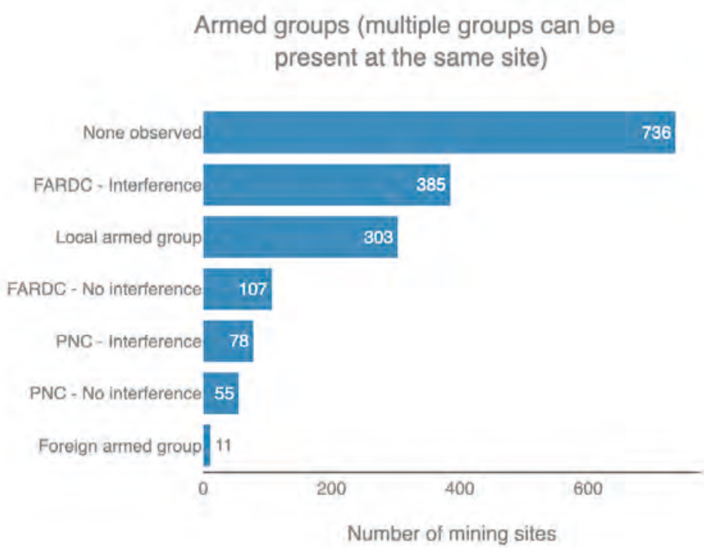
The map in Figure 6 shows the extent to which mining sites are affected by the interference of armed men. Of the mining sites visited by IPIS between 2018 and 2023, 47% (655 out of 1,391 sites) is still suffering from the interference of armed men, ref. Figure 7.

FIGURE 6 | INTERFERENCE BY ARMED ACTORS AT MINING SITES IN EASTERN DRC, 2018-2023




Source: IPIS

FIGURE 7 | PRESENCE OF ARMED ACTORS AT MINING SITES IN EASTERN DRC (TOTAL OF 1,394 SITES), 2018-2022



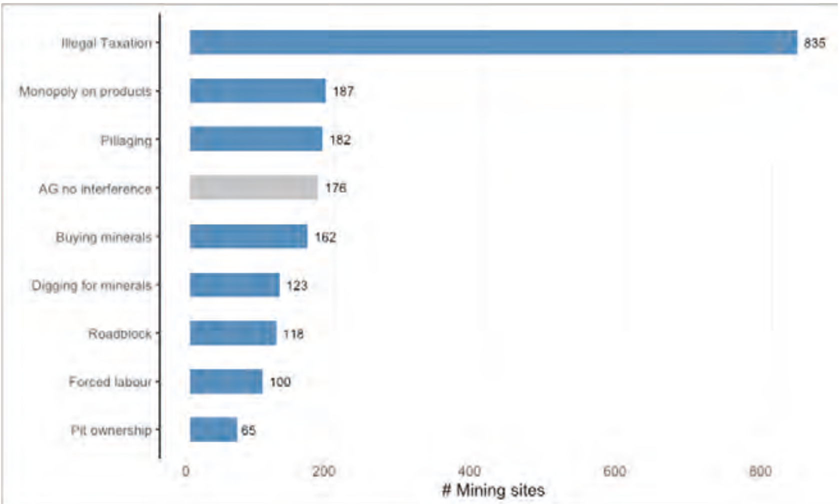

Source: https://ipisresearch-dashboard.shinyapps.io/open_data_app/

## 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 8. Several armed groups do not exercise this level of control, but rather turn to regular pillaging of mining sites (IPIS/CIFOR, 2012).

FIGURE 8 | 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 1,391 mines visited by IPIS between 2018 and 2023, the main culprits of armed interference were the FARDC. They were responsible for armed interference at 59% of the 'affected' mining sites, 385 out of 655.

The criminal behaviour and lack of discipline within the FARDC are the results of various factors: including 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 regarding 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 non-state armed actors 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 and mineral supply chains).

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 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). Other resource generating activities include 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 resulting in misleading policy advice.

It is very difficult to put one's finger on conflict and insecurity in eastern DRC. Conflict drivers include disputes, political and economic interests at the local level, up to national and regional level. 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 national 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.

LSM in Tanzania

# MINERAL PROCESSING IN ASM

*By Professor Salvador Mondlane Junior; Eduardo Mondlane University, Geology Department and Geo-Management Services and Constancy, 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 forms 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).

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 liberated 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 of 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 valuable metals 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 is used.

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 (between 15th and 18th century). 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 9. 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 minerals which includes gold, magnetite, and other minerals.

FIGURE 9 | GOLD PANNING IN THE MUNHENE STREAM, MANICA, MOZAMBIQUE


Source: Professor Salvador Mondlane Junior

The coarse gold is also recovered using locally home-made sluices, ref. Figure 10. 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 10 | HOME MADE SLUICES FOR GOLD RECOVERY IN MANICA, MOZAMBIQUE

Source: Professor Salvador Mondlane Junior

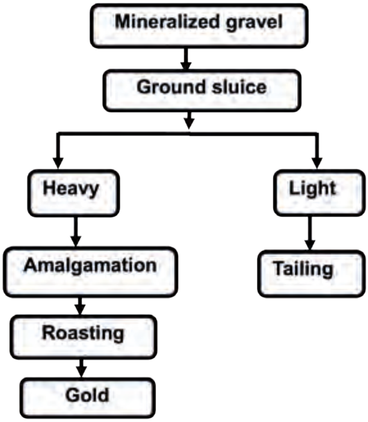
Figure 11 below shows the gold processing flow chart for the coarse gold. In some countries, the concentrate is amalgamated using mercury and then the sponge gold (mixture of gold and mercury) is roasted, and the mercury evaporates at 60 degrees Celsius and gold bullion is obtained. This bullion might 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, grinding, sieving, and milling as shown in Figure 12.

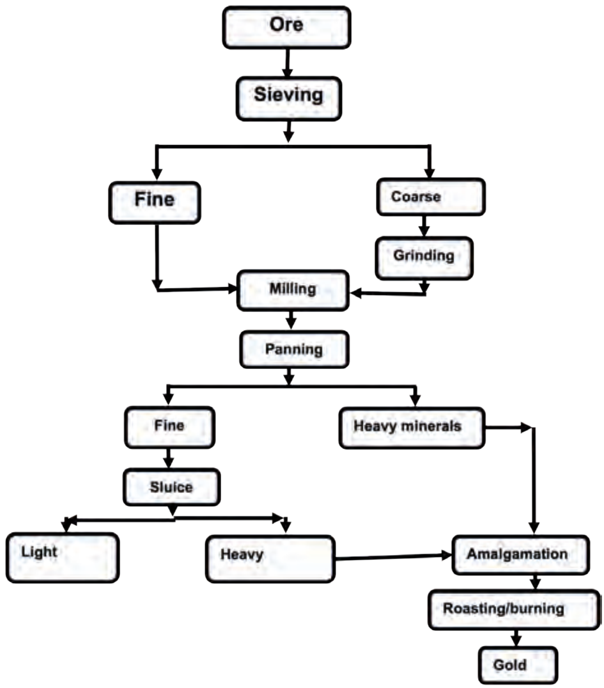
Other gold processing methods include the direct smelting technique – in this process, the melting point of the materials is lowered by adding borax to an extent of reducing the melting point. The major disadvantage of this method is that it requires a lot of energy, something that is difficult to achieve with use of firewood, it requires the use of gas tosh or high-temperature ovens.

FIGURE 11 | FLOW CHART OF FREE GOLD PROCESSING (EXAMPLE)




Source: Professor Salvador Mondlane Junior

FIGURE 12 | 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/abrasion. 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 generally 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 especially by ASMs.

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 to increase the performance of ASM.

ASM in Bareta in Ethiopia

ASM in Bareta in Ethiopia

# ASM SECTOR OF ETHIOPIA

*By Dejene Hailemariam Feyissa (PhD) and Guta Legesse Tessema (PhD)*

## Geographical Context of Ethiopia

### Demography of Ethiopia

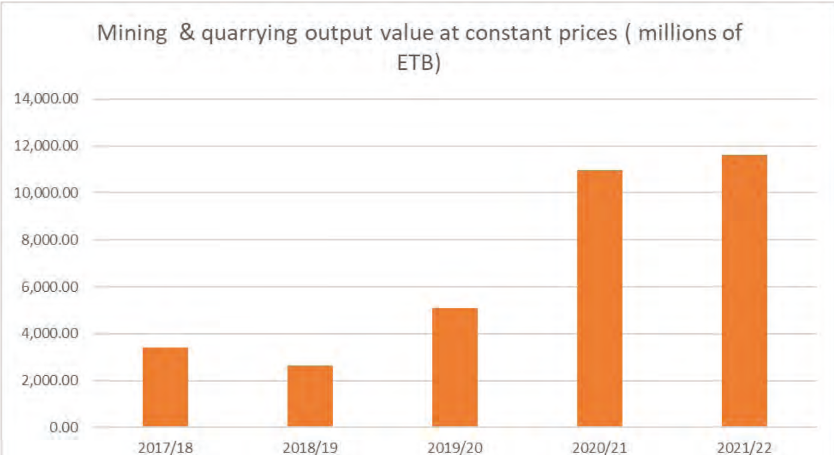
Ethiopia is the second most populous country in sub-Saharan Africa. It currently inhabits about 120.7 million people, of which 84% resides in rural areas (UNDP, 2015). The population of Ethiopia is expected to grow by 2.6 million in 2023, reach 123.4 million in 2024, and be among the ten most populous countries by 2050 (World Bank, 2014). The demographic makeup of Ethiopia comprises 60.4 million women and 60.3 million men. When it comes to age distribution 48.6% are below 19 years old, 47.7% is between 20 and 64 years old, and 3.7% is over 65 years old. This shows that the country has a large trainable workforce, which is a potential for future development.

### Economy of Ethiopia

Ethiopia is one of the fastest-growing economies in the world with a real GDP growth rate of 6.1% in 2021/22 (National Bank of Ethiopia, 2022). Ethiopia had a real GDP of 2.2 trillion ETB in 2022 (National Bank of Ethiopia, 2022), which is equivalent to USD 48 billion. However, using current price approach, the country's GDP is USD 126.783 billion. The economy is a mixed and transition economy with a large public sector; however, the country is in the process of privatising many of the state-owned sectors, such as the banking, telecommunication and transportation sector and moving toward a market economy.

Mining offers an important diversification potential from agriculture, which has dominated the economy of Ethiopia to date. The mining sector is one of the five growth pillars of the economy following the introduction of home-grown economic reform in 2019. Currently, mining comprises less than 1% of GDP (National Bank of Ethiopia, 2022), 14% of exports, 1% of government revenue and was only able to create 4,000 formal jobs in 2018. Gold, gemstones (opal, sapphires etc.), and industrial minerals are important commodities for the country's export-oriented growth strategy. The country has deposits of coal, opal, gemstones, kaolin, iron ore, soda ash, and tantalum, but only gold is mined in significant quantities. In its Growth and Transformation Plan, Ethiopia has set as a target for its mining sector to contribute to 10% of GDP by 2025, ref. Figure 13 and Figure 14.

FIGURE 13 | MINING AND QUARRYING OUTPUT VALUE AT CONSTANT PRICES (MILLIONS OF ETB) OF ETHIOPIA FOR THE PAST 5 YEARS




Source: National Bank of Ethiopia, Annual Reports (Various Years)

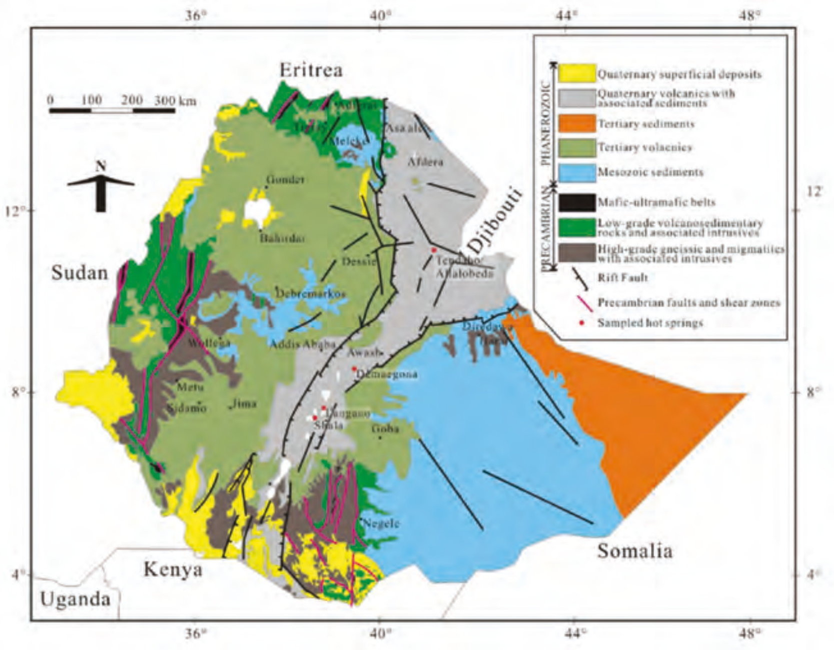
FIGURE 14 | MINING AND QUARRYING OUTPUT SHARE FROM GDP OF ETHIOPIA FOR THE PAST 5 YEARS


Source: National Bank of Ethiopia, Annual Reports (Various Years)

# Geological context of Ethiopia

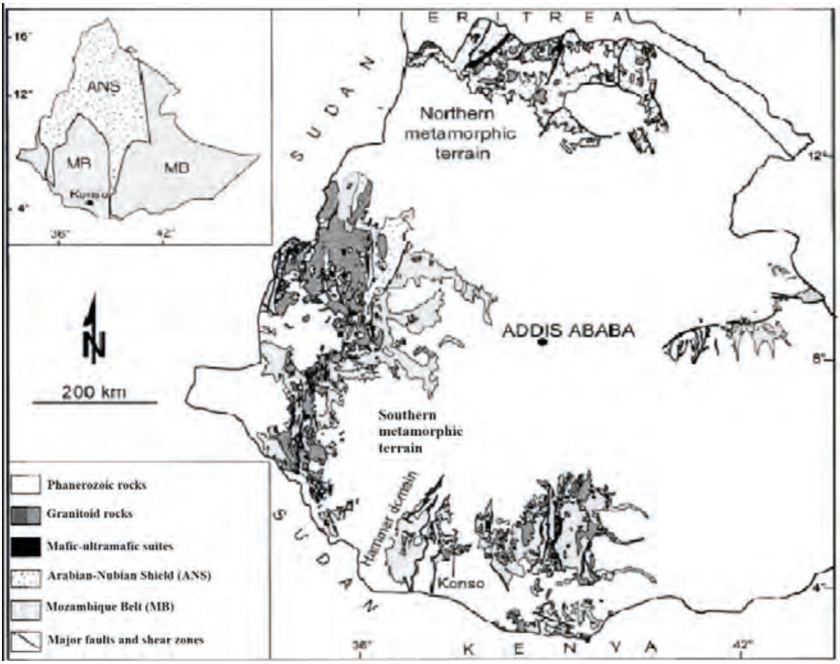
## Simplified Geological Map of Ethiopia

FIGURE 15 | A SIMPLIFIED GEOLOGICAL MAP OF ETHIOPIA




Source: Geological Survey of Ethiopia, Ministry of Mines, Addis Ababa, Ethiopia

FIGURE 16 | A SIMPLIFIED GEOLOGICAL MAP OF THE METAMORPHIC TERRAINS OF ETHIOPIA




Source: Geological Survey of Ethiopia, Ministry of Mines, Addis Ababa, Ethiopia

**Brief Description of National Geology**

The geology of Ethiopia is represented by rock types ranging in age from Precambrian to Recent. These rocks are categorised into the following geologic formations:

a) Precambrian rocks;
b) Paleozoic-Mesozoic sedimentary rocks; and
c) Cenozoic volcanic rocks and associated sediments.

*Precambrian Rocks Evolution*

Precambrian metamorphic and associated intrusive rocks make up 25% of the Ethiopian landmass. They are exposed in the northern, western, southern, and eastern parts of the country and have a fundamentally important tectonic position and occupy the interface between the Mozambique Belt (MB) in the south and the Arabian-Nubian Shield (ANS) in the north as shown in Figure 15 and Figure 16.

The Precambrian rocks of Ethiopia were traditionally divided into Lower, Middle and Upper Complex based on the variation in grade of metamorphism (Kazmin et. al., 1978). The low-grade rocks belong to the Upper Complex, the high-grade to the Lower Complex, and the medium grade to the Middle Complex. Kazmin et. al. (1978) also considers the Upper Complex rocks to be Late Proterozoic in age and Middle and Lower Complexes to be Middle and Early Proterozoic (or Late Archean). But subsequent studies based on the geochronological and isotopic data have suggested that the Precambrian basement rocks are dominantly Neoproterozoic in age and have experienced different grades of metamorphism (Gera, 2000; Teklay et al., 1998; and others). Furthermore, Asrat et.al. (2001) in tune with the geochronological and other data regrouped the basement rocks into two major blocks: Volcanic-sedimentary terrain (including the younger metasediments), and the Gneisic-migmatitic terrain, separated by numerous Ophiolitic sutures.

*Paleozoic-Mesozoic Sedimentary Rocks*
A thick succession of Palaeo-Mesozoic sediments covers 25% of the country's landmass and is represented by three distinct sedimentary basins, as shown in Figure 15, namely the Ogaden Basin (350,000 km$^2$), the Abay (Blue Nile) Basin (63,000 km$^2$), and the Mekele Basin (8,000 km$^2$) (Dow, 1971; Kazmin 1972 and 1975; and Davidson, 1983). The development of the basins can be thought of as relating to the polyphase break-up of Gondwanaland, which was accomplished, in general by reactivation along the preexisting Precambrian structures. The Ogaden Basin contains places with over 10,000 m thick sediments, which consist of non-marine to deep marine clastics, very thick, shallow-to-deep marine carbonates and evaporites. The Abay Basin consists of Paleozoic and Mesozoic sedimentary succession exceeding 2000 m, which are represented by pre-Adigrat clastics, equivalent to the Karoo system in the Ogaden, the Antalo limestone, and the Amba Aradom Formation (the Upper Sandstone). The sedimentary succession of the Mekele Basin comprises 2000 m thick sediments ranging from fluvio-lacustrine to shallow and deep marine types.

*Cenozoic Volcanic Rocks and Associated Sediments*
Cenozoic volcanics and sediments cover 50% of the country's landmass and range in age from the late Eocene up to historical times. Volcanism started during the Eocene-late Oligocene with the eruption of flood basalts that have generally been related to either one or two mantle plumes impinging the base of the lithosphere under Afar or Afar-Northern Kenya rifts (Pik et. al., 1999; and Kieffer and Arndt, 2004). The total areal coverage is estimated at 720,000 km$^2$ and 720,000 km3 (Rooney, 2017). The earliest flood basalts forming the Ethiopian Plateau apparently erupted in a rather short time interval (<5 Ma) with the greatest eruption rates occurring from 31 to 28 Ma (Hofmann et. al., 1997; Rochette et. al., 1998). This strong eruption was concomitant with the onset of continental rifting in the Red Sea-Gulf of Aden systems by 29 Ma but predates the main rifting phases associated to the development of the Main Ethiopian Rift (MER) (Hofmann et. al., 1997; Davaille et. al., 2005). Immediately after the peak of volcanic activity related to the flood basalt emplacement, several large shield volcanoes developed on the surface

of the volcanic plateau. This subsequent less voluminous volcanic activity formed some of the highest relief of the plateau (such as Mts. Ras Dashen, Guna and Choke) (Hofmann et. al., 1997; Kieffer and Arndt, 2004). Time correlative basaltic units are widespread both in the western (Wollega and Lake Tana basalts, 11- 9 Ma) and in the southeastern Ethiopia Plateau at about 10.5-9 Ma. After these episodes of widespread flood basalts and subordinate silicic volcanics, volcanism is closely associated with the tectonic development of the MER (Chernet and Hart, 1999). Rifting in the various MER sectors was characterised by volcanism with fundamentally bimodal character. Widespread late Miocene-Pliocene rhyolitic ignimbrites (~7-3 Ma) with intercalated minor mafic lavas occur throughout the Northern and Central MER (Rooney et al., 2005). In the Quaternary (<1.6-1.8 Ma), bimodal volcanic rocks (lava, pyroclastics and volcanoclastic strata) were generally closely associated with Wonji Fault Belt affecting the rift floor.

In the course of the development of parts of the Great East African Rift System in Ethiopia, a variety of continental sedimentary basins were developed since Miocene (Le Fournier et. al., 1985). In the Afar Depression, sediments originating from the rapid erosion of the steep escarpments together with abundant volcanic products tended to fill the depression, but tectonic deepening was more rapid than volcano-sedimentary infilling. Moreover, the nature of the sediments was dependent on whether the basins are marginal or axial. Evaporite beds have also been formed during the restricted marine invasion of the northern Afar Depression (Danakil Depression). Plio-Pleistocene fluvo-lacustrine sediments are also widespread in the Ethiopian Rifts in the MER. Lacustrine sedimentation is widespread during the pluvial periods of the Quaternary.

All this shows that Ethiopia is endowed with the above-mentioned three main rock types and the country has huge untapped resources, such as diversified minerals, geothermal and petroleum, which has led the Government to consider the mining sector as one of its priority areas and growth pillars recently.

## ASM in Ethiopia

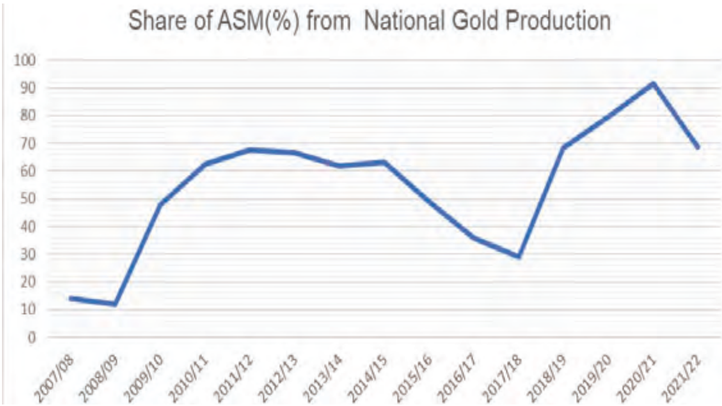
### Substances Exploited by ASM Operators in Ethiopia

ASM refers to a mining operation carried out by individuals or small and micro enterprises that is mostly of manual nature and that does not involve the engagement of employed workers (Proclamation No. 678/2010 and its Amendment No. 816/2013). ASM often provides the only means of obtaining income for many low-income Ethiopians in remote rural areas, who have few off-farm livelihood alternatives and it has the potential to economically empower disadvantaged and vulnerable groups in the resource rich areas of country.

Currently, ASM miners are engaged predominantly in the mining of metallic minerals mainly gold, gemstones, coal, industrial minerals, and construction materials, such as gypsum, marble, pumice, kaolin, salt, silica sand and gravel. ASM can play an important role in the discovery of new minerals deposits and reduce urban migration.

The number of ASM miners is estimated at 1.26 million, with direct and indirect beneficiaries totalling 7.5 million people of which more than 30% are women (Ethiopian Extractive Industries Transparency, 2016). In gold production, the role of ASM miners has been quite significant. In 2020/21, they contributed over 90% of the total gold production in the country as shown in Figure 17.

FIGURE 17 | SHARE OF ASM (%) FROM NATIONAL GOLD PRODUCTION




Source: Ministry of Mines, Ethiopia

The Government of Ethiopia and the Ministry of Mines have demonstrated political will to support ASM as part of their reform agenda and guide its formalisation as evidenced by the National ASM Strategy Roadmap, which has four thematic areas: 1) Governance; 2) Business; 3) Economic linkages; and 4) Social, environment, health and safety.

There is wider recognition of the ASM sector's role and potential in contributing significantly to the Ethiopian economy through employment for both women and men, export earnings and household income. The Government, through the Ministry of Mines, intends to formalise and improve management of the sector to maximise its potential as a vehicle for poverty alleviation and inclusive economic growth. The National Artisanal and Special-Small Scale Mining Strategy defines a roadmap that sketches the vision, objectives and key activities needed to boost compliance with existing laws and regulations, address administrative bottlenecks with licensing, and sustainably build the capacity of government agencies, ASM stakeholders and civil society to sustain progress. Formalisation is of utmost importance to increase the mineral yield produced by ASM miners. By formalising the ASM activity it is possible to mechanise the mineral production by ASM miners.

**Legislative Framework for the ASM Sector in Ethiopia**

In Ethiopia, the following laws and regulations govern ASM activities:

a) Mining Operations Proclamation No. 678/2010, Amended under Proclamation No. 816/2013;
b) Mining Regulation No. 423/2018;
c) Transaction of Minerals Ratification Proclamation No. 1144/2019;
d) Definition of Powers and Duties of the Executive Organs Proclamation 1263/2021;
e) Transaction of Precious Minerals Proclamation No. 651/ 2009;
f) Mining Operations Regulations No. 182/ 1994, Amended under Regulations No. 27/1998;
g) Mining Income Tax Proclamation No. 53/ 1993, Amended under Proclamation No. 23/1996; and
h) Different Mining Directives.

Legal ASM miners are those organised as a formal Mining Development Group or as a Mining Cooperative.

Regions have the full authority to issue rules and regulations applicable within their geographical jurisdictions; hence, ASM miners operating in different regions may face heterogeneous incentive packages and privileges. These laws and regulations are supposed to work under the umbrella of the federal governmental laws and in case of conflict, the federal governmental laws supersede the regional laws as stipulated in the Constitution of the country. Some inconsistencies are observed between rules and regulations of the regional governments and the federal government.

The federal government regulates the transaction of minerals produced in the country by all and monitors the environmental safety and standards. Local community empowerment, development of youth employment, and capacity building initiatives are indeed the duties of the federal government too.

In 2013, when the Mining Operations Proclamation was amended, the licensing period was reduced to a maximum of two years with no possibility of extension/ renewal from initially three years with an option to extend for another two times three years. This has created a lot of confusions and concerns on its practicability and environmental protection. The first concern is related to the sufficiency of the duration of the license for graduation and promotion of ASM. The second concern is that if the ASM miners know that their license will not be renewed, they will become more reluctant to care about the mining site's rehabilitation aggravating the existing environmental degradation of the area in and around the mining sites. Finally, non-renewability could be a source of potential conflict that may arise due to the transfer of rights from the old to the newcomers. Given limited off-farm activities in many of the mining sites, taking a mining site from one group and giving it to another could prove risky and difficult for local administrators. It is therefore important to design a mechanism to understand and facilitate graduation and promotion of ASM into Speal Small-Scale Miners.

**Degree of Organisation of the ASM Sector**
The ASM sector in Ethiopia is organised and has developed as follows:

a) Cooperatives: Individual miners come together and form a cooperative, which include 50 to 200 members on average. This was a common form of organisation until year 2013;
b) Miro and Small-Scale Enterprise: This form may comprise 2 to 35 members represented by an enterprise bureau/office. This form began developing from year 2013 and onwards; and
c) Special Small-Scale Miners: This is an upgrade of a cooperative or an enterprise, since ASM miners can use modern technology and machinery. This form came into implementation from year 2014.

**Role of the National Geological Survey to Support the ASM Operators**
The Geological Institute of Ethiopia (formerly known as the Geological Survey of Ethiopia) provides training and other capacity building initiatives to ASM miners. It also collects, analyses, and disseminates geosciences data and identifies ASM sites. Since 2021, The Ministry of Mines of Ethiopia also comprises the Mineral Industry Development Institute, which is mandated to support the mining business through technology, market research, human resources, and policy related interventions.

## Environmental and Health Issues Related to the ASM Sector in Ethiopia

The ASM miners are aware of the impact of their practices on the environment and to what extent they should be responsible for that according to the Mining Proclamations. In all series of Proclamations, it is clearly indicated that ASM miners are required to “fill pits and plant trees” and not make use of “mercury” or other hazardous chemicals. Additionally, all mining sites are required to undertake and submit an EIA to the Environmental Protection Agency at zonal or woreda level.

The damages to the environment by mining activities are enormous:

d) Mining activities are depleting forest, bush lands and farmlands. Miners cut trees to develop roads to get to the cliffs and around the tunnel. In some regions, excessive tree felling was observed in and around mining villages.

The trees and soil were left on the ground and no effort was made to back-fill the holes with soil;

e) Stone and soil disposed is destroying the trees and vegetation down the cliff of the mountain. There are cases in which agricultural land is found at the base of a steep slope, whereby it will be severely affected by the excavated soil thereby affecting land productivity; and

f) Mining areas are vulnerable to flooding and soil erosion and in most cases agricultural areas are irreversibly degraded.

**Impact on Water Ways**

ASM miners, specifically those mining gold, negatively impact water ways since chemicals used to wash and extract gold mix with the river/lake water.

**Impact on Deforestation**

Given that ASM miners tend to live in the place of work, i.e. mine, they build a temporary settlement by using trees and grasses and they dig many holes to find minerals, such as gold, which all lead to deforestation

**Impact on the Landscape**

In most parts of the country, ASM activities negatively impact the landscape causing deformities and landslides.

**Impact on Health among ASM Operators**

Few ASM miners in Ethiopia use proper PPE to protect their own health and safety; hence, many suffer from different health problems.

## Socio-Economic Issues Related to ASM Sector in Ethiopia

### Role of Women

In Ethiopia, prospecting and exploration activities are mainly dominated by men although women also engage in traditional gold production. However, women's main disadvantage is that they lack skills and experience in identifying gold. In addition, they have limited ability to travel away from home, which is a major challenge. There is a clear division of labour between men and women at the different stages of gold production. Women working individually or in peer groups tend to dominate placer gold mining Women also travel along with their community and prefer to extract from "false" gold, which is a remnant from the crushed and washed rock.

Women are engaged in the panning, transporting, crushing, washing, and sorting of gold while men typical dig the ground for primary gold and crush the stones. Cooperative memberships are usually family-based and include women in supervisory roles. These women supervise the labourers and manage their time. They are also responsible for measuring the daily gold output.

**Role of Child Labour**
There are few cases of the use of children in mining operations in Ethiopia. The average age of miners is 30-35 years. However, children can be involved in gold ores crushing, digging holes, washing, and sometimes buying gold.

**Conflicts with Local Farmers and Other Stakeholders**
Conflicts in and around mining sites are less common in Ethiopia since a mining license is granted by the local government. However, there are reports showing conflict and mining site overlap between local ASM miners and companies (large-scale miners) due to a lack of well-organised data on mining sites by ASM miners.

**Conflicts with Criminal Gangs in the Mining Area**
To date there are no criminal gangs or terrorist groups operating in and around mining areas.

## Conclusion and Recommendations

ASM is a primary source of employment for job seekers from various parts of the country and it is also an important source of income for the country's rural population. In addition to providing opportunities for alternative livelihoods and contributing to poverty reduction and export earnings, it also plays an important role in the discovery of new minerals deposits and in reducing urban migration.

The Government of Ethiopia and the Ministry of Mines have demonstrated political will to support ASM as part of its reform agenda and guide its formalisation.

The following measures are recommended to enable ASM to play its expected role in the country's economy:

a) Strict implementation of the National ASM Strategy Roadmap including formalisation/organisation of ASM activities in various forms is of prime importance to render technical support to ASM;
b) Allowing for renewability of ASM license is quite important for many reasons including environmental protection; hence, it is recommended that ASM license holders be granted at least one round of license renewal and more work on their graduation and promotion to special small-scale miners level;
c) More regulation on environment degradation and rehabilitation. Although ASM miners are not required to provide EIA for their operation, licensing authorities need to make sure that they are working on environmental rehabilitation;
d) Harmonization of the procedures and legal frameworks of the federal government with that of the regional governments;

e) Although the licensing procedure at the federal government is automated, the licensing procedure at the regional level is done manually. This needs to be automated to avoid site overlap and conflicts between ASM miners and large-scale miners; and
f) Increase support from the Geological Institute of Ethiopia, such as 1) access to viable mineral resources by discovering more fertile placer deposits; 2) training miners with more efficient mining techniques; and 3) introducing new mechanised mining equipment/systems.

ASM in Minch in Ethiopia

ASM in Kisolegaba in Ethiopia

# ASM SECTOR OF SUDAN

*By Mohammed Ali Hassabalkreim Siddg and Abd El Karim Mohamed*

Since ancient times, Sudan has been famous for its gold and mineral resources just as the Kingdom of Meroe (300 BC) was famous for its gold resources. Throughout different historical eras, Sudan has received immigrants in search of mining and gold deposits. Many of them settled in the countryside and in the mountains of Benishangul, the Wadi Al-Sangir area and the Red Sea in Northern Sudan.

The ASM profession has remained limited to a narrow scope of gold and chromium in the areas of Karmuk and Qaysan in the Blue Nile State. The modern boom in ASM in Sudan began around 2008. Artisanal gold mining in Sudan is spread across 16 of the country's 18 states, comprising 300 sites and more than 1.5 million workers involved in the exploration and extraction of gold. Additionally, 35 professional associations serve these miners. The official gold production statistics show the success of this economic shift. In less than ten years, national production increased from less than 10 tons per year up until 2010, to 100 tons in 2017, propelling Sudan among the leading gold producers in Africa. The production rate then slowed after 2018, partly because of a fuel crisis, which immediately translated into a decline in official exports. This decline in official production could also be explained by an increase in illegal trade boosted by the determination of the central authorities to capture this new rent.

Until the early 2010s, most of Sudan's gold production was based on ASM using very little equipment, apart from detectors, and basically represented an additional source of income for the rural population. Its tax treatment was variable and not specific to the activity: it was managed by the localities and by the federated states, which taxed the use of machinery for extraction and the service activities generated by the exuberance of these new artisanal mining activities. The latter were covered by categories provided for by law but had long been considered insignificant before 2007; practically, anyone could therefore operate without a license as long as "larger" interests were not interfered with. At the time, the central state either ignored gold panning or tried to eradicate it.  The influential people called illegal random mining traditional mining and impose this name on the official and popular domains.

## Summary of Geology

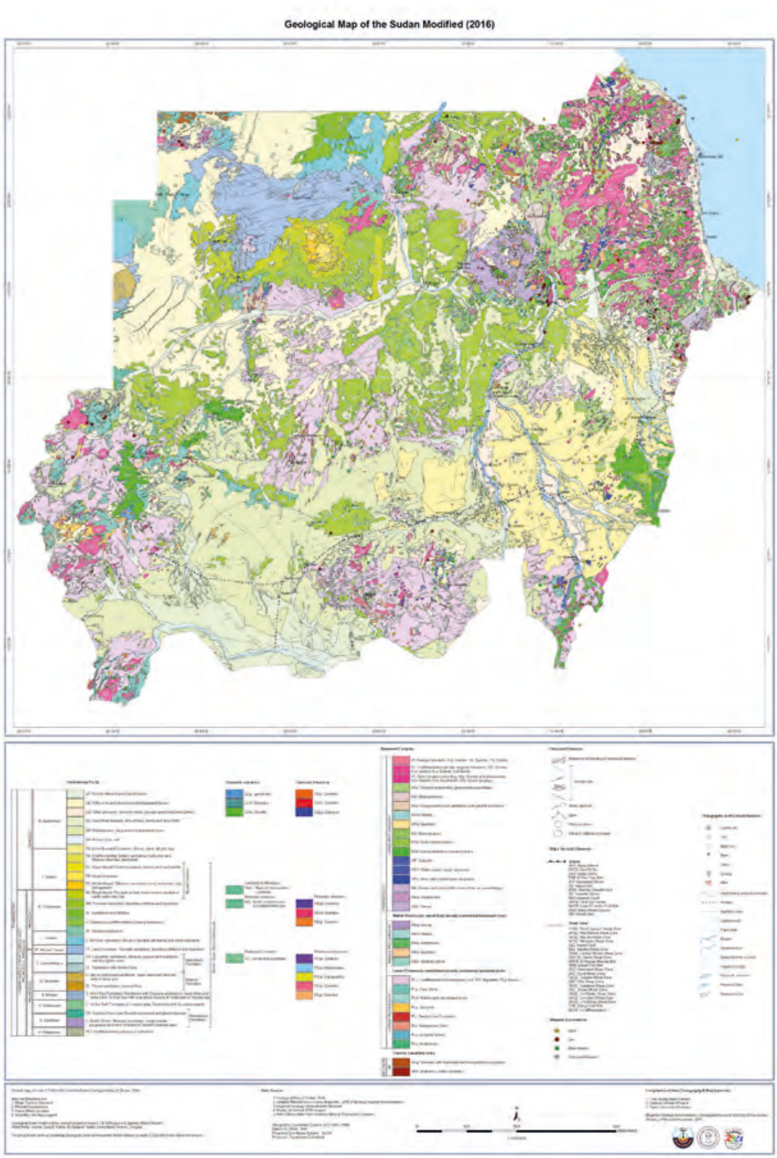
Sudan is a vast plain located in the subtropics of north-east Africana and surrounded by the countries of Egypt, Red Sea, Eritrea, Ethiopia, South Sudan, Central African Republic, and Libya The high mountains of Ethiopia and Uganda provide most of the water of the rivers, which enter the Sudan from the south and south-east and unite to form the Nile flowing northwards through flat and dry land crossing six waterfalls from South to North.

The Sudan plain consists partly of dark clays and red or brown sands and is so flat that railway lines have been laid on it for dozens of miles without embankments or cuttings. This flatness, however, is broken in places by rocky hills or mountains, sometimes isolated, sometimes in groups or chains. Some of the Ethiopian and Eritrean hills extend into the Sudan in the east - a mountainous and hilly country. In Darfur there are groups of mountains, which are the remains of old volcanoes which once erupted there, and in south Kordofan there are many rocky hills, which are collectively called the Nuba Mountains. In the north-east of the Sudan is the long range of the Red Sea Hills, which extend into Egypt and Eretria. Elsewhere, the Sudan plain is only occasionally broken by isolated" jebels", which rise sharply from the flat ground.

Sudan is largely underlain by Precambrian rocks, particularly in the southwest, centre, and northeast, which were almost exclusively reactivated during the Neoproterozoic Pan-African tectono-thermal event, ref. Figure 18.

Large parts in the north of the country are covered by continental clastic sequences of the predominantly Mesozoic Nubian cycle (previously Nubian Sandstone), and in the south by Tertiary to Quaternary unconsolidated superficial sediments. Some Tertiary and younger basalts occur in the border zone with Ethiopia.

FIGURE 18 | GEOLOGICAL MAP OF SUDAN




Source: GRAS, Updated 2012

**Stratigraphy and Tectonics**

Some rifted fragments of the East Saharan Craton occur as high-grade metasedimentary exotic terranes among the Sudanese Red Sea Hills and near Haya, southwest of Port Sudan. These terranes are also termed the "older shelf sequences" and contain mostly quartzites associated with marbles probably representing a passive continental margin about 900–800 Ma ago.

Otherwise, the basement complex of Sudan includes reworked Precambrian inliers reactivated during Pan-African tectono-thermal activities, namely the Nuba Mountains, the Darfur block and the Bayuda and Nubian deserts. In the latter area high-grade granitoid gneisses with minor inliers of high-grade metasediments were migmatised and intruded by voluminous granitoids late in Pan-African times. Small inliers of amphibolite-facies gneisses and metasediments occur also within the lower-grade volcanogenic ophiolite assemblages of the Red Sea Hills of the country. Generally, it has been assumed that the metasedimentary belts scattered between the East Saharan Craton and the Red Sea Fold and Thrust belt represent a zone of early rifting that developed along the eastern margin of the East Saharan Craton during the initiation of a Neoproterozoic Ocean.

The Jebel Rahib Belt in central northwestern Sudan contains complex deformed ultrabasic and basic igneous rocks and a thick sequence of arenaceous and subordinate carbonaceous metasediments, which have been interpreted as a Red Sea-Type Pan-African rift basin. An age of 570 Ma from post-orogenic granitoids, which were not affected by the penetrative NNE-SSW strike-slip shearing in this belt, sets the minimum age for its deformation and low-grade metamorphism. An ophiolite assemblage with ultramaifc rocks, pyroxenites, podiform chromites, massive and layered gabbros, dykes, pillow-lavas and chert deposits furnish the evidence of newly formed oceanic crust in the Jebel Rahib rift. These ophiolitic rocks imply the suggestion that juvenile Pan-African rocks were generated in the Nubian Shield outside the Red Sea Fold and Thrust belt. In its depositional setting and structural style, the North Kordofan Belt in central Sudan is similar to the Jebel Rahib Belt, except that ophiolites have not been found. Among intrusive granitoids, a tourmaline-bearing granite has been dated at about 590 Ma. Late Pan-African shear zones, which are sealed by mica-bearing pegmatites, have yielded ages of about 560 Ma.

The low-grade metasedimentary Darfour Belt in central western Sudan, structurally overlying basement gneisses in the southeastern Darfour block, may also be equivalent to the North Kordofan and Jebel Rahib metasediments. Intrusive granitoids have yielded ages of about 570–590 Ma in the Darfour Belt. In the eastern Nuba Mountains in central Sudan a NE-SW to NNE-SSW striking belt of low-grade volcano-sedimentary rocks is exposed, which contains fragments of highly dismembered ophiolites and basic to acidic plutons. These arc ophiolitic assemblages were metamorphosed at about 700 Ma, with post-tectonic magmatism ceasing at around 550 Ma. The Pan-African juvenile terrane of the eastern Nuba. Mountains represents either a klippe thrust over a considerable distance from the east, or more likely a minor ocean basin behind a large, probably rifted of continental fragment. Pan-African rocks occur also as two different tectono-stratigraphic units in the Bayuda Desert in northern central Sudan. First, on the eastern part along the river Nile, is a narrow strip of low-grade metasediments, metavolcanics and granitoids, which range compositionally from early tonalites through granodiorites to large peralkaline granites. Granitoids were emplaced twice, at about 898 Ma and at about 678 Ma. Anorogenic within-plate magmatism followed and yielded an age of about 549 Ma. An extensive metasedimentary sequence of marbles and intercalated metaquartzites is exposed between River Nile and the Red Sea Hills west of Gabgaba, which may represent an autochthonous continental margin deposit.

A long period of pediplanation ensued after the formation of the basement complex structures, and as a result unmetamorphosed Paleozoic and Early Mesozoic rocks are unknown or uncommon in Sudan.

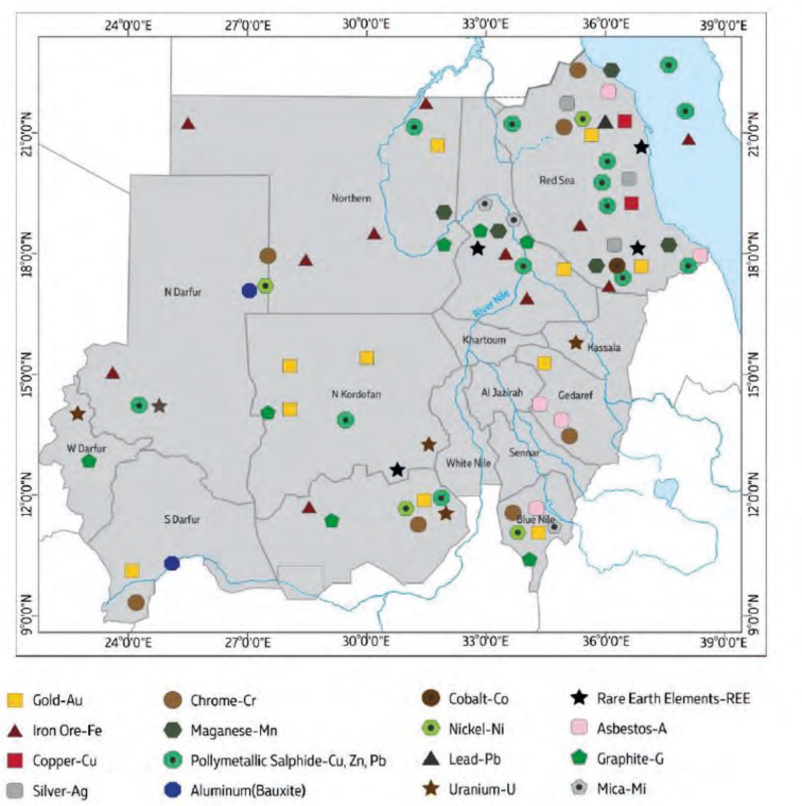
Early Cambrian rocks occur at Sabaloka, which yielded an age of about 530 Ma.

The overall structural picture, which emerges for the Red Sea depression is that it is not fault bounded. Apparently developed during Carboniferous times a zone of subsidence in the Gulf of Suez, and probably during Mesozoic times this had extended to the central zone, the Red Sea depression having developed largely between two marginal monoclonal flexures situated near the present Sudanese and Arabian shores. The swell continued to rise reaching a culmination in Late Eocene times. The climax of rift-system faulting took place in Oligocene and Early Miocene times. Subsidence accompanied by faulting continued on the downside of the Sudan monocline zone resulting in the accumulation of more than 4,300 m of sediments in the near-shore part of the Suakin Archipelago. The sediments probably filled the trough from shore to shore. In Miocene times lagoonal conditions apparently prevailed throughout the Red Sea and evaporates were laid down. Intense faulting took place in Pliocene and Early Pleistocene times culminating in the formation of the central trough and the intrusion of ultrabasic and basic dykes derived from the upper mantle. By this time the Red Sea depression had attained much of its present shape. In Pliocene times the connection with the Mediterranean Sea was closed, but the connection with the Indian Ocean via the Bab el Mandeb opened. During Late Pleistocene times the area was apparently reasonably stable and undeformed marine benches were cut into Monastirian elevated reefs.

## Economic Mineral Deposits

Gold, iron, and copper were first discovered in Sudan centuries ago, i.e. gold originates from the Pharoic time and Sudan was the first country to smelt iron in Africa, ref. Figure 19.

FIGURE 19 | MAP OF MINERAL POENTIAL IN SUDAN




Source: GRAS

## Artisanal Mining in Sudan

Gold, chrome, manganese, kaolin, gypsum, quartz, granite, marble, fluorite, talc, copper, limestone, and trona are all mined by the artisanal miners in Sudan.

Whiteman (1971) listed over 75 known gold occurrences in Sudan all but 17 of which are in the north-east of the country.

Gold found in Sudan is different from most African countries related to late Pan-African events and not to the Archaean mineralisation.

The Gebeit gold mine is one of the oldest mines in the country located in the Red Sea Hills west of Dangunab. Gold is found in quartz veins with minor pyrite and arsenopyrite gold bearing quartz veins in many directions following the fractures.

A number of adjacent mines occur in Wadi Oyo and Onib drainage basins in the northern Red Sea Hills.

About 30 ancient gold mining sites are located in the northern Sudan, in the basin of Wadi Gabgaba near station no. 6. The best one is Nabardi, which operated from 1910 to 1945 but opened again in 2012.

80 km south of Wadi Halfa, along the Nile operated, is the Abirkateib mine, which operated from 1904 to 1960 but opened again in 2013.

There are more than 10 occurrences of alluvial gold in Khors around the upper end of the Roseiris Dam on Ethiopia border in the valley of Blue Nile. The source of this mineralisation is not known, but recently gold in quartz veins associated with volcano-sedimentary sequence was discovered.

Gold has been found in Nuba Mountains since early times, but not in sufficient economic quantities to warrant actual mining operations. GRAS is now exploring for gold in the eastern Nuba Mountains.

In recent years many occurrences of gold were discovered in the Rubatab region associated with quartz veins in the low-grade rocks.

Artisanal gold exploitation in Northern Sudanese mines is similar to other parts of West Africa: gold occurs in alluvial deposits of sand, clay, and silt, which are gradually deposited through moving water, typically along riverbeds or water courses, or deposited in variant associations with rocks, for instance, as inclusion deposits in granite rocks.

Artisanal mining in Sudan depends upon two technologies of extraction: first, digging mines following gold veins, which involves the laborious process of cutting out gold ore from hard rock veins, crushing the stones, grinding them to powder, washing the ground material and bringing the slurry in contact with mercury where it amalgamates with the gold particles, and heating the amalgamate to separate the gold and the mercury; and second, searching for surface gold with metal detectors that find nuggets in the ground up to 40–50 cm deep. These two extraction technologies have diverse spatial trajectories: the mines are territorially fixed pits of several meters, usually dug by excavators, whereby individual shafts can reach to depths of dozens of meters. New productive mines usually draw many treasure hunters, leading to a multiplication of mines in the area, and if mining activities are sufficiently large, soon an entire mining infrastructure will follow marketplaces with grinders, washing pools, restaurants, grocery shops, gas stations, electricians, gold vendors from Khartoum and so forth.

Similar to many other African mining jurisdictions, the State is the custodian of all mineral resources in Sudan. Owing to this, it has the exclusive right to explore for, prospect, mine and dispose of Sudan's mineral resources.

FIGURE 20 | ILLEGAL MINE, BUTANA AREA, CENTRAL SUDAN

Source: Abd El Karim Mohamed

## Governmental and Legal Framework of Mining

### Governmental Bodies and Sub-bodies

The Ministry of Minerals, established in 2010, is the governmental authority responsible for matters related to the country's metals and mineral resources.

The Ministry is supported by various administrative bodies including:

- Technical Committee for Mining, which must:
    - receive and evaluate applications for licenses and mining contracts;
    - submit recommendations to the Minister in respect of these applications; and

    - supervise and regulate the exploitation and exploration of Sudan's mineral resources.
- Geological Research Authority of Sudan (GRAS), which is empowered to:
    - supervise the marketing, production and disposal of mineral resources that are mined;
    - organise, promote, and develop the mining sector in Sudan; and
    - maintain an inventory of Sudan's mineral resources, which have been identified through geological mapping, and geophysical as well as geochemical exploration programs.
- Sudan Mineral Resource Co. Ltd (SMRC), which has the mandate as the fee Collector Company but also acts as the mining controller.

To legalise and regulate artisanal mining, the Ministry of Minerals and the Geological Research Authority of the Sudan (GRAS)
have implemented the following policies:

After the secession of South Sudan in 2011, which resulted in the loss of 75% of the oil reserves (comprising 50% of Sudan's fiscal reserves in 2013), accompanied by currency depreciation, shrinking of nonoil exports, General Omer Al- Bashir and his party had to find a new source of income for the country, the best one proved to be artisanal mining.

Even though the current regime wishes to eradicate artisanal mining in the long-term, it tolerates it at present since it is needed to achieve sufficient production quotas to ensure the country's balance of payments and the availability of jobs for a population prone to challenge the regime's domination if it is unable to control the disastrous economic situation. The central government is thus promoting two opposing points of view, i.e. simultaneously encouraging both the industrial and the artisanal sector.

Nevertheless, the artisanal sector is tolerated only because of the deliberate vagueness of wording in the laws; nothing has been done to guarantee the rights of artisanal producers. Workers in this sector, dependent on the arbitrariness of power, thus have to live in an increasingly precarious context,

**The Central Bank of Sudan**
Starting in 2012, the Sudanese Government created a monopoly from scratch for the export of artisanal gold for its own benefit, even though the country boasts that it is pursuing liberal economic policies. Since then, only the Central Bank of Sudan is permitted to export gold produced by the traditional sector.

**Local Authorities**
The local authorities grant land access to thousands of gold-seekers who, locally,

ignore governmental agreements by extracting the precious minerals in areas reserved for state-promoted mining projects. They also play a mediating role between national investors launching their activities in a new concession and the local populations, especially in the case of conflict. In practice, national investors most often try to win the support of local authorities before seeking a license from the central government. Foreign companies do the same, often through a local partner.

**Legal Frameworks Mining**

Until 1953 the Government Geologist Office was the main authority on mining. Its successor was the Geological Survey Department until 1978, when the Geological and Mineral Resources Department was formed. This department continued its work until 1986 when the name changed to the Geological Research Authority of Sudan (GRAS). Until recently, GRAS' website presented the following documents as legal reference points for prospective investors:

- Mines and Quarries Act 1972
- Mines and Quarries Regulations 1973
- Investment Encouragement Act 1999 (Amended in 2000)
- Mineral Resources and Mining Development Act 2007 (Amended in 2010 by the Organisation of Artisanal Mining Regulation)
- Mineral Resources Development Act 2015
- Procedures for the Acquisition of Exploration and Mining Rights in an Area
- Memorandum of Understanding (as preparation for a concession)
- Final Concession Agreement

The legal arrangements described in these documents indicate a gradual exclusion of land ownership and usage rights below the state level.

The Organisation of Artisanal Mining Regulation of 2010 amended the Mineral Resources and Mining Development Act of 2007 but confirmed its spirit and referred to its penalties. The Regulation officially allows artisanal mining but only under restrictive conditions and by following official procedures (registration, license): no use of heavy machinery or equipment (diggers, excavators with belt loaders, etc.), mining may not exceed depths of 10 meters; artisanal miners may only work in designated sites that do not interfere with investors' licenses.

The Mineral Resources Development Act of 2015 lists five types of mining licenses or mining contracts:

- a general license for prospecting, which entitles a licensee to enter the area identified in the license, or with respect to which a mining contract has been concluded, and search for minerals and mining materials;

- an absolute or exclusive exploration license, which grants the licensee the exclusive right to explore in the area identified in the license;
- a mining contract and a small mining contract, which grants the contractor the exclusive right to mine the mineral resources regulated under the contract and which are located within the licensed area;
- a traditional mining contract, which grants the contractor the right to extract specific minerals by traditional means in the area identified in the contract; and
- a contract for the extraction of minerals and industrial rocks.

To obtain any of the licenses or conclude any of the contracts, an applicant must satisfy the minimum requirements imposed under the 2015 Act. These, among other things, include that an applicant must:

- show that it has the technical competence to conduct the proposed activities;
- have “ample experience” in the mining sector;
- show that is has the financial capability to fulfil its contractual obligations;
- submit a certificate of registration, where the applicant is a company;
- provide a tax clearance certificate and Zakat;
- provide a certificate from the competent authority which confirms that the proposed license area is clear of conflicts; and
- Pledge that it will pay the prescribed fees, rents and meet its other financial obligations.

Applications for licenses or contracts must be submitted to the Technical Committee. The Technical Committee must, in turn, consider the applications and make a recommendation to the Minister on whether the application should be granted. After the recommendation is provided, the Minister must issue the license or conclude the contract.

**Licensees’ and Contractors’ Statutory Duties**

The holder of an exploration or prospecting license, or who is a party to a mining contract, shall pay all the fees and rents associated with the license in question.

All licensees and contractors have an obligation to protect and preserve the environment. As part of this duty, they must protect the environment from any pollution or damage which their operations may cause. Where the prospecting, exploration or mining activities cause damage to the environment, the licensee or contractor will be liable for “the whole” damage as well as the costs that result from the damage.

FIGURE 21 | WET WHEEL MILLING NORTH SUDAN (GAAB ALLAQIA AREA)

Source: Abd El Karim Mohamed

## Women and Children Involved in Mining

The gold market in the Blue Nile, Darfur and South Kurdfan, is situated in an area where women play an important role in the mining process, both collecting ore and washing the gold. Historically in Sudan this role was not unusual. Along the Blue Nile valley and its tributaries gold washing was an activity that women would do in addition to agriculture and small livestock herding. But, in most other parts of Sudan - particularly Darfur, North Kordofan, Northern State, River Nile State and Red Sea State - the recent gold rush has been exclusive to men. Female miners have become a rarer phenomenon, mostly limited to the Blue Nile and South Kordofan. In these areas, women are most visibly involved in the collection of stones and washing of gold-bearing dust, although some also own mine shafts where they will occasionally employ men as workers. Others will collect stones and dust around abandoned mining shafts, partly crushing and washing the ore locally, partly bringing what they collected to the market to process it there. This also applies to the children who find some economic opportunities in the gold market. Many can be observed around the stone crushers collecting dust, which they then wash with water or mercury. At first glance this appears to be an extension of the duties that the region's children assume in their early years, which also includes helping in the fields and taking care of livestock. But many of the children in the gold market are from families that have been broken by displacement and abandonment. Gold is a short-term remedy that partially tackles economic hardship, but daily exposure to toxic chemicals and dust, without any form of protective equipment, causes physical damage that will have a more lasting effect.

FIGURE 22 | ORE WASHING BASIN IN KASSALA STATE (TLATA GEBAL AREA)

Source: Abd El Karim Mohamed

## The Environmental Impacts of Artisanal (Traditional) Gold Mining

The destruction of many forests in South Kurdfan, Blue Nile and South Darfor as a direct result of mining activities has indeed had important negative implications for the economies concerned, particularly agriculture, which is often the other main economic activity for the population.

The impact of mining activities on the environment is very remarkable. First, mining activities require the acquisition of large tracts of land. Both deep and surface mining degrade the land surface following the destruction of the entire forest. Consequently, land for farming and other agricultural purposes is lost. Furthermore, spillages of chemicals such as cyanide, mercury and other toxic materials into the nearby streams cause water pollution, destroying water bodies and aquatic life.

Furthermore, large wild reserves, such as the Dander Reserve, Radoum Reserve and Jabal Al -Hassania, are subject to contraction due to deforestation caused by ever-expanding agriculture, timber trade, and mining activities.

ASM in Minch in Ethiopia

ASM in Bareta in Ethiopia

# ASM SECTOR OF EGYPT

*By Dr. Khaled Zaghlol and Geo. Yosra Mohammad, Egyptian Mineral Resources Authority*

## Geographical Context of Egypt

### Demography of Egypt

Egypt is a country located in the northeastern corner of Africa, ref. Figure 20. Pharaonic Egypt thrived for some 3,000 years through a series of native dynasties that were interspersed with brief periods of foreign rule. The ancient Greek historian Herodotus called Egypt the "gift of the Nile." Indeed, the country's rich agricultural productivity makes it one of the region's major food producers, which has long supported a large rural population devoted to working the land. Present-day Egypt, however, is largely urban. The capital city, Cairo, is one of the world's largest urban agglomerations and manufacturing and trade have increasingly outstripped agriculture as the largest sectors of the national economy. Tourism has traditionally provided an enormous portion of foreign exchange, but that industry has been subject to fluctuations during times of political and civil unrest in the region.

FIGURE 23 | LOCATION MAP OF EGYPT IN THE NORTHEASTERN CORNER OF AFRICA


Source: Google Maps

Egypt's land frontiers border Libya to the west, Sudan to the south, and Palestine to the northeast. In the north, its Mediterranean coastline is about 1,000 km, and in the east, its coastline on the Red Sea and the Gulf of Aqaba is about 1,900 km.

The population of the Nile valley and delta, which are home to most Egyptians, forms a fairly homogeneous group whose dominant physical characteristics are the result of the mixture of the indigenous African population with those of Arab ancestry. The official language of Egypt is Arabic, and most Egyptians speak one of several vernacular dialects of that language. Islam is the official religion of Egypt, and nearly all Egyptian Muslims adhere to its Sunni branch.
Despite the many ancient civilisations with which it has come into contact, Egypt unquestionably belongs to a social and cultural tradition that is Arab and Islamic. This tradition remains a constant factor in determining how Egyptians view both themselves and the world.

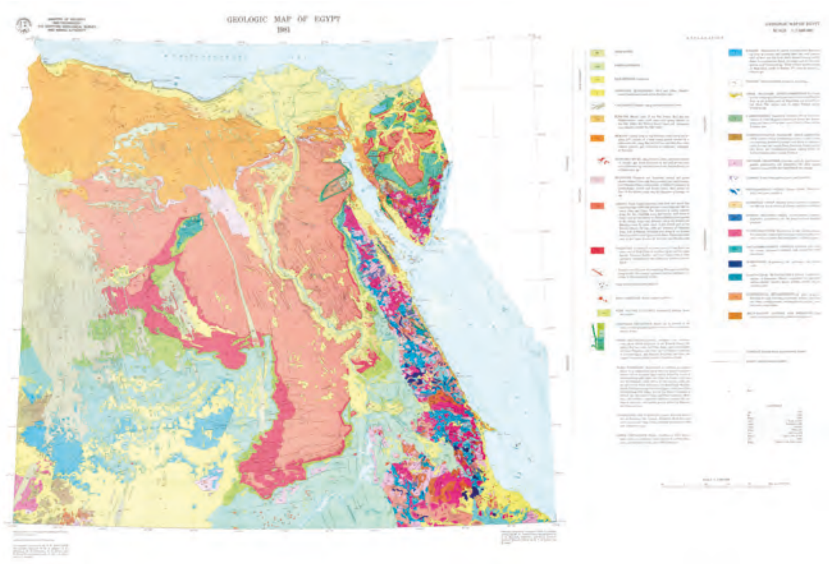
**Economy of Egypt**
The Egyptian state is targeting about one billion dollars in investments, through the licenses it granted to a number of local and international companies in 2022 to explore for gold and minerals in eight areas in the Eastern Desert, as part of its endeavours to increase investments in the mining sector. The state also aims to increase the contribution of the mining sector to GDP - from currently about 0.5% to 5% over the next ten years.

## Geological Context of Egypt

### Simplified Geological Map of Egypt

Figure 24 shows the geological map of Egypt, published by Egyptian Geological Survey in 1981.

FIGURE 24 | GEOLOGICAL MAP OF EGYPT




Source: Egyptian Geological Survey and Mining Authority, 1981. Scale: 1:2,000,000

**Brief Description of National Geology**

The geology of Egypt consists of a Phanerozoic sedimentary cover and the crystalline basement rocks. Phanerozoic sedimentary rocks are mainly Paleozoic, Mesozoic and Cenozoic.

The basement rocks of Egypt occupy the northern part of the Nubian segment (Red Sea hills and southern part of the Sinai Peninsula) of the Arabo-Nubian Shield in addition to sporadic areas in the southern parts of the Western Desert.

The Egyptian geology has received considerable attention over several decades. The geological setting and evolution of Egypt were first interpreted in the scope of the geosynclinal theory (e.g. Hume, 1934, 1935; Ibrahim, 1941; Schurmann, 1966; Amin, 1955; El-Shazly, 1964; El Ramly and Akaad, 1960; El Ramly, 1972; Akaad and Nowier, 1969). Since the advent of the plate tectonic hypothesis in the Egyptian geology, the rock units were reinterpreted in the view of this new hypothesis (e.g. Akaad and Nowier, 1980; Takla and Hussein, 1995; Takla, 2002; Akaad and Abu El Ela, 2003; Said, 2006; Sakran et al., 2008.; Said, 2010; Zoheir and Weihed, 2014; Ali et al., 2015; Said et al., 2015; Abdel-Karim et al., 2016; Hamdy et al., 2017; El Bahariya, 2018; Hamimi et al., 2019; Fowler and Hamimi, 2020; and Abd El-Rahman et al., 2022).

Three tectonic-magmatic stages could be recognised in the evolution of the Nubian Shield in Late Proterozoic times. These are the island-arc stage, the orogenic stage and the cratonization stage. During the island-arc stage, an intra-oceanic island arc was formed as a result of subduction between two converging plates of oceanic lithosphere (Gass, 1982). During the orogenic stage (Pan-African orogeny), that gave the Egyptian basement its present-day configuration (Gass, 1977).

Takla (2002) proposed a simplified tectono-stratigraphic classification of the shield rocks, which is mainly applicable and satisfying, ref. Table 4.

TABLE 4 | TECTONO-STRATIGRAPHIC CLASSIFICATION OF THE EGYPTIAN BASEMENT ROCKS

| | UNIT | AREIAL DISTRIBUTION | MAJOR ASPECTS |
|---|---|---|---|
| VII | Intraplate Magmatism and Sedimentation | Allover Egypt in Shield domains | Mafic, intermediate and felsic dikes; basalt, dolerite, andesite and rhyolite. |
| | | ED and Sinai | **G3** granites, *Alkalic-peralkalic*. |
| | | Allover Egypt in Shield domains | **G2** granites, *Calc-alkalic*, biotite granites monzogranites, syenogranites and leucogranites. |
| | | ED and Sinai | Ultramafic-mafic layerd intrusions dunite, peridotite, pyroxenite, gabbro, norite, troctolite and leucogabbro (**YOUNGER GABBRO**); *calcalkalic and alkali.* |
| | | ED and Sinai | Clastic molasse sediments (**HAMMAMAT SEDIMENTS**) poorly sorted polymectic conglomerate, immature graywacke and limestone with minor calcareous beds; deposited in intermontane basin. Rhyolite (**Post-Hammamat felsite**) |
| VI | **Continental Margin Volcanics** | ED and Sinai | Basaltic andesite, andesite, rhyodacite and Rhyolite. *Calcalkali-alkali*; includes **DOKHAN VOLCANICS** and some felsites. |
| V | **Subduction-Related Granitoids (Arc Granitoids)** | Allover Egypt in Shield domains | Diorite, tonalite & granodiorite; = **G1** granitoids = older granitoids; *Calcalkalic.* |
| IV | **Arc Metavolcanics** | CED and SED only | Intermediate-felsic metavolcanics and metavolcaniclastics. Meta-andesites, metadacite, metarhyolite, metatuffs and occasional BIF. |
| III | **Ophiolitic Mélange** | CED and SED only | Ophiolitic fragments of unit II in a matrix of paraschists of pelitic and psammopelitic composition. Mostly greenschist facies and rarely amphibolite facies metamorphism. |
| II | **Ophiolites** | CED and SED only | Metaultramafites and mafites; include serpentinites, talc-carbonates, minor dunite and harzburgite relics, chromitites, metagabbro, metabasalt (massive and pillowed), metadiabase, occasional rodingite. The whole sequence is formed in ***back-arc*** setting. Greenschist to amphibolite facies metamorphism. |
| I | **Gneisses & related rocks** | Allover Egypt in Shield domains | Ortho- and para-gneisses, migmatites, high grade schists and ortho- and para- amphibolites. |

Source: Takla, 2002. ED = Eastern Desert, CED = Central Eastern Desert, SED = Southeastern Desert

## ASM in Egypt

The Egyptian Government (The Egyptian Mineral Resource Authority (EMRA)) established the Shalateen for Mineral Resources Company (SMRC) to search for gold with the aim of legalizing the conditions of random mining, through the work of small companies with limited responsibilities for these illegal miners within areas between 10-15 km$^2$, using safe and environmentally friendly extraction methods and materials, ref. Figure 22.

In the past, illegal miners used mercury to obtain gold, but after the establishment of the SMRC, the Egyptian Government, represented by the EMRA, directed them

to use environmentally friendly materials, such as a substance called Jinshan and others.
The EMRA has played an important role since 2013 in establishing legislation governing random mining continuously following-up until the ASM sector becomes fully legal and sustainable.

FIGURE 25 | LOCATION MAPS OF THE SMRC CONCESSIONS IN EASTERN DESERT, EGYPT

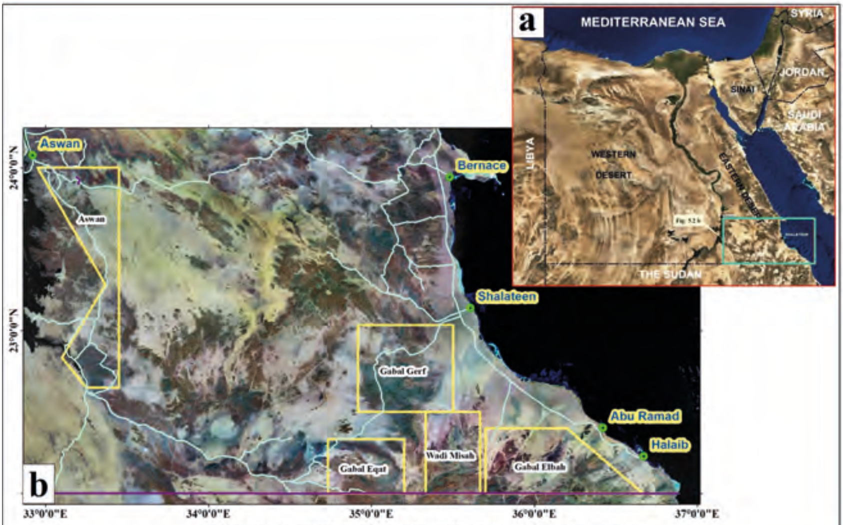


Fig. (3) (a) and (b) Location maps of the Shalateen for Mineral Resources Company Concessions. (after GIS Lab EMRA 2013b)

Source: GIS Lab EMRA/ Internal Report, Geological Survey of Egypt, 2013

## Environmental and Health Issues Related to the ASM Sector in Egypt

In general, there is low environmental risk from the type of mining performed by the Egyptian ASM sector. This is mainly because of the climatic conditions of the country. Most of the mining activities are taking place in the desert or in poorly vegetated areas. In addition, mining is mainly conducted using hand tools resulting in a moderate to low impact on the landscape and mountains. Where machines are used, the larger pits are generally measuring around from 10 to15 m deep and up to 3 to 7 m wide, ref. Figure 23. Mining waste management and rehabilitation are neither practiced nor known to illegal miners. In addition, pits are sometimes periodically worked and reworked after a certain time. Legally, mining is prohibited in national parks and nature reserves, although illegal mining does occur. No major known diseases are known among illegal miners.

FIGURE 26 | PIT OF ILLEGAL MINERS, EGYPT

Source: Dr. Khaled Zaghlol and Geo. Yosra Mohammad

## Socio-Economic Issues Related to ASM Sector in Egypt

### Role of Women

The Egyptian Labor Law (Law No. 12 of 2003) guarantees a number of rights to Egyptian women, such as the right to paid maternity leave and hours for breastfeeding. However, many articles represent a form of moral guardianship over women. For example, working hours are set for women, while the matter does not apply to men, and it determines the morally and healthily acceptable work for women, but it does not address the same issue with regard to men.

The decision by the Egyptian Minister of Manpower affirms the inadmissibility of employing women to work underground in mines and quarries of any kind and in all work related to the extraction of minerals and stones from the ground. The decision also excludes women who hold administrative positions and who, during their studies spent a training period in the underground mine departments, and any other women who must go down - for some time - to the underground mine departments to perform manual labour. Accordingly, there is no work in mining for women in general, whether legal or illegal.

### Role of Child Labour

The fourth chapter of the Egyptian Labor Law specifies prohibitions and controls related to child labour as it prohibits the employment of children under the age of 15, but with the permission of training them from the age of 14. The law further requires the employer, who employs a child under the age of 16, to provide him/her with a card indicating his/her work for him as a trainee with a picture of him, as well as the parents or guardian of the child. The law also prohibits children from working for more than 6 hours a day.

**Conflicts with Local Farmers and Other Stakeholders**

When it comes to the Egyptian mining sector there are no disputes with local farmers or others because most of the mineral raw materials are concentrated in desert areas and there is no vegetation cover on the mountains in Egypt.

**Conflicts with Criminal Gangs in the Mining Area**

In general, there are no conflicts with criminal gangs within the mining areas of Egypt, except for some illegal actions. Mining areas are agreed upon during customary sessions between the Government, the tribes, and the owners of mining companies

ASM in Minch in Ethiopia

# ASM SECTOR OF SOUTH SUDAN

*By Alma Anthony and Martin Kwaje Musa, Geologists*

South Sudan is a landlocked country in east Africa, situated between latitude 12ºN southwards to 3º35’N with an area of 644,329 km$^2$. It is bordering the Central Africa Republic, the Democratic Republic of the Congo, Uganda, Kenya, Ethiopia, and Sudan. South Sudan gained independence from Sudan on 9th July 2011; the capital is Juba. The country is endowed with geological resources and biodiversity. The latter includes lush savannas, swamplands and rainforests that are home to various species and wildlife. The river Nile is the major water body flowing northward through the country from Lake Victoria and beyond. The main tributaries are Sobat River, River Kiir.

The population of South Sudan was estimated around 11.5 million during the 2008 Census and 64 Indigenous ethnic groups are known exist in South Sudan. The people of Africans origin are Christians, Muslims, or believers in other traditional African religions.

The educational system of South Sudan is modelled after that of the Sudan with English as the official language at all levels.

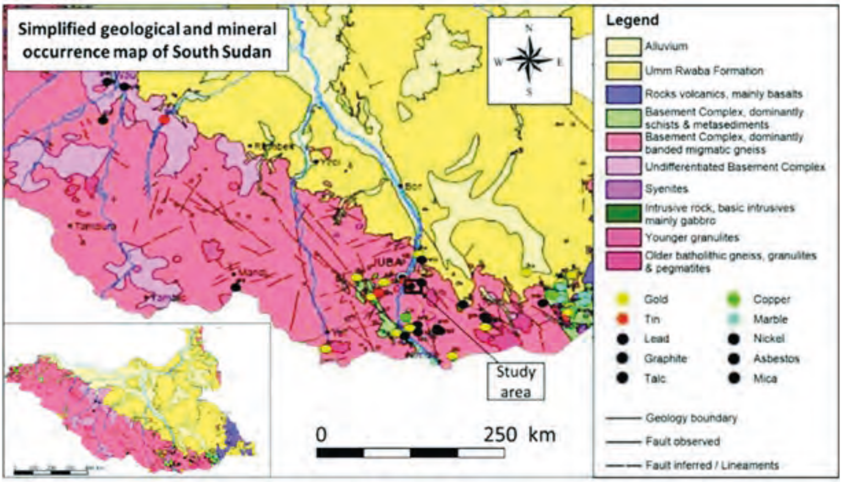
South Sudan is among the poorest and least developed countries in the world. The economy depends heavily on oil despite the endowment of various minerals and other natural resources, such as livestock, agriculture, wildlife, and forestry.

The contribution of mining to the economy of South Sudan is minimal, due to the absence of industrial large-scale mining. The current mining activities are artisanal mining for gold. The Government does not benefit from the gold produced by the artisanal miners because it is smuggled out of the country. The only benefit for the Government is the fees from the licenses, which is minimal, i.e. USD 1.43 per cadastral unit. According to Cord-Aid 2016 estimates, about USD 600 million worth of artisanal mining gold exits South Sudan annually. The miners are not even getting their fair share from the gold they produce, because they are not formalised and not regulated in the Republic. Currently all artisanal miners are unregistered and operate illegally even though the law requires individuals to register. There are several reasons for this. First, the Mining Act of 2012 gives the control of the artisanal mining to the state governments, which do not have the capacity to register and control the thousands of the artisanal miners, who change their working sites from day to day, even from hour to hour. Second, the secrecy in artisanal gold production is universal. Artisanal miners avoid registration as it may enforce transparency on them. Third, artisanal miners sell their gold to buyers, who are willing to pay the highest price out of government control, given that the international borders are porous.

## Brief Description of National Geology

The geological configuration of South Sudan can be categorised into four main lithological domains, ref. Figure 27: (i) Basement complex (Imatong charnockites, Nile Gneiss group, Karasuk group, Madi metasediments); (ii) Igneous intrusions; (iii) Tertiary volcanics; and (iv) Umm Ruwaba formation.

FIGURE 27 | SIMPLIFIED GEOLOGICAL AND MINERAL OCCURRENCE MAP OF SOUTH SUDAN




Source: Geological Research Authority of Sudan (GRAS)

### Basement Complex

The Basement Complex covers about 40% of the surface area of South Sudan and is mainly Archaean to Proterozoic in age. It can be divided into four groups based on structure and metamorphic regime: (i) Gneissic group, including the Imatong Charnockites; (ii) Nile gneisses; (iii) the Karasuk Group (Supergroup); (iv) and the Madi metasediments. The oldest rock unit is the Imatong Charnockite and Kinyeti metasediments. West of the Nile, the gneisses are occasionally covered with lateritic soil commonly referred to as an ironstone.

### Igneous Intrusions

The Precambrian granitoids (granites and granodiorite) bodies include the porphyritic granites of Lyria and Lokiliri mountains extending south to southeast to the Imatong-Acholi mountains. They vary from foliated to non-foliated with minor intrusion of gabbroic and ultrabasic between Juba-Lainya and Nimule. The younger intrusion comprises several post tectonic intrusions of granitic and syenite composition, such as Jebel Lado Syenite, dated 112-122 Ma (Civetta et al 1980), Jebel Wiya, Jebel Kunufi (Luri), and doleritic dykes, known as The Great Juba Dyke Swarm.

### Tertiary Volcanics

The basic volcanic rocks of tertiary age (Belgian Project, Civetta et al.1980) occupy the southeast extreme of South Sudan. They are augite and basalts and extend to western Ethiopia and northwest Kenya. They are believed to be associated with East African Rift volcanics. They are presumed partially to associate with gold mineralisation in South Sudan (Vail, 1978).

### Umm Ruwaba Formation

The Umm Ruwaba Formation dominates the northern part of the country stretching south-eastward near Kapoeta. It consists of unconsolidated sands, silts, clays, and gravels. Its boundary with superficial swamp deposit is murky. Together they constitute about 51% of the surface area of South Sudan.

### Structure

According to several geological researchers (Hepworth and MacDonald, 1966; Hepworth, 1967; Almond, 1969; Leggo, 1974; Vail, 1976; Hunting, 1976; Hunting, 1980), four tectono-thermal events occurred in South Sudan, which correlate with those registered in Uganda, namely: (i) Watian, east-west structural trend; (ii) Aruan-North to northeasterly trend; (iii) Mirian-east to east-northeast; and (iv) Chuan- north-westerly trend. The dominant foliation trend of rocks in South Sudan is NW-SE, which overlay the earlier structures. The conspicuous fault system is the Aswa Shear Zone usually referred to as the Aswa-Nimule shear zone. It is believed to extend north-westward to Jebel Mara and south-eastward beyond Mount Elgon east of Uganda (Vail, 1978). This fault is related to Mozambiquan orogeny (Civeta et, al, 1980) and is associated with gold mineralisation in South Sudan (Hunting1980; Belgian project, 1985; Adde, 1990).

## ASM in South Sudan

### Substances Exploited by ASM Operators

South Sudan is believed to have significant mineral resources based on assessments of known mineral deposits in its neighbouring countries, such as the Democratic Republic of Congo. However, reliable information reported of a similar occurrence in South Sudan is poorly documented.

There is no existence of systematic large-scale mining in the country - all mining related activities are artisanal mining for gold. Exploration and mining activities commenced between the 1940s and 1950s, initiated by Greek merchants or British administrators. In the early 1980s, the Sudan People's Liberation Army took over these mining activities to obtain resources for the liberation struggle.

FIGURE 28 | WASHING OF ALLUVIAL SOIL SAMPLE IN NAPOTPOT, KAPOETA

Source: Yoasa Matatia. Ministry of Mining

The recent exploration activities are concentrated mainly on precious and base metals including copper at Hofrat en Nehas in Western Bahr al Ghazal and gold at River Luri area southwest of Juba and Kapoeta district Eastern Equatoria. There are several gold occurrences reported in crystalline basement rocks.

**Legislative Framework**

The Mining Act of 2012 and the Mineral Title Regulations of 2015 comprise the framework for managing South Sudan's mining sector according to international standards. These documents cover licensing, environmental protection guidelines, and the use of the technology to ensure as many mineral resources as possible are recovered from the ground. The Mining Act of 2012 established six types of licenses: artisanal mining; exploration; large-scale mining; reconnaissance; retention; and small-scale mining. Exploration licenses are awarded for an initial 5-year term and are renewable for additional 2- to 5-year terms. Reconnaissance licenses are granted for a non-renewable 2-year term. Large-scale mining licenses are awarded for a 25-year term and can be extended for 20 years. Small-scale licenses are granted for a 10-year term and can be renewed for another 10 years. Licenses are issued for up to 5 years for exploration and up to 6 years for mining. Artisanal mining licenses, however, must be renewed annually and can be extended an unlimited number of times. The Mining Act sets the corporate tax rate at 20% and allowed the Government to purchase as much as a 15% share in large-scale mining operations.

### Degree of Organisation of ASM Sector

There are no mining cooperatives or associations in South Sudan - most of the miners tend to work individually rather than in a group to form cooperatives. Although at some mining sites in Lobonk Payam they established an organisation called the “Karpeto Development Organisation” to organise mining activities and to create benefits for the community through mining (Cordaid, 2016).

The community in Ganji, southwest of Juba, lacks trust in the concept of a mining cooperative because they have had bad experiences in the past with an agricultural cooperative society fund, which was misused by some members of the society (Cordaid, 2016).

### Role of Geological Survey of South Sudan to Support the ASM Operators

The Geological Survey of South Sudan is not yet supporting the ASM miners, but it has taken steps to formalise the artisanal miners together with the State Government, but the project has stopped due to lack of financial support and insecurity.

## Environmental and Health Issues Related to ASM in South Sudan

Despite national policies and institutions, environmental degradation at most mining sites in South Sudan is still a major problem and concern. The extent of environmental devastation caused by mineral mining in South Sudan is well observed but not yet documented due to no study being carried out on the mining activities in South Sudan. Environmental degradation is not as big a problem compared to the negative social impact of mining activities, but with an increasing number of miners, further erosion, and deforestation may occur.

### Impact on Water Ways

According to Leju and Lado (2019, the main sources of water for domestic purpose in the surrounding villages of the Gorom mining sites showed signs of heavy pollution from mining activities, especially those of illegal small-scale mining.

### Impact on Deforestation

Deforestation will become a problem soon as result of uprooted trees unless reclamation and recovery are undertaken by the mining community and/or public authorities.

**Impact on Landscape**
So far, the negative impact on landscape by mining activities in South Sudan is minimal but it may increase in the near future, if abandoned mining pits are not refilled and the surrounding landscape is restored.

According to the study done at the Gorom mining sites by Leju and Lado (2019), the mining activities have caused a disproportionate amount of damage to the land. Furthermore, huge patches of forest have been cleared in certain areas to establish resting ground for miners. Mining activities often result in removal of large quantities of topsoil leaving the land bare and susceptible to erosion.

FIGURE 29 | SMALL SCALE MINING OPEN PIT AT NGAURO

Source: Yoasa Matatia. Ministry of Mining

**Impact on Health Among ASM Operators**
There are various health risks involved in artisanal mining - sanitation conditions tend to be very poor and water streams used for panning for gold and bathing are also used for drinking water, why waterborne diseases are very common. Barrow pits are also left open and thus a potential breeding ground for mosquitos or snakes. The mining sites are often also far away from any settlement and health centres.

Tunnels dug by artisanal miners to connect several vertical holes also often collapse due to poor safety guards resulting in miners getting injured or killed, such as what happened in Raja where a vertical hole collapsed due to heavy rain causing one death.

Knowing that artisanal gold mining areas are money-making areas, sex workers often invade them and spread HIV/AIDS at the mining sites due to unprotected sex within the initially healthy local communities.

Businesspeople also tend to bring alcoholic beverages to the mining sites and nearby business centres to barter with the gold miners. The increased consumption of alcohol at the mining sites and surrounding local communities leads to quarrels which often result in violence (Cordaid, 2016).

## Socioeconomic Issues Related to ASM in South Sudan

### Role of Women

Women of all ages play important roles at the mining sites. In Kapoeta and at some other mining sites most of the artisanal miners are women, whereas men herd the cattle. However, sometimes they work as a family, in which the men extract the ore material, and the women and children carry it for panning in a nearby water stream. Women work hard to get enough gold to pay for school fees for their children, who are studying in neighbouring countries, such as Uganda and Kenya. Women also bring goods to sell at the mining sites, which are usually located far away from any settlement.

FIGURE 30 | ARTISANAL MINERS AT NGAURO MINING SITE, KAPOETA

Source: Yoasa Matatia. Ministry of Mining

**Role of child Labour**

ASM is very attractive to children as a means to earn money. They dig pits and sift through soil daily so that their families can sell gold to buy food. Sometimes they work overnight at the mining site. Children thus drop out of school to go help their families to earn an income. Furthermore, most mining sites are in remote places where there is no school.

Bad as it may appear, children who lack schools to go to in their areas of home turn to the lucrative artisanal gold mining instead of getting into criminal activities, including cattle raiding, robbery and rebellion.

**Conflicts with Local Farmers and Other Stakeholders**

Artisanal miners often drive away exploration license holders and small-scale miners as evident from the case observed in East Narus in which armed youth, who are artisanal miners, attacked a small-scale mining company, named Fortune Mineral.

In most cases, local miners also own the farmland of the mining area. Conflicts often occur due to poor or a lack of communication between license holders and farmers. In Budi County in the eastern Equatoria state, a farmer was annoyed because a small-scale company, “Manajem Mining Company”, took samples on his farms without his knowledge. In the Wonduruba area in central Equatoria state, the Ramciel International Company, undertaking small-scale mining, was disrupted by the surrounding communities as it failed to agree on sharing the benefits of the mining endeavours with the communities causing the company to stop mining whereafter its properties were looted by cattle raiders.

**Conflicts with Criminal Gangs in the Mining Area**

Some artisanal mining sites are controlled by criminal networks, which do not hesitate to use violence to protect their interests. As a result of this, communities feel the need to arm themselves for self-defence and deterrence since violent conflicts over pasture and water resources are common (Cordaid 2016).

At the Nauru (Budi) mining sites, anyone who wants to mine needs to be accepted by the network that controls the specific sites, such as Vaka. However, in the Kapoeta counties people choose freely where to mine and there is no rivalry since local regulations control the mining activities (Cordaid 2016).

**Impact of Criminal Gangs or Terrorist Groups on the ASM Sector**

There is no terrorist group in South Sudan. However, criminal gangs are present, and they often attack miners. In 2019 in Gorom, it was reported that some people were killed, and their gold was stolen. Similar attacks were reported for the Wunderbar, Lobonk, and Karpeto areas.

Traders in the Ngauro area fear robbers at large at the mining sites of Vaka. Gold trading is therefore carried out secretly and there is a great deal of mistrust (Coraid 2016).


ASM in Minch in Ethiopia

# ASM SECTOR OF SOMALILAND

*By Jama Mohamed Adem*

## Geographical Context of Somaliland

### Demography of Somaliland

Somaliland, officially named the Republic of Somaliland, is located at the Horn of Africa, on the southern coast of the Gulf of Aden. It is bordered by Djibouti to the northwest, Ethiopia to the south and west, and Somalia to the east. Its capital and largest city is Hargeisa. Its claimed territory has an area of 176,120 $km^2$. The population of Somaliland was estimated to be 3.6million in 2014 (47.9% male and 52.1% female) and projected to increase to 4.2 million in 2020, using a growth rate of 2.93%, with the bulk of the population living in urban centres as indicated in the National Development Plan III (2023).The population of Somaliland has an average household size of six with 48% of the population being under the age of 15 and roughly 72% of the population being under the age of 30. Similarly, 48% of the population is within the working age group (15-64 years old).

### Economy of Somaliland

Over the last twenty years, Somaliland's economy has undergone an important transformation. The pastoralism is the dominant economic activities, whilst livestock exports remain the mainstay of the economy, accounting for nearly a third of the Government's total revenue, although there has been a new policy shift and economic development trajectory paving the way for diversification of the economy. This has led to the development of new sectors including telecommunication, agriculture, and the mining of minerals. From 2013 to 2016, GDP grew at an average of 2.6%, while the negative growth of 2017 was due to issues with droughts and livestock export. GDP grew again in 2018 (2.5%) and in 2019 (6.2%). In 2020, GDP contracted by 3.1%, primarily due to the global COVID-19 pandemic.

TABLE 5 | CONTRIBUTIONS TO SOMALILAND'S GDP BY SECTOR

| Economic Sector | 2019 | 2020 |
|---|---|---|
| **AGRICULTURE A** | **8.1** | **6.9** |
| Crops | 3.0 | 5.1 |
| Livestock | 87.5 | 75.6 |
| Forestry | 9.4 | 8.0 |
| Fishing | 0.2 | 0.5 |
| **INDUSTRY** | **18.6** | **15.0** |
| Mining and Quarrying | 2.4 | 2.7 |
| Manufacturing | 3.3 | 3.9 |
| Electricity, gas, and water supply | 0.0 | 0.0 |
| Construction | 94.4 | 93.4 |
| **SERVICES (HH + G + service export)** | **73.3** | **78.1** |
| Food and Beverages | 54.6 | 58.1 |
| Housing | 19.5 | 18.7 |
| Government sector | 7.0 | 6.4 |
| ***Central Government*** | ***90.2*** | ***88.8*** |
| ***Local Government*** | ***9.8*** | ***12.7*** |
| Other services | 18.9 | 16.8 |

Source: Somaliland's National Development Plan III, 2023

Somaliland's Vision for 2030 is a stable, democratic, and prosperous country, where the people enjoy a high quality of life, ref. Figure 31.

FIGURE 31 | SOMALILAND'S VISION 2030


Source: Somaliland's National Development Plan III, 2023

Somaliland is endowed with varied mineral resources, including gold, silver, base metals, chromium, cobalt, industrial minerals (gypsum and celestite), and precious stones (emerald and agate).

The recent attention to ASM in rural areas communities has resulted in rapid economic development of the country. Nevertheless, efficient and effective governmental institutions to coordinate and manage a sustainable development of the sector is crucial to positively improve the socio-economic status of the local mining communities.

## Geological Contexts of Somaliland

### Geological Map of Somaliland

The Somaliland basement consists of five basements complex outcrop:

a) **Qabri Complex**: Consists of high grade of poly metamorphic, paragneisses, migmatites porphyric, orthogenesisand plagioclase;
b) **Mora Complex**: Consists of marbles, quartizes and amphibolites associated with high-grade paragenesis and migmatites;
c) **Abdul-Qadir Complex**: Consists of numerous bodies of layered gabbro with minor alkaline granitoids;
d) **Mait Complex**: Consists of low grade often fine-grained metaclass tics with interbedded billow metabasalts; and
e) I**nda Ad Complex**: Consists of the low to very low grade essentially meta-sedimentary sequences located in the easternmost part.

The crystalline basement is covered by Mesozoic quaternary sedimentary and volcanic sequences (Ali & Watts, 2016):

a) The **Jurassic sequences** consist of adigrat sandstone, which is conformably overlying by transgressive marine carbonates with minor interbedded marlstone of Bihendule group;
b) The **Cretaceous secessions** consist of highly weathered course-grained quartz-rich sandstone;
c) The early **Cenozoic successions** consist of carbonate of Auradu, Taleh, or Gypsum anhydrite series and Karkar formations; and
d) The **Oligocene and Miocene** consist of thick sequences of red-brown-green sand and silt, gypsiferous, sandstone, sand, and marl.

### Brief Description of National Geology

The country is underlain mainly by Mesozoic and Tertiary continental-margin and marine sedimentary rocks deposited uncomfortably on Precambrian metamorphic and igneous rocks (Ali, 2006).

Three major plate boundaries meet in the Horn of Africa - the oceanic spreading ridges of the Red Sea and the Gulf of Aden and the continental East African Rift system. As a result, the structure of the country is dominated by the Gulf of Aden, Red Sea and East African trends. The opening of the Gulf of Aden has subjected the country to extensional tectonics, giving rise to a major system of E-W to ENE-WSW striking normal faults. These faults divide the country into two morphological regions - the downfaulted Guban area and the relatively uplifted Somaliland plateau, which exposed high-grade Proterozoic migmatites, granitoid's and pegmatites. Faults of the Red Sea have a trend of NW-SE to WNW-ESE direction whereas the East African faults trend almost due N-S. The East African faults are less frequent, and they mainly affect the western part of the country. Field observations indicate that NW-SE faults are the most dominant trends and old basement structural trends exerted a controlling influence on younger fault trends. The movement of older faults appears to have taken place during the Mesozoic time and may be related to the early breaking up of Gondwanaland (Somaliland Oil Exploration Company, 1954; Bosellini, 1992).

The Daban Basin (southeast of Berbera) is an example of an onshore basin that was formed as a result of the reactivation of the older NW-SE trending fault and subsequently filled with Oligocene-Miocene continental to marginal-marine sediments (Bott et al., 1992).

## ASM in Somaliland

### Minerals Exploited by ASM Operators in Somaliland

ASM is recognised by the World Bank as a mechanism of poverty alleviation in developing countries. ASM plays an essential role in developing societies, because small mines can be a major source of revenue for rural communities and can provide income for investment. ASM miners in Somaliland produce gemstones such as gold, emerald and garnet, and industrial minerals, such as copper, lead, manganese, and jade.

FIGURE 32 | ASM SITE, SOMALILAND

Source: Ministry of Energy and Minerals

**Legislative Framework for the ASM Sector in Somaliland**
ASM is an important source of income and employment, particularly for poor, rural populations. In many developing countries, the government's ability to regulate the ASM sector is weak.

Many ASM miners continue to operate in an informal manner, where legal or regulatory frameworks may not exist. Legal access to minerals may be limited as well as access to capital, equipment, and technical assistance.

The Ministry of Energy and Minerals, responsible for minerals, set out a policy to regulate and formalise ASM to better support ASM workers. The formalisation process includes legal and regulatory frameworks, provision of legal access to mineral information about geological data, organisation of miners into flexible and dynamic organisations, i.e. the creation of corporations, and provision of access to capital, equipment, and technical assistance.

**Degree of Organisation of the ASM Sector**
The degree of organisation in the ASM sector is limited or non-existent given that the sector is still new and growing; hence, fewer people organise themselves and motivate each other to form cooperatives and associations.

**Role of the National Geological Survey to Support the ASM Operators**
One of the most fundamental constraints that hinder the ability of ASM miners to upgrade their operations and achieve better returns is the lack of financial capacity and support. With limited cash on hand, ASM miners find it hard to invest in equipment and supplies.

Financing for mining operations is a key pre-requisite for sustainable development. By strengthening their access to financing and credit, greater profitability is achieved, since ASM miners will use best practices in their mining operations and participate in the broader market.

Somaliland's ASM policy seeks to address the problems through a variety of measures and strategies including:

a) Facilitating and devising mechanisms to enable access to financing and credit;
b) Encouraging initiatives for standards and certification of ASM "Fair trade", conflict-free minerals to harmonise and grow in scale;
c) Legalising and formalising ASM operations through licencing and permitting;
d) Designating dedicated zones for ASM;

e) Providing technical training to improve productivity, safeguard the environment and to comply with health and safety standards;
f) Strengthening, monitoring and enforcing laws on child labour in ASM operations; and
g) Strengthening the role and security of women involved in ASM.

## Environmental and Health Issues Related to the ASM Sector in Somaliland

### Impact on Waterways

Water pollution is a major concern in mining operations. ASM operations in Somaliland do not have nor use proper waste disposal facilities. ASM poses a risk to public safety by the threat of toxic water overflowing from the water sources, such as lakes and rivers, which significantly impacts downstream communities that rely on this water source for their livelihoods. Spills and leakages of effluent containing toxic chemicals or discharge of leachate from mine waste and surface runoff from overburden dumps, result in the degradation of the water quality. Typical surface mining methods activities always disrupt the surface and this, in turn, affects soils, surface water, and near-surface groundwater.

### Impact on Deforestation

ASM and its subsequent activities in Somaliland have been found to degrade the land to a significant extent. Extensive areas of land and vegetation have been cleared to make way for surface mining activities. The environment is undergoing rapid dreadful changes, and its immense economic value is dwindling from year to year, due mainly to the heavy concentration of mining activities. The surface mining method by ASM often results in the removal of large quantities of topsoil, leaving the land bare and susceptible to erosion. The removal of the topsoil often renders the land practically incapable of supporting crop farming in the future. The deforestation that has emanated from surface mining has long-term effects even when the soil is replaced, and trees are planted after mine decommissioning.

### Impact on the Landscape

ASM has a huge impact on the landscape of mining areas. In Somaliland, there are weak regulations, policies, and inspections on mining sites especially ASM operations, which has a negative impact on the landscape. ASM often cut down a lot of trees to make roads, to produce valuable minerals, and when there is a need to expand the mining area or the shaft itself.

Moreover, ASM operators use a large amount of wood, which is used to cook food, but also as a material used to build supports in deep shafts. Thus, ASM has its highest impact on deforestation in Somaliland where, in addition to forest loss, there is also a decline in soil quality, with the damage proving irreversible. The above factors have an impact on the safety and the landscape of the mining areas.

### Impact on Health Among ASM Operators

ASM remains one of the most dangerous occupations in the world, both in terms of short-term injuries and fatalities. The ASM sector in Somaliland has become a major concern in both local and international communities. ASM in Somaliland has a poor reputation for occupational health and safety. Most of the miners are not familiar with safety regulations. Safety inspections are weak because the number of safety inspectors is insufficient because of the nature of the task and the number and a wide dispersion of small-scale mines. Apart from these, there are other issues, such as tensions and conflicts of interest between the communities and ASM operators. The health risks associated with the ASM sector in Somaliland are work-related injuries/fatalities, respiratory diseases due to dust breathing, which lead to asthma, and as well as increased exposure to infectious diseases. Yet the most significant causes of the above health-related risks are the lack of safety equipment and sanitation facilities at ASM sites.

FIGURE 33 | ASM PIT, SOMALILAND

Source: Ministry of Energy and Minerals

## Socio-Economic Issues Related to ASM Sector in Somaliland

### Role of Women

ASM continues to proliferate in many parts of Somaliland as a large number of rural people get involved in the sector. Women labourers are limited in participating in this male-dominated economic pursuit. The Somaliland Mining Policy aims at enabling gender equality and gender mainstreaming as part of the solution to inform decision-making to improve gender balance in the mining industry. Women, including those in communities, are often seen as being more vulnerable in each of the mining development stages - from exploration to closure. They are at risk of being excluded from employment and the consultation process and are affected differently by mining operations due to their gender-related roles.

**Role of Child Labour**

As the Government continues to consider mining to be among the emerging drivers of the economy, ASM is expected to further expand in scope and volume. There is, therefore, the need for policy to address the broader context of mining in the country particularly concerning the involvement of children. An increasing number of children are engaged in low-cost, low-tech, labour-intensive excavation and processing of minerals. It is difficult to estimate the number of children working in mines due to a lack of clear data on the topic and the lack of uniform definitions of what constitutes child labour. Moreover, ASM is by definition informal and often illegal, thus practitioners operate in secret making assessment of this menace to be difficult.

Some of the risks of child labour include work which, by its nature or the circumstances in which it is carried out, is likely to harm the health, safety, or morals of the children, and work which exposes children to physical, psycho-social, or other forms of abuse.

**Conflicts with Local Farmers and Other Stakeholders**

Natural resources, such as mining conflicts are typically severe and debilitating, resulting in violence, resource degradation, the undermining of livelihoods, and the uprooting of communities. ASM projects often cause land-based conflicts; these conflicts occur between the mining companies and the indigenous people of surrounding communities, who depend largely upon the land for their livelihoods.

In the Somaliland context, ASM caused many conflicts between the local communities and the stakeholders. In the Fiqi-Ayoub district in 2019, there was a dispute between residents and companies over the interests of both parties. Some residents clashed with the companies operating the Fiqi-Ayoub project, leading to clashes between security forces and the rebels. These clashes resulted in many injuries as well as deaths.

ASM in Minch in Ethiopia

ASM mining site in Tanzania

# FORMALISATION OF EFFORTS OF THE ASM SECTOR IN DRC

*By Lotte Hoex and Ken Matthysen, International Peace Information Service (IPIS)*

When effectively monitored and managed, legal and responsible ASM supply chains can promote stability and peace while providing livelihoods and contributing to rural development. This chapter illustrates the importance of a formal ASM sector by giving the example of the DRC.

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.

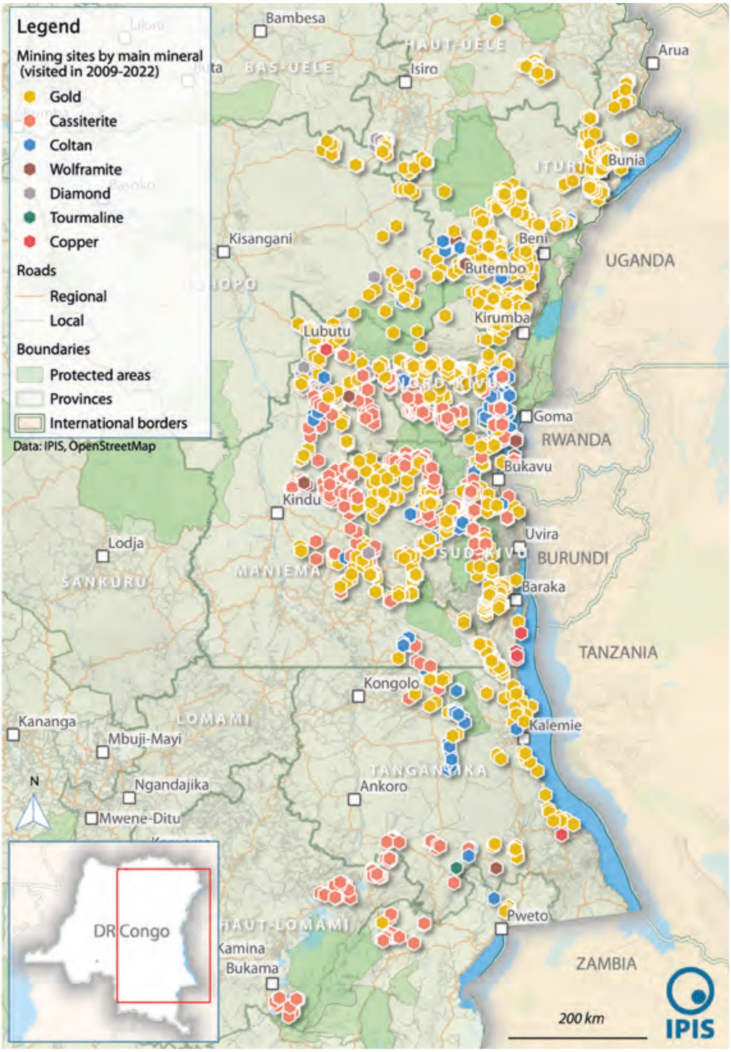
## Historical Context of ASM in DRC

ASM has a long history in the DRC, dating back to colonial times (Fahey, 2008). Cassiterite (tin) and coltan were discovered in the DRC's Kivu region in 1910. The tin sector soon fell entirely into the hands of private Belgian companies. The 1960 independence of the country did not initially appear to have a significant impact as Belgian private companies continued to operate in the country. However, over the next three decades, industrial exploitation of the 3Ts (cassiterite, coltan and tungsten) ceased entirely; the instability of world markets and a failing state were 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, 2012). As of today, large-scale mining investments in eastern DRC continue to be limited (Schütte, 2018).

Since 2009, the independent research institute, IPIS, has collected data about the on-the-ground situation at mining sites and the trade routes in eastern DRC. Between 2009 and 2022, IPIS mapped 2,723 mines, employing 376,000 artisanal miners, covering virtually all-relevant mining areas of eastern DRC, ref. Figure 34. 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 35. Today, ASM supports at least 1.7 million people directly and indirectly in eastern DRC.

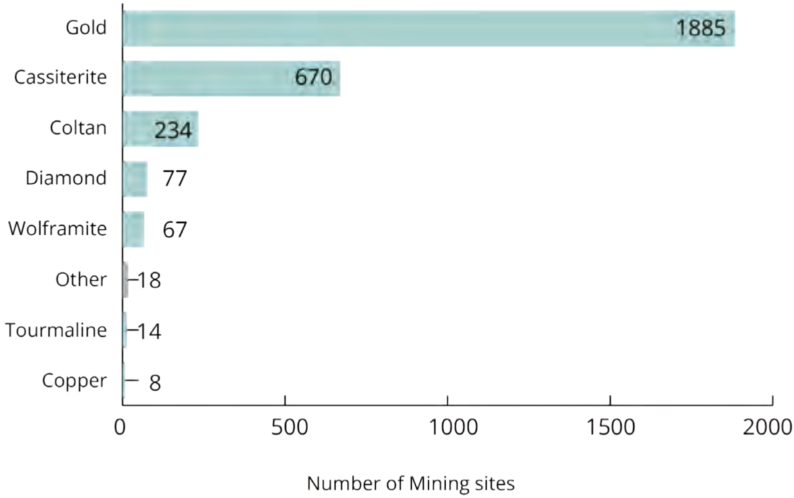
The collected data demonstrates the predominant importance of the gold sector. The DRC is one of the global top-ten ASM gold producers. ASM gold production is mainly focused in the eastern DRC but there are also gold mine sites in Kasai and in Congo Central in western DRC. Traditionally, ASM gold production 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 34 | MINING SITES VISITED BY IPIS IN EASTERN DRC, 2009-2022




Source: IPIS

FIGURE 35 | 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 specifically designated Artisanal Exploitation Zones (Zone d'Exploitation Artisanale, ZEA), 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 of the Ministry of Mines 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 mining cooperatives at the level of the mine. They are mandated to promote safety regulations and the national Mining Code.

The Centre for Evaluation, Expertise and Certification (Centre d'Evaluation, d'Expertise et de Certification, CEEC) 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 (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 on 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.

**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, and regularly establish trade monopolies. They ask for financial contributions from the miners and therefore increase the costs linked to the formal sector. As such, for the moment mining cooperatives rather affect miners' already fragile socio-economic situation. 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 more informal 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, by several state agents and customary authorities, but also by armed groups and the national army. The transport of minerals is also systematically subjected to illegal taxation at roadblocks operated by the very same actors, including state agents, customary authorities, armed groups and army units. 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).

An IPIS research published in 2023 found that miners paid on average USD 251 in Ituri and USD 63 in South Kivu in taxes, during a six-month period in 2021 at a selected number of mining sites. More than 60% of these payments were claimed illegal, due to unclear regulations and a lack of transparency in their application, for example when it comes to determining the amount of a levy (de Brier et. al., 2023).

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 in eastern DRC, in terms of the number of artisanal miners, 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 illegally “export” the gold directly from the DRC to international gold trading hubs such as Dubai.

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 (3T and Gold). The RCM includes mine site and mineral export certification criteria, traceability, and chain of custody requirements.

In the DRC, the evaluation of mining sites, within the framework of the RCM, is carried out by multi-stakeholder teams (the so-called ‘équipe conjointe de qualification’). 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. After validation by the Minister of Mines, 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.
Only few ASMs have been validated by government inspectors. 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.

**(Inter)national Due Diligence Requirements**
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 (Ministère des Mines, 2011).

In 2010, Section 1502 of the American Dodd-Frank Act imposed due diligence measures for companies trading on the US stock exchanges sourcing gold and 3T minerals from the 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 on the short term, as most international mineral traders abstained from sourcing minerals from the DRC in 2010.

In 2017, the EU 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 Act 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 provide 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 (ITA) 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, which are actually 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 the ASM sector in eastern DRC (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 due diligence and traceability programs 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 informal. 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. Consequently, their impact on formalisation of the ASM sector has been limited.

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.

ASM mining site in Zambia

# APPLICATIONS OF REMOTE SENSING, GIS, AND GEOPHYSICS FOR GROUNDWATER MAPPING

*By Tadele Dagne, Remote Sensing and GIS Specialist at Acacia Water*

## Groundwater and Mapping

Groundwater resources can be expected to be increasingly relied upon in the near future, as a consequence of rapid population growth and global environmental change. Cost-effective and efficient techniques for groundwater exploration are gaining recognition as tools to underpin hydrogeological surveys in mid- and low-income regions.

Groundwater mapping is a multidisciplinary technique to characterise the occurrence, distribution, movement, and quality variation of resources in different aquifer systems.

Groundwater maps may be used to develop strategies for sustainable management, allowing water planners to identify zones suitable for siting productive wells. Moreover, mapping contributes to understanding the vulnerability of aquifers and their associated ecosystems to contamination and overexploitation, to identify areas for artificial recharge, and to convey information to groundwater users. Furthermore, groundwater maps may reveal links between groundwater resources and human settlements.

A groundwater map is the synthesis of many thematic layers that has a role on the occurrence. These layers can be prepared and combined/integrated in a GIS environment.

## Linking Remote Sensing to Groundwater

Remote sensing is the science and technology of gathering information about the biophysical characteristics of objects without making physical contact. The collection of information is possible by means of space-borne, air-borne, ground-based, and drone-borne platforms. Optical cameras, Light Detection and Ranging (LiDAR), Radio Detection and Ranging (RADAR), thermal infrared (TIR) etc. are among the main widely used sensors in today's remote sensing-based data collection efforts. However, despite the many remote sensing instruments currently operated by various agencies and organisations, there are still challenges when it comes to the collection of information on sub-surfaces.

Groundwater is stored in rocks, which act like sponge, called an aquifer, and when drilled the water will flow out.

The occurrence of groundwater is controlled by various factors, such as the characteristics of rocks, geological structures, geomorphology, rainfall and recharge, surface water bodies, land use and land cover conditions, drainage network and characteristics etc.

Remote sensing data is unable to provide any direct information on groundwater in most cases given that is below the surface. However, the surface morphological-hydrological-geological regime, which primarily governs the subsurface water conditions, can be studied, and mapped on remote sensing data products. Besides, controlling factors that governs the occurrence of groundwater can be interpreted and mapped. According to Gupta (2004), the controlling factors can be taken as a direct or an indirect indicator of groundwater resources, ref. Table 6.

TABLE 6 | IMPORTANT INDICATORS OF GROUNDWATER ON REMOTE SENSING DATA

| FIRST ORDER OR DIRECT INDICATORS | SECOND ORDER OR INDIRECT INDICATORS |
|---|---|
| - Features associated with recharge zones: rivers, canals, lakes, ponds etc.<br>- Features associated with discharge zones: springs etc.<br>- Soil moisture<br>- Vegetation (anomalous) | - Topographic features and general surface gradient<br>- Landforms<br>- Depth of weathering and regolith<br>- Lithology-hard rock and soft rock areas<br>- Geological structure<br>- Lineaments, joints and fractures<br>- Faults and shear zones<br>- Soil types<br>- Soil moisture<br>- Vegetation<br>- Drainage characteristics<br>- Special geological features, such as karst, alluvial fans, dykes and reefs, unconformities, buried channels, salt encrustations etc., which may have unique bearing on groundwater occurrence and movement |

Source: Gupta, 2004, p. 363

## Remote Sensing Data Sources

Satellite sensors are designed with certain missions and their applications are mostly limited to certain particular objectives. Currently there are several kinds of satellite imageries, which are available for access both freely and commercially. Table 7 outlines some of the data sources and their potential application during a groundwater mapping activity.

TABLE 7 | REMOTE SENSING AND GIS DATA SOURCES AND APPLICATIONS

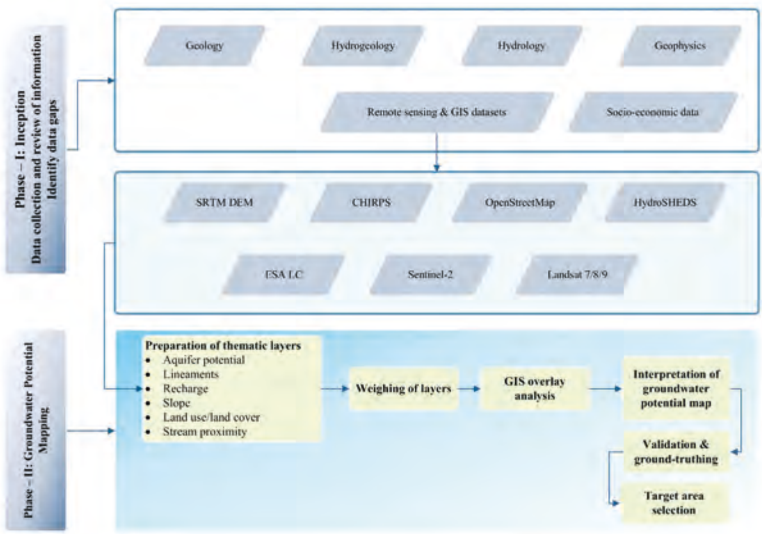
| PRODUCT NAME | PROVIDERS | DESCRIPTION OF DATA CHARACTERISTICS | USE |
|---|---|---|---|
| **Sentinel-2** | European Space Agency (ESA) | - Free optical satellite data - https://scihub.copernicus.eu<br>- Have a total of 13 bands<br>- 10m spatial resolution - B2, B3, B4 & B8<br>- 20m spatial resolution - B5, B6, B7, B8a, B11 & B12<br>- 60m spatial resolution - B1, B9 & B10 | - Lithological interpretation & geological mapping<br>- For Land-use & land-cover (LULC) classification<br>- Assessment of condition of vegetation coverage & index such as Normalized Difference Vegetation Index (NDVI) and red edge |
| **Sentinel-1** | European Space Agency (ESA) | - Free RADAR satellite data - https://scihub.copernicus.eu<br>- Single band with 5.405GHz (C band)<br>- 5m spatial resolution | - For detecting lineaments and geological structures |
| **Landsat-9 OLI-2 TIRS-2** | United States of Geological Survey (USGS) | - Free optical satellite data - https://earthexplorer.usgs.gov<br>- Have a total of 11 bands<br>- 30 m spatial resolution - B1, B2, B3, B4, B5, B6, B7 & B9<br>- 15 m spatial resolution - B8<br>- 100 m spatial resolution (TIRS) - B10 & B11 | Integration with sentinel-2 for an improved interpretation of features |
| **SRTM Digital Elevation Model** (1-arc second) | United States of Geological Survey (USGS) | - Freely available DEM data - https://earthexplorer.usgs.gov<br>- Derived from single band (c) RADAR data<br>- 30 m spatial resolution<br>- 16 m vertical accuracy | For the study of geomorphologic & topographic features including for the derivation of profiles and section |
| **ALOS PALSAR DEM** | Alaska Satellite Facility (ASF) | - Freely available DEM - https://search.asf.alaska.edu/#/<br>- A resampled version of STRM during Radiometric Terrain Correction Project of Advanced Land Observing Satellite (ALOS) - Phased Array type L-band Synthetic Aperture Radar (PALSAR)<br>- 12.5 spatial resolution | Depending on the mapping resolution, the data could be considered for detail studies replacing the 30m SRTM DEM |
| **Lithology** | National geological surveys or other providers | - Depends on the available with a scale of certain areas | - For preparing geological maps, hydrogeological maps, geological cross-section & hydrogeological conceptual models<br>- Serve as a basis during the interpretation of lithology's from remote sensing data |
| **Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)** | Climate Hazards Center (CHC) of the University of California, Santa Barbara (UCSB) | - Freely available Rainfall Estimates from Rain Gauge and Satellite Observations - https://www.chc.ucsb.edu<br>- 0.05-degree spatial resolution | - For making an estimation rainfall as well as groundwater recharge |

Source: Tadele, Acacia Water

## Methods and Mapping Procedures

The Geographic Information System (GIS) overlay method is as an effective approach to locate potential groundwater areas. Figure 36 shows the steps in groundwater mapping using remote sensing and GIS techniques.

FIGURE 36 | STEPS IN GROUNDWATER MAPPING USING REMOTE SENSING AND GIS TECHNIQUES




Source: Tadele, Acacia Water

## Variables in Groundwater Mapping

Variables are parameters used to pinpoint areas of potential groundwater occurrences. As stated above, the occurrence of potential groundwater resource is because of different governing factors/variables, such as geology, geomorphology, structures, drainage, land-use and land-cover conditions (soil, vegetation, water bodies, settlements, cropland, grass etc..). From a remote sensing perspective, these factors are seen as direct indicators and indirect indicators of water beneath the surface of the earth. Different authors choose different variables for many reasons (Díaz-Alcaide and Martínez-Santos, 2019; Prasad et. al., 2008). During a mapping process, these variables can be calculated or derived from different remote sensing and GIS datasets following the implementation of appropriate processing and post-processing techniques.

### Lithology (Geology)

The porosity and permeability of a geologic formation control its ability to store and transmit water. This layer could be prepared from the exiting shapefile of a geological map, or a new data interpreted from remote sensing data. Each lithological unit needs to be classified according to its importance to the groundwater potential and available well data may be used to support during classification.

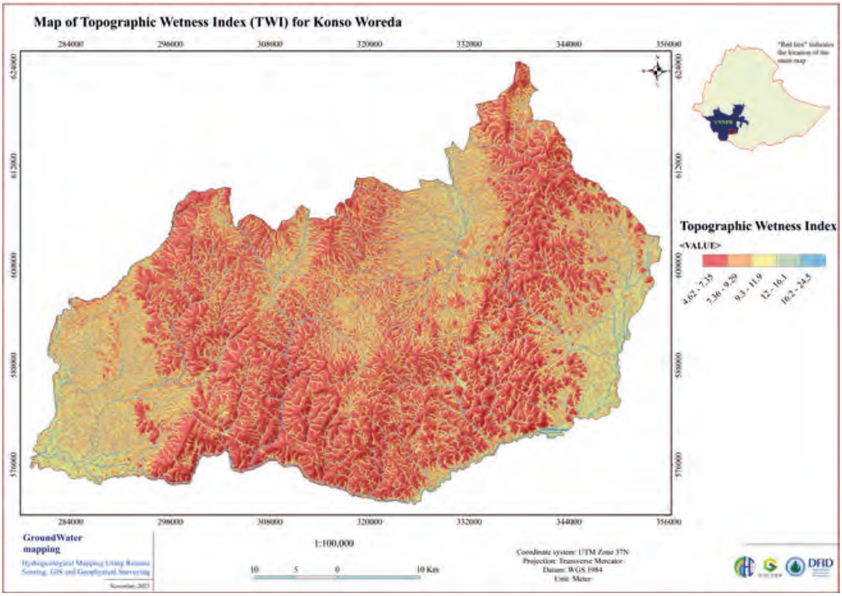
FIGURE 37 | SENTINEL 2 IMAGE OF BORENA AREA (ETHIOPIA AND KONYA BORDER) – PROCESSED FOR GEOLOGICAL INTERPRETATION

Source: https://earthexplorer.usgs.gov

### Topographic Wetness Index

This index is commonly used to quantify topographic control on hydrological processes (Beven and Kirkby, 1979). It is a function of both the slope and the upstream Specific Contributing Area (SCA). This layer provides information on where the water could accumulate as a result of elevation differences. This index be calculated from digital elevation model data using the formula; **Ln (SCA/Tan(Slope)).**

FIGURE 38 | TOPOGRAPHIC WETNESS INDEX OF KONSO DISTRICT IN ETHIOPIA




Source: Tadele and Desta (2021)

## Lineament Density

As first described in the work of Hobbs (1904), lineaments are geological features that are identified as significant lines in a landscape caused by joints and faults, associated with the hidden architecture of the rock basement. Lineaments and their intersections play a significant role in the occurrence and movement of groundwater resources in different lithological units. The presence of lineaments may act as a conduit for groundwater movement, which results in an increased secondary porosity and, therefore, can serve as groundwater potential zone. For the preparation of this layer, first the lineament features need be interpreted from the Digital Elevation Models (DEM) and/or RADAR data. Then the lineament density, which is defined as the total length of all the recorded lineaments divided by the area under consideration, can be derived.

## Groundwater Recharge

Recharge is the primary method through which water enters an aquifer and is a very important factor for the occurrence of potential groundwater resources. It is estimated from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) and infiltration coefficient (IC) of geological units (lithology). Other recharge estimation approach should be assumed like Soil water assessment tools (SWAT) if only for shallow groundwater investigation or water balance technique.

**Land-Use and Land-Cover**

These two variables are useful when it comes to aquifer recharge. Different land-use and land-cover types have different effect on the groundwater potential. A land-use and land-cover layer can be prepared from sentinel-2 satellite images using a supervised classification techniques of digital image processing. For regional studies, existing land-cover datasets, such the ones produced by the European Space Agency (ESA) or Environmental Systems Research Institute (ESRI), can be used.

**Drainage Density**

Drainage density is computed as the total length of the streams per catchment unit area; thus, it represents how close together the drainage channels are. A very high drainage density means that runoff can be banished quickly, and thus, that infiltration is less likely. A DEM can be used to develop drainage density layers. For this, a network drainage will be generated from DEM in the first place. Alternatively, an existing drainage network data available freely from HydroShed could be considered.

**Soil**

The variation in soil characteristics, such as soil texture, chemistry, and others, has its own influence on groundwater potential. Groundwater relies on distinctive factors, such as soil permeability and porosity. For example, clayey soils have less porousness contrasted with different soils, i.e. loamy soils have good infiltration of water, clayey soils have lesser permeability. This thematic layer could be derived from existing soil data, such as that of the FAO as well as via interpretation from a remote sensing imagery.

## Multi-Criteria Decision Analysis and Analytical Hierarchy Process

Once the required variables are produced, a specific weight is needed to be assigned to each thematic layer. A decision made by an expert still needs to be considered, but with the help of relevant tools subjectivity could be avoided. The Analytical Hierarchy Process (AHP) is a structured technique for organising and analysing complex decisions. It was developed by Thomas L. Saaty in the 1980s and is frequently further improved (Goepel, 2013). AHP represents an accurate approach to quantifying the weights of a multi-decision criteria.

In mapping groundwater potential, where different variables are involved, the use of AHP for decision making is important. Hence, the weightage of thematic layers will be employed in accordance with their respective importance for the groundwater occurrence. Suitable weights will be assigned to each theme and their individual features after understanding their hydrogeological importance in causing groundwater occurrence. Furthermore, each of the thematic maps will be then assigned a weight in the range of 1-9 according to Saaty's scale of assignment, ref. Table 8, which depicts the relative importance of the respective themes to groundwater potential.

TABLE 8 | EXPLANATION OF INTENSITY SCALES FOR WEIGHT ASSIGNMENT

| INTENSITY | DEFINITION | EXPLANATION |
|---|---|---|
| 1 | Equal importance | Two elements contribute equally to the objective |
| 3 | Moderate importance | Experience and judgment slightly favour one element over Another |
| 5 | Strong importance | Experience and judgment strongly favour one element over Another |
| 7 | Very strong importance | One element is favoured very strongly over another, it dominance is demonstrated in practice |
| 9 | Extreme importance | The evidence favouring one element over another is of the highest possible order of affirmation |
| 2,4,6,8 can be used to express intermediate values | | |

Source: Goepel, 2013

The Consistency Index (CI) of the assigned weights is calculated following the procedure suggested by Saaty, while the Consistency Ratio, which indicates the probability that the matrix ratings will be randomly generated, will also compute using the values of Random Consistency Index (RI), which is the average value of CI for random matrices using the Saaty scale that will be obtained based on the following relations:

Consistency Index = $(\lambda max - n)/(n-1)$

Consistency Ratio =CI/RI

Where n is the number of criteria or variables

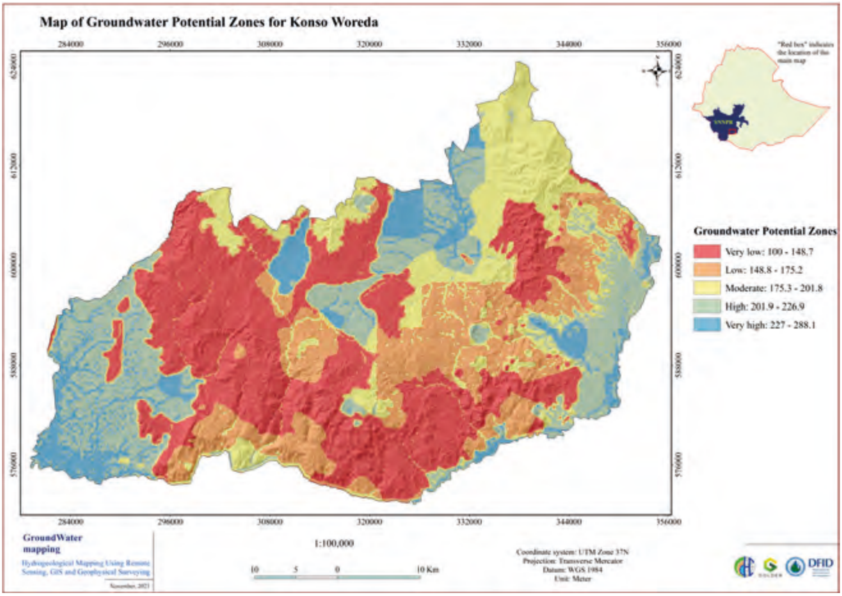
It should be noted that the CR value should be less than 0.10 for consistent weights; otherwise, corresponding weights should be re-evaluated to avoid inconsistency.

## GIS Overlay Analysis for Groundwater Mapping

Overlay is the integration of all the pre-defined variables in GIS to produce a result that shows the distribution of groundwater potential zones. Before doing the integration, all the layers (variables) need to come into similar format, coordinate system as well as similar spatial resolution. This may require reprojection into a common projection system, rasterization of vector layers, reclassification into the required sub-classes, resampling of raster layers into a common pixel size and so on.

During the process, the assigned weights using AHP need to be implemented in a GIS environment. Once the result is derived, using the exiting water well data (e.g., yield, transmissivity), the groundwater potential zones need to be validated at office level as a useful guide for a quick assessment of groundwater occurrence. The data may or may not reflect the actual groundwater situation unless complete information about the well (borehole) and scheme is provided. In the meantime, the output may be classified into different groundwater potential zones, such as very high, high, moderate (medium/intermediate), low and very low (unsuitable). Figure 39 shows a groundwater potential map of the Konso district in Ethiopia.

FIGURE 39 | GROUNDWATER POTENTIAL MAP OF KONSO DISTRICT IN ETHIOPIA




Source: Tadele and Desta (2021)

## Field Validation and Ground Truthing

Any remote sensing work is suggested to be followed by designed field validation and ground truthing activities. Same for the groundwater potential map, i.e. after overlay analysis and result interpretation, it is always necessary to carry out field validation and ground-truthing of the result. Selected groundwater potential areas need to be systematically addressed using pre-designed sampling schemes. This will be able to allow the experts to:

a) Verify ambiguous features and possibly misinterpreted features in the ground;
b) Acquire positional information (GPS coordinates) and make verification of maps where positional errors might have occurred because of inherited resolution of datasets or data processing;
c) Carry out water point survey and mapping;
d) Observe, describe, and measure structural, geomorphologic features and setting in order to obtain onsite scientific inferences;
e) Observe and characterise geological and hydrogeological conditions of the area;
f) Capture the limitations from the groundwater potential mapping outputs for further considerations and possible refinements; and
g) Observe, describe, and select possible detailed survey areas for ground-based geophysical study.

FIGURE 40 | HANDHELD XRF MEASUREMENT AS A PART OF FIELD VALIDATION AND GROUND TRUTHING OF REMOTE SENSING WORK

Source: Monique, Acacia Water (2019)

## Geophysics for Imaging the Unseen

It is obvious that geophysics in an indispensable method for imaging sub-surface features and further extend the understanding of groundwater resources. Geophysics is something that uses the principles of physics for understanding the interior of the earth. Its role on the groundwater mapping comes a little later than remote sensing efforts. It is recommended to carry out geophysical work at selected potential target areas where field validation and ground truthing have been done. There are different approaches within geophysics, such as electrical resistivity (1 dimensional or 2 dimensional), electromagnetic and so son. The purpose of the two-dimensional resistivity imaging survey is to provide lateral and vertical subsurface information related to the occurrence of groundwater. The objectives are:

a) To determine the thickness and nature of the unconsolidated sediments;
b) To determine the nature of the rocks under the unconsolidated sediments;
c) To determine the vertical and lateral variation of the sediments;
d) To detect and outline geological structures (faults, contacts, etc..); and
e) To map the saturated zones.

There are various devices to be considered for groundwater investigation applications, such as an ABEM terrameter, SYSCAL pro-resistivity meter, Superstring WIFI etc.

## Summarising Remarks

Owing to the scientific and technological advancements around the world, it has come clear that using contemporary methods, such as remote sensing and GIS, are highly helpful compared to classical mapping methods. Specifically in terms of addressing a given area of interest without missing nowhere unseen. Hence, remote sensing driven information and integration of them with GIS and conventional geoscience datasets have been clearly demonstrated to pinpoint where potential groundwater sites are likely to occur. This in turn helps to localise scale of observation, reduce time, energy, and financial expenses. However, it has to be underlined that since many kinds of information (satellite images, GIS datasets, geological, hydrogeological, geophysics etc..) are being used and integrated for addressing an objective, the issue of data quality, consistency, data lineage and related issues should be carefully considered. The lack of critical data handling may eventually lead to misinterpretations and/or even appear to have a totally non-sense result.

There is no question that there are millions of peoples living in the remote areas of Africa and a large proportion of them do not have access to water. This brings a couple of questions to mind. First, there is not a lot of history on water related studies and development activities in rural areas and there is no sufficient data with appropriate scale, quality, and format to use for groundwater exploration. Second, the collection of ordinary field data of larger areas is typically time and resource intensive, which the country or a certain institute cannot afford nationwide. Hence, for the African countries where there is a large share of rural population which still lacks access to drinking water, one must design an alternative approach to make groundwater exploration as efficient as possible, such as remote sensing and geospatial technologies. Remotely obtained data is especially important in the area where hydrogeological data collection and monitoring is rarely systematic and where the potential of groundwater resources remains largely unknown. This is one of the reasons why many countries and institutions around the world have become accustomed to making use of remote sensing and GIS. Therefore, water and geoscience institutions shall continue utilising remote sensing and GIS techniques for hydrogeological/groundwater exploration projects.


LSM in Tanzania

ASM in Assoca in Ethiopia

# INVOLVEMENT OF WOMEN AND CHILDREN IN THE ASM SECTOR IN EASTERN AND NOTHERN AFRICA REGION

*By Ms. Monica Gichuhi, Kenya*

Fortitude is what you observe when watching women working at an ASM site. They silently go about crushing, sorting, sieving, washing, sluicing, and panning ore that is transported and brought to them from the various pits where the men are extracting. Perched at a slightly higher ground, these women have separated themselves into groups depending on the task allocated for the day. Usually termed as the invisible laborers in ASM operations, they make up to 40 or 50% of the work force in the ASM sector in Africa.

Women's duties start at dusk when they wake up to prepare their children for school and make meals for their families. They will then finalise their household chores, which include washing clothes, tending to the chicken and the kitchen garden after which they will lock up and proceed to the mines to start on paid work. Depending on the age of their children, some will be brought along to the mining sites as there are no daycare centres around for the kids to be left. The children will be left at a location within the mining site where their mothers can keep an eye on them as they go about their work.

The women are paid based on the quantity of ore produced and crushed. Payment at ASM sites is basically done by dividing the ore. Despite the amount of work undertaken by the women, their work is considered "less" important than that of the men; hence, their pay is also significantly lower than that of the men. This is despite the fact they crush, pan, and wash all the ore that has been produced by the men each day.

The mine owners who are rarely women are also not keen to provide these female workers with any PPE. They crush the ore without any gloves, masks, or helmets despite the huge amounts of dust being produced and the rock chips that fly about. They wash the ore and handle the mercury to make amalgam without using gloves. Some are known to burn the amalgam on the little charcoal stove (jikos) in the open air to recover the gold, thereby inhaling the mercury fumes in the process.

They labour for their children and families and some of them are the bread winners. They cannot solely rely on the men, since some end up drinking most of their income and often they do not earn enough to meet all the household needs. Therefore, the women must work to assist their spouses and supplement the household income.

Some of the other duties, which women perform at the mining sites, include cooking for the workers or hawking around ready cooked meals, selling mobile phone airtime and other small consumables to the casual laborers. These are the few lucky women who engage in decent work at the mining sites. The migratory nature of ASM sites and the workers also leads to a lot of prostitution at these sites, which results in spreading of HIV/AIDs among the miners. The women are drawn into the mining centres due to the ready cash from the mine workers, who rarely move around with their families. As more women increasingly participate in ASM, promoting awareness of women's health and safety at mine sites is important for their personal safety and decent work as well as their general health and well-being (Hinton et al., 2013).

Other negative implications of ASM activities on women in and around ASM sites include the prevalence of gender-based violence. This mainly occurs due to the informal environment in which the miners operate. These ASM sites lack law enforcement officials to ensure a safe environment for the women, there are no reporting centres in case of incidences occurring and a general lack of education and training on gender-based violence among the ASM workers.

## Support for Women in ASM

The resilience demonstrated by the women in ASM requires to be supported. This can be done by ensuring the women work in a safe environment where they can be productive and renumerated fairly for their work. Some of the interventions that can be undertaken include:

a) Availing PPE for the women at the mine sites. Gloves, gumboots, helmets, masks should be available for these women to protect them against the health and safety risks that they are exposed to on a daily basis as they go about their work;
b) Fair pay for their labour. These women undertake multiple roles as both caregivers at home and laborers at the ASM sites. They should be compensated fairly and offered fair pay as their male counterparts for work done. Fair portion of ore bags for a day's job just like the men;
c) Supporting women in obtaining mineral rights and land rights. Women are rarely mine owners as land is traditionally owned by men, who subsequently end up obtaining the mineral rights as well. Women are relegated to casual laborers; hence, limiting the opportunities of increasing their incomes by owning the mines. Governments should support more women to own mines by designating some specific areas for them to mine as has happened in some areas in Tanzania and Kenya. This support can also be coupled with assistance in obtaining geological information over these allocated areas;

d) Availing of financing options to women miners. In order to empower women miners, financing must be available coupled with training on financial literacy. Financing for them to apply for mining rights, buy equipment, pay their workers, and run their mining operations professionally. Various creative models for availing financing could be through cooperatives where the women miners save and borrow. Willing development partners can also avail grants that can be given to women in mining as seed capital to start their mining ventures. Where upon, as their mine operations develop and grow, these women could be motivated to approach other financial institutions like banks and microfinances for formal loans;
e) Training is key in promoting women in mining. Training on various diverse topics to support the women. These trainings should include: 1) technical training on mine management; 2) basic geology; 3) finance and operating a business; and 4) occupational health and safety issues. These trainings should be ongoing and targeted depending on the role the women are undertaking in the mines;
f) natory practices against women. Women should be made aware of their rights and their economic freedom to earn a living. Mechanisms for reporting perpetrators of gender-based violence should be set up by the Government and other well-wishers to curtail the prevalence of gender-based violence at ASM sites. Distribution of condoms at ASM sites and training on HIV/AIDS and other preventative measures should also be availed;
g) Availing markets. Women miners struggle to access fair markets for their minerals and mainly end up selling through middlemen, who shortchange them. Supporting women to access markets and train them on how to go about valuation of the grades and quality of their minerals hence knowledge on how to price their products competitively to fetch better market prices;
h) Formation of women in mining associations to advocate and lobby for the women and highlight their plight. These umbrella bodies give women a chance to network, facilitate knowledge sharing as well as amplify their voices on areas where they need support. Such associations also provide a platform for women to lobby for leadership positions within the mining cooperatives and other relevant institutions where they can influence policy and other important decisions pertaining their welfare; and
i) Inclusive development requires that as Governments aim to achieve formalization of the ASM sector, gender issues should be streamlined into the process. The participation of women in the ASM sector should be acknowledged and supported as they are a significant part of the success of the operations and the sector.

## Child Labour in ASM

Child labour is a prevalent issue at most ASM sites. Due to the general informality in the ASM sector, it is challenging to estimate the number of children working at the mining sites at any particular time. In 2006, the International Labor Organisation (ILO) estimated that about 1 million children work in ASM. Children are often used in mining operations to help transport, sort, or wash material and because of their size, they may also work in narrow underground tunnels. There are various reasons why the children end up at these sites. ILO defines “child labour” as work that deprives children of their childhood, their potential, and their dignity, and that is harmful to physical and mental development.

Poverty is one of the main reasons that leads to child labour at the mine sites. Parents force their children into the mines to work to increase the household income or to fend for their own school fees. School going kids are forced to work at the mines unwillingly instead of going to school. This essentially means denying a child the rights and freedoms of enjoying their childhood. In other instances, children work in the mines during the school holidays as part of assisting their parents with light duties at the mines.

Some of the children find their ways into the mines due to peer pressure despite their parents and authorities warning against it. During a mining boom, where everyone in the village rushes to a “boom” site, the children also get roped in due to the allure of making quick money. The assumption is the more the hands digging, the greater the production or higher chance of making more. Hence, the children around these mining boom sites are attracted or lured into the get-rich-quick fallacy.

Children born in mining communities also lack mentors or role models to show them the merits of going and staying in school. These children live in communities where everyone depends on mining for a living. The only source of livelihood and income the children have seen is from working in the mines. They have not been exposed or seen people undertake other successful economic activities or careers. These children lack the motivation to continue with their schooling and opt for an early start into the mining business to earn money.

In some instances, young children end up at the mining sites due to lack of childcare facilities in the community or women do not have the resources to pay for such facilities; hence, they carry them to the mining sites. The children end up playing around the mining sites, which can expose them to a myriad of health and safety risks including the likelihoods of fatal falls into the pits, dust and noise exposure and the most severe being exposure to mercury fumes at a very tender age.

The ILO considers mining and quarrying as hazardous work, and children working in mines one of the worst forms of child labour. Children working at the mines are at risk of exploitation, physical and psychological abuse, and are subjected to working conditions where physical strain and chemical exposures may result in lifelong disabilities.

## Addressing Child Labour Issues

Various initiatives should be implemented to combat child labour. Most importantly, governments must enact laws that ban child labour and impose severe punishment on adults, who are found to be guilty of forcing school going children to work in the mines. This should be coupled with continuous monitoring and inspections of the mines to ensure they are free of children working at the sites. Governments should also aim to promote free primary school education in their countries to eliminate the cases of children being forced to work for their school fees due to the costs associated with going and staying in school.

Communities especially the women, should create childcare systems or mechanisms. This could include some women being left behind in the homesteads during the day to take care of the younger ones on a rotational basis or a small fee paid to volunteers willing to stay behind and watch the children. Such initiatives would act to drastically reduce the number of non-school going age children who are brought to the mines as well as lower the risks and dangers these children are exposed to in such environments.

Awareness creation on the dangers and effects of child labour should be undertaken for the miners and the mining communities. Non state actors have played a key role in creating awareness and combating child labour in the ASM sector. Collaboration among various stakeholders to train and come up with frameworks and guidelines for monitoring and abolishing child labour should be fostered as well as availing the necessary funding for such initiatives. These efforts should be encouraged and amplified until there are no children in and around the mining sites.

Counselling and mentoring of school going children should be encouraged. Children born around mining communities should be exposed to mentors and shown various alternative successful career paths over and above working at the mines that they could aspire towards. This could provide the necessary motivation for the children to go and to stay in school. The children already working at the mines, should also be counselled to encourage those who might be willing to get back to school and as well as assist those who might be battling with any psychological issues and abuse.

Finally, all stakeholders involved in the sector should collectively speak out strongly against child labour at the mines and combating the same by ensuring minerals mined at sites where there is evidence or suspected child labour do not get to the market. Calling out and reporting on such areas to mount pressure to discontinue with these practices.

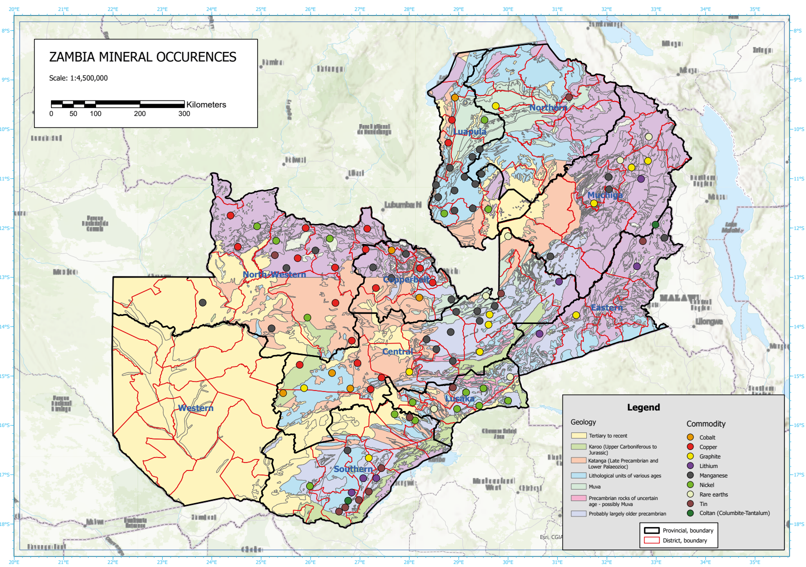
ASM mining site in Zambia

# ASM SECTOR OF ZAMBIA

*By Lungu Kachila*

Zambia is endowed with a variety of Development Minerals that include mineral commodities, such as sand, clay, limestone, dolomite, basalt, micaceous shale, stone aggregate, and construction sand, dimension stones, ref. Figure 41 (Ministry of Mines and Minerals Development, 2018). ASM miners mine mostly the Development Minerals. Based on estimates, in 2018, Zambia collected an estimated mine revenue of USD 1.4 billion from an estimated ASM population of 100,000 (Buxton, 2013). ASM is an important source of labour more than 100,000 Zambians, almost 30% of which are women and youth. ASM work is mostly manual, disorganised, and informal.

FIGURE 41 | MINERAL OCCURRENCE MAP OF ZAMBIA




Source: Ministry of Mines and Minerals Development

In terms of extraction costs, Development Minerals in Zambia offer the least costs and act as a motivating factor for citizens to engage in the business, despite the sheer number of ASM miners in Zambia. Therefore, only a few individuals, who can afford to make substantial investments in the industry, have been able to reap good profit while hundreds of thousands of people continue to operate marginally at the ASM level.

The ASM players of Zambia are organised into different associations from different region of the country:

a) ZAGEMA: Eastern Kalomo Miners Association;
b) ESMAZ: Southern Copperbelt and Luapula Miners; and
c) AZWIM: Countrywide.

All these association are affiliated to a mother body called, Federation of Small-Scale Miners Association of Zambia.

## The Role and Work of the Ministry of Mines and Minerals Development

The Ministry of Mines and Minerals Development (MMMD) has four technical department:

a) Geological Survey: The major role of the survey department is to acquire geological data through mapping, but it is also the repository institution for all geological information. Additionally, it owns and manages the laboratory facilities for all mineral analysis;
b) Mines Development: This department undertakes inspections of mines, issues export permits, and develops mines;
c) Mining Cadastre: This departments takes care of licencing of mining operation and acts as the custodian of the register of all licence holders; and
d) Mines Safety: This department oversees the safety of the mines and the workers and issues explosive permits.

## Legislative Framework

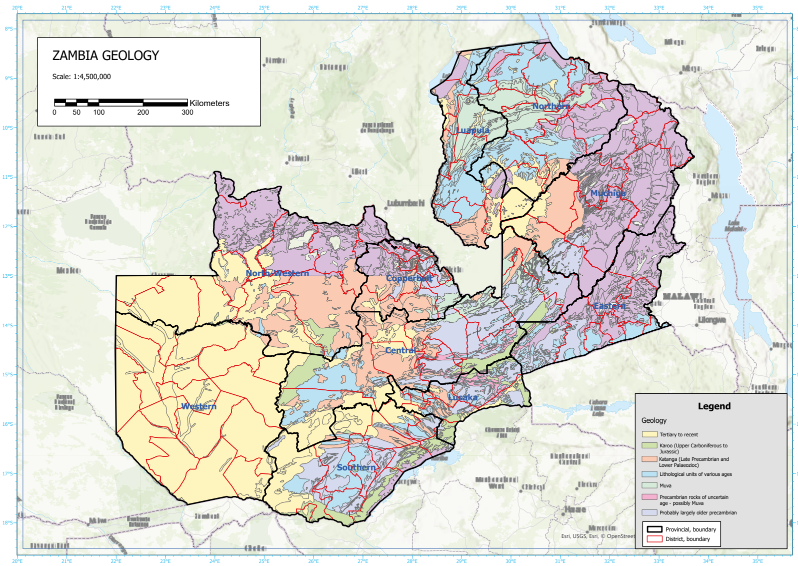
All mining activities in Zambia are governed by the Mines and Minerals Development Act of 2015 and the General Mining Regulation of 2016. There are three types of licences granted to ASM miners:

a) Artisanal Mining Licence: Granted to a citizen of Zambia undertaking ASM in an area covering not more than six hectares.
b) Small-Scale Exploration Licence: Granted to a citizen of Zambia for exploration of an area not more than 1,000 hectares; and
c) Small-Scale Mining Licence: Granted to a citizen of Zambia undertaking small-scale mining of an area not exceeding 400 hectares.

## Geology

The complex geology and multiplicity of tectono-thermal events reflect Zambia's somewhat unique position effectively sandwiched between the Kasai, Zimbabwe-Kaapvaal, and Tanzania cratons. Differential movements between these stable blocks, together with their but-stressing effects, have played an important role in the geological evolution of the country and hence in the genesis of the country's mineral and energy resources.

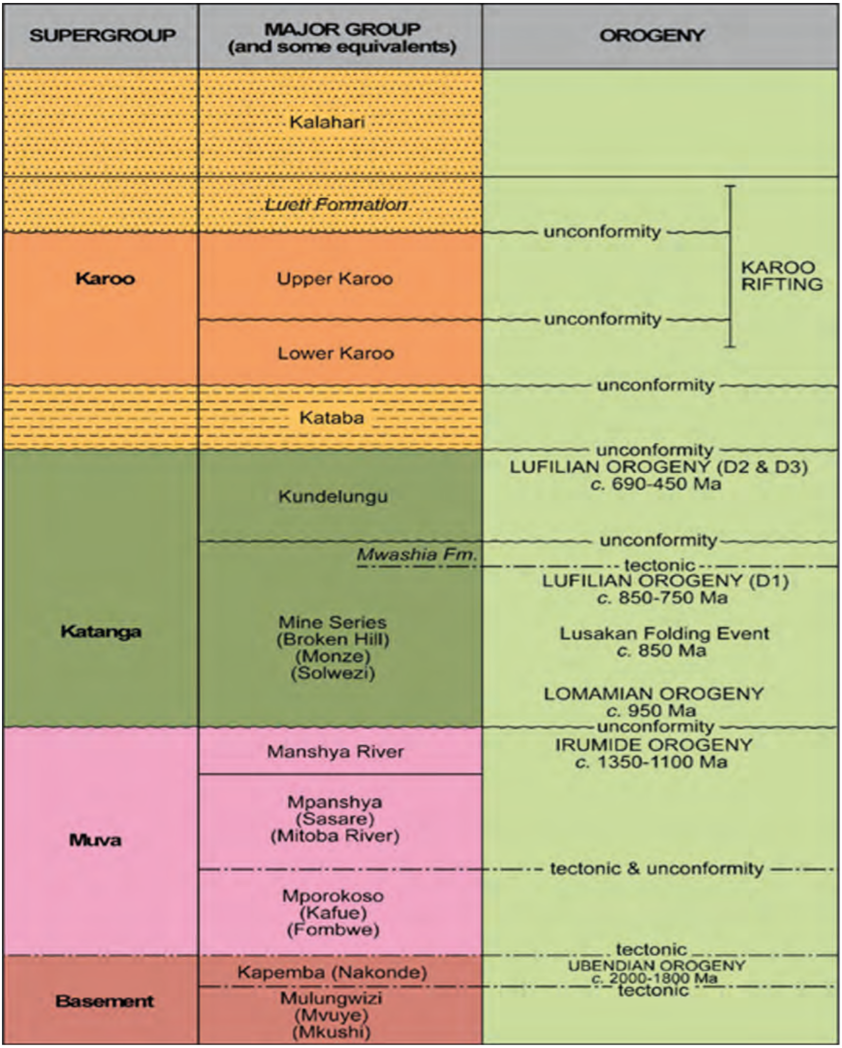
FIGURE 42 | GEOLOGICAL MAP OF ZAMBIA




Source: Ministry of Mines and Mineral Development, Scale of 1:1,000,000

Figure 43 shows the stratigraphy of Zambia.

FIGURE 43 | STRATIGRAPHY OF ZAMBIA




Source: Ministry of Mines and Mineral Development

## Challenges of ASM in Zambia

### Degradation of the Environment

The land tends to lose its value due to the massive digging, pollution of the area, both water and air, upstream erosion of rivers due to downstream extraction, and downstream sedimentation and turbidity of rivers due to upstream extraction.

### Lack of Formalisation

Formalisation is defined as “the authorities’ efforts to have individuals, groups of persons or an established Association or Cooperative obtain a license to work following prescribed legal requirements of the national mining legislation”. Authorities use different types of interventions, such as policies and incentives to support this process in terms of providing technical, administrative, and financial support, monitoring as well as further extension services. In short, formalisation is the process of bringing informal income-earning activities and economies such as ASM into the formal sector through legal, regulatory and policy frameworks. Table 9 lists the challenges and proposed measures in the formalisation of the ASM sector in Zambia.

TABLE 9 | CHALLENGES AND PROPOSED MEASURES IN THE FORMALISATION OF THE ASM SECTOR IN ZAMBIA

| NO. | CHALLENGE | PROPOSED MEASURES TO PROMOTE FORMALIZATION |
|---|---|---|
| 1. | ASM feel there is little difference between being legal and illegal | Linking technical support and capacity building activities to formalisation |
| | | Linking access to credit to formalisation |
| | | Government purchasing commodities at a higher price than informal markets |
| 2. | ASM lack of knowledge of legal requirements | Capacity building/awareness programmes |
| | | Communicating more regularly and effectively with miners |
| 3. | Traditional and cultural practices of ASM, e.g., operating individually without seeking permits; chieftaincy systems | Baseline information to understand target community |
| | | Increasing local participation, including traditional authorities, in initiatives linked to formalisation |
| | | Working closely with local organisations and communities |
| 4. | Licensing fees are too high for miners | Reducing costs in licensing, royalties, taxes and fees |
| 5. | Miners fear having to pay taxes, royalties and fees if legalized | Tax incentives |
| | | Incentives that provide direct access to markets which pay higher prices for commodities than the informal market.<br><br>Capacity building and training programs linked to formalisation. |
| 6. | The complex, bureaucratic process to formalize | Simplifying licensing procedures |
| | | Providing decentralised support to ASM in the formalisation process |
| 7. | ASM have to travel to large centres to apply for a license | Decentralising licensing procedures to regions where ASM is taking place |
| 8. | Miners have to re-apply for licenses every two to three years, making it difficult and costly for miners to maintain legal status | The increasing license expiration period |
| | | Reducing bureaucratic procedures for reapplication of license |
| 9. | Free access to most convenient buying agents (Inc. non-licensed) as informal enterprises | Provide access to markets that pay higher prices for commodities than the informal market, |
| 10. | Mobility of small-scale and artisanal miners – informality helps to maintain flexibility in shifting from one site to another | Geospatial data and Geological mapping |
| 11. | Limited access to mining concessions for small-scale and artisanal miners | Demarcation of areas for ASM |
| 12. | Rare visits and inspections of ASM mines | Decentralization of offices to mining areas.<br>Decentralizing monitoring responsibilities<br>Up-skilling miners to monitor health, safety and environmental practices |
| 13. | Providing incentives requires a level of capacity from the government that might not exist | Capacity building for government |
| | | Increased advocacy to encourage resources and attention to be directed at ASM |
| | | Public-private partnerships |

Source: Ministry of Mines and Mineral Development

**Development and Acceleration of Development Minerals**

Some of the significant challenges in the development and acceleration of Development Minerals in Zambia by the ASM sector include:

a) Lack of a sector-specific business acceleration program;
b) Lack of capacity building on training and access to financing and equipment;
c) Lack Identified ASM competitive advantages; and
d) Weak value chain and minimum diversification of local economies.

Table 10 lists the different strategic goals and corresponding measures to further develop and accelerate the exploration and exploitation of Development Minerals by the ASM sector in Zambia.

TABLE 10 | PROPOSED IMPLEMENTATION PLAN FOR DEVELOPMENT AND ACCELERATION OF DEVELOPMENT MINERALS

| STRATEGIC GOAL | SPECIFIC OBJECTIVES | ACTIVITY | TARGETS TO BE ACHIEVED BY END OF 2026 |
|---|---|---|---|
| Strategic Objective #1 Improve Business Management and Entrepreneurship Skills of Development Minerals ASMs | A. Training of ASMs in business start-ups, management, and sustainability | 1. Conduct training in business startup, management, and sustainability | 1. All Development Minerals ASMs trained have their entities formalised |
| | B. Training of ASMs in Computer literacy and establishing internal business management structures | 1. Conduct computer literacy trainings for ASM operators | ASM operators to have the ability to use computers and engage in e-business |
| | | 2.Estblish internal business management structures | ASMs transformed into Small Scale Miners |
| | C. Build and operate an online platform dedicated to marketing and selling Development Minerals products with interface provided to both supply and demand sides for direct and easy access. | 1.Develop an online platform | Increase visibility of Development Minerals in both local and international markets |
| | | 2.Facilitae ASMEs access to online platform | Increased Knowledge of DM markets |

| | | | |
|---|---|---|---|
| Strategic Objective #2: To improve the value chain and maximize diversification of local economies | A. Undertake a scoping study on the status of value addition, required skill sets and skills gap in the Development Minerals Sector | 1. Undertake a scoping study | Increased information and knowledge on the status of value addition in the Development Mineral Sub-sector |
| | B. Strengthen enforcement of the industrial development policy | 1. Monitor value addition activities in the DM Sub-sector | Enhanced value addition activities of development minerals |
| | C. Training of miners in value addition of development minerals | 1. Conduct training on value addition for ASMEs | All the ASMs trained on value addition of development minerals |
| | D. Create a fund that can be accessed by legalised ASMs to start small scale industries for example cement, building blocks, etc. | 1. Create fund for legalised ASMs | Increased the number of small-scale industries |
| | E. Enhance collaborations with existing innovation and incubation centres. | 1. Facilitate collaboration with innovation and incubation centres | ASMs have access innovation and incubation services |
| | F. Build partnerships with SMART Zambia and other e-business platforms to innovate digital business solutions for the Development Minerals Sector. | 1. Identify and build partnerships with SMART Zambia and other e-business platforms | ASMs have innovative digital business solutions for the Development Minerals Sector. |
| Strategic Objective #3: To improve Market Access | A. Enhance capacity of ASMs to understand public procurement processes to enable them to compete in bidding processes | 1. Undertaking training on public procurement basic processes | More ASMs competing in bidding processes |
| | B. Capacity building of ASMs to negotiate effectively for the best price at the right quality with traders/dealers | 1. Train ASMs in effective negotiations | ASMs equipped with effective negotiating skills and |
| | C. Facilitate ASMs access to market information for quality decision making | 1. Link ASMs to sources of market information | ASMs accessing market information of making quality decision |
| | D. Promote producer to consumer links by creating partnerships between ASMs and MSM, LSM, construction companies and other supply chain actors | 1. Create partnership between ASMS and MSM LSM, construction companies and other supply chain actors | ASMs is fully integrated in DM supply chain. |
| | E. Engage the Zambia Bureau of Standards to put in place a quality control, verification, and standardization system for Development Minerals production | 1. Conduct engagement with Zambia Bureau of Standards | ASMs quality control, verification, and standardization system in place for Development Minerals production |
| | F. Facilitate ASMs to participate in local and international trade fairs. | 1. Organise ASMs to participate in trade fairs. | ASMEs fully participating in all the local and international trade fairs |
| Strategic Objective #4: To facilitate Accessing to finance | A. Create linkages with financial institutions and other institutions that can provide financial support to ASM | 1. Identify and link ASMs to financial institutions and other institutions. | Increase access for ASMs to start up and working capital |
| | B. Creating grants or funds to bridge challenges in accessing capital | 1. Develop grants or funds for ASMEs | Improved access to capital for ASMs |
| | C. Promote the use of digital financial and payment solutions at ASM production sites and markets | 1. Sensitize ASMs on the use digital financial and payment solution | ASM fully exploiting digital and financial solutions |
| | D. Build the capacities of Development Minerals supply chain actors to partner with financial service providers. | 1. Train and encourage DM supply chain actors create partnership | All DM supply chain actors partnered with financial service providers |

| | | | |
|---|---|---|---|
| *Strategic Objective # 5 To facilitate access and acquisition of appropriate equipment* | *A.* Facilitate the production of affordable equipment produced locally | 1. Promoted local production of mining equipment | ASMs to have access to affordable mining equipment made locally |
| | B. Bridge the gap between ASMs and financial institutions to access bank guarantees and/or equipment leasing. | 1. Promote collaboration between ASMEs and financial institutions | Improved ASMs accessing bank guarantees/or equipment leasing |
| *Strategic Objective #6* To provide training to address skills gap | A. Partner with Technical Education, Vocation, Entrepreneurship and Training Agency (TEVETA) in collaboration with Trade Schools located indifference provinces to develop tailor made short courses for ASMs | 1. Develop short trainings in collaboration with TEVETA and Trade Schools | ASMs trained in running the business and managing mining operations |
| | B. Create partnerships between MSM/LSM and the ASMs in order to enable market-oriented apprenticeship and internship placement programmes | 1. Create partnership between MSM/LSM and the ASMEs | ASMs capacity built through market-oriented apprenticeship and internship programmes |
| | C. Work with partners in government, international development partners and the private sector to launch a scholarship programme that addresses the skilling and skills gaps in the sector. | 1. Develop and Lunch scholarship programme that addresses the skilling and skills gaps in the sector. | ASMs skill gap addressed through scholarships |
| *Strategic Objective # 7* To Increase access to geological data and information | A. Facilitate access to affordable geological information to in simplified and easily accessible formats | 1. Develop an e-platform for Geological data and information | ASMs to have easy access to affordable Geological data and information for decision making |
| | B. Engage with Financial Institutions to advocate for utilisation of geodata and reserve estimations to inform credit and other financing decisions | 1. Sensitize Financial institutions on the availability of Geodata | Financial Institutions using Geodata and reserves estimation to inform credit and other financing decisions |
| *Strategic Objective # 8 To Mapping out of Development Minerals ASM zones* | A. Map and gazette Development Mineral rich areas specifically for the ASMs in all the provinces as a form of affirmative action | 1. Undertaking mapping of DM rich areas | All Development Minerals ASM zone captured on the map |
| | | 2. Gazette DM rich areas | All the Development Minerals ASM zone gazzeted and information made available |
| *Strategic Objective # 9 Improve ASM technical capacity to improve mining and quarrying practices* | A. Provide soft skills to miners and extractors on best practices in mining and quarrying | 1.Conduct training for miners and extractors | Enhanced miners and extractors best practices in mining and quarrying |
| | B. Train miners and extractors on the use and applicability of mining equipment in resource extraction | 1. Train miners and extractors | Enhanced use and applicability of mining equipment in resource extraction by miners and extractors |
| | C. Incentivise good mining practices | 1. Develop incentives to encourage good practices | Miners and extractors to engage themselves in good mining practices |
| | D. Support cross-regional learning and sharing among ASMs about good mining practices | 1. Facilitate regional learning and sharing among ASMs | ASMs employing good mining practices |
| *Strategic Objective # 10 Enhance participation of women and support women owned ASMs* | A. Develop gender policy on women participation ASM activities | 1. Develop the gender policy document | Gender policy developed and implemented |
| | B. Build the capacity of women led ASMEs to enhance their business management and negotiation skills Prepare for future operational effectiveness. | 1. Conduct training for women led ASMs | Increased participation of and support of women led ASMs |
| | C. Engage Local Governments to give special consideration to women led ASMs in the local tendering processes | 1. Facilitate for special consideration for women led ASMs | Increased number of women led ASMs participating in local tendering process |
| | D. Develop training programmes for Women in Earth Science | 1. Conduct training for women | Capacity built for women led ASMs in Earth Science |

Source: Ministry of Mines and Mineral Development

ASM mining site in Zambia

# ASM SECTOR OF MALAWI

*By Victor Nyalugwe and Martin Kameza*

## Geographical Context of Malawi

### Demography of Malawi

Malawi is a landlocked country with a population of approximately 19.13 million by 2020 and 19.63 by 2021 representing a 2.17% population increase. Malawi is ranked 61st in terms of population and 18th in terms of population growth rate. Around 3.69 million people live in urban areas, representing about 17.7% of Malawi's population. Malawi is ranked 225th in terms of urbanisation.

The Sex Ratio in Malawi in 2021 was 97.33 males per 100 females. There were 9.69 million males and 9.96 million females. The percentage of the female population is 50.68% compared to 49.32% male population. Malawi has 0.27 million more females than males. Malawi is at 72nd position out of 201 countries/territories in terms of female-to-male ratio (UN, 2021).

### Economy of Malawi

The mining sector in Malawi accounts for about 1% of the country's GDP. In 2017, growth in the mining and quarrying sector was estimated at 1.6%. Growth in 2018 was projected at 2.3%. Malawi has several minerals with economic potential, such as Phosphates (apatite), Bauxite, Kaolinite, Coal, Kyanite, Limestones, Rare Earth (including Strontianite and Monazite), Graphite, Sulphides (Pyrite and Pyrrhotite), Titanium minerals along the Lakeshore, and Vermiculite. Most of these minerals have been evaluated in the past by either the Geological Survey Department or private companies. Only phosphate, coal, limestone, and uranium have been partly exploited. In addition, rock aggregate is exploited in many parts of the country for the construction industry (Malawi-Mining and Minerals).

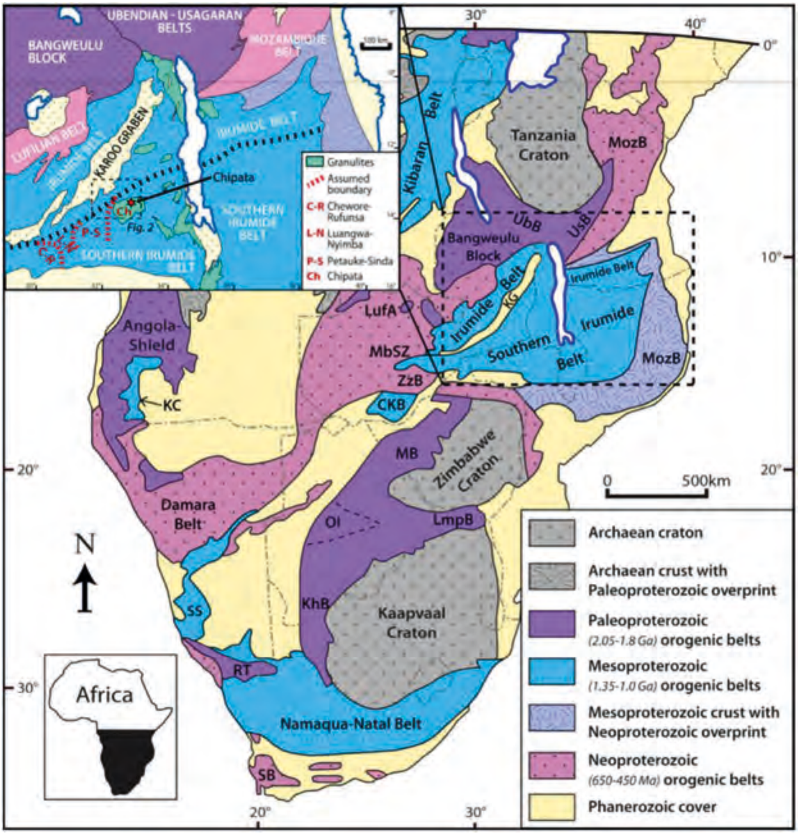
ASM in Malawi is generally carried out through labour-intensive methods for lime production, clay for pottery, and gemstones. Small-scale mining is facilitated by Mineral Permits, Mining Claim Licences, and Reserved Mineral Licences.

The Malawi Geological Survey Department recently released the results of the High-Resolution Airborne Geophysical Survey whose data can be readily procured for use by the academia, the private sector and the general public. Follow-up field surveys, that include geological mapping and geochemical sample collection, were carried out by the Geological Survey of Malawi through the Geological Mapping and Mineral Assessment Project (GEMMAP) from 2016 to 2021.

### Brief Regional Geology

The African continent contains several cratons that are separated by a network of younger orogenic belts of broadly Paleo-, Meso- and Neoproterozoic ages (Karmakar and Schenk, 2016). Malawi lies at the junction of three mobile belts namely Ubendian (2300–1800 Ma), Irumide 1350 –950 Ma, and Pan African or Mozambican 900-450 Ma (Lenoir et al., 1995; Ring et al. 1997; Ring et al., 2002). The Mozambique Belt (Southern portion of the East African Orogeny) represents a major north-south continental collision zone between the various cratonic elements that formed East and West Gondwana (Johnson and Oliver, 2003). Figure 44 shows the regional geological and tectonic map of southern Africa.

FIGURE 44 | REGIONAL GEOLOGICAL AND TECTONIC MAP OF SOUTHERN AFRICA, SHOWING DISTRIBUTION OF DIFFERENT PRECAMBRIAN ROCK UNITS




Source: Karmakar and Schenk, 2016; CKB: Choma-Kalomo Block; KC: Kunene Complex and associated granites; KG: Karoo Graaben; KhB: Kheis Belt; LmpB: Limpopo Belt; LufA: Lufilian Arc; MB: Magondi Belt; MbSZ: Mwembeshi Shear Zone; MozB: Mozambique Belt; OI: Okwa Inlier; RT: Richtersveld Terrane; SB: Saldania Belt; SS: Sinclair Sequence; UbB: Ubendian Belt; UsB: Usagaran Belt. Inset: Overview map of the Irumide and Southern Irumide Belt.

## Brief Local Geological Context of Malawi

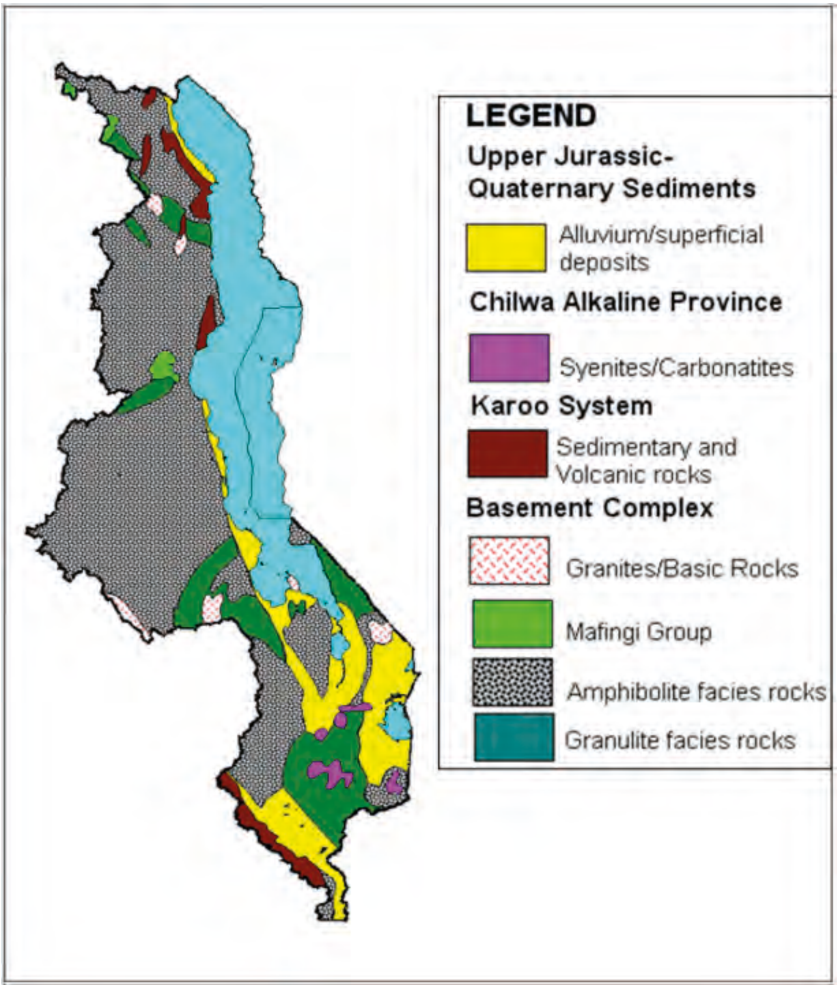
The geological history of Malawi is that of a Precambrian "mobile belt" that is overlain by Permo-Triassic sediments (Karroo system), cut by Mesozoic igneous intrusions (Chilwa alkaline Province), and disrupted by Cenozoic rift faulting. Most of Malawi's geology is overlain by Precambrian to early Palaeozoic sequences of metamorphic rocks of both sedimentary and igneous origin. This complex geology is termed the "Malawi Basement Complex". The bulk of the most significant economic mineral occurrences occurs within the igneous metasomatic and high-grade metamorphic rocks of this Complex. Marble is the most important economic rock type found in this unit. Other mineral commodities associated with the Malawi Basement Complex include vermiculite, corundum, graphite, iron sulphides, kyanite, and apatite (Carter and Bennet, 1973).

The Karroo System occurs in the northern and southern parts of the country. This consists of sedimentary and subordinate volcanic rocks, which unconformably overlie the Basement Complex. These are restricted to six small-fault-blocked outliers. Coal is the main mineral commodity in this category. Other potential mineral commodities include uranium and limestone.

The Chilwa Alkaline Province comprises at least two large syenitic massifs as well as numerous small, but economically significant nepheline syenite, pyroxenite bodies, carbonatite centres, alkaline dykes, swarms, and agglomerates veins. In the north, the equivalent Mesozoic intrusive activity includes kimberlite breccias cutting Karroo sedimentary rocks in the Livingstonia coalfield and numerous dolerite dykes, diorite, and pyroxenite intrusions. The main mineral commodities associated with this group include REEs and niobium.

The upper Jurassic-Quaternary sediments comprising superficial tertiary plus lacustrine and alluvial deposits occur in the north along the western shore of Lake Malawi and in the Vwaza Basin along the Zambian border. Extensive deposits also occur along the southern shoreline of Lake Malawi and in the general vicinities of the Lake Malombe, Lake Chilwa, and the Shire Valley. Important residual and alluvial/eluvial concentrations in this category also include ceramic and brick clays, phosphates, gypsum, and silica sand. Figure 45 shows the simplified geological map of Malawi.

FIGURE 45 | SIMPLIFIED GEOLOGICAL MAP OF MALAWI




Source: Geological Mapping and Mineral Assessment Project (2023)

## ASM in Malawi

### Substances Exploited by ASM Operators in Malawi

In Malawi, ASM operators exploit and mine various minerals and rocks. Some of the minerals and rocks that are commonly exploited by ASM operators in Malawi include Gemstones, Gold, Industrial minerals and Coal (ECA, 2023).

a) **Gemstones**: Malawi is known for its deposits of gemstones, such as garnets, amethysts, tourmalines, rubies, quartz, and beryl. ASM operators engage themselves in the extraction and trading of these precious stones;
b) **Coal**: Some parts of Malawi, mostly the northern and southern, have coal deposits, and ASM operators engage in small-scale coal mining activities. Coal is used primarily for electricity generation and other industrial processes;
c) **Industrial Minerals**: ASM operators in Malawi mine various industrial minerals, such as limestone, gypsum, clay, and silica sand. These minerals find applications in construction, manufacturing, agro-minerals, and other industries; and
d) **Gold**: Although not as prominent as in some other African countries, there are limited gold deposits in Malawi. ASM operators engage in small-scale gold mining activities to extract this precious metal. Gold mining activities are undertaken in districts like Kasungu, Dowa, Nkhota-kota, Machinga, Mangochi, Nkhata-bay, Nsanje, and Karonga.

**Legislative Framework for the ASM sector in Malawi**

The legislative framework for the ASM sector in Malawi is primarily governed by the Mines and Minerals Act of 1981, which was later amended in 2018 and recently in 2023. This legislation sets out the legal framework for mineral exploration, development, and mining activities in the country.

Under the Mines and Minerals Act, the ASM sector is recognised as a distinct category within the mining industry. It defines artisanal mining as mining operations carried out by individuals, groups, or cooperatives using basic equipment and techniques. Small-scale mining, on the other hand, refers to mining operations that are not classified as large-scale, with defined criteria based on the size of the mining area and the investment involved (Government of Malawi, 2018).

The key provisions related to ASM in the Mines and Minerals Act of 2023 include:

a) **Licensing**: ASM miners are required to obtain licenses from the Ministry responsible for mining to carry out their activities. The Mines and Minerals Act of 2023 provides specific procedures and criteria for the issuance of these licenses;
b) **Environmental and Social Responsibility**: ASM operators are expected to comply with environmental regulations and mitigate the impacts of their activities on surrounding communities and the environment;
c) **Health and Safety**: The Mines and Minerals Act of 2023 stipulates health and safety standards for ASM operations, aimed at protecting miners and promoting safe working conditions;

d) **Trading and Marketing**: The Mines and Minerals Act of 2023 establishes provisions for the trading, buying, and selling of minerals produced by ASM operators, including the requirements for mineral dealers and the establishment of mineral markets; and
e) **Revenue Sharing and Royalties**: The Mines and Minerals Act of 2023 outlines the mechanisms for revenue sharing and the payment of royalties from ASM activities, ensuring that the government receives its fair share of the proceeds.

In addition to the Mines and Minerals Act of 2023 other legislation and regulations may also apply to the ASM sector, including environmental laws, labour laws, and regulations related to occupational health and safety.

**Degree of Organisation of ASM Sector**

The ASM sector in Malawi has undergone various developments in terms of organisation and formalisation. The ASM sector primarily comprises small-scale miners, who engage in activities such as gemstone mining, quarrying, and small-scale mineral extraction. Historically, the sector has been characterised by informal small scale mining operators and a lack of organisation. However, efforts have been made to enhance the organization and formalization of the ASM operations.

One notable development is the establishment of the Malawi Artisanal and Small-scale Mining Association (MASMA) in 2018. MASMA aims to represent and advocate for the interests of ASM miners in the country. It seeks to promote responsible and sustainable mining practices, provide capacity-building support, and facilitate access to markets and finance for its members. MASMA plays a crucial role in bringing together miners and fostering their collaborations.

Furthermore, the Government of Malawi, in partnership with international organisations and donors, has been implementing programs and initiatives to support the formalisation and organisation of the ASM sector. These efforts focus on providing technical assistance, training, and access to finance to ASM miners. The aim is to improve their mining techniques, ensure compliance with environmental and safety standards, and enhance their productivity and profitability.

Cooperatives and associations also play a vital role in organizing ASM activities in Malawi. These groups bring together small-scale miners to collectively address common challenges, share resources, and collectively negotiate with buyers and stakeholders. Cooperatives and associations provide a platform for miners to voice their concerns and access various support services.

It is important to note that the degree of organisation in the ASM sector can vary across different regions and on commodities exploited in Malawi. Some areas may have more organised cooperatives and associations, while others still face still challenges in terms of formalisation and organisation.

**Role of the Malawi Geological Survey to Support the ASM Operators**
The Geological Survey Department (GSD) of Malawi plays several roles in supporting ASM operators in Malawi and these include:

a) **Geological Mapping and Exploration**: The GSD conducts geological mapping and exploration activities to identify and assess mineral resources in Malawi. This information is valuable for ASM operators as it helps them locate potential mineral deposits and plan their mining activities more effectively;
b) **Resource Assessment and Evaluation**: The GSD carries out resource assessments to estimate the quantity and quality of mineral resources in specific areas. The information helps the ASM operators to understand the economic viability of their mining operations and make informed decisions;
c) **Technical Assistance and Capacity Building**: The GSD offers training sessions on geology, mining techniques, environmental management, health and safety, and best practices in ASM operations. This support helps improve the skills and knowledge of ASM operators, leading to more efficient and sustainable mining practices;
d) **Regulatory Framework Development**: The GSD provides technical expertise and advice to the government in formulating policies and regulations that govern ASM activities. This ensures ASM operators adhere to environmental standards, land use regulations, and social responsibility requirements; and
e) **Geological Information Dissemination**: The GSD collects, archives, and disseminates geological data and information to the public, including ASM operators. This includes geological maps, reports, and databases that ASM operators can access to understand the geology of specific areas, identify potential mineral deposits, and plan their mining activities accordingly.

## Environmental and Health Issues Related to the ASM Sector in Malawi

**Impact on Waterways**
ASM has significant negative impacts on waterways, such as:

a) **Sedimentation and Water Pollution**. Most ASM activities often involve the excavation of soil and sediment, which increases the erosion rate in mining areas. As a result, sedimentation occurs in nearby waterways, leading to the siltation of rivers and lakes. Excessive sedimentation degrades aquatic habitats, affects fish populations, and impacts the flow dynamics of water bodies (Longwe, Van Den Berg and Njoloma, 2020);

b) **Habitat Destruction**: ASM activities involve clearing vegetation and altering riverbanks and shorelines to access mineral deposits. This leads to the destruction of natural habitats, which are crucial for various species of plants and animals. Loss of habitat disrupts the ecological balance and reduces biodiversity (Kalinda, Nkhoma and Chiotha, 2021); and

c) **Stream and River Pollution**: ASM activities, such as quarrying, often involve the use of explosives and other heavy machinery which uses fuel and lubricates. Improper handling and disposal of these substances result in water and land pollution, affecting nearby streams and rivers. Contaminated water bodies have adverse effects on aquatic life and can lead to ecosystem disruption and degradation (Chachage, Nelson and Mwafulirwa, 2018)

FIGURE 46 | SILTATION OF A RIVER DUE TO ALLUVIAL GOLD

Source: Geological Survey Department and Department of Mines (2017)

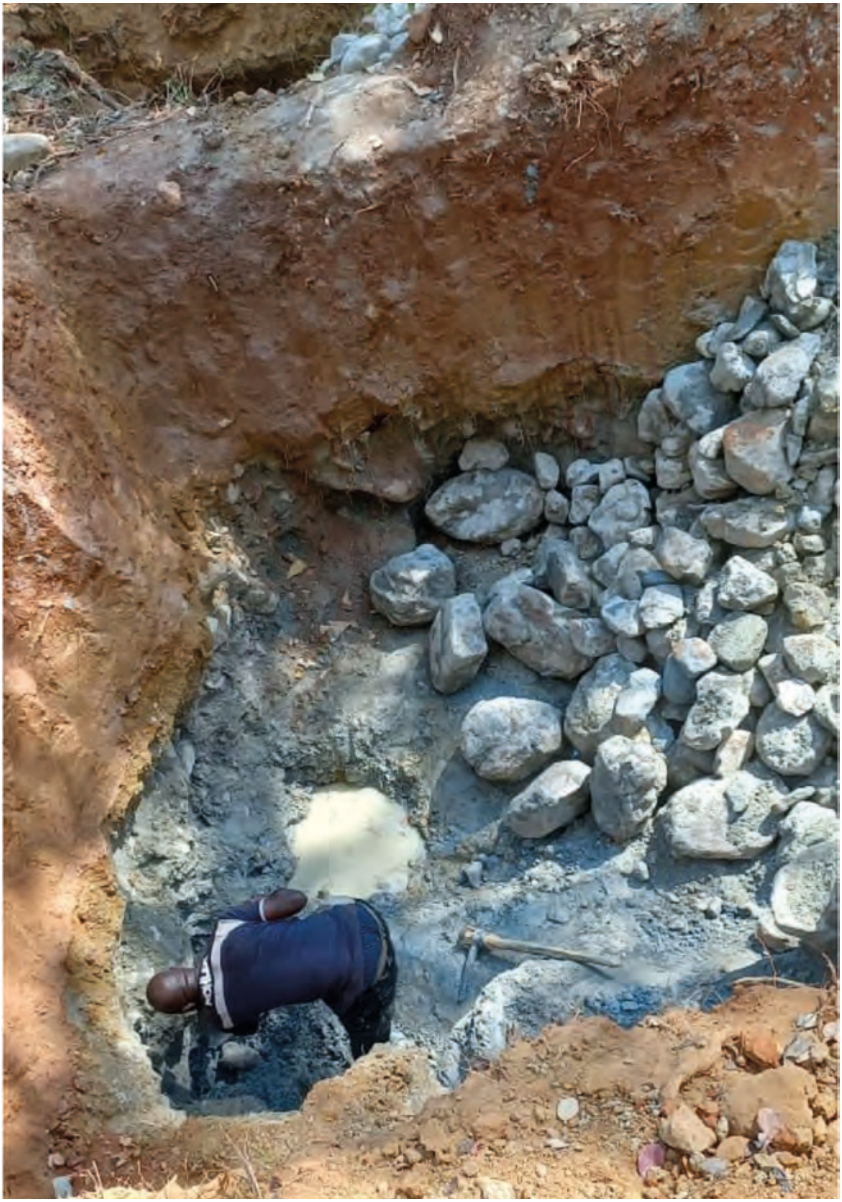
**Impact on the Landscape**
ASM also has significant negative impacts on the landscape, such as:

a) **Impact on Forests**: The ASM sector's activities, particularly gold mining and quarrying lime burning, have contributed to deforestation in several ways, e.g.:
  - ASM gold mining operations in the Ntcheu District of Malawi have caused extensive deforestation. ASM Miners clear forests to access gold-rich areas, leading to the loss of vegetation and habitat destruction; and
  - Quarrying activities associated with the ASM sector in the Mzimba District have resulted in deforestation. Forests are cleared to establish quarries for the extraction of granite and other minerals (UNDP, 2020).

b) **Clearing of Vegetation**: ASM operations require clearing vegetation to access mineral deposits. Forests are often cleared without proper planning or consideration for sustainable land use practices. The removal of trees and plants leads to deforestation, resulting in the loss of wildlife habitats and ecosystem services.

c) **Landscape Fragmentation**: ASM operations, particularly in alluvial or placer mining, often involve the excavation and alteration of riverbeds and floodplains. This fragmentation of the landscape disrupts natural drainage patterns, affects water flow, and impacts the habitats of various flora and fauna.

FIGURE 47 | EXCAVATION FOR GOLD PANNING IN TUKOMBO NKHATA-BAY



Source: Geological Survey Department of Malawi (2022)

### Impact on Health Among ASM Operators

ASM has both positive and negative impacts on the health of ASM operators in Malawi.

a) **Positive Impacts**: ASM provides livelihood opportunities for many individuals and communities in Malawi. It contributes to poverty reduction and improves living standards, which indirectly affects health outcomes; and
b) **Negative Impacts**: Most of the ASM activities involve digging and excavation of earth materials in order to access the target minerals. Poor mine pit and benching design lead to collapsing, accidents, and injuries to the environment. On top of that ASM operators often face challenging working conditions, economic uncertainty, and social instability. These factors, combined with the high-risk nature of ASM, can contribute to mental health issues such as stress, anxiety, and depression.

## Socio-Economic Issues Related to the ASM Sector in Malawi

### Role of Women

Women play various roles in the ASM Sector in Malawi, that contribute to socio-economic development.

Women in ASM engage in different mining activities, such as digging, sorting, crushing, and washing minerals. They may work independently or as part of a team, extracting minerals like gold, gemstones, and coal.

Women are involved in the trading and marketing of minerals. They mine and buy minerals from miners, process them, and sell them to local markets or middlemen. They may also engage in cross-border trade, exporting minerals to neighbouring countries.
Income Generation: Women in the ASM sector use their earnings to support themselves and their families. They contribute to household income and often invest in education, healthcare, and other basic needs.

Women in ASM contribute to the development of their communities. They may invest their income in community projects, such as building schools, healthcare facilities, or infrastructure. They also play an essential role in community decision-making processes related to mining activities.

Women are often more attuned to the social and environmental impacts of mining. They advocate for sustainable practices, ensure the welfare of their communities, and promote responsible mining activities.

Women's participation in the ASM sector can contribute to their empowerment and promote gender equality. Through their involvement in mining, women gain economic independence, acquire new skills, and challenge traditional gender roles. Women in the ASM sector also face numerous challenges, such as limited access to financial resources, lack of ownership rights, and occupational health risks. However, efforts are being made to create opportunities for women's participation, including capacity-building programs, access to finance, and policies promoting gender inclusion.

It is important to note that the roles and experiences of women in the ASM sector may vary depending on the specific context and local dynamics within Malawi.

**Role of Child Labour**

Child labour in the ASM sector in Malawi can have various socioeconomic impacts.

Child labour in ASM is often driven by poverty. Families living in poverty may send their children to work in mining activities to contribute to household income. This perpetuates the cycle of poverty as children are denied opportunities for education and better prospects.

Child labour in ASM negatively affects children's access to education. Working in mines can prevent children from attending school regularly or force them to drop out entirely. The lack of education limits their potential for higher-paying jobs in the future and perpetuates intergenerational poverty.

Children engaged in ASM often face hazardous working conditions. They may be exposed to toxic substances, work long hours, and undertake physically demanding tasks that can harm their health and well-being. This exploitation not only violates their rights but also hampers their overall development.

Child labour in ASM poses significant risks to children's health and safety. They may work in dangerous environments without proper protective gear or training, increasing the likelihood of accidents, injuries, and long-term health problems.

The prevalence of child labour in ASM can hinder the overall economic development of Malawi. By employing children instead of investing in education and skill development, the country misses out on the potential contributions of a well-educated workforce, ultimately impeding progress.

Addressing child labour in the ASM sector requires a comprehensive approach involving government regulations, enforcement of labour laws, access to education, poverty reduction initiatives, and awareness campaigns. By addressing the root causes and providing support systems, Malawi can work towards eradicating child labour and promoting sustainable socio-economic development.

**Conflicts with Local Farmers and Other Stakeholders**

ASM leads to conflicts with local people and other stakeholders, including communities, government authorities, and environmental organizations some of the examples include:

a) **Land and Resource Competition**: ASM operations may overlap with agricultural lands, causing conflicts over land use rights and access to resources. Farmers feel that their livelihoods and agricultural activities are threatened by mining operations;
b) **Environmental Concerns**: ASM activities can have detrimental effects on the environment, including deforestation, soil erosion, water pollution, and habitat destruction. Farmers and environmental organizations may oppose ASM operations due to the potential negative impacts on ecosystems and agricultural productivity;
c) **Livelihood Disruption**: ASM can result in the displacement of communities and disruption of traditional livelihoods, particularly when mining activities encroach upon agricultural areas. Farmers may resist or protest against mining operations that threaten their access to productive land and natural resources; and
d) **Lack of Consultation and Benefit Sharing**: When ASM activities are carried out without proper consultation and the equitable sharing of benefits, conflicts can arise. Local communities and farmers may feel marginalized or excluded from decision-making processes and demand a more inclusive approach.

**Conflicts with Criminal Gangs in the Mining Area**

The country still enjoys the absence of gangsters as well as terrorist groups; hence, no criminal violence in the country affecting the ASM Sector in Malawi.

ASM training in Assoca in Ethiopia

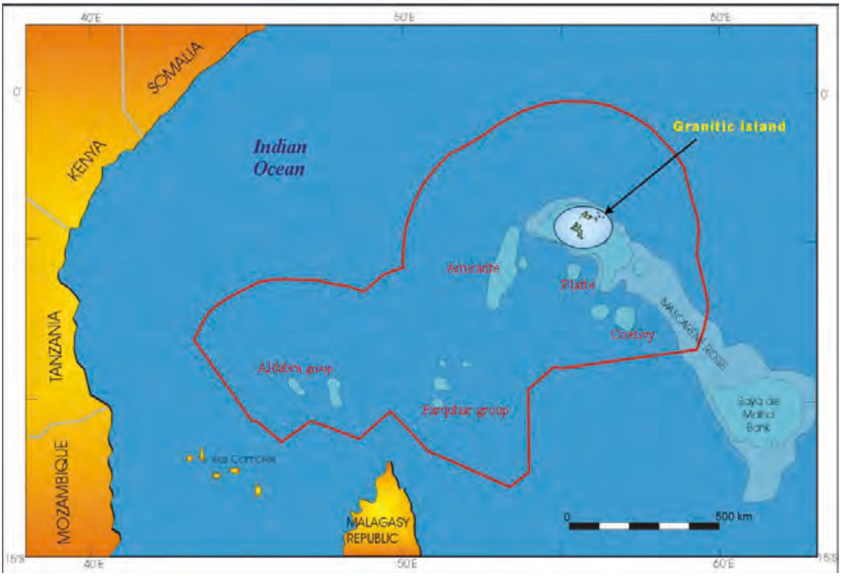
ASM mining in Hetsatsec in Ethiopia

# MINERAL EXTRACTION SECTOR OF THE SEYCHELLES

*By Patrick Samson, Exploration Manager, PetroSeychelles*

## Geographical context of the Seychelles

FIGURE 48 | GEOGRAPHICAL LOCATION OF THE SEYCHELLES




Source: PetroSeychelles

### Demography of the Seychelles

The Republic of Seychelles is a Small Island Developing State located in the South-west Indian Ocean. The Republic of Seychelles comprises 115 islands, totalling only 457 km$^2$ of land, within an Exclusive Economic Maritime Zone of some 1.37 million km$^2$, ref. Figure 48. Lying between 1° and 12° south latitude within the western Indian Ocean, Madagascar and the East African states of Tanzania, Kenya and Somalia are its nearest neighbours.

The inner islands, emerging from the main shallow water of Seychelles Plateau, lying at the north-western end of the Mascarene Ridge, are rugged, verdant granitic peaks that testify to their continental origin as part of the onetime supercontinent of Gondwana. The largest of this core group of 41 granitic islands, Mahe, averages only 3-6 km across yet reaches a maximum elevation of 905 m.

Climatically, the Seychelles is dominated by two seasons: a hot, wet monsoon of fickle northwest winds from November to April, and a cooler, drier trade wind with more persistent southeast winds between May and October. Diurnal temperatures range from 23 ° to 30° C and humidity averages 70-80% year-round. Rainfall averages some 2,300 mm annually.

The population of the Seychelles, some 100,000 people, grew from an amalgamation of African, European, Chinese and Indian immigrant ancestry and is of predominantly Christian (Catholic) faith. The market-place language is Creole, a French-derived patois, whilst English and French are the languages of official business.

There are three main inhabited islands namely Mahe, Praslin and La Digue. About 90% of the Seychellois live on the island of Mahe and the rest live on Praslin and La Digue with the remaining smaller islands either sparsely populated or uninhabited.

**Economy of the Seychelles**

Since the mid-1980s, the Government's policy has aimed at inducing investment, predominantly in fisheries and tourism, as well as increasing its involvement in commercial development through the creation of parastatals. Today, tourism is the major industry and foreign exchange earner, followed by fisheries. Overall, however, despite a stable currency (the Seychelles rupee), the economy is still largely dependent on external financing, and will remain so until a more diversified industrial base is established with export potential. To this end, the Seychelles International Trade Zone has been established to attract capital intensive, export oriented, value-added industries.

In 1984, the Government of the Seychelles established a national oil company, currently PetroSeychelles, to strengthen its capabilities to deal with exploration and other activities related to the development of the petroleum potential of the State. The upstream petroleum sector of Seychelles is still at its exploration stage. Exploration started in the early 1970s and since then, several geological and geophysical surveys have been conducted with the aim of finding commercial accumulations of hydrocarbons. The first three exploratory wells were drilled in 1980-81 by Amoco and although no commercial hydrocarbons were discovered, the drilling proved the existence of a working hydrocarbon system. Enterprise Oil drilled an exploratory well in 1995 that did not reach the pre-Tertiary sedimentary target.

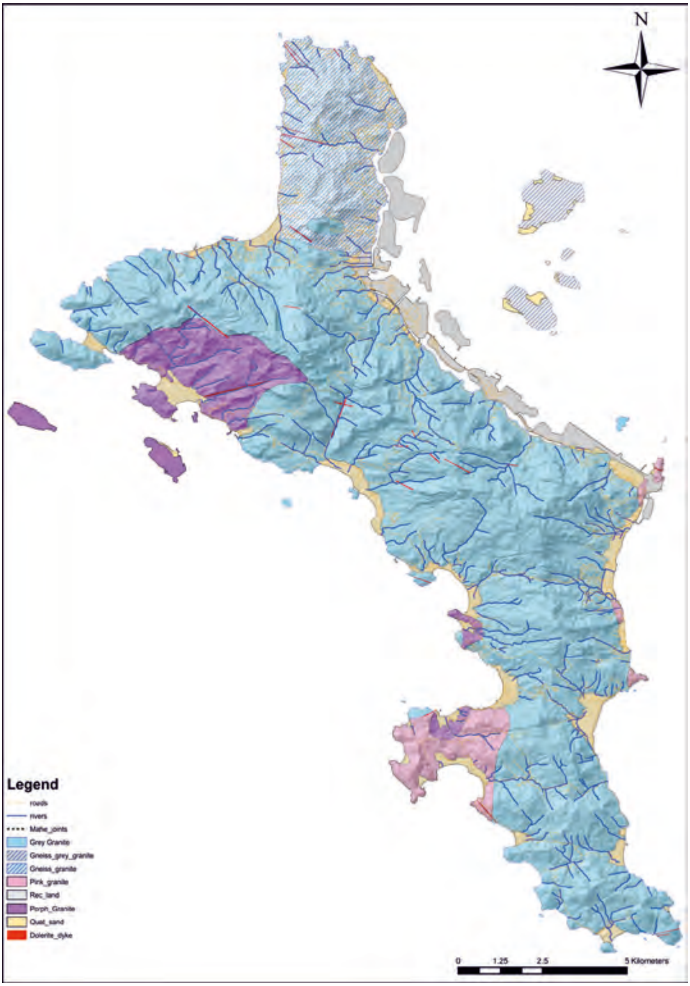
There was no contribution from the Oil and Gas sector to GDP during the years 2021 and 2022. Based on the data provided by the Central Bank of Seychelles and companies, no minerals export contribution has been identified in the country's total exports.

Revenues collected from the extractive industries contributed 0.39% and 0.16% to the total revenues of the Government during the fiscal years 2015 and 2016 respectively. In accordance with the data collected from reporting entities, the contributions of the quarrying sector to total employment in Seychelles is around 1.07% and 1.2% during 2015 and 2016 respectively.

## Geological context of the Seychelles

### Simplified Geological Map of the Seychelles

FIGURE 49 | GEOLOGICAL MAP OF THE ISLAND OF MAHE




Source: PetroSeychelles

**Brief Description of National Geology**

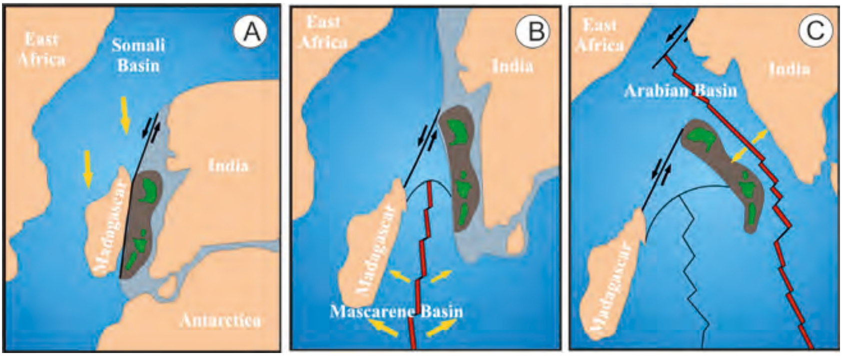
The outcrop geology is quite simple comprising granite intruded in places by basaltic dykes. This makes the Seychelles unique among mid-oceanic islands and it is this fact that attracted geoscientists to conduct geophysical investigations in the Seychelles in the late sixties. The coastal plateaus are quaternary sands deposited as the sea level receded to the present level.

These granites have been dated and they are Precambrian in age at approximately 750 million years old. It is generally accepted in the scientific community that the islands are the emergent peaks of a micro continent that once formed part of the super continent of Gondwana. The exact extent of this micro continent is currently still enigmatic but there is evidence to support a south-easterly extension at least as far as the Saya de Malha Bank.

The Seychelles became stranded in the middle of the Indian ocean as a result of 3 phases of rift drift tectonics, ref. Figure 50. The pre-drift reassembly of Gondwana is based on magnetic anomalies of the Indian Ocean floor, paleo magnetic data, geometric fit, and geological evidence. The southern tip of the Indian Plate in the Ordovician was close to the southern end of Madagascar. In this interpretation, the western part of the Seychelles is part of the West Somali Basin (three wells have proven that the West Somali Basin contains 2,000 m of syn-rift Karoo sediments), and the eastern margin is part of the proto-Malagasy embayment. The north-eastern and eastern margins of the Seychelles shelf were adjacent to the Kathiawar Horst, and the southern Western Shelf was adjacent to the north-eastern coast of Madagascar.

Although it has been speculated that the Seychelles–Mascarene Ridge represents a relict island arc (Kamen-Kaye and Meyerhoff, 1980), it is now generally believed to represent a composite ridge founded on both continental and oceanic crust (Goslin & Patriat, 1984; Mart, 1988). Gravity and magnetic data suggest a full 30 km continental crust in the central part of the Seychelles Bank, thinned to approximately 20 km where stretched. However, a thick sedimentary sequence is also outlined by gravity and magnetics in these areas of crustal attenuation. The drilled stratigraphic section includes over 2,000 m of non-marine Triassic to Lower Jurassic deposits, almost 3,000 m of Jurassic to Lower Tertiary series (with Upper Jurassic, Cretaceous, and Earliest Tertiary volcanic rocks), and a Palaeocene to recent carbonate section. From seismic evidence, such a section also exists off the southern margin of the Seychelles Bank (especially under the Constant, Coevity, and Platte banks). In general, the evolution of the sedimentary basin offshore the Seychelles was tectonically controlled by faulting, which continued to the Early Cretaceous. The continental margin of the Western Shelf of the Seychelles probably began forming during the Permian as part of the Early Karoo/Gondwana rift system. Afterwards, the marginal basins of the Seychelles developed in a passive margin setting with repeated listric growth faulting related to thermal subsidence. Later, the basin underwent episodes of faulting or rejuvenation of older faults, upheavals, and alternate episodes of transgression and regression. In the Tertiary, the basin appears to have remained stable.

FIGURE 50 | PHASES OF RIFT DRIFT TECTONICS, THE SEYCHELLES




Source: PetroSeychelles; The first diagram (A) shows an Early Cretaceous (~ 150 Ma) after the separation of East and West Gondwana. Middle diagram (B) shows an Early Late Cretaceous (~80Ma) with Seychelles and India separating from Madagascar. The last diagram (C) a Paleocene (~60 Ma). During the separation of India from Mascarene Plateau.

## Mineral Extraction in the Seychelles

### What Commodities are Exploited in the Seychelles

The Seychelles is composed of 115 islands with a total land area of 457 km$^2$ of land. During the colonial times guano was mined on the outer coralline islands and exported to Mauritius for the sugar cane plantations. Guano is longer removed on the outer islands. Granite in the bedrock of Mahe and nearby islands had some economic potential. It was quarried for dimension stone on a trial basis by an Italian firm in the early 1980s. In 1992, Gondwana Granite, a South African company, was granted a licence to extract and export up to 3,000 cubic meters of granite. Tile and statuary products reportedly were the most likely end uses. Lime and cement production from the abundant coral also continued to be considered during the mid-1990's. However, preservationists and other environmentally concerned groups opposed both the granite and coral use projects. Polymetallic nodules occur on the ocean bottom near the Amirante Islands. Limited sampling was done in the mid-1980's, but funds for further planned work were not available. Mineral commodities produced in the Seychelles included clay for bricks and pottery, crushed stone, granite dimension stone and sand. Presently there are two quary companies producing aggregates, crusher dust, plastering dust, crusher waste and rocks for the construction industry. The two quarry companies are the

United Concrete Products Seychelles and the Consolidated Construction Consortium Limited. Sand and coral fragments are also mined offshore and stockpiled to be used as back fill in construction.

**Legislative Framework for the Mineral Extraction Sector in the Seychelles**

The mining sector is governed by the Mineral Act of 1962. According to Section 5 of this Act, prospecting shall be lawful under three types of agreement:

a) A prospecting right;
b) An exclusive prospecting licence; or
c) A special exclusive prospecting licence granted by the Minister.

Section 6 of the same Act stipulates that mining activities should be lawful under:

a) Mining rights;
b) Mining leases; or
c) Special mining leases granted by the Ministry.

.

The quarrying industry in Seychelles is governed by the Ministry of Habitat, Infrastructure and Land Transport (MHILT). MHILT is responsible for land policy and land related legislation and timely review thereof. MHILT is the government institution that grants rights to mining companies to conduct quarrying activities on state-owned lands.

Mining companies are subject to tax payments such as Business Tax, VAT and Income and Non-Monetary Benefits Tax to the Seychelles revenue Commission.

The Constitution of the Republic of Seychelles of 1993 stipulates that the State is the owner of all underground water or unextracted oil or minerals of any kind or description. A quarry licence is valid for about 25 to 30 years.

For quarry operations on Government land the quarry company enters into agreement with MHILT and some of the fiscal terms are rental on the land and a royalty of SR5 per ton of rocks extracted from quarry sites and payable monthly. The United Concrete Products Seychelles also carries out quarrying activities on its own private land in Praslin. Exploiting private property does not require land rental to the Government and there has been no licence nor right of any kind provided to the United Concrete Products Seychelles to sell quarried product from its private land.

**Role of the PetroSeychelles in the Mineral Extraction Sector**

PetroSeychelles acts as the defacto geological survey and advises the Government on many geological issues from landslide, rockfall and flooding. PetroSeychelles also consulted on issues of coastal erosion and identification of new quarry sites. However, the main activity of PetroSeychelles is hydrocarbon exploration and other activities related to the development of the petroleum potential of Seychelles. The Seychelles petroleum sector is regulated by the Petroleum Mining Act of 1976, the Petroleum Taxation Act of 2008, as amended in 2013, and the Model Petroleum Agreement of 2013.

## Environmental Issues Related to the Mineral Extraction Sector in the Seychelles

### Impact on Waterways

The Model Petroleum Agreement (Clause 20) defines the requirement of extractive companies to take out insurance policies that cover risks related to environmental damages resulting from the company's operations. The company is also obligated to require its contractors and sub-contractors to obtain and maintain such insurance covers as operators. Clause 21 of the Model Petroleum Agreement details extractive companies' obligations in relation to environmental protection. Accordingly, companies shall act in accordance with the relevant provisions of environmental laws and regulations in force in the Seychelles, including with respect to requirements for conducting EIAs and the terms and conditions of any approval or authorisation granted to the companies under relevant environmental laws and regulations. In the absence of such laws and regulations, or when such laws and regulations are inconsistent with best international petroleum industry practices, the companies shall act pursuant to sub-clause 21 (2) of the Petroleum Agreement by employing techniques, practices and methods of operation and taking other steps as deemed necessary and adequate in accordance with Best International Petroleum Industry Practice, in order to: (a) protect the environment and the living resources of the sea and prevent pollution; (b) ensure the protection from contamination of strata containing potable water or treatable water; (c) provide an effective and safe method for the disposal and discharge of drill cuttings and drilling muds generated during drilling operations; (d) provide an effective and safe method for the disposal of waste materials generated by the company's operations; (e) control the flow of petroleum so as to prevent avoidable waste and escape into the environment; and (f) ensure adequate compensation for injury to persons or damages to properties proved to have been caused by carrying out the activities under this Agreement by the company. Where the activities of the company result in pollution or damage to the environment or marine life or otherwise, the company shall take all necessary measures in accordance with Best International Petroleum Industry Practices to effect immediate remedy of the failure and the effects thereof. If such pollution or damage is the result of gross negligence or wilful misconduct of the company, the cost of the remedy shall not be an allowable deduction in the computation of PIT and PAPT.

Quarries operating in Seychelles must ensure that runoff from the quarry does not pollute the streams and the ocean. Due to the size of the island all water drains directly into the ocean. As soon as something goes wrong, and water ways turn red due to massive erosion there is a public outcry, and the quarry company is tasked to remedy the situation.

**Impact on Deforestation**

This is not a big issue in the case of the Seychelles as the quarries are on a small-scale and the quarry area is well defined within a set boundary. At the end of the life of the quarry the site can be developed for housing or other infrastructure, ref. Figure 51.

FIGURE 51 | THE EXTENT OF THE CCCL QUARRY ON THE EAST COAST OF MAHE


Source: Seychelles GIS Department (2011)

**Impact on the Landscape**

The Seychelles is a high-end tourist destination and as such rely on a clean and healthy environment. Quarries tend to be an eyesore. Quarries are also located close to infrastructure and housing and there are regular complaints of vibration from rock blast damaging houses and dust. All quarries in the Seychelles have to install water sprays at their rock crushing plant to minimise dust. Massive erosion in the quarry is a constant issue during the rainy season. However, due to increases in development there are increased demand for building material and one of the quarries located at the airport is approaching the end of its lifetime. Locating a different site for a quarry is now proving difficult.

FIGURE 52 | THE CCCL QUARRY FACE WITH SETTLEMENT POND

Source: Patrick Samson

## Socio-Economic Issues Related to Mineral Extraction in the Seychelles

### Role of Women

This is not obvious, but available statistics show that the private sector is male dominated, while women are concentrated in the public sector at 61% compared to 33% men. Higher paid jobs favour men, while women are mostly present in low paid jobs such as home carers and other service industries. The gender wage gap is at 19%. In general, women are more prone to facing redundancies in the male dominated labour market. Cohorts of young and disadvantaged women, including some single mothers and early school leavers tend to lack professional skills, including IT skills, which are today necessary to shore up the technologically driven labour market of Seychelles.

### Conflicts with Local Farmers and Other Stakeholders

The present two quarries are not located in a farming area and as such has no conflict with the farming community. The quarries are located close to infrastructure and houses and as such there are regular claims that vibration from regular blasting are damaging houses in the area and noise a nuisance. Although not common there has been one or two issues of fly rock, during blasting falling on people's houses. Heavy quarry vehicles create pollution, increase traffic congestion and damage roads.

ASM training in Assoca in Ethiopia

ASM in Bareta in Ethiopia

# MINERAL RESOURCE EXTRACTION OF MAURITIUS

*By P. Thaunoo-Chadee, For Permanent Secretary*

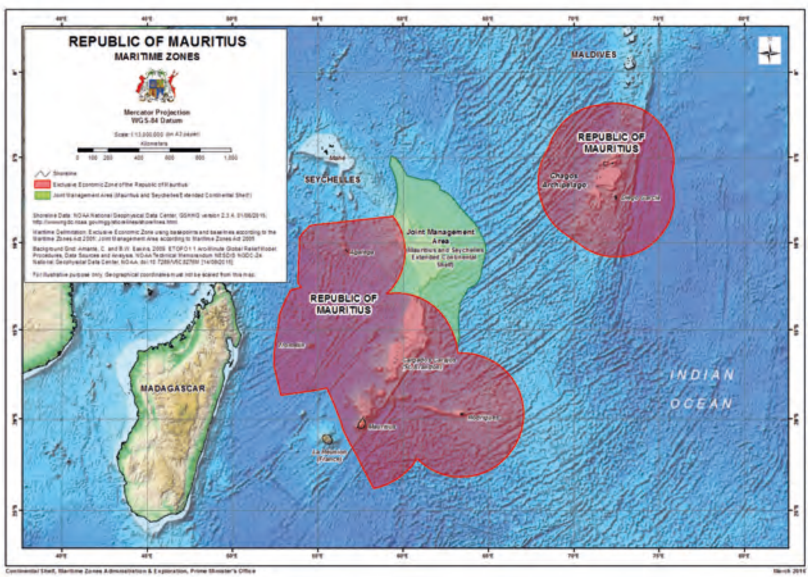
Mauritius relies heavily on its natural environment for the provision of resources required to support the nation and its industries. With the banning of coral sand extraction in 2001, there has been an increase in the exploitation of volcanic basalt rocks for aggregate and rock sand production. The exploitation of rock reserves sustains the local construction industry by providing an essential resource for infrastructural development.

## Geographical and Socio-Economic Context of Mauritius

### Geographical Context of Mauritius

Situated in south-western Indian Ocean, the Republic of Mauritius has a total land area of 2,040 km$^2$, with the two main islands: Mauritius and Rodrigues having an overall surface area of 1,865 km$^2$ and 109 km$^2$, respectively. The Republic's jurisdiction also extends to a group of outer islands scattered in the Indian Ocean namely: Agalega, Tromelin, the Cargados Carajos Shoals (Saint Brandon) and the Chagos Archipelago, including Diego Garcia. Mainland Mauritius is positioned slightly north of the tropic of Capricorn, at latitude 20.17°S and longitude 57.33°E and is almost entirely surrounded by fringing coral reefs. Furthermore, the Republic of Mauritius claims an Exclusive Economic Zone (EEZ) of 2.3 million km$^2$. An additional expanse of extended continental shelf area of approximately 400,000 km$^2$ is co-managed with the Seychelles, which makes the Republic of Mauritius the 20th country in the world with the largest EEZ (Intercontinental Trust Ltd., 2013).

FIGURE 53 | MARITIME ZONES MAP OF THE REPUBLIC OF MAURITIUS




Source: https://csmzae.govmu.org/Pages/Maps/MaritimeZonesMaps.aspx; Exclusive Economic Zone of the Republic of Mauritius (light red); Joint Management Area - Mauritius and Seychelles Extended Continental Shelf (light green)

FIGURE 54 | PHYSICAL MAP OF MAURITIUS


Source: https://www.worldometers.info/img/maps/mauritius_physical_map.gif

**Demography of Mauritius**

Mauritius is a multi-cultural society with people of African, Indian, Chinese, and European descent. As of 31 December 2022, the estimated resident population of the Republic stood at 1.3 million. The population estimates on main island Mauritius was 1.2 million that for Rodrigues was 44,783, while there were 274 inhabitants on Agalega and St. Brandon. Overall, the Republic had a population density of 628 persons per km$^2$ as at end of 2022 (Statistics Mauritius, 2022).

**Economy of Mauritius**

Over the years, Mauritius has crafted a strong growth-oriented developmental path, which has enabled the country to rank among the highest per capita income nations in Africa. Gross National Income (GNI) per capita has evolved from USD 400 in 1968, when Mauritius became an independent nation, to USD 10,243 (Rs. 456,864) in 2022. This is primarily due to a mix of political stability, strong institutional base, and favourable regulatory environment. Additionally, open trade policies have been crucial in sustaining growth, gradually transforming Mauritius from a mono-crop-based economy to a competitive and well-diversified one. Policy and institutional reform programmes to enhance competitiveness, consolidate fiscal performance, improve public sector efficiency, and widen the circle of opportunity through participation, social inclusion and sustainability are being continuously pursued to improve the business climate (Zafar, 2006).

Today the country's economy is diversified and relies on offshore financial activity, tourism, textile, and sugar production. Medical tourism, outsourcing, renewable energies, new technologies and the luxury industries are among the developing sectors. Despite the highly volatile and uncertain global economic environment, the Mauritian economy has steadily continued the recovery path post-COVID-19 pandemic and the Russian-Ukrainian conflict. In 2022, the manufacturing sector grew by 10.4%, while the food processing sector performed at a pace of 15.4%. Textile and other manufacturing grew moderately at 6.8%. Other sectors, such as financial and insurance activities, wholesale and retail trade, and public administration and defence, also significantly contributed to economic growth. For 2023/2024, GDP growth rate has been estimated to be 8.7% (Mauritius Chamber of Commerce and Industry, 2023).

**Contribution of the Mining Sector in Mauritius**

As a small island developing state, Mauritius does not have major exploitable resources like coal, petroleum, natural gas, or minerals. The local mineral industry is relatively small, privately-owned and concerns mainly the exploitation of volcanic basalt rocks for aggregates production, inland sand quarrying for use in the construction and agricultural industry and salt production. According to Statistics Mauritius, mining and quarrying represent only 2% of the output of the local industrial sector. GDP from mining in Mauritius increased from 486 MUR million in the third quarter of 2022 to 557 MUR million in the fourth quarter of 2022 (Statistics Mauritius, 2022).

TABLE 11 | GROSS VALUE-ADDED DISTRIBUTION BY INDUSTRY GROUP AT CURRENT BASIC PRICES, 2019 – 2022 (IN RS. MILLION)

| SECTOR/YEAR | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|
| Mining and quarrying | 1,615 | 1,472 | 1,658 | 1,879 |

Source: Statistics Mauritius, 2022

TABLE 12 | GROSS VALUE ADDED AT BASIC PRICES – SECTORAL REAL GROWTH RATES (% OVER PREVIOUS YEAR), 2019 – 2022 (IN RS. MILLION)

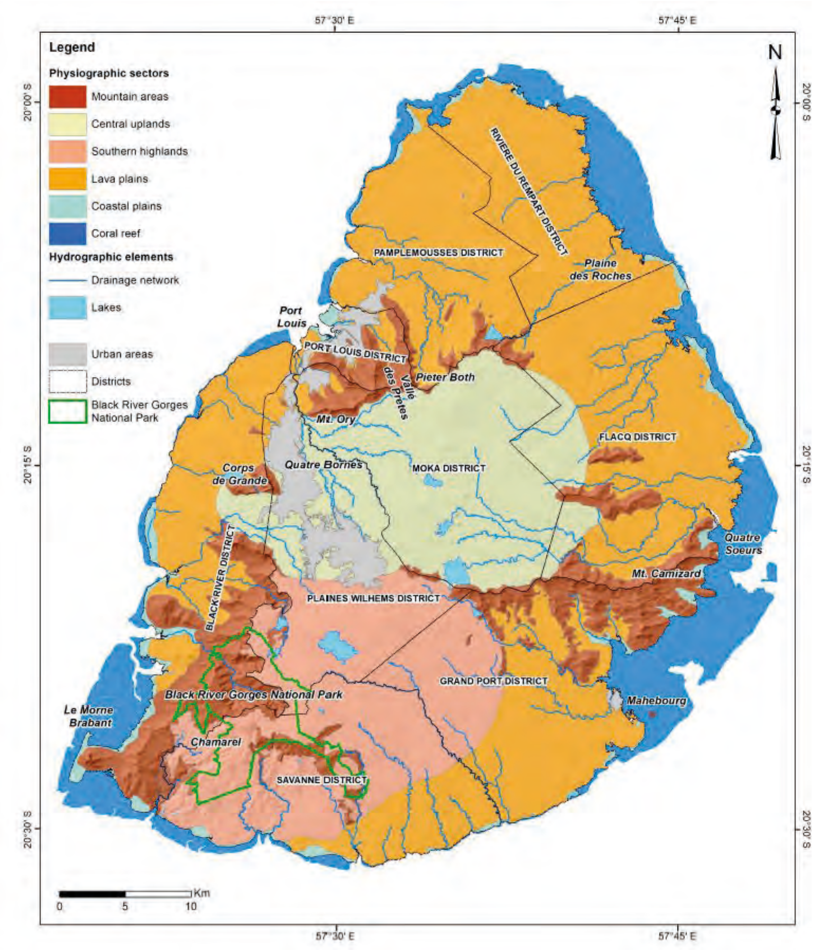
| SECTOR/YEAR | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|
| Mining and quarrying | +3.3 | -16.6 | +10.9 | +9 |

Source: Statistics Mauritius, 2022

## Geological Context of Mauritius

Mauritius is an entirely volcanic island and has been formed by four distinct eruptions starting from the mid-Miocene. The Breccia Series caused the emergence of the island around 10 million years back from a particularly explosive volcanic phase that shaped the relief of the island. Later, the island was entirely covered with the Old Lava Series. In this phase, ancient basalt and phonolite comprised the island shield volcano. However, the latter's central part collapsed to form the Caldera and the mountain ranges. At present, Old Lavas cover 21% of the island (Proag, 1995; Paul et. al., 2005).

FIGURE 55 | GEOLOGICAL MAP OF MAURITIUS




Source: Marsala et. al., 2019

The Intermediate Lava or Early Volcanic Series date back to 3.5 – 1.7 My and consist of pyroclasts and basaltic flows. During the Early Lavas Series compact olivine basalts were emitted and they now cover 4% of the island. Lastly, the Recent Lava Series or Late Lavas (0.7 – 0.02 My) constituted the most significant and far-reaching volcanic event, which shaped the island. Basalt, scoria, tuff and pyroclasts from this lava series cover at least 70% of the island (Proag, 1995; Paul et. al., 2005).

Three soil order have been mapped namely: Zonal, Intrazonal and Azonal soils (Parish and Feillafé, 1965). Zonal soils comprise of matured latosols and cover approximately 33% of island's surface area. Intrazonal soils, which are still in the process of weathering, occupy about 47% of the island's surface. Located mostly on Old Lavas, Azonal soil groups have little or no profile development. They are mostly eroded rough broken land of mountains and gorges; soils from recent alluvium; and coral deposits or soils of unconsolidated deposits other than alluvium. As far as rocks are concerned, they are categorised in two types: igneous and sedimentary rocks. Igneous basaltic rocks can be further subdivided into three main strato-spheric series: ancient/old; intermediate and recent/young. The sedimentary rocks consist mainly of coral formation.

Today, mainland Mauritius exhibits varied topography with a central plateau, southern highlands, lava plains and coastal areas, except for three distinct areas, which comprise steep mountain ranges (Marsala et. al., 2019):

a) The mountain areas range from about 600 to 800 m above sea level and are located in the northwest, southwest and southeast of the island. They largely comprise peaks and ridges with steep slopes landwards and more gentle slopes seaward-side;
b) The central plateau is about 400 m above sea level and includes most of the caldera's area. The southern highlands consist of the southern side of the caldera and is about 500 m above sea level;
c) The lava plains comprise the surrounding coastal plains and inland gentle slopes. These occur mostly at 300 m above sea level and also comprise the main rivers of the island as well as gorges and valleys; and
d) The coastal areas occur at 200 m above sea level and are characterised by flat lowlands with varied coastline such as beaches, cliffs, and sea caves. The island is surrounded by fringing coral reefs except for two stretches along the south and west of the island.

## Mineral Extraction in Mauritius

### Coral Sand Extraction from the Lagoon

A few decades ago, coral sand used to be extracted from the lagoon by sand miners and boat owners in the shallowest parts of the largest lagoons on the northern and eastern coast of the island. Sand extraction was undertaken at a rate of 800,000 tonnes annually. Coral sand was mainly used as a raw material in the construction industry. Studies commissioned by the Government showed that lagoonal sand extraction was having adverse, irreversible impacts on the marine environment by destroying marine habitat and causing coastal erosion. In 1997, the Government took the bold decision to ban lagoonal sand mining. Sand miners were given a moratorium of up to 2001 to stop their activities and were compensated. This decision was enforced in October 2001. Compensation was paid to those engaged in the sand mining business (Ministry of Environment, 2002).

**Inland Sand Mining**

There are two inland sand quarry sites, which are still in operation at St. Felix, Chemin Grenier and La Prairie, Baie du Cap. At these sites, coarse sand and coral debris occur at a depth of up to 12m. These coarse sands were deposited by thousands of years back. Quarried calcarenite products are of various gradings and have a range of uses: a source of calcium in animal feed (poultry, deer, cattle and dogs), pH control for plant growth, floor and wall finish, plastering, water-tight flooring, as a concrete blocks, grass top dressing, beach top dressing and landscaping works. For the site at St. Felix, Chemin Grenier, which is of an extent of 6Ha, some 23,500 tonnes of sand were quarried from December 2018 to March 2020. However, further to the COVID-19 pandemic, sand mining was halted. It is to be noted that after exploitation of the quarry site, the proponent has to rehabilitate the site by backfilling same with rocks and soil at a consolidated compaction value of 90% with a cover of 750 – 800 mm of topsoil. On the other hand, the sand quarry site located at La Prairie, Baie du Cap extends over an extent of 54,513 $m^2$. Quarrying activities thereat started in August 2016 and has been planned over an area of 1Ha at a time. As of April 2023, some 246,402 tonnes of materials have been exploited over an area of 25,840 $m^2$. It is to be noted that the proponent must strictly implement an Execution and Restoration Plan, which stipulates that the exploited areas must be rehabilitated with pasture and native plants in order to create a native coastal forest ecosystem.

FIGURE 56 | SAND QUARRY AT LA PRAIRIE

Source: Ministry of Environment, Solid Waste Management and Climate Change

**Mining Basalt Rocks**

Further to the banning of coral sand extraction, studies undertaken by the University of Mauritius recommended the use of basalt (rock) sand in the construction industry. It is to be noted that prior to the banning of coral sand extraction, there were no large or regular quarries and rocks were supplied from de-rocking of sugar cane fields and were used for the production of various grades of coarse aggregates. In 2001, a Technical Advisory Committee (TAC) was set up under Section 10 of the Environment Protection Act of 1991 to look into the aspects of rock quarrying, including amongst others, the estimation of rock reserves in Mauritius. Due to limited information, the TAC provided only a basic analysis, with an indication of the location of potential rock quarry areas in Mauritius. Thus, the TAC recommended that a more detailed study be carried out.

Consequently, in 2004, the Government commissioned a detailed GIS study for the estimation of rock reserves in Mauritius. The purpose of the study was to locate and estimate the volume of rock reserves in Mauritius, both at the surface and underground, that could be exploited for the production of aggregates and rock sand for the construction industry and to recommend the best method of extraction for the rocks and the different options for the rehabilitation of the sites. As part of the study, quarry sites were identified based on their geology and existing core hole data. Areas containing Recent and Intermediate basalt were considered to be first priority. Detailed ground magnetic surveys and geological outcrop mapping of many of the priority areas were used to select ten areas for diamond drilling. The main findings of the study were as follows:

a) Surface rocks, available for aggregate and rock sand, were assessed at 58 million tonnes, while the potential tonnage of underground rocks of commercial quality was assessed at 93 million tonnes;
b) Two categories of mineral resource sites were identified: priority and potential sites. The 6 priority sites were those sites where drillings and geotechnical surveys were carried out. These sites had good quality rocks that could be exploited and it was estimated that 93 million tonnes of commercial quality rocks were contained at six priority quarry areas; and
c) There were 21 potential quarry sites, where drilling was not undertaken to determine the quantity and quality of rocks. Geophysical surveys carried out on some of these sites showed that the latter could be potentially suitable for quarry. However, further studies, especially drilling, were to be carried out at these sites.

## Policy and Legislative Framework for Mineral extraction in Mauritius

With a view to prevent the mineral resource sites from being encroached by residential and other types of development, it was critical that appropriate planning instruments be used to protect both priority ad potential sites. Subsequently, in 2006, provisions were made under the various Outline Planning Schemes for District Council and Municipal Council Areas to include policies for the protection of Mineral Resources and same were transcribed on Development Management Maps.

**Technical Advisory Committee on Mineral Resource Sites**
In 2009, a second TAC was set up, in line with Section 12 of the Environment Protection Act of 2002 (as amended) to inter alia develop the methodology for assessing the quarry potential in terms of quality and quantity of rocks and the exploitability of the potential mineral resource sites by providing a benchmark against which the findings of site investigation can be assessed; establish the criteria to determine the economic feasibility for development of mineral resource sites as rock quarries; develop a policy for the sustainable management and protection of mineral resource sites, including which sites could be incorporated in the Outline Planning Schemes and advise on the best way to proceed with the implementation of quarrying activities, including any environmental considerations.

The main recommendations of the TAC can be summarised as follows:

a) Any permanent development proposed to be undertaken on a potential mineral resource site or within its 1 km buffer shall be preceded by a site investigation on the mineral resource site to demonstrate its quarry potential in terms of quality and quantity of rocks and its exploitability. The TAC recommended that for core drilling in potential sites, 4 – 6 drills of 50mm each using Rotary Core Drilling System with Recovery be used. Drilling should be undertaken at 20 m where no groundwater table is encountered and 1m below groundwater level, where groundwater is encountered. Other tests to be undertaken to determine rock quality include: relative density, water absorption, point load index, Los Angeles abrasion, aggregate impact value, unconfined compressive strength and magnesium sulphate soundness;
b) A Technical Committee chaired by the Ministry of Environment, Solid Waste Management and Climate Change comprising several technical Ministries would meet on an ad-hoc basis to assess the site investigation reports with respect to potential mineral resource sites. The TAC developed a set of criteria to guide assessment;
c) The TAC noted that many permanent developments like residential and Integrated Resort Scheme have encroached into the buffer zones of mineral resource sites. Also, some sites or their buffers were located in catchment areas of dams, reservoirs and lakes. After thorough screening of all mineral resource sites, the TAC agreed to delist part or the whole of the mineral resource sites from the Development Management Maps of the Outline Planning Schemes, where these were in close proximity to settlement boundary, were situated within the 1 km catchment areas of dams, lakes

and reservoirs or where investigation reports showed that the sites did not have significant quarry potential. In this regard, the TAC recommended the delisting of 4 priority and 9 potential mineral sites. As such, while initially the Study on rock reserves identified 6 priority and 21 potential sites, only 2 priority and 10 potential mineral resources sites were mapped on the Development Management Maps; and

d) The TAC reviewed the policy for the protection of the Mineral Resource Sites in the Outline Planning Schemes of 2006 regarding the safeguarding of priority sites, allowing for temporary development outside the 200 m buffer of potential mineral resource sites and establishing the modus operandi for permanent development on potential mineral resource sites and recommended that the Outline Planning Scheme and the respective Development Management Maps be amended to include new recommendations.

**Policies of the Outline Planning Scheme**

"Policy MR 1 on Mineral Resources" states that mineral resource sites should be protected from most forms of development as these sites hold reserves which are important to the national economy and for the building construction sector. In this regard, Policy MR 1 states inter alia that:

a) There should be a general presumption against development likely to undermine the long-term quarrying capability, unless and in the national interest or is a government approved scheme which has already been identified or committed or where suitable alternatives are not available;
b) Buffer zones of 1 km should be established between such sites and sensitive uses including housing, education and health facilities as well as from boundaries of catchment areas of dams and reservoirs;
c) Priority quarry areas and their buffer zones of 200m from the quarry boundaries will be protected from all types of development. Temporary undertakings may be allowed outside the 200 metres buffer zone up to 1 km from the quarry boundaries, subject to relevant permits and licences being obtained from statutory authorities;
d) Temporary development may be allowed on a potential mineral site and its 1km buffer subject to relevant permits and licenses being obtained from statutory authorities. Any proposal for permanent development on potential mineral sites and within the 1km buffer may be considered based on site investigations carried out and demonstration that these sites do not have significant quarry potential in terms of quality and quantity of rocks and their economic exploitability. Upon examination of the site investigation report by a Technical Committee at the Ministry of Environment, Solid Waste Management and Climate Change, a decision will be taken as to whether the site needs to be retained for quarrying or released for other developments. The final decision of the Ministry of Environment, Solid

Waste Management and Climate Change shall prevail over the provisions of the Outline Scheme in respect of that potential mineral resource site; and

e) All temporary development shall be subject to termination upon issue of prior notice when the site will be required for quarry operations. No claim for compensation or liability for damages from the Government of Mauritius would be entertained at closure of operations to allow for quarry activities.

FIGURE 57 | MINERAL RESOURCE SITES AS PER DMM


Source: Development Management Maps of the Outline Planning Schemes

Furthermore, as per “Policy ID4 on Bad Neighbourhood Development” of the Outline Planning Scheme, a number of activities have been categorised as bad neighbourhood development and these include quarries. Policy ID 4 acknowledges that bad neighbour uses are essential for the continued economic growth, but that a precautionary approach to siting new facilities is required to safeguard local environment and amenity. Bad neighbour developments are considered a potential nuisance to adjoining residential neighbours by reason of noise, dust, smoke, fumes, smells, abnormal hours of operation or parking or excessive loading problems or through the appearance and scale of the proposal. Therefore, as per Policy ID 4, new sites for bad neighbour developments should be planned up to 1km distant from sensitive land uses, which include residential areas, hospitals, and schools.

In addition to the above, bad neighbourhood activities like quarries have to satisfy other buffer distances from environmentally sensitive areas, namely, to be at least 50m and 35m, respectively from the coastline and rivers and up to 1 km from lakes.

Likewise, bad neighbourhood developments should also comply with the buffer zones prescribed for the protection of environmentally sensitive areas as per the Study on Environmentally Sensitive Areas 2009.

**Environment Protection Act**

Rock quarry by reason of its scope and scale is associated with a number of environmental impacts. The Environment Protection Act of 2002 (as amended) is the key legislative framework governing environmental protection and management in Mauritius. As per Item No. 39 of Part B of the Fifth Schedule of the Act, “rock quarrying” is a scheduled undertaking warranting an EIA Licence. Common to all EIA reports on rock quarrying are the extent and depth of excavation, duration of activity, methodology to be used, presence of groundwater table, distance from sensitive land uses, presence of Environmentally Sensitive Areas and whether the site is found in a rock reserve site as identified in the GIS study for the estimation of rock reserves in Mauritius.

After thorough assessment of a project’s scale and scope by various governmental departments, an EIA Licence is delivered subject to terms and conditions. Below are some of the conditions imposed in EIA Licences for the operation of quarry sites:

a) Exploitation of the quarry shall be undertaken in conformity with the methodology and the mitigating measures proposed in the EIA Report;
b) Proponents have to submit an environmental monitoring plan in accordance with Section 18(2)(l) of the Environment Protection Act 2002 (as amended), prior to start of works, after which they are called to submit regular environmental monitoring reports on the status of their activity;
c) A proper line of communication shall be established to ensure effective monitoring and prompt actions in addressing grievances and environmental nuisances;
d) A decommissioning plan shall be submitted to the Department of Environment for approval prior to the start of rehabilitation and site restoration works in line with Section 18(2)(m) of the Environment Protection Act 2002 (as amended);
e) Submission of an Aquifer Protection Management Plan prior to start of quarry operations to the satisfaction of the Water Resources Unit;
f) Quarrying below the first 20m shall be subject to additional hydro-geological investigations to assess feasibility of further quarrying potential. Same shall be assessed by the Ministry of Environment, Solid Waste Management and Climate Change together with relevant stakeholders.
g) Appropriate flood mitigating measures shall be adopted to prevent flooding in and around the site;
h) Heavily planted earth bunds shall be provided to mitigate dust emissions and noise propagation;

i) A green belt with fast growing trees shall be planted along the site boundaries;
j) Provision for a buffer zone from public access road; and
k) Use of explosive for blasting purposes is normally not allowed except under the control and strict supervision of the Mauritius Police Force.

After receipt of an EIA Licence, proponents are required to submit regular Environmental Monitoring Reports showing compliance to conditions laid down in their EIA licences and regular site inspections are undertaken to assess compliance. A Monitoring Committee comprising representative of the different ministries/authorities concerned has been set at the Department of Environment to follow up on the implementation of the project after issue of the EIA licence and to conduct monitoring exercises to ensure that the conditions of the EIA licence are being complied with. In the event of any non-compliance, the Ministry of Environment, Solid Waste Management and Climate Change in collaboration with the relevant authority determines the appropriate enforcement measures required. Non-compliance to an EIA licence condition amounts to an offence punishable by fines and imprisonment under the Environment Protection Act. Additionally, when a person is contravening or is likely to contravene an environmental law, an Enforcement Notice or a Programme Approval is issued. On the other hand, Prohibition Notices are served, when an enterprise or activity involves a serious pollution or an imminent risk of serious pollution. Lastly, when a person commences or carries on any development or activity without the relevant licence or permit; and where such development contravenes an environmental law a stop order is issued to stop the activity.

**Quarry Operations**

From 1996 to-date, ten EIA Licences have been granted for rock quarry activities and there are presently four operational quarries. One EIA Licence was delivered in 2022 and another application for EIA Licence is under process. All quarries are privately operated and managed subject to conditions stipulated in the respective licences. The table below summarises the above four quarry activities.

FIGURE 58 | ROCK QUARRY SITE AT BEEMANIQUE

Source: Ministry of Environment, Solid Waste Management and Climate Change

TABLE 13 | OPERATIONAL QUARRIES FOR WHICH EIA LICENCES HAVE BEEN ISSUED

| LOCATION OF QUARRY SITE | LA CHAUMIÈRE | BEEMANIQUE | ST. JULIEN | LA CHAUMIÈRE | BEEMANIQUE |
|---|---|---|---|---|---|
| **Issue of EIA Licence** | 9-Mar-2005 | 22-Sep-2011 | 3-Nov-2011 | 20-Oct-2021 | 20-Oct-2022 |
| **Site Extent** | 30ha | 44A 79p | 39A 34p | 31ha | 19.8ha |
| **Depth of quarry (m)** | -24 | -40 | -40 | -24 | -21 |
| **Overall quarry potential (tonnes)** | NA | 7,492,834 | 3,513,962 | 5,788,800 | 2,085,504 |
| **Annual Extraction (tonnes)** | 200,000 | 450,000 | 230,000 | 440,000 | 312,825 |
| **No. of phases** | 5 | 5 | 4 | 7 | 5 |
| **Years of operation** | 20 years | 16 years | 15 years | 20 years | 20 years |
| **Operational** | Yes | Yes | Yes | Yes | Not yet |

Source: Ministry of Environment, Solid Waste Management and Climate Change

Extraction of basaltic rocks is done by mechanical derocking in open pit mining and in a phased manner. The methodology employed for quarrying is as follows: removal of overburden, rock extraction, transport of extracted rocks for processing and site rehabilitation:

a) Overburden removal consists in the extraction of loose boulders in compact soil matrix, topsoil and vegetation over a depth of the order of 1 m. Bulldozers and excavators equipped with hydraulic hammers are used. Overburden materials are usually stacked to form earth bunds or stored for future backfilling of the quarry;
b) After removal of overburden, massive basaltic boulders are ripped from the basaltic matrix into transportable sizes by excavators equipped with BRH rock hammer. Quarrying is usually undertaken in phases, that is the quarry is exploited to a predetermined depth at a time. Once the required level of extraction is reached, vertical rock extraction for this particular area will cease. Furthermore, as recommended by the Water Resources Unit, the proponent has to place survey marker level at various locations of the project site to monitor the excavation depth; and
c) After a particular area has been quarried, backfilling takes place in phases. For instance, if a quarry started in 2023, backfilling will start as from 2029 and would stagger over the lifespan of the quarry. Quarry rehabilitation usually starts by placing at least 1m of soil at the bottom of the exploited area, followed by rock dust and inert construction and demolition wastes. After all phases of backfilling are completed, 1m of soil is again added as the final layer, covering the whole site.

It is to be noted that previously blasting was used to rip basaltic rocks. All blasting operations were carried out in line with the Explosives Act (as amended) and under the strict guidance and supervision of the Special. However, over time this practice was discontinued as it was costly, dangerous, generated seismic vibration and generated toxic gases from explosion, among others. Rock hammering is presently the preferred option for quarrying as it is safer and fairly low cost.

## Environmental Impacts Related to the Rock Quarry Activities in Mauritius

The operation of a rock quarry generates environmental impacts, namely: land degradation and disruption of landform, emission of dust and particulates, noise and vibration, traffic generation, impacts of fauna and flora and generation of solid wastes, among others.

### Land Degradation and Disruption of Landform

Quarrying automatically leads to a disruption and modification of the existing landscape by creating a void. Although temporary in nature, the activity irreversibly changes the drainage pattern of the site, land surface subsidence and damages the site features. To mitigate changes in landform, soil, rock dust and inert construction and demolition wastes are used as fill materials. Topsoil initially stripped is reutilised for the in gradual rehabilitation of the site, which may be used in the future for agriculture or as grazing lands. Considering of the degradation of the site, proponents have to mandatorily submit a decommissioning plan to the Department of Environment for approval, prior to the start of rehabilitation and site restoration works of the subject site.

**Emission of Dust and Particles**

Dust particles will be essentially generated from the basaltic rock extraction processes as well as from the movement of vehicles on access roads and internal roads, from earth bunds along the periphery of the quarry site, from windblown dust over materials stockpiles and loading and hauling of trucks with soil/rock materials. While dust particles are inorganic and non-toxic, they may in the long run affect neighbouring vegetation. Inhalation of dust particles can lead to health problems among workers exposed to these. To mitigate dust propagation, all rock benches and ledges, rock stockpiles and quarry access roads must always be kept damp. To that effect, all quarry sites must be equipped with sprinkler systems. All vehicles and machinery being used on site shall be regularly serviced and maintained in good working conditions. Furthermore, earth bunds of at least 4m planted with fast-growing trees along the site boundaries also contribute to abate dust emissions.

**Noise and Vibration**

The sources of noise and vibration will be from hammering and ripping of boulders using hydraulic rock breakers, breaking of rocks into transportable sizes, loading of boulders and movement of vehicles. To mitigate noise and vibration during rock breaking operations, hydraulic rock breakers are equipped with noise dampers. Furthermore, quarry activities are undertaken at least 1 km from sensitive land uses and there is no quarrying at night, thus noise and vibration generated from these sites do not propagate to these sensitive receptors. On site, it is imperative that workers are given necessary personal protective equipment, namely earmuffs, and that all quarry equipment are properly maintained.

**Traffic Generation**

Overloaded trucks can cause damage to the road network or through material spillage. On the other hand, with the siting of quarries next to stone crushing facilities, public roads are not used in the haulage of boulders.

**Contamination of Water Resources**

If undertaken in an uncontrolled manner, quarrying can lead contamination of surface water bodies and groundwater. For instance, during periods of heavy rainfall, rainwater will automatically accumulate at the low points in the quarry. Consequently, stormwater runoff management is of utmost importance, and it is recommended that provision be made for peripheral cut-off drainage networks at quarry sites. To ensure that groundwater resources are not contaminated during quarry operations, proponents should submit an Aquifer Protection and Management Plan detailing the measures to be taken to safeguard groundwater quality, the preventive measures to avoid contamination of surface runoff and infiltration of contaminated water into subsoils and the remedial actions to be taken.

**Solid Wastes**

Solid wastes will be generated from site clearing and quarrying activities. However, these spoils will be used to create the earth bund. Poor quality rocks and rock dust to be generated are usually used for future backfilling of the quarries.

**Destruction of Habitats**

Quarrying causes irreversible destruction of habitats and the species they support. The sites earmarked as quarry sites contain fauna and flora of low conservation value, which are common and widespread. As per ecological surveys, there were no endemic flora or fauna and Environmentally Sensitive Areas at these sites. For instance, Beemanique and La Chaumière are classified as industrial sites as per the Outline Planning Scheme. The site at St. Julien is located amidst sugar cane fields.

## Challenges

### Illegal Quarry

Although rock quarrying is a scheduled undertaking warranting an EIA Licence for operation, a number of illegal quarry sites are being exploited under the guise of de-rocking or land preparation. These unlicensed activities are associated with a range of environmental nuisances namely: noise/vibration due to hammering onsite, loading of rocks into lorries and movement of lorries; dust nuisances from earthmoving and breaking of boulders and movement of heavy vehicles; damage to public roads and change in the landform as well as modification of natural drainage paths.

FIGURE 59 | ILLEGAL ROCK QUARRY SITES

Source: Ministry of Environment, Solid Waste Management and Climate Change

Since 2017 to-date, some 17 complaints have been registered at the level of the Ministry of Environment, Solid Waste Management and Climate Change with regard to illegal quarrying activities being undertaken near residential areas or when lorries loaded with rocks are passing near residential areas. The regions where illegal rock quarrying activities are taking place include several localities in the north of the island and in the villages of Bambous, Albion and Palma. As per the surveys carried out by the Ministry, these sites have been quarried up to a depth of 3 – 8 m.

To address illegal quarrying, a sub-committee was set up, which inter alia, looked into the definition of rock quarrying and demarcated those activities for which rock quarrying should not apply to namely: excavation works being undertaken for the purposed of carrying out any building, civil engineering or engineering construction works or any development works as defined in Local Government Act on the site at which the extraction has taken place; construction of public road or any infrastructural works by a public department and land preparation for agricultural purposes that will not entail a change in land form and material change in the topography of the land. An environmental guideline has also been prepared to assess and mitigate impacts associated with derocking activities and which do not fall under rock quarrying for which an EIA Licence is required (Ministry of Environment, Solid Waste Management and Climate Change, 2023).

**Competing Land Uses in Potential Mineral Resource Sites**

In Mauritius, a large extent of land is privately owned either by large conglomerates or by individuals. The areas earmarked as mineral resources sites in the Development Management Maps of the Outline Planning Scheme are private lands and no compulsory land acquisition has been undertaken by Government. Given that Mauritius is relatively small, competing demand for land use is resulting in the buffers of mineral resource sites being encroached by development. The Ministry of Environment, Solid Waste Management and Climate Change is also receiving numerous requests for the release of these lands. Consequently, authorisation has been given for temporary development at these locations.

## Conclusion

Quarrying of basaltic rocks is of critical importance in Mauritius as there are no other alternatives for the supply of raw materials for production of aggregates, rock sand and other ancillary products. During the past years, the Government has been massively investing and implementing various national projects in a range of sectors from flood management programmes, road decongestion and upgrading, expanding water storage and treatment, airport, and port expansion to construction of social housing, just to name a few, thus boosting the construction sector. As a result, it is more than essential that quarry sites earmarked in the Outline Planning Scheme be protected both from development thereat as well as from encroachment within their 1km buffer zones.

In an effort to reconcile both environmental safeguard and economic development, the Ministry of Environment, Solid Waste Management and Climate Change has, amongst other, adopted a precautionary approach by allowing only temporary development within the 1km buffers of mineral resource sites. Furthermore, development control through Environment Impact Assessment and post-EIA monitoring are important tools to ensure that quarrying activities are undertaken within strict environmental parameters. Finally, a clustering approach is also being favoured to ensure that bad neighbourhood activities are clustered to promote industrial symbiosis.


LSM in Tanzania

ASM in Bareta in Ethiopia

# ASM SECTOR OF UGANDA

*By Muheirwe Morris Tabaaro, Inspector of Mines, Ministry of Energy and Mineral Development, Directorate of Geological Survey and Mines*

## Geographical Context of Uganda

### Demography of Uganda

The Republic of Uganda is a land-locked country located in East Africa with a surface area of approximately 250,000 km$^2$.

As of 2021, the estimated population of Uganda is around 44 to 46 million people. The age structure is as follows; 0-14 years: Approximately 49% of the population, 15-64 years: Approximately 48% of the population and 65 years and older: Approximately 3% of the population.

Uganda is ethnically diverse, with over 56 different ethnic groups.

There are numerous indigenous languages spoken across the country. English is the official language of Uganda, inherited from British colonial rule.

The literacy rate in Uganda has been gradually improving. As of 2021, the literacy rate is estimated to be around 75% to 80%, with slightly higher rates in urban areas compared to rural areas.

### Economy of Uganda

Uganda's economy weathered successive shocks in 2022 with GDP growth expected to recover to 5.7% during the Fiscal Year 2023. Accelerated growth may reduce poverty (measured at USD 2.15/day international poverty line) from 41.4% in 2023 to 39% by 2025. Real GDP per capita grew by only 1.0% per year between 2011 and 2022 in a context of rapid population growth, drought and other external shocks, a less supportive external environment, and weakening policy and institutional framework, including centralisation of policymaking (World Bank, 2023).

The population of 34.6 million, 53% of whom are between 0-14 years (Uganda Bureau of Statistics, 2014), is one of the fastest growing in the world. Urbanisation rates in Uganda are soaring, with a predicted urban population of 20 million by 2040, over a three-fold increase from 2013. Furthermore, an estimated 700,000 Ugandans annually enter a job market with limited capacity to absorb new entrants (United Nations Development Programme, 2018).

With ASM production estimated at more than USD 630 million in 2008, its contribution to total GDP is 3.5%, well above the 0.3% attributed to mining and quarrying in national statistics. Only 0.6% of Ugandans are directly engaged in ASM as miners compared to 73% in agriculture, forestry, and fishing (to which 23.7% of the GDP is attributed), suggesting that the average miner contributes almost 20 times more to GDP than the average person engaged in these other sectors (Uganda Bureau of Statistics, 2009).

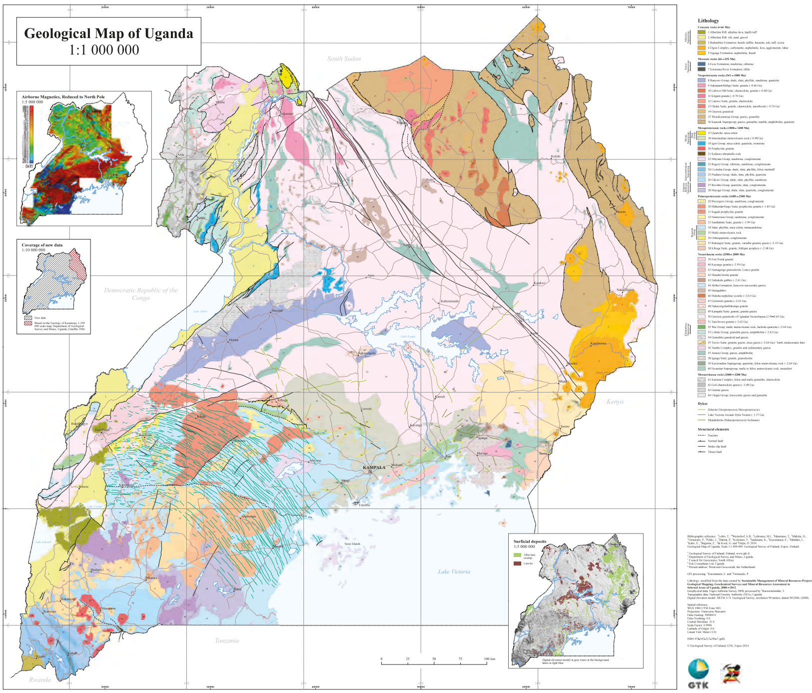
Despite the rudimentary methods used, more than 90% of most mineral production in Uganda is attributed to ASM and, when indirect labour, induced labour and Ugandan dependency ratios are considered, an estimated 4.2 million Ugandans directly rely on the ASM subsector. Roughly 70% of ASM miners also rely on other livelihoods, including in agriculture and trade (Hinton, 2009).

The value added for mining and quarrying activities grew by 18% in the Fiscal Year 2021/2022, down from 6.9% in the Fiscal Year 2020/2021. The good performance of this activity is majorly attributed to the increasing support services to the oil and gas sector. Mining and quarrying activities contributed 1.4% to GDP in the Fiscal Year 2021/2022 compared to 1.9% in the Fiscal Year 2020/2021 (Uganda Bureau of Statistics, 2022).

Minerals resources attracted increased Foreign Direct Investment in the sub-sector from USD 5 million in 2003 to over USD 800 million in 2017. Similarly, revenues from license fees and royalties increased from USD 0.5 million in 2003 to USD 14.6 million in 2011 then back to USD 2.06 million by the end of Fiscal Year 2014/2015, which was attributed to global decline in mining industry (Ministry of Energy and Mineral Development, Directorate of Geological Surveys and Mines, 2018).

# Geological Context of Uganda
## Simplified Geological Map of Uganda

FIGURE 60 | GEOLOGICAL MAP OF UGANDA




Source: Directorate of Geological Survey and Mines

### Brief Description of National Geology

More than two thirds of Uganda is underlain by Archaean and Proterozoic rocks. These shield rocks are part of the African or Nubian Plate and are located between the eastern branch and the western branch of the East African Rift System. The Western Rift Valley runs the entire length of Uganda.

Apart from the vast Archaean Gneissic-Granulitic Complex in the north there are at least three major Proterozoic belts exposed in the country: the Paleoproterozoic Buganda-Toro System; the Mesoproterozoic Karagwe-Ankolean System; and the Neoproterozoic Mozambique Belt. Tabular Neoproterozoic sediments are also widespread. Tertiary to Recent sediments filled parts of the down faulted Western Rift.

Tertiary carbonatites and Cenozoic volcanics are related to rift activities and occur along the eastern and western borders of the country.

In Uganda, the Precambrian is divided into wholly granitised formations, including basement and granitised equivalents of the cover formations, partially granitized formations, non-granitised formations and other rocks.
The first group includes metamorphic rocks of the granulite metamorphic facies, acidic gneisses, metamorphic rocks of epidote–amphibolite, biotite, and hornblende–biotite facies and marbles and quartzites.

The second group consists of rhyolites, porphyries, tuffs and basalts of the Nyanzian System; argillites, basalts, amphibolites of the Buganda-Toro System (1800 Ma); arenites, siltstones, quartzites, sandstones and conglomerates of the Karagwe-Ankolean System; and shales and quartzitic sandstones of the Kioga Formation.

The third group consists of molasses type sedimentary rocks.

The last group, the 'other rocks' category, includes undifferentiated gneisses and mobilized basement, mantled granite–gneiss domes in the south-west and various granites.

The Ecca shales (Karoo formation) occur in small down faulted outliers on Dagusi Island and also underly part of Entebbe. These outliers are remarkable in being the most northerly occurrences of the Karoo formation in Africa.

The Mesozoic and Cenozoic rocks in Uganda are composed chiefly of rift valley sediments, volcanic formations, and more recent alluvial overburden. The eastern volcanic rocks generally comprise sodarich agglomerates, lavas, and tuffs, extruded from central volcanoes. The carbonatite ring complexes at Tororo, Sukulu, Bukusu and Napak, and the syenite complexes such as Zulia, represent the eroded remnants of former volcanoes of a similar rock suite.

The Western Rift Valley sediments are divided into several series and are of Pliocene age.

## ASM in Uganda

### Substances Exploited by ASM Operators in Uganda

Common metallic minerals mined by the ASM sector include gold, cassiterite, wolfram, iron ore/hematite, columbite and tantalite.

Common industrial minerals include salt/halite, granite, aggregate, clay, sand, diatomite, gypsum, kaolin, gemstones, quartz, volcanic ash, pozollana and marble/limestone.

**Legislative Framework for the ASM Sector in Uganda**
The major legislation governing the mining sector in Uganda include:

a) The Constitution of Uganda, 1995
b) Mining and Mineral Policy 2018
c) Mining and Minerals Act, 2022
d) Mining (Licensing) Regulations, 2019
e) International Conference on the Great Lakes Region (Implementation of the Pact on Security, Stability and Development in the Great Lakes Region) Act, 2018
f) International Conference on the Great Lakes Region (Implementation of the Pact on Security, Stability and Development in the Great Lakes Region) Regulations, 2023
g) National Environmental Management Authority Act, 2019
h) Land Act, 1998
i) The Occupational Safety and Health Act, 2006
j) Local Government Act, 1997
k) Local Government (Amendments) Act, 2010

**Degree of Organisation of ASM Sector**
The Mining and Mineral Policy of 2018 defines ASM as mining operations run by individuals, families or groups of local communities or migrant workers or local enterprises, the majority of whom have no formal technical training and depend on rudimentary tools (Ministry of Energy and Mineral Development, 2018).

The Mining and Minerals Act of 2022 defined ASM operations as mining operations that do not exceed ten meters depth and undertaken under an artisanal mining license (Ministry of Energy and Mineral Development, 2022).
Although ASM is largely informal in Uganda, miners are usually organised into groups to improve on occupational safety and health standards as well as reduce operation costs. There are increasing numbers of associations and cooperatives (both at local government and national level) due to deliberate government policies, programs, and projects.

The ongoing Biometric Registration of Artisanal and Small-Scale Miners project to register all artisanal miners operating in the country will fast track efforts to formalize and effectively manage the ASM.

**Role of the Geological Survey and Mines Department of Uganda to Support the ASM Operators**
The overall strategy of the government policy towards minerals is to ensure that the country's mineral wealth supports sustainable national growth and socio-economic development.

The objectives of the Mining and Mineral Policy of 2018 comprise:

a) To strengthen the legal and regulatory framework for the development of the mineral sector;
b) To ensure efficient, equitable, accountable and transparent management of mineral revenues;
c) To establish, manage and promote the country's mineral potential;
d) To enhance and strengthen the institutional capacity for effective governance of the mineral sector;
e) To organize and legislate artisanal and small-scale mining in Uganda;
f) To promote and protect Health, Safety and Environment in the mineral industry;
g) Provide a framework for gender mainstreaming, equity and human rights and eradication of child labour in the mining industry;
h) To provide a framework for marketing and value addition of minerals;
i) To promote local content and national participation in the mineral industry; and
j) To promote regional and international cooperation.

To meet the objectives set-out in the Mineral Policy, the Government vis-à-vis the Department of Geological Survey and Mines is mandated to:

a) Collect geo-information: Carry out geological, geochemical, and geophysical surveys of the entire country at various scales;
b) Understand the mineral potential of Uganda: Process, analyse and interpret geoscientific data;
c) Promote investment in Uganda: Archive, package and disseminate the data to potential users through print and electronic media and avail mineral prospects to investors;
d) Help ASM miners get organised: Encourage ASM miners to form associations and other organisations in order to improve capacity to produce and market their mineral commodities;
e) Support improvements to ASM: Apply light-handed regulations in small-scale mining, maintain a continuous dialogue with miners' organisations to address matters of small-scale mining and carry out awareness campaigns targeting artisanal and small-scale miners; and
f) Develop a supportive legal framework: Put in place competitive laws and regulations that support private sector investment.

Key achievements and roles of Department of Geological Survey and Mines include:

a) Establishment and maintenance of a framework for licensing, regulation and monitoring of ASM activities;

b) Registration and encouragement of ASM to form associations for their operations;
c) Mapping and demarcation of areas for ASM;
d) Ensure that artisanal mining is a preserve for Ugandan citizens and encourage joint ventures for small-scale mining operations;
e) Providing extension services and technical assistance to ASM and other mining communities in adoption of safe, environmentally and socially acceptable mining and processing practices;
f) Encouragement of ASM to participate in supply chain initiatives, such as ICGLR's Regional Certification Mechanism;
g) Promotion of technological transfer and use of appropriate equipment;
h) Establishment of mechanisms for ASM to access financing; and
i) Collaboration with development partners and civil society to promote best practices in the ASM subsector.

## Environmental and Health Issues Related to the ASM Sector in Uganda

### Impact on Waterways

Filling or draining of streams, lakes, ponds greatly impact fish, aquatic invertebrates, and amphibians. Food supplies for predators are reduced by the disappearance of these land and water species.

### Impact on Deforestation

Among a number of environmental impacts, main concerns relate to land degradation, consumption of forest resources from clay brick and lime production and degradation of wetlands from sand and clay mining.

ASM Development Minerals extracted in Uganda are estimated to directly impact approximately 515 km$^2$, or approximately 0.3% of the country's total land area, far below that affected by agriculture (41%). Wetland degradation from clay and sand mining is extensive, covering an estimated 221 km$^2$. Clay brick production alone is estimated to consume 2.9 million tonnes of wood per annum, impacting an estimated 457 km$^2$ of forests annually. Although positive examples of management strategies exist in specific ASM sites (e.g. backfilling of abandoned pits, tree planting), these are few and far between (Hinton, 2018).

### Impact on the Landscape

Although a small percentage of the population is involved in mining activities, ASM mining areas are associated with poor mine design and land degradation. The known sites are rarely rehabilitated or restored. Formerly mined out are areas are characterised by abandoned pits, quarries, and drained wetlands.

### Impact on Health Among ASM Operators

Occupational health and safety risks are severe. Rocks falls and pit wall collapses are the main sources of serious injury and fatality with 34% of quarry sites assessed reporting at least one fatality. This suggests that fatalities could be as high as 1.1 deaths per 1,000 stone quarry workers per annum. Other serious risks are posed by dust exposure, heat stress and overexertion, flying rock fragments, alcohol abuse at some sites and poor sanitation and hygiene, among others. This situation compounded by average workdays amounting to 9-10 hours per day and lack of on-site first aid, PPE and other much-needed management measures (Hinton, 2018).

In areas where gold mining is occurring, the effects of mercury are prevalent. This is because mercury is a cheap and accessible tool for recovery of gold.

The World Health Organisation considers 4 μg/L as a normal mercury level in human urine12 and 5 μg/g creatinine an alert value. The action level is considered at 20 μg/g creatinine. However, values as high as 1,168 μg/L in urine were found in gold shop workers in confined environments. A NBO study of 2019 revealed that Mubende District had the highest median blood levels of mercury (136 μg/L) relative to Busia (60 μg/L), Ibanda (43 μg/L) and Amudat (less than 0.001 μg/L). Similarly, the same study revealed that Mubende District had the highest median urine levels of mercury (105.5 μg/L) relative to Busia (70.6 μg/L), Ibanda (58 μg/L) and Amudat (less than 0.001 μg/L).

Findings from the NBO study of 2019 revealed that environment samples under the category of community natural portable water sources (spring wells, boreholes and ponds) in Busia, Ibanda and Mubende districts had mercury levels reading 31 μg/L, 13 μg/L and 11 μg/L respectively which are all above the permissible levels of Natural potable water limit of Mercury (total as Hg) concentration of 1 μg/L using the SO 12846 as the method test13.

It was observed that there were no designated places for collection of waste generated nor were there waste disposal mechanisms put in place at the mine sites visited, making mercury contamination of the environment inevitable (NEMA, 2019).

## Socio-Economic Issues Related to ASM Sector in Uganda

### Role of Women

In terms of its impact on Ugandan employment rates, the sector plays an important role in the employment of women in the country. In 2012/2013, although 51% of the potential working force were women, only 45% of the employed force were women. In the Development Minerals sector, however, the high participation of women in the extraction and processing of certain commodities, such as salt and stone, reverses this imbalance (Hinton, 2018).

Production of ore in mining is generally resigned for men, while women mostly carry out processing operations. For example, at a stone quarry or gold mine, a man works in a pit while a woman crushes the rock for aggregate or pans ore for gold recovery (Hinton, 2009).

Impacts from long working hours are expected to be more pronounced for female mineworkers than male. In 2008, consultations with female and male miners engaged in salt, limestone, stone quarries, dimension stone and sand production in Uganda, found that women's work burdens far exceed those of men. In addition to their commercial roles, women miners spend, on average, an additional eight hours daily on domestic functions including childcare, fuelwood and water collection, food preparation, washing clothes, tending to the elderly and sick and cleaning. Time spent by men on non-commercial roles amounted to three hours per day on domestic chores with an additional 7-8 hours spent on social activities (Hinton, 2018).

In a cooperative or association, leadership is primarily comprised of men and women resigned to supporting positions such as secretary or treasurer. At a majority of mining sites, women are more likely to hold the role of "supervisor" because it is not socially acceptable for women to do hard labour (Project, 2009).

Special attention should also be put on the critical role played by women and girls in provision of care to the sick family members as well as the community.

**Role of Child Labour**

Whilst there are no formal structures in place to mitigate against child labour at ASM Development Minerals sites, these risks are mitigated informally by the acceptance that young children should be protected from hard labour, meaning that children normally play supporting roles at the mine sites, e.g. hauling water, older children caregiving for infants (Project, 2009).

There are generally 5 categories of children found at mine sites (Hinton, 2018):

a) **Category 1**: Children (perceived to be) under the age of 14 who were present at the mine site, but were accompanying a family member and were not working;
b) **Category 2**: Children (perceived to be) under the age of 14 who were performing certain jobs at the mine site, but whose work would not be deemed as harmful or hazardous;
c) **Category 3**: Children (perceived to be) under the age of 14 who were performing the same jobs as the adults at the mine site, which could be deemed as hazardous work;

d) **Category 4**: Children (perceived to be) between the ages of 14-17 who were performing certain jobs at the mine site, but whose work would not be deemed as harmful or hazardous; and
e) **Category 5**: Children (perceived to be) between the ages of 14-17 who were performing the same jobs as the adults at the mine site, which could be deemed as hazardous work.

In terms of distribution, the vast majority of children observed at Development Minerals sites fall into Category 1, wherein children were commonly observed to be near where their parents or guardians were working. Their ages ranged from a few months old to 13 or 14 years, and they were often present in groups of various ages, where older children in the group would play a role in caring for the younger children. A large number of female miners consulted (including those who were tending to infants below school age) indicated that ASM had enabled them to send their children to school.

Out of the two categories where the children's' work could be deemed as harmful or hazardous, those in category 5 (aged 14-17) were observed much more commonly than those in category 3.

It is likely that most children who fell into categories 2 and 4 were accompanying parents or guardians, and any work performed would be to help the parent or guardian. Whether children fell into categories 2 and 4 was the most difficult to ascertain with accuracy using observation methods, as light tasks are more likely to happen on an ad hoc basis, and so the research team may not have been present at the mine site at a time when the child was working.

**Conflicts with Local Farmers and Other Stakeholders**
As subsistence farming is a major source of food and livelihood, in areas where mining takes place, it is a disruption to the food supply chain due to its higher potential for earning than other economic activities.

Since a large percentage of miners are informal, their contribution to local and national development is not known; hence, they are usually in conflict with local and national authorities, because they tend to not pay taxes or for services that they access to be productive.

**Conflicts with Criminal Gangs in the Mining Area**
There are no serious crimes within mining areas or communities. Petty crimes regularly recorded are common theft of equipment and ore amongst fellow miners within the same communities. There are no known criminal gangs known to carry out crimes in the mining sector.

ASM mining site in Zambia

Endaselassie in Ethiopia

# ASM SECTOR OF RWANDA

*By Happy Sabine Kami*

## Geographical Context of Rwanda

### Demography of Rwanda

The analysis of the fifth Rwanda Population and Housing Census indicates that Rwanda's population was 13.3 million as of August 2022, indicating an intercensal annual growth rate of 2.3% between 2012 and 2022.Overall, there were 6.8 million females representing 51.5% of the population, which is slightly higher than 6.5 million males, representing 48.5% of the population.

The ratio of Rwandan urban-rural population indicates that there are approximately three urban residents (i.e. 27.9%) for every seven rural residents (72.1%). The City of Kigali is the most urbanised Province (86.9%) while the Southern Province has the lowest urban population (14.8%). The provincial population distribution shows that Eastern and Southern Provinces are the most populous, constituting half of the total population of Rwanda.

### Economy of Rwanda

Rwanda now aspires to achieve Middle Income Country status by 2035 and High-Income Country status by 2050. It plans to achieve this through a series of seven-year (2017–2024) National Strategies for Transformation (NST1), underpinned by sectoral strategies focused on meeting the UN's Sustainable Development Goals. The NST1 followed two, five-year Economic Development and Poverty Reduction Strategies from 2008 to 2012 and from 2013 to 2018, during which Rwanda experienced robust economic and social performance.

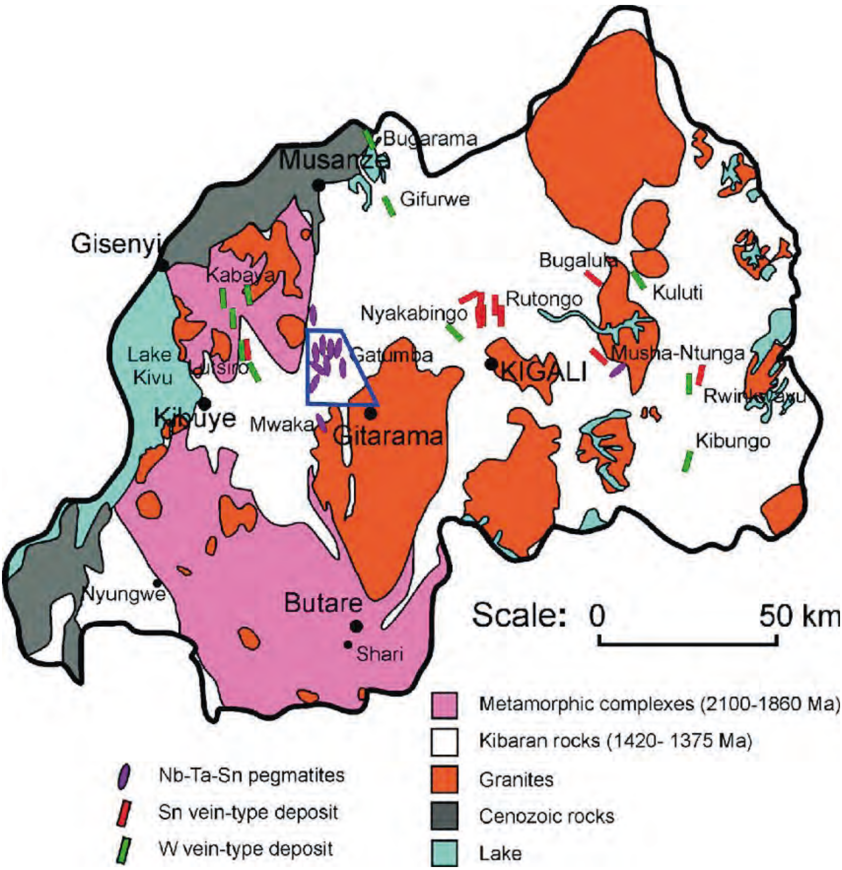
GDP growth reached 10.9% in 2021 before declining to 8.2% in 2022 due to climate shocks on domestic food production; high energy, food, and fertilizer prices; and weak external demand on exports. GDP growth is projected to reach 7.6% in 2023 and 8.0% in 2024 on account of continued slow recovery in domestic agricultural production and recovery in exports and conference tourism. In the first quarter of 2023, GDP at current market prices was estimated at Frw 3, 901 billion, up from Frw 3,021 billion in Q1 2022. In this quarter, the services sector contributed 44% of GDP, the agriculture sector contributed 27% of the GDP, the industry sector contributed 22% of the GDP, and 8% was attributed to adjustment for taxes and subsidies on products. Even though GDP from mining in Rwanda decreased to 42 RWF Billion in the first quarter of 2023 from 47 RWF Billion in the fourth quarter of 2022, the mining sector, as the second largest export sector in the Rwandan economy after tourism, is expected to contribute to the above targets as they recently set an ambitious target of generating USD 1.5 billion in export revenues by 2024. In addition, the mining sector will also contribute to the Rwandan economy through social economic development by increasing the number jobs in the mining sub-sector from 47,000 in 2017 to 62,000 by 2023.

## Geological Context of Rwanda

### Simplified Geological Map of Rwanda

The simplified geological map shows the main ore deposits in Rwanda, ref. Figure 61.

FIGURE 61 | SIMPLIFIED GEOLOGICAL MAP OF RWANDA




Source: Geological Survey of Rwanda

### Brief Description of National Geology

The geology of Rwanda generally is made up of sandstones alternating with shales, which are all assigned to the Mesoproterozoic Burundian Supergroup, sometimes interrelated by granitic intrusions. In the eastern part of the country older granites and gneisses dominate. Neogene volcanics are found in the northwestern and southwestern parts of Rwanda. Young alluvials and lake sediments occur along the rivers and lakes.

Generally, the stratigraphic sequences established in Rwanda can be identified with those, which appear in neighbouring Burundi. The sedimentary succession of the Burundian Supergroup can be subdivided into the following units: the Lower Series (la Série Inférieure), the Byumba Series, and the Miyove Series; each of these can subdivided into formations of quartzites and various undifferentiated rocks. The base of the Lower Series is the most developed formation, characterised by black sericitic shales. The metamorphic rocks in the east of the country probably represent metamorphosed Burundian formations. All these sedimentary sequences indicate a former shallow marine, high-energetic environment, as often shown by the oblique stratification, the conglomerates and the symmetric ripple marks within the layers.

At least four types of granitic rocks are known within the Kibaran Belt. Of these, the two first are synorogenic and the two last postorogenic. The culmination of the Kibaran orogeny occurred from about 1370 to 1310 Ma; the first of these ages dates early granites in Rwanda. Postorogenic granites are also known from Rwanda and have been dated at about 1136 Ma. Cenozoic to Recent volcanic rocks occur in the northwest and west of the country. Some of these volcanoes are highly alkaline and are extensions from the Virunga volcanic area of southwestern Uganda and eastern Democratic Republic of the Congo. Tertiary and Quaternary clastic sediments fill parts of the Western Rift in the western part of the country.

Rwanda is located in the Central African Mesoproterozoic Karagwe-Ankole Belt (KAB), The KAB is present in Rwanda, Burundi, the Kivu and Maniema Provinces in the DRC and part of Uganda and Tanzania. The KAB forms the northern segment of the classical “Kibara Belt, which was formerly thought as a single continuous orogenic belt trending northeast from the Katanga region in the DRC up to the Ankole region in southwest of Uganda.

The KAB of Central Africa is composed of Meso and Palaeoproterozoic metasedimentary and metavolcanic rocks (± 1450 – 1000 Ma). The KAB forms a metallogenetic province with principally Nb-Ta, Sn and W commodities. The ores occur associated with peraluminous S-type granites that intruded the KAB around 986 ± 10 Ma. Niobium-tantalum and part of the tin are present in pegmatites that have a spatial relation with these S-type granites. Tin is especially concentrated in greisenized cupolas of the granites and greisenized zones of the pegmatites. In the pegmatites or altered zones of the pegmatites, tungsten can only be found as an accessory ore mineral,Tungsten, but also tin occurs in quartz veins in the metapelitic rocks intruded by the granitic rocks. Tungsten-mineralized quartz veins are dominantly present in dark-coloured (often organic-rich) metapelites that alternate with more coarse-grained siliciclastic rocks, such as sandstones and quartzites (Fernandez-Alonso, 2012).

## ASM in Rwanda

### Substances Exploited by ASM Operators in Rwanda

Rwanda contains many of the mineral commodities that are of major significance for the current high-tech industry worldwide. The main metals exploited in Rwanda historically and nowadays are tantalum-niobium, tin and tungsten, exports gold and gemstones, including amethyst, Topaz, Sapphire and Ruby. Rwanda also possesses a variety of minerals such as Lithium Minerals, beryl minerals, silica sands, kaolin, vermiculite, diatomite, clays, limestone, talcum, gypsum, Granite, amphibolite, and pozzolan. ASM operators participate in the exploitation of all the aforementioned minerals.

### Legislative Framework for the ASM Sector in Rwanda

The Official Gazette No. 29 of 2019 is the main piece of legislation that defines legal framework for mining in the Rwanda.

The following specific legislation applies to the ASM sector:

a) Ministerial Order No. 007.01 of .2019 relating to mining and quarry operations;
b) Regulations of the CEO No. 001.MINES.RMB.2019 of 2019 determining the nature amount and deposit of environmental rehabilitation guarantee;
c) Regulations of the CEO No. 004.MINES.RMB.2019 of 2019 determining the format and content of a mineral license and the content of an agreement with a mining or industrial quarry license holder;
d) Regulations of the CEO No. 005.MINES.RMB.2019 of 2019 determining potential mining areas criteria for categorisation of mines modalities and requirements for mineral license application and for tenders;
e) Ministerial Order No. 002/MINIRENA/2015 of 2015 relating to criteria used in categorisation of mines and determining types of mines; and
f) Law on Minerals Tax of 2013.

### Degree of Organisation of ASM Sector

By means of the Rwanda Mines Petroleum and Gas Board, all small-scale mining shall be authorised before commencement of mining activities. In addition, all small-scale mining must adhere to all applicable rules and regulations governing mining and quarries in Rwanda and be subject to various inspections by competent authorities for compliance. ASM administrative structures vary from company to company; however, all ASM cooperatives shall have a president and a vice president in addition to competent mining engineers and environmentalist before an mining license is issued.

**Role of the Rwanda Mines Petroleum and Gas Board to Support the ASM Operators**

The main role of Rwanda Mines Petroleum and Gas Board in supporting the ASM Operators is to integrate ASM into the formal legal system through appropriate legal frameworks, technical support, formalisation strategies, promote capacity building in ASM companies, and attract big investors to enter into a joint venture with local ASMs.

## Environmental and Health Issues Related to the ASM Sector in Rwanda

### Impact on Waterways

Despite an effort of Rwanda Mines Petroleum and Gas Board and other stakeholders to improve mining practices, including establishing of prohibited distances in wetland, main rivers and riverbanks, most ASM companies lack enough capital for mechanising their mines. Based on Rwandan topography too, most ASM companies lack skills for wastewater and tailing management. even though some ASM operators try to build local mineral processing facilities, including cemented ground sluicing and tailing pond, most of them prefer to wash minerals near rivers, which causes the degradation of riverbeds, riverbanks, and changes in water flow. The result of these activities can be observed too in the lower reaches of rivers, where sedimentation of suspended sediments, widening of the watercourse, reduction in water flow and drying of the riverbed are evident.

### Impact on Deforestation

The majority of ASM operations are carried out in remote areas surrounded by forest, where at some point they need to strip away different vegetation, including plant, to obtain an adequate area for operating a mine site, i.e. houses, roads, tailing dump and water dam, and storage.

In addition, more than 50% of ASM operations in Rwanda are underground; hence, most of them use timber to support openings and tunnels, which result in the cutting down of trees. To remedy this, the Rwanda Mines Petroleum and Gas Board and the Rwanda Environmental Management Authority now require mining companies to plant forest for future use and not harvest existing forest without official approval from a competent authority.

FIGURE 62 | IMPACT ON DEFORESTATION AND LANDSCAPE

Source: Happy Sabine Kami

**Impact on the Landscape**

Mining in Rwanda started in the 1930s. In early age, the majority of the mining was done by artisanal surface mining which was later just abandoned. At that time, there were no requirements for environmental impact assessments and environmental management plans, including a reclamation plan, which resulted in landscape deformation. Deformation of hills slope caused several environmental issues, such erosion, formation of sinkholes and loss of biodiversity. This is evident in the western and southern provinces, which were and still are one of the largest mining regions.

**Impact on Health Among ASM Operators**

Regardless of the efforts of the Rwandan Government in establishing different measures for improving health among ASM operators, mine accidents have killed at least 419 people, while 272 were injured in a period of five years from July 2018. Accidents happen in both licensed and non-licensed (illegal) mines and quarries. Furthermore, 337 mine accidents were recorded from July 2018 to 2022 of which 252 accidents happened in mines owned by companies that were legally operating, while 85 accidents happened in sites owned by companies that were operating illegally. The accidents that happened in mines owned legally operating were caused by different factors, such failing to comply with safety and health standards, poor waste management procedures, lack of modern mining operations and environmental protection.

## Socio-Economic Issues Related to ASM Sector in Rwanda

### Role of Women

It is well known that Rwanda is one of the most gender-sensitive countries in the world and Rwanda's constitutional, legal and institutional framework is gender-mainstreamed. However, gender equality in the mining sector has yet to record similar achievements and appears to be lagging behind given the notable male dominance in the sector. To tackle this issue, the Rwanda Mines Petroleum and Gas Board partnered with its stakeholders to develop a gender strategy for the mining sector. The journey started with a baseline study, which confirmed the male dominance in the sector and defined the tasks to be performed, including the development of the current gender strategy.

This strategy serves as a guide for all gender, mining, and economic stakeholders to play their specific coordinated roles in the promotion of gender equality in mining. The strategy suggests various interventions to end gender stereotypes that hinder women's participation in mining, to ensure the gender-mainstreaming of mining and quarrying companies and cooperatives, to build women's capacities, recruit and retain them, to avail a gender-sensitive workplace environment, and to ensure women's socio-economic empowerment.

Rwanda's mining sector, which also includes quarrying operations, employs 40,519 workers, of whom only 11.7% are women, while the vast majority (88.3%) are men, according to figures published in February 2023 by the National Institute of Statistics of Rwanda.

Women play a significant role in the mining industry in Rwanda, such as participating in the establishment of related mining policies and guidelines, minerals processing plant supervisor, panners, provision of food services, security guards, shift supervisors, mining engineers, environmentalist, geologist, mineral recovery operator, captain, and supervisor.

According to records from the Rwanda Mines, Petroleum, and Gas Board, there are also 22 women, who own mining licenses, or 16% of the total.

FIGURE 63 | WOMEN IN MINING

Source: Happy Sabine Kami

**Role of Child Labour**
As per laws governing mining in Rwanda and different guidelines and policies related to this law, it is prohibited to employ children (under 16 years) in the mining sector. To ensure that ASM companies comply with this laws, different joint inspections by the Rwanda Mines Petroleum and Gas Board and/or local authorities happen regularly with the aim to safeguard children in mining sector; nonetheless, some cases of child labour in non-licensed mines do exist.

**Conflicts with Local Farmers and Other Stakeholders**
Conflicts with landowners and farmers do occur, primarily in connection with expropriation of land for mining purposes and over the payment of money for access and exploration, but also following mismanagement of wastewater and land erosion by the miners.

ASM in Hetsatsec in Ethiopia

# MINING SECTOR OF LIBYA

*By Mr. Ahmed Mahmoud Arara and Mr. Jalal Hashem Mansour, The National Mining Corporation. Libya*

## Introduction

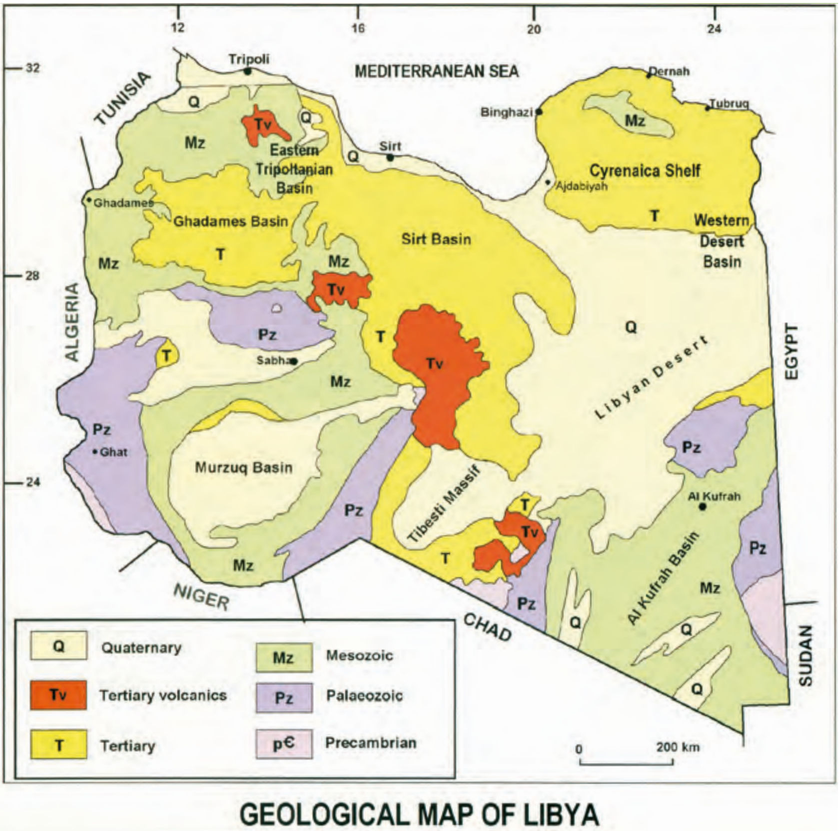
Libya's mining sector is one of the strategic sectors that is receiving great attention from the Government. The National Mining Corporation aims to activate the mining sector to become a strong contributor to the national Libyan economy, and to prepare plans and educational programs that contribute to the exploitation of available raw materials and exploit them in an optimal way, which will increase the total national production. In addition, the National Mining Corporation seeks to attract local and foreign investors alike, and one of the most important competencies is to explore, extract, and supervise mineral wealth to achieve the best economic returns.

The National Mining Corporation is a pioneer in the mining industry in Libya, as the institution strives to achieve its goals in this field. It continuously develops and improves mining operations and strives to achieve the highest standards of quality and safety in its operations.

## Geology of Libya

Libya is bounded in the north, from the geological point of view, by the southern part of the Mediterranean basin, and in the south by the northern edge of the so called the African Shield. Accordingly, Libya may be divided into two parts: the northern part which is considered the extension of the ancient Mediterranean and composed of marine environmental deposits; and the southern part, which is composed mainly of basement rocks and old rocks composed of igneous, metamorphic, and continental sedimentary rocks.

FIGURE 64 | GENERAL DISTRIBUTION OF GEOLOGICAL COMPOSITIONS IN LIBYA




Source: National Mining Corporation

Libya has been affected by many tectonic movements and volcanic activities during the different geological episodes. These primary facts are considered to be the base on which all the geological research and studies depend on in order to know the nature and the type of the suitable environment of deposition of raw materials and the rocks extruded from the earth's interior or those formed by the different tectonic movements.

## Geological Exploration by the Industrial Research Centre

Based on available information, the Industrial Research Centre (IRC) undertook the following programmes using different exploration methods:

**Regional Mapping Program**

The objective of the Regional Mapping Program is the collection of primary geological data by knowing the different geological formations and their depositional environment in order to obtain indications of the presence of raw materials.

**Prospecting and Exploration Work**

Prospecting and exploration work goes on in parallel with the geological mapping program in which one can know the extension and the nature of the primary raw materials in the area under investigation. The data of this stage is also compared and tied with other similar sites in terms of depositional environment and the geological nature. Different methods and tools are used in this work to determine the preliminary reserves.

FIGURE 65 | IRC USES DRILLING MACHINES IN ORDER TO OBTAIN SUBSURFACE SAMPLES


Source: Industrial Research Center

An important work carried out as a prospecting work was the coverage of nine different areas by an airborne geophysical survey that cover a total surface area of about 250,000 km$^2$ beside numerous other exploration studies and research oriented towards the exploration of primary raw materials and metallic minerals in different parts of the country.

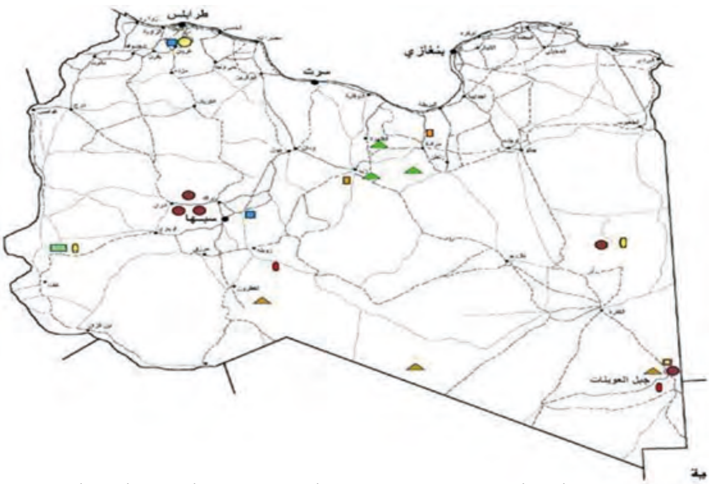
**Detailed Geological Studies**

Detailed geological studies include evaluating different ore bodies in terms of quality and quantity by calculating the ore proved reserves and their suitability to be used for industrial purposes and studying the method of mining for the discovered deposits and the methods that may be used to upgrade the ore quality or development different uses of the ore in question.

## Primary Raw Materials and Metallic Minerals

The IRC carried out geophysical studies and airborne magnetic and spectrometric surveys for the purpose of prospecting and exploration for various materials and metallic and radioactive minerals especially in the southern parts of Libya where nine areas were covered by airborne geophysical survey. The regional geological mapping program and the geological exploration work led to the discovery of many indications of metallic and non-metallic minerals, such as iron, gold, and phosphate besides other radioactive elements, such as uranium and thorium and others, which all need more detailed geological studies, especially in the southeast of Libya and the necessity of finishing the regional geological mapping of the Tebisti area in which numerous metallic raw materials are expected to exist.

FIGURE 66 | MAP OF RAW MATERIALS AND METALLIC MINERALS




Source: Industrial Research Center; Legend: Brown: Iron; Green Triangle: Celestite; Green Square: Zeolite; Yellow Circle: Phosphate; Brown Square: Sulphur; Blue Square: Coal; Red Square: Feldspar; Orange Square: Gold; Yellow Square: Radioactive Element; Blue Triangle: Lead, Copper.

**Metallic Raw Materials in Libya**

This is material from which metallic minerals can be extracted, such as iron, copper, nickel, chromium, lead, aluminium, and others.

Iron ores have been discovered in Wadi Shatti area. Traces of other metallic ores, such as gold, iron, lead, and copper were found in the eastern Al Awaynat area and strontium ore in the mid regions of Libya as well as radioactive elements in the south-western regions. The mentioned discovered raw materials need to be followed up by more detailed studies to make sure of them and accordingly studying the best methods of their exploitation.

**Non-Metallic Raw Materials in Libya**

This is material that is used as primary materials in numerous industries, such as building materials, phosphate, and salts. This category of materials is also known as industrial rocks. Several industrial rocks have been discovered and studied and some of them are currently used industrially.

The following types are the most significant non-metallic raw materials:

*Limestone*

Limestone is calcium carbonate compound, which has different uses within the industrial and agricultural sector. Limestone is the basic material that is used in lime and cement industries, in iron and steel industry as a catalyst material, and as a filler in various industries, such painting, plastics, and binding materials.

Limestone is also used in many chemical industries. Limestone deposits can generally be found in many different areas of Libya and especially in the northern regions, where many limestone sites were studied in detail.
Plenty of these studied sites are currently under exploitation by different lime and cement factories and by the iron and steel factory as well as by the factories producing glass painting and plastics.

FIGURE 67 | DOLOMITE AND LIMESTONE QUARRY IN AL AZIZIYAH AREA EXPLOITED FOR CONSTRUCTION AGGREGATES

Source: Industrial Research Center

*Dolomites*
Dolomites is a type of carbonate rocks formed by the interference of calcium carbonate and magnesium carbonate in different percentages. The rock type grades from limestone to dolomite as the percentage of magnesium carbonate increases. Dolomite is used for different industrial applications, such as refractory bricks and in the glass industry, filler, manufacturing of polishing blades and aggregates. Dolomites can be found in many areas of the Great Jamahiriya where it is extensively used as an aggregate and as a refractory in the iron and steel complex in Misurata in many other industries.

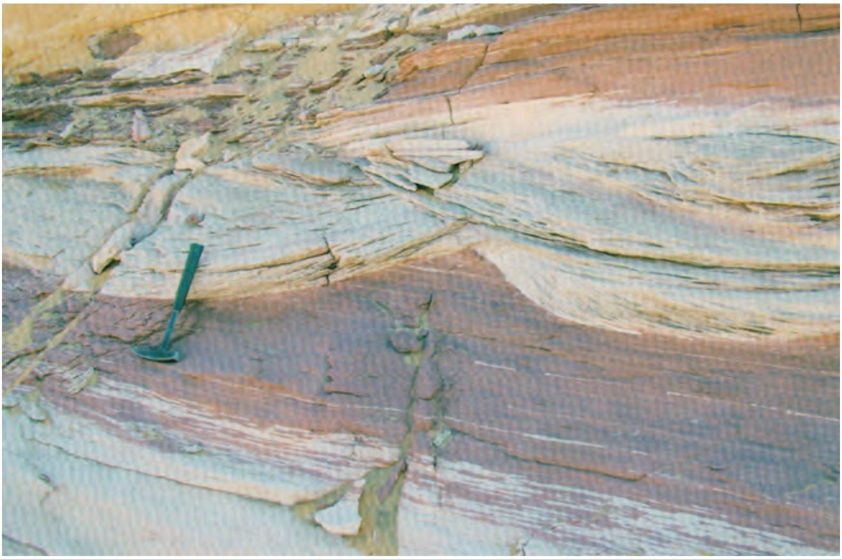
*Calcarenite*
Calcarenite is a marine type of carbonate rock that is formed by the assemblage of marine shells mixed with different portions sand. It is spread along the coastal area of Libya with different thicknesses and degrees of consolidation and chemical composition that vary from one area to another area. Because of their discontinuous and friable bedding nature, calcarenites are currently widely used to produce construction block moulds as well as construction sand (fine aggregate). The over-exploitation of these deposits in the north-western regions of Libya caused environmental problems, which make it necessary to look for alternative building

materials, such as sand lime bricks, gypsum bricks, and light bricks.

*Clay*

Clay plays a significant role in the industrial sectors as one of the raw materials of cement and the main raw material in pottery, ceramics, and refractories. Clay is also used in paper manufacturing and in the oil industry, where it is primarily used for its physical properties rather than its chemical constituents. Clay deposits cover most parts of Libya where they are mined for use in cement, pottery, ceramics, and refractory industries.

FIGURE 68 | EXPOSURE OF CLAY IN DIFFERENT COLOURS THAT ARE USED IN THE HOLLOW BRICK INDUSTRY



Source: Industrial Research Center

*Silica Sand*

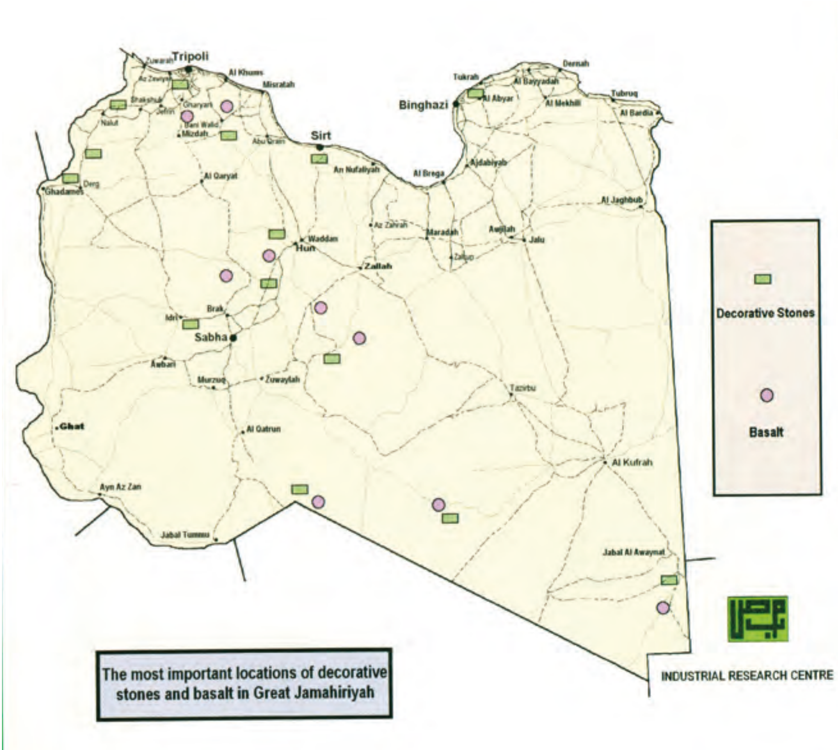
Silica sand is silicon dioxide (silica) compound, which exists in nature in many types that vary in physical nature and colours. The most famous type is quartz mineral and chert that form consolidated beds of sandstone or in the form of sand dunes or as quartzite in metamorphic rocks. Given the hardness nature of silica, it is used in the glass industry, as an abrasive, in metallic casting moulds, as a corrective material in building material, as a filler material in painting industry, and in the electronics industry whenever it is found in its purest form. Sandstone deposits are found in many areas of Libya where some of these deposits are used in cement, glass, and construction materials industries.

*Diatomite*
Diatomite is a type of silica, which is an agglomeration of micro marine organisms' shells, which contain silicon dioxide. Diatomite is used in filters manufacturing and in paper, synthetic rubber, painting, and thermal insulators fort its high thermal resistance. in In Libya, there is only one single site of diatomite, namely in Sebkhet Al Gezayel in the middle part of the country; however, to date it has not be in use.

*Gypsum*
Gypsum is hydrated calcium sulphate found in nature in many forms that depends on the quantity and quality of water content Gypsum is transformed to anhydrite by losing its water content and vice versa. Gypsum has many uses in the industrial and agricultural sectors and is one of the raw materials used in the cement industry, the pharmaceutical and chemical industries, painting, paper, construction, and in small-scale in lime and sulphuric acid manufacturing. Different gypsum deposits can be found in many areas in the Great Jamahiriya with some of them under use by the cement industry and recently also for plaster production in Bir Al Ghanam.

*Decorating Stones*
Decorating stones are those types of rocks that have astonishing colours and characteristic mechanical properties that make them highly resistance to abrasion and the effect of atmospheric conditions; hence, they are used for different purposes, such as tile production or decorating the external and internal building faces. Decorative stones include many types of rocks, such as granite rooks, dolomitic limestone rocks, natural marble, and some types of cherts that are used in jewellery manufacturing. All these mentioned types of rocks have different geneses and formations. In Libya, different types of decorative stones can be found but more studies must be carried out in some areas especially the igneous and metamorphic rocks found in south-eastern parts of Libya.

FIGURE 69 | MAP OF DECORATIV STONES AND BASALT




Source: Industrial Research Center

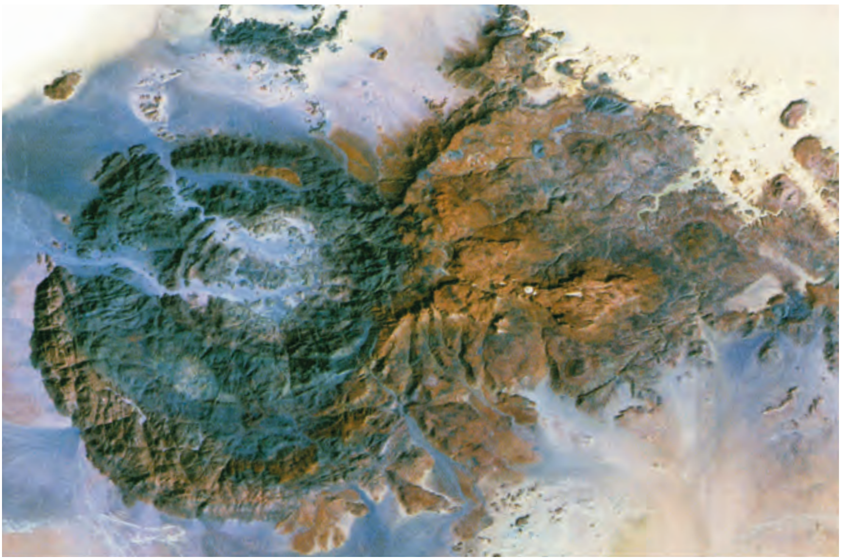
*Igneous Rocks*

Igneous rocks are rocks that are formed by the accumulation of group of minerals that are crystallised from the molten magma under certain temperature and pressure conditions. Igneous rocks form 95% of the rock components of the earth's crust and they form irregularly shaped blocks inside the earth's crust. Igneous rocks are the source of granitic, basaltic, rhyolitic rocks, nephelins synite, mica, feldspars and other rocks and minerals. Igneous rocks (granite) are used in road construction, railroad blast and as decorative stones. There are some types of basalts that are used in the production of mineral wool that is used as insulator material in domestic kitchen furnaces and also in the ceramic industry. In Libya, igneous rocks are found in different areas with most of them being volcanic basaltic rocks and some granitic rocks found in the southern parts of Libya.

## Results and Conclusion

Going over the results of the geological surveys and the studies carried out by the IRC with the aim of searching for raw materials and different metallic minerals all over Libya there exist numerous raw materials and metallic minerals some of them are under exploitation by huge industrial establishments that use these materials for building materials and cement. Still, quite a number of raw materials are not exploited yet besides many traces of metallic elements, such as gold, copper, lead and zinc and radioactive elements, which need more detailed studies specifically in the southern parts of Libya. If more positive results come out by studying these traces in the future, they will certainly be a source of national income that will be based on the mineral resources and accordingly plenty of mining projects will be established, which will accelerate the development progress whereby Libya will achieve a higher level of living standard.

FIGURE 70 | JALAL AL AWAYNAT RING COMPLEX IN SE LIBYA, COMPOSED OF DIFFERENT TYPES OF GRANITES AND GRANODIORITES AND METAMORPHIC ROCKS WHICH SHOW INTERESTING GEOCHEMICAL ANIMALIES OF SOME BASIC METALS



Source: Industrial Research Center

ASM training in Assoca in Ethiopia

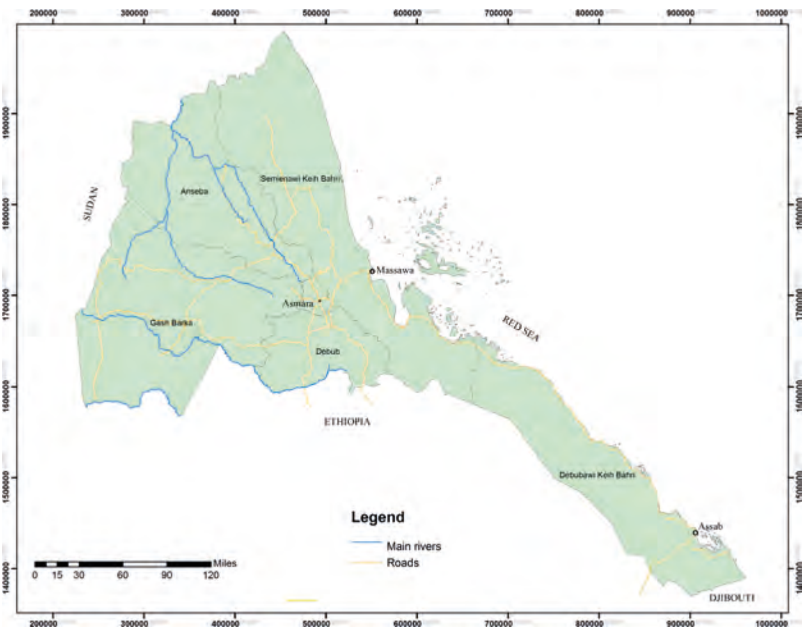
ASM mining site in Tanzania

# ASM SECTOR OF ERITREA

*By Ermias Yohannes Berhane, Director, Eritrea Geological Survey*

Geographical Context of Eritrea
Eritrea is located in northeast Africa between latitudes 12.3 and 18.0 ON and longitudes 36.4 and 43.1 OE, REF. Figure 71. It is bordered by the Red Sea in the east, Sudan in the north and west, Ethiopia in the south, and Djibouti in the southeast. It is covering an area of 124,320 km$^2$, comprising the mainland and more than 350 islands in the Red Sea. National parks and game reserves comprise about 13% of the country. The country has a high central plateau that varies in altitude from 1,800 to 3,010 m above sea level. The remainder of the country comprises the eastern (coastal) lowlands in the east with altitudes in the range of up to 600 m, and the western lowlands that rise from about 400 m in the north to about 1,500 m in the south. The country has a continental shelf of about 52,000 km$^2$ along its 1,200 km long coastline. The country is classified into six administrative Regions or Zobas; Southern Red Sea, Northern Red Sea, Anseba, Gash-Barka, Debub, and Maekel. Eritrea is divided into three physiographic regions, namely, the central highlands, the midlands, and the lowlands.

FIGURE 71 | LOCATION MAP OF ERITREA




Source: Ermias Yohannes Berhane, Eritrea Geological Survey

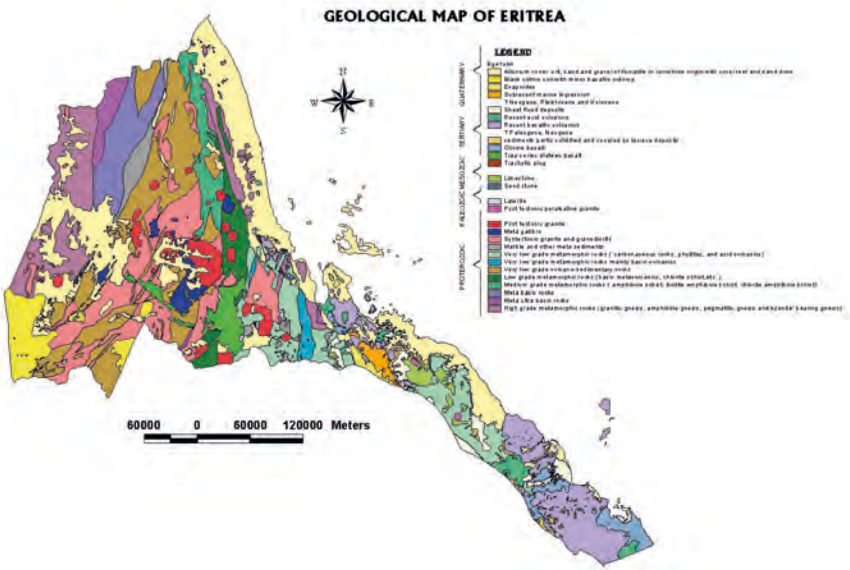
### Demography of Eritrea

The population of Eritrea was estimated at approximately 3.2 million in 2010 with an annual growth rate close to 2.91%. About 50–60% lives in highlands that comprise only about 10% of the country's total area. Eritrea is an ethnically heterogeneous country with nine recognised ethnic groups. Eritrea's population consists of various languages and cultural traditions. In addition to the languages spoken by the various ethnic groups, Arabic and English are widely understood, where English is commonly used as a medium of instruction in academic institutions and international relations.

### Economy of Eritrea

Mining plays a significant contribution to the economic development of the country. The mineral resources of Eritrea include gold, copper, potash, silver, marble, oil and natural gas. The potentials of gold, petroleum and gas are believed to be high. Eritrea's economy in recent years has been driven by mineral resources, the mining sector being one of the promising assets for the economic development of the country, especially with the start-up of commercial mining activities at the Bisha mine in early 2011 and Zara in 2015. The sector has attracted about 20 listed companies of which the Bisha mining company has been involved in the production and sales of gold, copper, and zinc. The growth rate, which reached a maximum of 3% over the period 2000-2010, has increased to 7-8% since 2011.

## Geological Context of Eritrea




Source: Department of Mines, 1997

**Brief Description of National Geology**

The Eritrean crustal segment is part of the Arabian-Nubian Shield; a composite terrane generated by the closure and accretion of juvenile volcanic arcs and back-arc basins, forming an important part of Gondwana (Johnson et al., 2011). During this period of Neo-Proterozoic time most of the geological formation were formed, ref. Figure 72. The western gneiss terrane is known as Barka terrane and the eastern as Ghedem-Arag terrane (Fritz et al., 2013); both of which are categorised as high grade metamprphic rocks. The intermediate terranes have been interpreted as an intra-arc system or paleo-oceanic troughs located above a W- to NW-dipping subduction zone. Rocks within E-verging imbricated thrust sheets were affected by subduction-related metamorphism of 5500C and 1.45 GPa. The Nakfa terrane is located a few kilometres east of the juxtaposition of the juvenile crusts of the terrane, in which the Adobha Terrane occurs. The Neo-Proterozoic terrane of Eritrea is comprised of volcano-sedimentary rocks, with low- to high-grade metamorphic facies and granitoids categorised into its pertinent terranes, followed by the deposition of Mesozoic sedimentary rocks, and later deposits from Tertiary to Recent volcanism that cover portions of Eritrea, particularly the eastern portion associated with the rift formation.

The marine transgression and regression during Mesozoic era created sandstone and limestone deposits, which are located in the southern and south-eastern part of Eritrea.

After a long period of peneplanation (erosion that leads to the formation of a plain) in Eritrea's geological history, the present highland part of Eritrea was uplifted by a mantle plume. This peneplain is marked by a laterite horizon, which is present as ferricrete, layered stratigraphically on top of the basement, preceding a trapped layer of flood basaltic outpouring. The plume eruption, dated at about 30 million years ago, is responsible for the thick flood basalt layer and subordinate trachyte flow layer, which covered most of the highland area.

The onset of rifting in the Danakil was marked by Miocene volcanism, which covers the rift floor of the depression. The successive rifting resulted in subsidence of the crust, which paved the way for the accumulation of a thick layer of sediment in the depression, with significantly large terrigenous and marine deposits, of which evaporite is the best example.

## ASM in Eritrea

**Substances Exploited by ASM Operators in Eritrea**

Materials exploited in Eritrea by ASM operations are mainly confined to construction materials; building stones, mainly basalt, ref. Figure 73, granite, and sand. Clay is also exploited for the use as bricks in areas close to towns and around the capital, ref. Figure 74.

FIGURE 73 | BASALT MINE, ERITREA

Source: Ministry of Energy and Mines, Maekel Branch

FIGURE 74 | CLAY BRICK INSTALLATION, ERITREA

Source: Ministry of Energy and Mines, Maekel Branch

In addition, mining of marine sea salt has commenced at the ASM stage. The production of sea salt is based on the circulation of sea water through a circuit of large and shallow lagoons. The water evaporates slowly due to the action of the wind and the sun, crystallizing the salt on the surface and settling to the bottom of the pond. The crystalized salt is harvested after the water evaporates. Most of the coastal areas suitable for this type of mining, but the production of sea salt is mainly concentrated close to the port cities of Massawa and Assab.

Mining for gold by ASM operators is not allowed by law in Eritrea.

Eritrea is endowed with mineral potential in its greenstone belts, why ASM operations are active around gold bearing ferruginized quartz veins, although an illegal activity.

**Legislative Framework for the ASM Sector in Eritrea**

The Ministry of Energy and Mines is the sole and formal licensing agency in Eritrea, responsible for the administration, regulation and coordination activities of the energy and mining sector.

ASM in Eritrea is governed by the Mining Regulation of 1995, known as Proclamation No. 68/1995, which aims to promote the development of mineral resources in the country. The Regulation states that all mineral resources are public property, which can make a significant contribution to the economic development of the country and that the State shall ensure the conservation and development of the resources for the benefit of the people. It also points out that prospecting, exploration, and exploitation of mineral resources should be carried out in accordance with appropriate technology and sound principles of resource management and to develop national expertise in the mining industry. It also recognises the significant role of private investment in the capital formation, technology acquisition and marketing of minerals.

The Mining Regulation of 1995 states that:

a) An artisanal mining license may be granted for part of the surface area of an existing exploration license provided that:
    - the artisanal mining license is restricted to construction minerals to a depth of five metres and/or mineral water and geothermal deposits.
    - the Licensing Authority is satisfied that the activities of the artisanal miner will not interfere with the operations of the existing license.
b) An artisanal mining license may be granted for minerals other than construction minerals, mineral water and geothermal deposits if the land in question is not the subject of any existing license or prior license application provided that mining in the artisanal license is restricted to a depth of 5 metres.
c) An artisanal mining license may be transferred, assigned, encumbered, or inherited subject to the approval of the Licensing Authority.
d) An artisanal mining license may be granted over a license if the Licensing Authority considers that the activities of the artisanal miner will not unduly interfere with the licensee's operations.
e) A license may be granted over an artisanal mining license on the condition that the licensee shall make every reasonable endeavour not to interfere with the artisanal miner's operations.

According to the proclamation on "Title to Sale and Export of Minerals Number 34", the holder of an artisanal or mining license shall obtain title to the minerals specified in the license upon their extraction.

In addition, the Obligations No. 30, 3 on prohibition of mercury use in the operation of mining clearly states that the holder of an artisanal mining license shall take all environmental protection measures commensurate to his operations; in particular, he shall fill pits and plant trees and shall not be allowed to use mercury or similar materials in his operation.

**Role of the National Geological Survey to Support the ASM Operators**
The Eritrea Geological Survey has outlined projects regarding assessment of raw materials for building stones and sands. This input will be important for resource allocation. However, the mines administration division follows up the activities of the miners.

## Environmental and Health Issues Related to the ASM Sector in Eritrea

### Impact on Waterways

Artisanal mining of construction materials is mainly localised around urban centres.

Basalt quarry mining areas are mainly situated at the watershed and thus pose no influence on water ways. But sand mainly occurs on stream beds and banks, therefore sand excavation has impacted the stream bed as well as the water way.

The impact of salt mining is minimal as the source is sea water and no materials are dumped into the sea.

### Impact on Deforestation

Deforestation due to mining of building stones is minimal where the quarry is barren, or few forests are grown.

Illegal artisanal mining for gold does impact the environment and often results in deforestation as the miners cut trees for access, cooking and other purposes.

### Impact on Health Among ASM Operators

Quarry worker may be subjected to injuries due to rock excavation.

## Socio-Economic Issues Related to ASM Sector in Eritrea

### Role of Women

Since the quarry and extraction of building stones are labour intensive activities, the involvement of women is minimal.

### Role of Child Labour

Child labour is not permitted under the Eritrean Labour Law. However, illegal activities in the sand and gold mining may involve children. Though it is difficult to get the exact figures on the involvement of children in the mining sector, reports indicate that child labour is a big problem within the illegal activities of artisanal gold mining. Most of the children, who are involved in artisanal gold mining are between the ages of 7 to 16.

**Conflicts with Local Farmers and Other Stakeholders**

The licenses given to the miners for building stones are located close to the urban zones, and the quarries are away of the farmland; therefore, no conflicts are yet reported between the miner and local farmers.

**Conflicts with Criminal Gangs in the Mining Area**

No criminal gangs are present in Eritrea, even in remote areas.

ASM training in Assoca in Ethiopia

ASM mining site in Zambia

# THE ROAD LESS MINED: CO-EXISTENCE OF ENVIRONMENTAL SUSTAINABILITY AND ASM IN EAST AFRICA

*By Meq Mchomvu*

## Background

ASM has been a significant source of income for many rural populations in Africa for hundreds of years. The sector has undergone minimal changes in recent history. In East Africa's mining region, however, a history of extraction is documented in opencast and underground mines, waste dumps, processing sites, and furnaces that contain fragments of furnace wall clay, tuyeres, and rare crucibles. Finding a nearly complete record of mining practice and skill is uncommon. In East Africa, artisanal and small-scale mining mainly focuses on high-value minerals, particularly gold and gemstones. Salt, limestone (aggregates and lime), kaolin, and gypsum are some additional minerals that Artisanal-Small Scale miners collect. However, industrial minerals normally do not appeal to Artisanal-Small Scale miners due to poor infrastructure and value chain complexity. It should be noted that ASM plays a significant role in the economies of East Africa region countries. However, ASM activities in these countries are often associated with environmental, social, and economic challenges. This Chapter focuses on the ASM Sector in the seven Partner States of the East Africa Community comprises of the DRC; Republic of Burundi; Republic of Kenya; Republic of Rwanda; Republic of South Sudan; Republic of Uganda, and United Republic of Tanzania

## East Africa's ASM Context

Tanzania is one of the largest gold producers in Africa, and ASM activities play a significant role in this production. In recent years, Tanzania formalised ASM in 1998 with the enactment of the Mining Act of 1998, which recognises and defines ASM as a formal sector of mining in the country. The Mining Act of 1998 provided the legal framework for the regulation of ASM activities, including licensing, taxation, and environmental management. In 2017, the Mining Act was amended again to increase transparency and accountability in the mining sector, and to ensure that the government receives a fair share of the revenue generated from mining activities. The amendments also established a Mining Commission, which is responsible for overseeing the implementation of the Mining Act and regulating the mining sector.

The amendments to the Tanzanian Mining Act of 1998 have not been specifically targeted at improving the situation of ASM in the country. However, they have created a more conducive regulatory environment for small-scale miners and have helped to address some of the challenges faced by the sector, such as inadequate financing, environmental degradation and weak technical capacity. Since then, Tanzania has been working to improve the regulation and management of the ASM sector to ensure sustainable and responsible mining practices, by establishing mineral buying centres and developing a national mineral policy to improve the sector’s governance.

In Kenya, ASM mainly focuses on producing gold and gemstones, particularly in the western and coastal regions. Kenya’s ASM sector is governed by the Mining Act of 2016, which recognises it as a formal part of the country’s mining industry. This act provides licenses and permits for small-scale mining operations and enforces compliance with health and safety regulations and environmental standards. Small-scale miners are mandated to obtain a license from the Ministry of Mining under this act for up to two years. Despite these legal frameworks, challenges such as illegal mining, technical capacity deficits, inadequate financing, informality, environmental degradation, and conflicts with other land user remain prevalent in the sector. Recent amendments to the mining law in 2019 and 2020 were not targeted at improving ASM and environment coexistence specifically, although the streamlining of the application process for mining rights through the Mining Cadastre Portal could facilitate easier licensing and formalization of operations for ASM operators.

Furthermore, ASM in Uganda mainly focuses on producing gold and salt. Uganda’s mining law of 2003 recognises the ASM sector and provides for the formalisation of small-scale miners through the issuance of licenses and permits. Recent amendments to the law in 2017 aim to improve the sector’s environmental impact and enhance the participation of women in ASM activities. However, challenges, such as health and safety, environmental degradation, land ownership for women continue to hinder the sector’s growth. Despite these challenges, the potential benefits of ASM to Uganda’s economy and local communities cannot be overlooked. The Government has taken steps to improve the governance of the ASM sector, including developing a national mineral policy and establishing mineral buying centres.

In Burundi, ASM mainly focuses on producing gold, tin, and coltan. The mining sector is governed by the Mining Code of 2013, which provides for the regulation and supervision of mining activities, including ASM. The law recognises the role of ASM in the country’s economy and provides for the establishment of a national fund for artisanal mining development. However, despite the existence of the law, ASM in Burundi faces challenges such as limited access to finance, inadequate technical skills, and poor environmental practices. There have been no recent amendments specifically targeted at ASM formalization and improvement, but the government is taking steps to promote responsible mining practices and environmental conservation. For instance, the government has established an environmental protection agency and is implementing the National Environmental Policy and Strategy, which seeks to promote sustainable development. Additionally, the Government is working with international partners to promote responsible mining practices and provide technical assistance to ASM operators.

In the DRC, ASM plays a significant role in the mining sector, particularly in cobalt, copper, and gold production. The DRC has a complex legal framework governing its mining sector. The main laws governing the mining industry in the DRC are the Mining Code of 2002 and its amendments, as well as the 2018 Mining Regulation. The amendments made to the Mining Code in 2018 introduced new provisions aimed at increasing the government's share of revenue from mining activities, such as higher royalties and taxes.

FIGURE 75 | NYAMALAPA, KAHAMA ALLUVIAL GOLD RUSH AREA LEFT AFTER GOLD RUSH

Source: Emmanuel Mchomvu (2016)

In terms of ASM formalisation, the DRC Government launched a national program in 2015 to support the formalisation of the ASM sector, which includes the issuance of artisanal mining permits and the establishment of cooperatives to facilitate access to finance and markets for ASM miners. However, the formalisation process has been slow, and many ASM activities in the country still occur outside of the legal framework. In terms of environmental protection, the DRC has established a number of laws and regulations aimed at mitigating the negative impacts of mining activities on the environment, such as the 2003 Environmental Code and the 2010 Forest Code. However, enforcement of these laws on ASM has been weak, and there have been numerous cases of environmental degradation and human rights abuses associated with mining activities in the country.

ASM in Rwanda mainly focuses on producing tin, tantalum, and tungsten, with gold and gemstones also produced in smaller quantities. Rwanda's mining sector is governed by the Mining Law of 2005, which provides for the exploration, exploitation, and processing of mineral resources. The law aims to promote the development of a sustainable mining industry that benefits both the state and its citizens. To further improve the mining sector, amendments to the mining law were made in 2018, with a focus on formalizing artisanal and small-scale mining activities, enhancing the role of women and youth in mining, and promoting environmental sustainability. The amendments also aimed to strengthen the governance of the sector, increase transparency and accountability, and improve the management of mineral revenues. the challenges facing the ASM sector in Rwanda include limited access to finance, inadequate technical capacity, and the use of rudimentary mining techniques, leading to environmental degradation and health risks for the miners. Additionally, there is a lack of awareness and enforcement of regulations, which can lead to illegal mining and negative impacts on communities (IISD. 2019).

The ASM sector is an essential source of livelihood for many people in South Sudan, particularly in areas where formal mining operations are absent (Hilson, 2020). In South Sudan, the mining industry is governed by the Mining Act of 2012, which recognises ASM as a formal part of the mining sector. However, the lack of regulations and institutional frameworks to support ASM activities has limited its development in the country. The Government has made efforts to reform the sector by amending the mining law in 2015 and 2016 to include provisions for the formalisation of ASM activities, the establishment of a Mining Cadastre System, and the creation of a Mineral Development Fund to support the development of the sector. The ASM has been active for the past 15 years with currently about 200 ASM formalised licenses, which are renewable annually. Despite these efforts, challenges, such as limited infrastructure, lack of technical capacity, environmental degradation, and the proliferation of illegal mining activities, continue to hamper the growth of the ASM sector in South Sudan.

Efforts to improve the sustainability of ASM in these countries have been limited, with the sector facing significant governance, regulation, and enforcement challenges. However, some initiatives have been aimed at improving the sustainability of ASM, including developing easy mineral certification schemes, and establishing mineral buying centres.

## Environmental and Health Issues Related to the ASM Sector in East Africa

ASM causes land degradation, deforestation, improper reclaiming of mining areas, and failure to fill mineshafts. There are also overlaps between land-use changes and other impacts, such as the effects of land-use changes on hydrological regimes. It is critical to distinguish between surface mining, which entails the removal of substantial amounts of topsoil, deep rock mining, which entails the construction of underground mine shafts, and alluvial mining (such as that for gold and diamonds), which occurs in and around riverbeds. Alluvial mining sometimes entails the erosion of river channels since the banks of the river and the riverbed are harmed by the usage of equipment and the actions of miners. This can have a localised impact on the course of the river, in the case of small rivers with many meanders (bends). The impacts of ASM on the water can be broadly categorised into those that modify the quantity of water available and those that modify the quality of the water (through pollution) (Barasa, Kakembo and Karl, 2016). ASM activities have been going on in most mining areas in the region Tanzania: Mwanza,Mererani, Morogoro,Tanga Singida, Chunya, Kahama and Geita in villages of Umba,Matombo, Nyakagomba, Bugarama, Ikungi, Namtumbo, Bugarama, Nyamalogo, Misungwi, Nyarugusu, Rwamgasa, and Mgusu, Kenya: Migori, Kakamega, Siaya, Turkana, and Vihiga In the villages of Mwatate, Voi, Rosterman, Ikolomani, Bushiangala and Nyatike, Uganda: Busia, Buhweju, Mubende, Namayingo, and Nakapiripirit , Rwanda: Rulindo, Gakenke, Gicumbi, and Kayonza ,Burundi: Rutana, Kirundo, Kayanza, and Cibitoke, South Sudan: Jubek, Maridi, Kapoeta, villages of Bahr el Jebel and Rajaf, Tombura, Kinyeti and Lomuding, Orientale, Maniema, Ituri, Kivu and Katanga in villages of Aru, Mambasa, Walikale, Masisi, and Kalehe.

There are considerable implications on water quality from such activities, notably because of the amount of silt that is disturbed and released into the stream. Surface mining involves the removal of topsoil by mechanical means (such as backhoe loaders and excavators), human means (digging), or hydraulic methods (washing away material by applying water using hoses or buckets) (washing out fabric by applying water using hoses or buckets). Overburden and waste rock, which are not necessarily harmful, can be distinguished from tailings material, which has undergone some processing (mechanical and/or chemical).

As opposed to the nearby communities, flora, and fauna, air pollution in ASM is often fairly localised and may primarily pose a risk to miners and those near the mine site, such as in Migori, Kakamega, and Vihiga, which have all been associated with water pollution and land degradation due to the use of toxic chemicals. In addition, gemstone mining in areas such as Taita Taveta has led to soil erosion and loss of biodiversity. For instance, gold mines in ASM mining areas, such as the Kibira Forest Reserve in Burundi and Kapoeta and Ikotos in South Sudan, have been associated with deforestation, soil erosion, and loss of biodiversity. Due to explosive blasting in tanzanite mine as well as the daily activities of numerous miners and those who live near mine sites, dust may be produced and spread throughout the local environment. The concentrated and contained dust in mining pits and shafts is particularly harmful to miners' health, and most do not have access to masks, goggles, or other PPE. A serious lung disease, called silicosis, poses a health risk to miners, especially those in hard rock mining that uses explosives as in gold mines in areas, such as Mubende and Buhweju. The use of mercury and cyanide in the extraction process has also been a concern. (Agwa-Ejona and Pradhan 2018). Naturally, dust is much more damaging if it contains special components that are themselves dangerous, e.g., radioactive.

FIGURE 76 | MOROGORO KILOSA GOLD ASM AREAS WITH MANY OPEN HOLES LEFT

Source: Emmanuel Mchomvu (2021)

## Socioeconomic Issues Related to ASM Sector in East Africa

ASM in East Africa cuts through several key sectors and issues. This chapter will limit the discussion to the agricultural industry and socio-development issues concerning women and children. Therefore, agriculture and ASM are intertwined in a complex and dynamic manner. They are complex because they share the same physical space and identical factor inputs—land, water, labour, and capital—or compete for them. They are dynamic because they are subject to outside influences like commodity prices. Due to this increased interaction between ASM operations and agricultural activities, there is a high potential for conflict as well as cooperation between their operations (Maconachie and Binns, 2007).

It should be noted that these two crucial economic sectors provide most rural people in developing countries with viable employment and income in rural agriculture (Reardon et. al., 2001). However, despite providing a wide range of socio-economic advantages, ASM also has harmful environmental effects and competes aggressively with agriculture for factor inputs. In this context, research has demonstrated that the synergy between ASM and agriculture has only sometimes been seamless with regard to the procurement and utilisation of factor inputs (Musemwa, 2009). The strong competition over access to land between these two rural development drivers has mostly resulted in resource-use conflicts (Musemwa, 2009), whereas the competition for space and resources has occasionally led to coexistence and synergies among forms of land use (Maconachie and Binns, 2007).

ASM is an extractive practice that can harm agriculture through a number of channels. Land deterioration is one important mechanism. Mine pits and excavated soils left behind by ASM can potentially make formerly productive fields unfit for crop production, decreasing the amount of land available for agriculture (Kitula, 2006). The adverse effects of ASM on the environment, such as bush burning and deforestation, also reduce the availability of grazing areas for livestock (Ncube-Phiri et. al., 2015). Due to the loss of income from farming and the consequent decrease in the production of food, cash crops, and livestock, this may further entrench a cycle of poverty in the rural economy. The asymmetry of the impacts of interactions between ASM and agriculture is another worrying aspect. However, it has been noted that the siting of ASM activities close to productive agricultural lands has been shown to reduce crop yields through farm invasions and the destruction of cultivated crops (Boadi et. al., 2016).

Additionally, land reclamation projects in mining hotspots that aim to return mining-degraded lands to nearly original conditions to make them suitable for a variety of other critical industrial applications, including agriculture production, can be costly for the national government's budget (Mantey et. al., 2020). For instance, the Congo Basin holds the second-largest rainforest, accounting for most of the rainfall for agricultural produce in the region. Yet, it faces a survival threat due to aggressive foreign investors who seek strategic and technological minerals to address the exacerbated impacts of climate change. Hence, they need these minerals to build clean technology that would facilitate climate change mitigation and adaptation, simultaneously harming the environment of remote regions in East Africa.

In the ASM sector in East Africa, children have been employed to mine and work in this sector. The youngest are with their mothers while the older children care for their younger siblings, who eventually end up in the mines. In Tanzania and the DRC, child labour has been prevalent and therefore condemned as this is notably the worst type of child labour (Gatsinzi and Hilson, 2022). Furthermore, promoting the child labour narrative for ASM needs to consider the severity of the issues or the difficulties of rural life in East Africa. Children are also pulled into the ASM sector due to the collapse of agricultural industries. The lack of diversification of some farm families in rural host communities is among several factors leading to the visibility of children in ASM.

The ASM sector also has a dichotomy of gender norms shaping the fundamental activities in the East African region. It should be noted that gender norms have long-term effects on both men's and women's livelihoods. One of the more lucrative components of ASM for individual artisanal miners is working in, owning, or managing the mine pit, which is typically done almost exclusively by men, ring-fencing women out of the profits. Although more accessible to women, mining activities like stone crushing, washing, and panning can be financially risky and less lucrative in the value chain. Thus, pit work versus everything else is the foundational, gendered binary upon which many ASM zones are built. Pit work, or removing ore from the ground, falls under this binary's definition of "mining," which makes it male. The gendered ordering of other modes of practice influenced by mining's fundamental gendering is similarly established by gender relations (Lahiri-Dutt 2013, 4).

For example, research shows that women comprise 10% of Rwanda's workforce in the ASM sector (Nsanzimana et. al., 2020). Though there is a lack of precise statistics where women are more prevalent in South Kivu sites of the DRC and some areas of the Central region site in Uganda, still, men are dominant in ASM in East Africa. The primary activity at a mine site is the excavation and use of mine pits, galleries, and shafts; additional activities, including ore crushing, sorting, and washing, as well as the production and sale of food, alcohol, and domestic and sexual services, are dependent upon this activity's continuous operation. In various labour, social, and physical arrangements in East Africa's mining zones, gender can be seen (although ethnicity and other identification markers can also be used). In many artisanal mining communities, stringent gendered norms and taboos prohibit women from entering the pits where the ore is dug out and extracted.

## Conclusion

ASM is a critical sector in East Africa, a region blessed with natural resources from the hill valleys of Uganda to the deepest lakes and highest mountains in Tanzania; underneath the earth's crust lies a fortune God-given to East Africa. The biggest challenge has been to translate these blessings into a lucrative source of income for host communities and the East African region. Several factors can be attributed to the failure of this success in East Africa, from the conflict war-torn cobalt-rich DRC to the never-ending tribal wars of South Sudan and the ethnic rift between Burundi and Rwanda to the rampant corruption in Kenya and Tanzania.

These all have hindered the development of the extractive sector in East Africa. However, the ASM sector is a panacea for the impoverished host communities that do not have access to sophisticated technology and gigantic capital to extract the minerals. But through ASM though not perfect, a livelihood value chain with its ecosystem has been created to serve the single mother in Kivu, the young adult in Geita, and the impoverished people of Northern Uganda.

ASM has brought massive environmental, social, and political challenges to East Africa. However, the formalisation of ASM operations under regulatory frameworks can promote adopting sustainable mining practices. For instance, in Tanzania, the government has introduced regulations to promote sustainability, reduce toxic chemicals, provide training and equipment to miners, promote non-toxic processing techniques, and support the rehabilitation of degraded land. Furthermore, education and training centres can be created to improve human rights practices and increase environmental sustainability. The training would facilitate land restoration and rehabilitation laboratories that could harvest their findings and implement them in the ASM value chain. There is still hope for ASM and environmental sustainability to coexist, as ASM is the only avenue through which the host communities take part in the extractive industry. The development of the ASM sector should consider the context and cultural differences of these host communities to ensure its sustainability. Furthermore, excluding women and children while regulating toxic masculinity should be paramount in developing an adequate, friendly, and sustainable ASM sector in East Africa.

ASM mining site in Zambia

# BENEFITS OF USING GEOPHYSICAL EQUIPMENT IN NATIONAL GEOLOGICAL SURVEYS

*By Hassan Steven Mdala*

## Background

The National Geological Survey Departments play a major role in the mining sector in each and every country across the globe.

In these modern days, availability of geophysical equipment at national geological surveys is an important aspect towards achieving notable progress in the mineral sector.

Not only is the availability of geophysical equipment is important at national geological surveys, but also the availability of well-trained personnel, who is able to operate the geophysical equipment, acquire data, analyse the acquired data and interpret it in an effective way so that they are able to detect and locate different geophysical anomalies relate to mineralization for further investigation (Mariita, 2010).

### Mineral Exploration

The aspect of baseline data on mineral exploration mostly lies in the hands of the Geological Survey Departments (or Ministry of Mining) at national level in different countries. There are different methods of mineral exploration that Geological Survey Departments employ when doing mineral exploration survey; however, these methods can be summarised into three major ones, namely, (i) Geological Methods, (ii) Geophysical Methods and (iii) Geochemical Methods. In addition to these three major methods, Remote Sensing and GIS have also been used as major tools in mineral exploration surveys.

### The Mineral Sector

The mineral sector in different countries can be categorised into three, i.e., ASM, MSM and LSM.

## Geophysical Exploration Methods

Joshua et. al., (2017) defined geophysics as a science, which applies physical and mathematical methods to study the earth's subsurface by measuring the physical properties of different materials both on the earth's surface and subsurface.

The study of the physical properties of the earth's surface and subsurface includes mineral exploration, geotechnical investigations, etc. A number of geophysical methods have been used to study the physical properties of different materials/minerals/elements both on the surface and subsurface of the earth,
ref. Table 14. Amongst the geophysical methods, the most commonly used ones

include: (i) Magnetics, (ii) Gravity, (iii) Radiometric, (iv) Electromagnetic, (v) Resistivity, (vi) Seismic among others. In every geophysical survey that is meant for mineral exploration, knowledge of the local geology and its structural setting, previous mining activities (if any), and previous land use (if any) should always be taken into consideration when collecting the data and interpreting results of a survey for an area. It is from this background that it becomes necessary that anyone involved in the analysis and interpretation of geophysical data must at least have a background of geology (Mussett & Khan, 2000).

TABLE 14 | PHYSICAL PROPERTIES AND THEIR ASSOCIATED GEOPHYSICAL METHODS

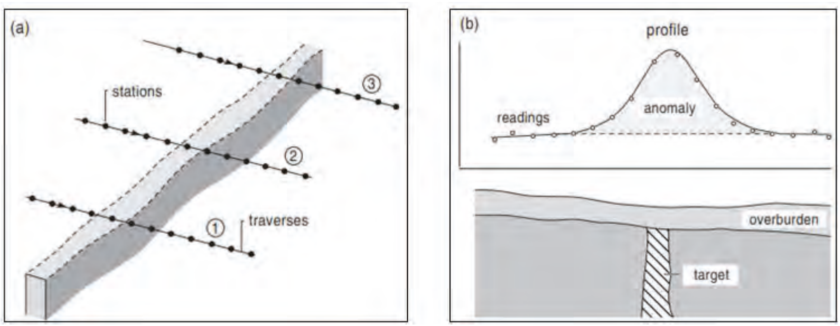
| *Physical Property* | *Field or Phenomenon* | *Geophysical Method* |
|---|---|---|
| *Density* | Gravity | Gravity |
| *Magnetic susceptibility* | Magnetism | Geomagnetic |
| *Electrical conductivity* | Electricity, low-frequency EM | Electrical, electromagnetic |
| *Dielectric permittivity* | High-frequency EM | Electromagnetic |
| *Elasticity* | Elastic waves | Seismic |
| *Radioactivity* | α, β, gamma rays | Radioactivity |

Source: Lucius et. al., 2006

**Geophysical Data Acquisition**

Geophysical data acquisition or data collection is a process of collecting geophysical data for specific study areas. In this process, geophysical measurements are done on the earth's surface using geophysical equipment where readings or recordings are taken continuously at regular intervals along a line/traverse, ref. Figure 77 (Mussett & Khan, 2000).

FIGURE 77 | GEOPHYSICAL DATA COLLECTION AND ANALYSIS




Source: Mussett & Khan, 2000; (a) data collection along traverses, (b) a plot of the collected readings showing a profile

**Magnetic Mineral Exploration Methods**

Magnetic survey can be carried out by either being airborne or ground based.

Magnetics is an essential geophysical method employed in locating subsurface magnetic materials for possible exploration. In geophysics, the anomalous magnetisation might be associated with local mineralisation that is potentially of commercial interest (Joshua et. al., 2017). It is not always that all anomalous magnetisations are associated with mineralization of commercial interest, some are of academic interest only.

Magnetic methods are mostly used to identify rocks and minerals that have iron properties in them (magnetic susceptibility); iron–titanium oxides are the dominant magnetic minerals in many rocks (Lowrie, 2007). The application of magnetic methods in mineral exploration measures variations in the magnetic field of rocks and minerals thereby defining their location in the subsurface. It has to be mentioned that what is mostly measured in these rocks and minerals is retained magnetism that has been acquired long time ago and this is called remanent magnetism (Mussett & Khan, 2000; Lowrie, 2007). It is measured normally using instruments called magnetometer, ref. Figure 78.

FIGURE 78 | MAGNETOMETER (CAESIUM G859)


Source: Malawi Geological Survey Department

**Gravity Mineral Exploration Methods**

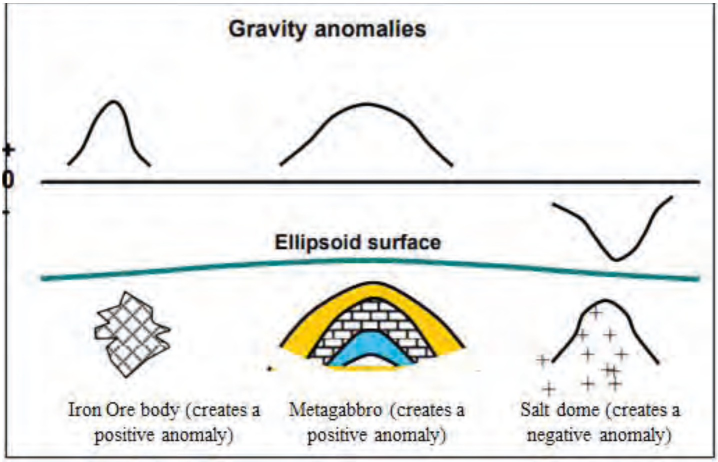
Gravity surveying methods mostly measures variations in the Earth's gravitational field caused by differences in the density of surface and subsurface rocks. It is these variations in the different subsurface rocks that produce gravity anomalies (Saibi, 2017).

Of all the three types of rocks, sedimentary rocks have the lowest density, and the highest dense rocks are the igneous rocks. In rocks that are magnetic, the density varies depending on their mineralogical composition, i.e. igneous rocks with high silica content are less dense than those with low silica content. On the other hand, the density of metamorphic rocks depends on acidity and grade of metamorphism, i.e. metamorphic rocks with high acidity are less dense than those with low acidity. Different rocks within the Earth's subsurface have different densities due to their differences in: (i) Grain density of minerals forming the rock mass; (ii) Rock porosity (pore space); and (iii) Fluid in the pore spaces.

Gravity methods are useful for finding buried bodies and structures that have associated lateral density variations (Mussett & Khan, 2000). These include ore bodies and intrusions, whose density differs from that of the surrounding rocks, basins in-filled with less dense rocks, faults if they offset rocks so that there are lateral density differences, and cavities. The density of exposed rocks is often less as compared to density of the same rock at depth because the exposed rocks are prone to denudation process thereby causing open cracks and because often it is not fully saturated with water (Mussett & Khan, 2000). It is therefore necessary to document all geological information surrounding every study area during gravity surveys.

In gravity surveys, the density contrasts between anomalous subsurface bodies/rocks and the surrounding medium causes a corresponding gravity anomaly (Alsadi & Baban, 2014). The corresponding anomalies vary in the sense that it can either be positive (if the subsurface body/rock is of high density) or negative (if the subsurface body/rock is of low density). This means that, relative changes in gravity values across a study area are directly related to variations in subsurface density of rocks, ref. Figure 79.

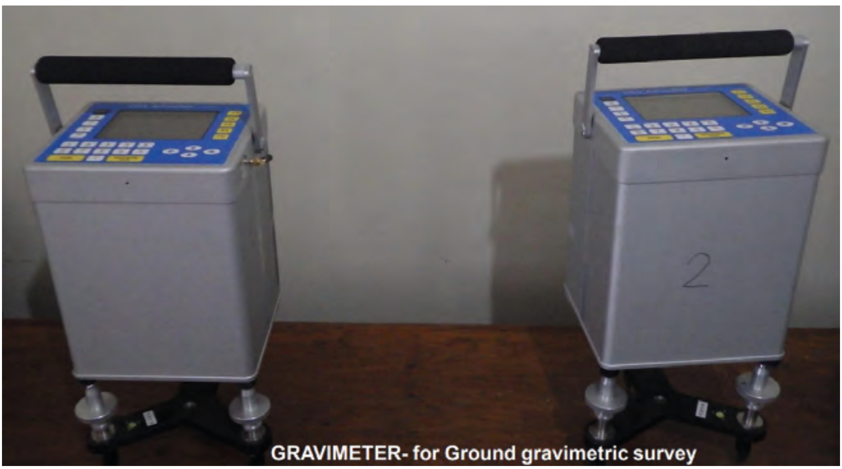
FIGURE 79 | GRAVITY ANOMALIES MODEL SHOWING EFFECTS OF DIFFERENT SUBSURFACE GEOLOGICAL BODIES/ROCKS




Source: Modified from Alsadi & Baban, 2014

Gravity surveys (either airborne or ground-based) are mostly carried out by using equipment called gravimeters, ref. Figure 80. It has to be noted that they are different types of gravimeters; however, they all serve the same purpose.

FIGURE 80 | SCINTREX CG-5 AUTOGRAV GRAVIMETERS

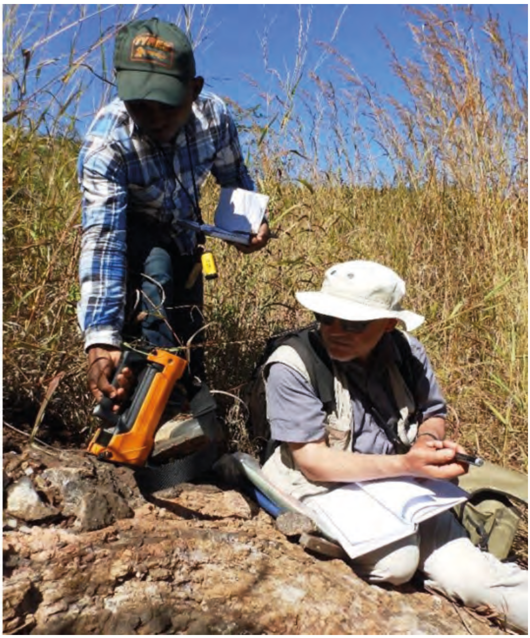



Source: Malawi Geological Survey Department

**Radiometric Mineral Exploration Methods**
Radiometric survey measures the natural radioactivity due to potassium, thorium, and uranium in the near-surface rocks (Mussett & Khan, 2000). Radioactivity is the spontaneous decay or disintegration of an unstable atomic nucleus usually accompanied by the emission of radiation. There are many radioactive elements in the Earth's crust; however, Uranium (U), Thorium (Th) and Potassium (K) are the most used elements in geological mapping and mineral exploration (Amadi et. al., 2012; Phillip et. al., (2002).

Radiometric methods are mainly applied in geological mapping because radiometric data (ternary image) has the potential to clearly define lithological contacts within an area (Amadi et. al., 2012). On the other hand, radiometric methods are also mostly used in mineral exploration, i.e. used to explore for ores of uranium and thorium or other types of ore that have associated radioactivity. The radioactivity of the elements, i.e. Uranium, Thorium and Potassium, is measured in concentration, either in parts per million (ppm), parts per billion (ppb) or percentages (%) by using a spectrometer, ref. Figure 81. Sometimes the spectrometer is coupled with a scintillation detector (Ademila et. al., 2018).

FIGURE 81 | A SPECTROMETER (RS 125) USED IN THE FIELD

Source: Malawi Geological Survey Department

There is a large number of radioactive minerals/elements on the Earth's surface and in the Earth's crust, but the most common ones, which are targeted in radiometric surveys, are Uranium, Thorium and Potassium. These elements and their possible sources/hosting rocks are outlined in Table 15.

TABLE 15 | RADIOACTIVE MINERALS, COMMON ELEMENT FOUND IN THEM AND POSSIBLE SOURCE ROCK

| | | |
|---|---|---|
| *Potassium* | | |
| Mineral | (i) | Orthoclase and microcline feldspars [$KAlSi_3O_8$] |
| | (ii) | Muscovite [$H_2KAl(SiO_4)_3$] |
| | (iii) | Alunite [$K_2Al_6(OH)_{12}SiO_4$] |
| | (iv) | Sylvite, carnallite [$KCl$, $MgCl_2 \cdot 6H_2O$] |
| Occurrence | (i) | Main constituents in acid igneous rocks and pegmatites |
| | (ii) | Main constituents in acid igneous rocks and pegmatites |
| | (iii) | Alteration in acid volcanics |
| | (iv) | Saline deposits in sediments |
| *Thorium* | | |
| Mineral | (i) | Monazite [$ThO_2$ + rare earth phosphate] |
| | (ii) | Thorianite [$(Th,U)O_2$] |
| | (iii) | Thorite, uranothorite [$ThSiO_4 + U$] |
| Occurrence | (i) | Granites, pegmatites, gneiss |
| | (ii), (iii) | Granites, pegmatites, placers |
| *Uranium* | | |
| Mineral | (i) | Uraninite [oxide of U, Pb, Ra + Th, rare earths] |
| | (ii) | Carnotite [$K_2O.2UO_3.V_2O_5.2H_2O$] |
| | (iii) | Gummite [uraninite alteration] |
| Occurrence | (i) | Granites, pegmatites and with vein deposits of Ag, Pb, Cu, etc. |
| | (ii) | Sandstones |
| | (iii) | Associated with uraninite |

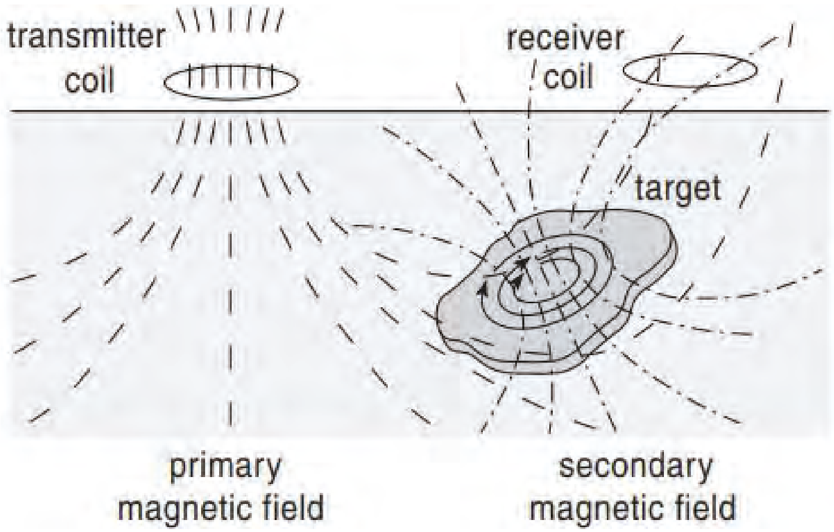
Source: Phillip et. al., 2002

### Electromagnetic Mineral Exploration Methods

Electromagnetic (EM) methods are similar to resistivity surveys because both respond to variations in the resistivity (or conductivity) of the subsurface materials. The only difference is that EM induces current flow in the subsurface without electrodes (Mussett & Khan, 2000). An EM geophysical survey method determines electrical properties (electric resistivity) of earth materials by inducing electromagnetic currents in the ground and measuring the secondary magnetic field produced by these currents (Brodie et al., 2015).

During EM surveys, a coil forms a transmitter to which a power supply delivers an alternating current into the ground thereby producing a magnetic field around it (called primary field). Alternating of the primary field produces a magnetic field. When the magnetic field is passing through a target, possibly an electrical conductor, it causes an alternating current to flow in the conductor thereby creating secondary field, which can be detected at the surface, ref. Figure 82 (Mussett & Khan, 2000). EM surveys are done by using electro-magnetometer, ref. Figure 83.

FIGURE 82 | PRINCIPAL OF THE ELECTROMAGNETIC METHOD




Source: Mussett & Khan, 2000

FIGURE 83 | DUALEM EM DURING A FIELD TRAINING

Source: Malawi Geological Survey Department

## Benefits of Using Geophysical Equipment at National Geological Surveys

Geophysical equipment and methods have been used in mineral exploration and geotechnical studies for a number of decades, since the 1900s (Lucius et. al., 2006); Alsadi & Baban, 2014). Over the years, their usage has proved to be beneficial in the sense that geophysical methods are typically non-destructive and most of the times environmentally friendly (Saibi, 2017).

Availability of geophysical equipment at national geological surveys enables the government department to acquire geophysical data (whether ground based or airborne) for the nation at different resolutions. This is one of the most important steps in generating and boosting the mineral sector information (geo-scientific information) for different clients (including ASM miners) that might have an interest in investing in the mineral sector in that country.

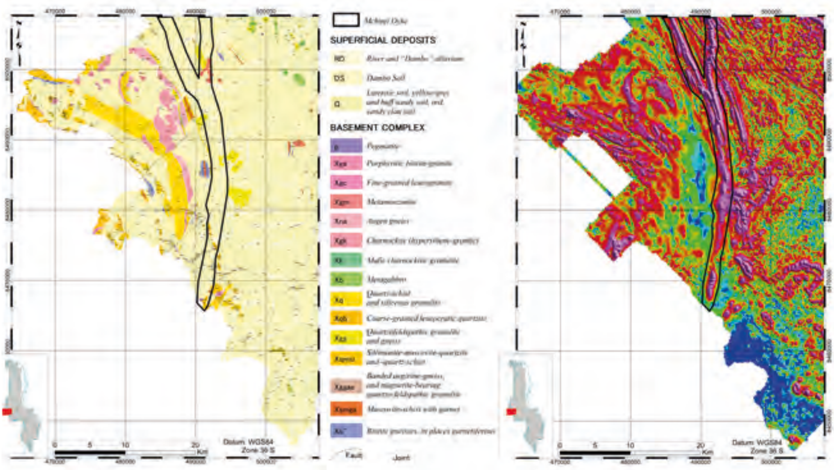
Most of the ASM miners in Africa have a low financial capability to hire geophysical equipment for mineral exploration activities. At the same time most ASM miners do not have the technical know-how on how to operate this equipment. For ASM miners, it becomes easy and cheap therefore to buy already acquired (existing) geophysical data at national geological surveys than hiring the equipment. It is therefore necessary and a must that national geological survey departments have or purchase geophysical equipment and acquire geophysical data as this will improve access to geophysical information by ASM miners and at the same time ease the burden of hiring geophysical equipment by ASM miners.

**Case Studies from Malawi, Australia, and India**

Geophysical equipment at national geological surveys and companies have been used in different countries over the decades in mineral exploration to reveal both surface and subsurface areas of mineralisation and in geological mapping exercises. In central western Malawi, aeromagnetic data has been used to locate and identify a dyke, called the Mchinji dyke, which was not previous observed on geological maps of the area.

Aeromagnetic data has the possibility of revealing subsurface bodies that can be sources of economic mineralisation. Analysis and interpretation of aeromagnetic data of the western side of Malawi border with Zambia has clearly revealed a dyke that could not be picked on geological map of the area, ref. Figure 84. Tilt derivative image of Mchinji area has clearly pronounced the north-south trending dyke, which could be a possible source of mineralisation.

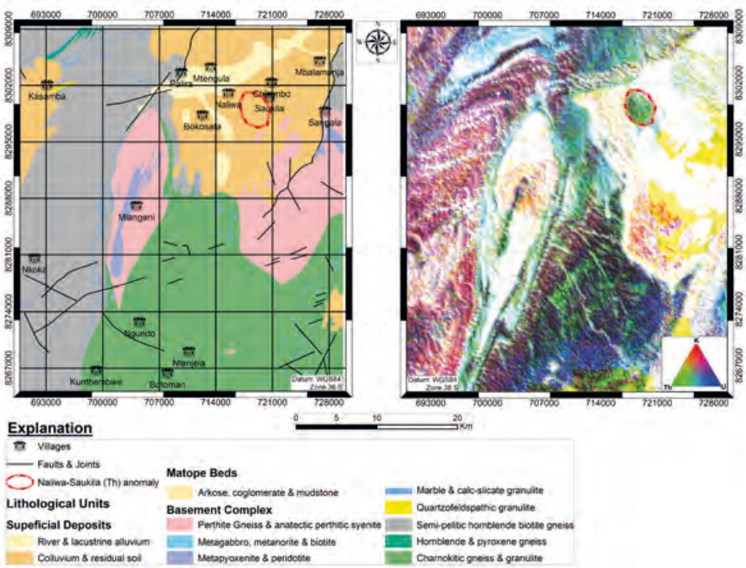
FIGURE 84 | THE MCHINJI DYKE OF CENTRAL WESTERN MALAWI




Source: Malawi Geological Survey Department; (Left) Geological map of Mchinji. (Right) Tilt Derivative map of Mchinji

In southern Malawi, aero-radiometric data has been used to locate and identify a clear thorium anomaly called the Naliwa-Saukila anomaly. The Naliwa-Saukila thorium anomaly has been able to be picked clearly on airborne radiometric data, ref. Figure 85. Geological information around Naliwa-Saukila area showed the area to be dominated by superficial deposits; however geophysical information has shown an anomaly of high thorium concentration within Naliwa-Saukila area that might possibly be related to possible mineralisation of Rare Earth Elements, e.g. monazite.

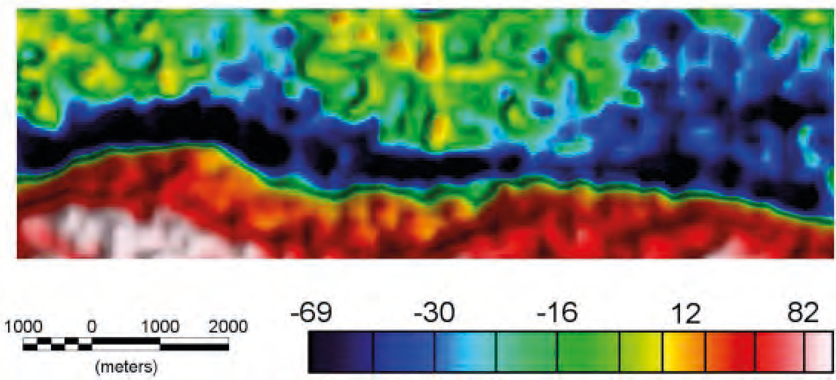
FIGURE 85 | THE NALIWA-SAUKILA THORIUM ANOMALY IN SOUTHERN REGION OF MALAWI




Source: Malawi Geological Survey Department; (Left) geological map of Naliwa-Saukila area and (Right) Radiometric map of Naliwa-Saukila area. Note the area in red dotted circle which shows a high thorium anomaly on the radiometric map.

In Gippsland Basin, Victoria, Australia, aero-gravity data has been used to locate and identify a clear coal seam in Latrobe Valley (Mahanta, 2003). The coal seam was mapped as a vertical gravity gradient low by Mahanta, ref. Figure 86. Mahanta showed that airborne gravity data can detect seams of greater than 10 m thickness and that detectability of coal seams is generally favoured by greater seam thickness.

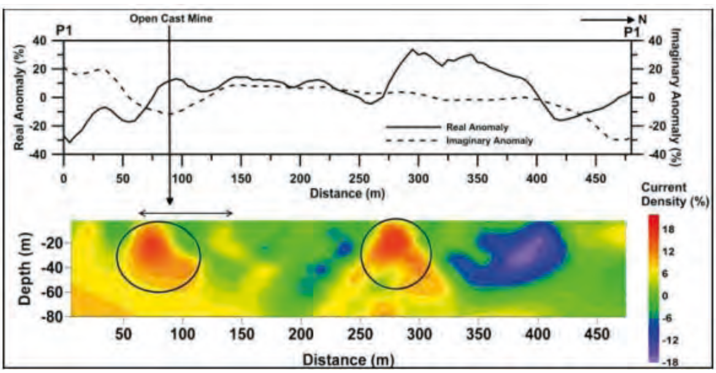
FIGURE 86 | MAPPING A COAL SEAM IN LATROBE VALLEY USING AIRBORNE GRAVITY GRADIOMETRY DATA




Source: Mahanta, 2003; The low density of the coal produces a gravity low.

In Daltangani Palamu District India, low frequency electromagnetic survey has been used to locate and identify graphite mineralized zones (Biswas and Sharma, 2015). Graphite is a non-metallic mineral with high conductivity; hence, it is easy to detect its mineralised areas (zones) by using an EM exploration method. An EM survey of an open cast mine site in Daltanganj, Palamu district has been able to locate possible graphite mineralised zones, ref. Figure 87.

FIGURE 87 | MAPPING GRAPHITE MINERALIZED ZONES AT DALTANGANJ PALAMU DISTRICT IN INDIA USING ELECTROMAGNETIC METHODS




Source: Biswas and Sharma, 2015; Note the anomalies at ~80 meters and ~275 meters which are possible graphite mineralized zones.

## Conclusion

Geophysical methods have proved to be very useful in geological mapping, mineral exploration, and geotechnical investigations over the past decades. Their application in geological mapping, mineral exploration and geotechnical investigations has shown that they are mostly non-destructive to the environment. The availability of geophysical information, equipment, and well-trained personnel in geophysics at national levels is one of the major steps in improving the mineral sector in a country in the sense that potential investors are readily provided with the much-needed geophysical services upon request.

Most of the ASM miners in Africa do not have a stable financial capability to purchase or hire geophysical equipment for their mineral exploration activities rather than accessing already existing geophysical information at national geological surveys. It is therefore necessary and a must that national geological survey departments have or purchase geophysical equipment and acquire geophysical data as this will improve access to geophysical information by the ASM miners.

ASM mining site in Zambia

# LARGE- AND SMALL-SCALE MINING – LESSONS LEARNED

*By Mattias Fackel. Consultant Geoscientist, Ethiopia*

This chapter does not primarily concern any of the more common topics discussed around artisanal and small-scale mining. It is not about safety, technology, nor the environment but is rather a summary of observations made from 24 years of often working in and around artisanal and ASM areas. These observations are from several African countries and straddle economic and social sciences while being observations made by a geoscientist.

Large and small-scale mining regularly take place side by side, but experience tells us that ASM does not transition to LSM. One does not become the other and there are few methods or technologies that can be directly transferred between them. These industries differ in scale and in almost all other aspects as well. They share the goal of turning minerals to income but what else? Can we understand ASM better when comparing the industries beyond the obvious. What can we learn about ASM when comparing it to LSM?

Some effort has been made by governments and organisations to support ASM and to improve the industry as a livelihood. Knowledge transfer, access to markets and to finance can be part of those efforts while the interaction between the two industries mostly involves removing conflict between them. This chapter will shed light on ASM by a examining some differences and similarities to LSM and it will also give a recent example from Ethiopia of the interaction between small- and large-scale scale mining.

## Introduction

Searching for and extracting rocks and minerals are the common goals for large-scale and small-scale miners. The aim for both is to extract value from minerals, minerals locked in rocks or found loose in the ground. The principles of separating valuable rocks (ore) from waste rock and of separating valuable minerals (ore minerals) from non-valuable minerals (gangue minerals) are also the same. The methods are not the same, but the principles are.

LSM extracts a larger range of minerals, while ASM generally searches for and extracts either high value minerals or low value industrial minerals. Examples of high value minerals are gold, cassiterite and columbite-Fe (containing gold, tin, and niobium respectively). Low value industrial minerals can be coal, silica sand, talc, or gravel. Complex methods of processing allow LSM to extract a larger variety of minerals and sometimes many different minerals from the same ore. LSM can also reach deeper, move larger tonnages of rock, and also extract ore minerals with a profit when the concentrations (the ore grades) are really small. LSM and ASM provides society with the materials to build and produce what we need or what we want.

ASM is an important economic opportunity to millions of people and can at the same time be a threat to society, to the environment, and to the individual. ASM can be almost uniquely poverty driven and ASM might conserve poverty. ASM can be a poverty trap. This is a fact in certain places and situations but can also be an argument or opinion not universally valid (Hilson and Hu, 2022). The insufficient income from farming, the small-scale farming poverty trap, can push people to other industries such as small-scale mining for income, for cash and to reduce poverty. The attraction of ASM can be many and the group of ASM practitioners is diverse (Hilson and Hu, 2022).

Research findings paint a diverse view of ASM mining:

“Poverty and a lack of education and training keep artisanal miners trapped in a cycle of rudimentary practices, which generate both environmental and health impacts. As the needs and motivations of artisanal miners are often ignored, previous attempts to deliver training projects have resulted in little sustained success” (Ruby Stocklin-Weinberg, 2019).

“The study provides evidence that participating in ASM is a viable economic livelihood option. However, its adverse effects on the natural, physical, human, and social livelihood assets in the mining communities are equally huge. The study recommends that effective policies on proper regulation of ASM activities should be put in place to offset the negative effects on the environment” (Baffour-Keyi et al. 2021).
“In one of Uganda’s poorest regions, Karamoja, artisanal gold mining provides 22,500 miners with an annual income that is significantly above the GNI. In the wider Kampala area, more than 90,000 informal clay miners and brick-makers produce about 8 billion bricks, generating a production value in the range of USD 500 million per year. If ASM would be included in the formal sector, Uganda’s GDP would increase by 5%” (PACT and ARM, 2018).

“An estimated 40.5 million people were directly engaged in ASM in 2017, up from 30 million in 2014, 13 million in 1999 and 6 million in 1993. That compares with only 7 million people working in industrial mining in 2013” (Intergovernmental Forum on Mining, 2017).

## Scale

The scale is maybe not the most important difference between the two economic activities, large- and small-scale mining, the names are somewhat misleading. Yes, LSM treats large tonnages of rock, have large machinery and LSMs have access to large finances. ASM is nevertheless in some ways a large-scale economic activity, ASM employs large numbers of people and take place over large areas. Some minerals such as gold and diamonds are to a significant extent produced by small-scale mining (Intergovernmental Forum on Mining, 2017).

An example of the scale of ASM is cobalt mining in the DRC, where ASM in 2018 is estimated to have produced 24% of the country's cobalt (IETI, 2023). That is not small-scale but involves a very large number of ASM practitioners. The ASM production of cobalt is estimated to have plunged to around 5% since then. The gold price has increased while the cobalt price plummeted with many ASM practitioners switching focus away from cobalt. At the same time government interventions and the closure of ASM sites further decreased ASM cobalt production (IETI, 2023).

FIGURE 88 | ARTISANAL MINING OF COPPER AND COBALT INSIDE A LARGE-LARGE OPEN PIT MINE (TENKE FUNGURUME, DRC)

Source: Mattias Fackel, 2017

## People, Decision-Making and Time

LSM is made up of people and their equipment, just like ASM. Both activities have economic goals and economic requirements. Major differences between the large-and small-scale industries beyond the obvious, such as the diversity of skills available, complexity of processes and ways of decision making, are the economic time horizon and extended project timeline and maybe above all the driving force.

LSM usually has several layers of decision making and of regulation, shareholders, board of directors, management team, professional and economic organisations, government regulators and international codes of conduct. ASM can be individuals or loosely organised groups with limited or no regulating environment. Decision-making in ASM is short-term and marginally influenced by regulation or other factors than current, pressing needs.

LSM has a fairly long period of initial investigation, due diligence and of financing. The period of economic returns and the "life of mine" tends to be long.

LSM extracts one or several minerals for a long period of time and in the same place. LSM cannot quickly change its location of operation, the investment and complexity of investment is too large.
ASM can and often must change focus from one mineral commodity to another depending on the conditions of the mining site (water ingress, stability, depth of operation) or because of rapidly changing mineral prices or quite often because of government intervention or security concerns in areas of conflict. The ASM practitioner often transitions between incomes and can sometimes quickly take up or leave ASM.

LSM is made up of and supported by many professional groups and a diversity of skills spanning all natural and social sciences.

The people working in ASM are often divided into two groups, the fortune seeker or opportunist, and secondly the vulnerable and poverty driven maybe living in or fleeing from conflict areas. The diversity of people in ASM obviously stretches far beyond that. ASM practitioners can be everything from entrepreneurs in remote locations to poverty driven and conflict-stricken child labour. It is important to be aware of the breadth of businesses and circumstances and to be very careful using the rather blunt and imprecise term ASM. The ASM operators not only have different backgrounds, skills and motivation but also accept change and acquire new knowledge differently. The individuals in an ASM area are not all the same and ASM camps can be organised around individuals, around groups of ASM practitioners or around a supplier or vendor of supplies and product. In the larger group of ASM practitioners not all are similarly attracted to external efforts of support. It can be useful to introduce a few more albeit still generalised ASM archetypes:

a) **The opportunist and the fortune seeker** - these might be few and are not necessarily driven by poverty but rather of opportunity. Quick to jump on the next venture but maybe not skilled;

b) **The expert** – the skilled and specialised ASM practitioner with experience from both successful and other ASM. This person often organises his/her own ASM groups and businesses;

c) **The local** – resident of an area where ASM coexists and is a part of other industries such as small-scale farming. Maybe where ASM is governed by traditional leaders and where ASM is seasonal as a complement to other economic activities. The local or traditional ASM practitioner can transition between industries and have some access to land other than an ASM site;

d) **The underprivileged** – refugees, very poor, indebted. These individuals share poverty and vulnerability as a starting point. They can be in very large numbers and seldom select area or technique other than by what is available. They will quickly become indebted to others in or outside the ASM community and will remain in the ASM poverty trap until forced elsewhere or moving to an area with other opportunities; and

e) **The labourer** - the individual coming to ASM for a long or short term to make an income and possibly as a complement to farming. These can be many in an area and can move in and out of an area and can transition between economic activities.

There are certainly more ways to understand the large group of ASM practitioners, by gender, by age by economic status or other. The above observations will however be complementary when efforts are made to communicate and interact with a an individual or group of ASM practitioners.

How do ASM practitioners transition between these groups and how do these groups cooperate or hamper other groups effort? Assuming the ASM practitioners as a homogenous group is not helpful to understand the dynamics of an ASM site. The poverty driven, the refugee, the indebted will not reply to or be interested in the same as the opportunist or the budding ASM expert. The poverty driven, under-privileged ASM practitioner can make up a large group and should not primarily be considered a professional group. The ASM practitioner in the poverty trap is unlikely to respond to efforts of a technical character. The individuals in this group will, if possible, transition between different informal sectors, farming, trading, domestic or other, depending on opportunities.

## ASGM in the Akobo area, Ethiopia

Artisanal and Small-Scale Gold Mining (ASGM) is growing in the Akobo area of Ethiopia. The area in and around the Dima Woreda (District) of Southern Gambela Region borders the southwest Ethiopia Peoples' Region in SW Ethiopia and is a few kilometres from the border to South Sudan. Conflicts in the region are many and at different levels from local to cross border conflicts. The Nuer-Murle conflict in South Sudan and SW Ethiopia is one of the conflicts and raiding of cattle and gold camps is often attributed to this or similar conflicts. The porous border and very weak government presence coupled with poverty and the industry of ASM gold aggravates ethnic conflicts and criminality in the area.

The four most visible types of ASGM operations in the Akobo area are firstly individuals or groups of panners along creeks or where water is sufficient to pan loose materials from other operations.

FIGURE 89 | GOLD PANNING, AKOBO AREA, GAMBELA REGION, ETHIOPIA

Source: Mattias Fackel, 2023

Secondly, manual underground mining by shafts and tunnels form small camps and sometimes merge to shallow open pits. These sites have crushing, milling, and panning on site or transport untreated or partially worked ores to informal processing plants.

FIGURE 90 | HOIST AT MINE SHAFT, UNDERGROUND ARTISANAL GOLD MINING, AKOBO AREA, GAMBELA REGION, ETHIOPIA

Source: Mattias Fackel, 2023

Thirdly, MSM operators using excavators and sluice plants operate by the larger rivers. These operations excavate larger amounts of materials along the rivers. These sites are distinct from the previous two activities and involve significant investment, destruction of riverine lands and displacement of people. The MSM is either attributed to foreign operators or to non-local operators with strong financial backing from other Ethiopian regions.

FIGURE 91 | INFORMAL MEDIUM-SCALE GOLD MINING OF ALLUVIAL SEDIMENTS ALONG MAJOR RIVER, AKOBO AREA, GAMBELA REGION, ETHIOPIA

Source: Mattias Fackel, 2023

Lastly, are the centralised processing plants where motorised crushing and milling takes place. These toll treatment plants also require substantial investment as compared to the panning and tunnelling sites. These plants receive ores from multiple sources and seem marginally regulated if at all.

FIGURE 92 | MILLING OF GOLD ORE, INFORMAL PROCESSING PLANT, AKOBO AREA, GAMBELA REGION, ETHIOPIA

Source: Mattias Fackel, 2023

Some of the underground operations are manned by only hoist operator and digger, while others have more people for crushing and panning. It seems the organisation and cooperation of sites are dynamic and complex. The gold production is not entirely documented or permitted, and government presence is generally low.

Supporting panners and underground miners are transporters of equipment and ores most often using light motorcycles and sometimes heavier vehicles. As common at many ASM sites, the largest industry appears to be support services in trading, suppies, lodging, restaurants, and entertainment.

There are several rapidly growing settlements in the Akobo area almost entirely made up by ASM practitioners, their families and support industries. The population of mine villages in the area is by the company Etno Mining estimated to comprise 20,000 to 30,000 people. The company states that the area was thinly operated by 2007 and that the recent influx of people is from entire Ethiopia (Jackson, 2021).

## LSM at Segele Mine, Akobo area, Ethiopia

ASGM in the Akobo area has taken place before gold exploration commenced in the area. The Akobo area was in 2003 listed as an area with minor gold occurrences and some ASM (Solomon Tadesse, 2003). An increased ASM activity can have taken place when access and security in the area improved with the arrival of mineral exploration. There is mineral exploration reported as far back as the 1930s (Tariku, 2021).

The areas' only major mining company, Etno Mining (Akobo Minerals), reports an increase in ASM with the arrival of recent mineral exploration (Jackson, 2021). Etno Mining employs approximately 200 people and are underway to establish a small underground mine by two winzes and one decline. The Etno Mining Segele Mine is by international standards a very small large-scale mine but is a significantly larger and more complex operation than surrounding ASGM also including lightly mechanised mining of alluvial deposits along the larger rivers. The company has established scoping studies and resource estimations and environmental and social studies. The environmental and social studies investigate and plan for how to mitigate impacts on societies and the environment. The company initiatives also plan for how the company will relate to, compensate and interact with ASGM operators (Akobo Minerals, 2022).

FIGURE 93 | EARLY STAGES OF ESTABLISHING THE SEGELE MINE (ETNO MINING).) MINE DEVELOPMENT WITH UNDERGROUND ACCESS, LEACH TANKS AND GRINDING CIRCUIT, SEGELE MINE. AKOBO AREA, GAMBELA REGION, ETHIOPIA

Source: Akobo Minerals

The past and current interaction between ASGM operators and the mining company is largely three-fold. The company's exploration activities, trenches, mapping, and drilling is used by ASGM operators to find and access areas of gold mineralisation. The people in the area also find employment in mineral exploration and with the establishment of the mine. The mine brings the possibility of an alternative income.

The mining company is actively using the results and extension of ASGM as a tool to better delineate gold mineralisation within the existing exploration and mining permits.

The company is establishing a sustainable natural resource management plan (SNRMP) to amongst other things guide the relationship to communities and the environment. The company's understanding and involvement of communities and the social structure was already well-developed before mining started.

Etno Mining are currently not buying ASM gold ores to ensure compliance with regulations and to guarantee buyers of a product that the Segele Mine is the sole source of the company's gold. Although not current practice nor expressed by studies or reports the possibility exists that a smaller mining company, such as Etno Mining, could receive ores from ASGM and be an alternative processing centre and an alternative to informal and unregistered processing plants.

LSM and ASM often exist in the same geographical and geological area. The interfaces and interchanges are seldom mutually beneficial, at least not in an extensive way.

So far, the Akobo area is already plagued by conflicts and poverty, but the tension between mining company and ASGM seems minimal. There are so far mutual benefits, and the company communicates a strong focus on supporting and engaging with the local communities.

It is common that LSM arrives to a region with mineral exploration in areas where ASM is or has been active. Mineral explorers and LSM companies will be attracted to an area with strong indications for mineralisation by both geological indicators and by pre-existing ASM. The benefit is in this case largely the LSM using ASM as an indicator for mineralisation. There are, but rarely, LSM operators buying product from ASM to treat in their own concentrators.

It is also common that ASM moves into areas where LSM has commenced or where LSM permits are granted over pre-existing ASM. In these areas the LSM often works open pits and underground mines indirectly making ores available to ASM. The ASM can happen in closed LSM mines or where LSM is still on-going. The ASM benefits but commonly with noticeable conflict between LSM operators and ASM.

The Segele Mine has so far at the early stages of mine development made use of ASM sites for exploration while the future mine is providing alternative livelihoods and is improving a dire security situation. There is at this stage mutual benefit. The expansion of LSM will provide further alternative incomes in the area and with time maybe also purchase ASM production. Time will tell.

## Lessons

It can help the professional working to support ASM to be aware of a few important differences between the two industries, apart from the obvious such as scale and the level of regulation. The economic horizon, diversity of skills and the transition to other industries can be important aspects to keep in mind. LSM develops over many years while ASM can be simply poverty driven and with a time frame of weeks or months. ASM can be a sole and important income and an only alternative for the vulnerable. Transfer of skills and knowledge to ASM operators is very difficult when mouths must be fed, and decisions are made with a very short perspective.

Making available more diversity of skills to the ASM area can be important. To station professionals close to ASM areas can help facilitate the transition between ASM and other industries. The presence of professionals, government, or company employees can make skills available to support ASM operations and can allow ASM to develop beyond a short-term activity.

If the timeline and economic horizon of ASM operations can be extended beyond months or a dry season, then opportunities can more easily be benefited from. Any support must not only transfer skills or provide finance but also extend the economic horizon of the ASM operations. If the urgent situation can be mitigated by alternative incomes other long term support efforts can follow.
How can the transition between industries be made easier and how can one category of ASM operators transition to another? Is there a way to make the labourer and expert ASM practitioners more dominant in an ASM area? These groups of ASM practitioners might more easily adopt new practices and accept higher levels of organisation and regulation. The poverty driven and vulnerable portion of the ASM workforce must of course become smaller either by transition to other incomes or by upgrading into a more skilled part of the ASM hierarchy.

It should be important to extend the economic horizon and timeline of ASM operations with supporting economic activities so that the migration of labour can take place between ASM and other industries such as agriculture and LSM.

Large-scale mining can be an alternative income in an ASM area. LSM can extend the economic horizon for people in an area and there can be mutual benefit from exploration to mining. Many places suffer from mostly conflict between LSM and ASM, but this can maybe be averted if companies commence operations with a very good understanding of a society, including the ASM industry. Achieving this where government presence is very small might make this more difficult but there is at least one example where there is some promise.

Both possibilities and difficulties appear when many people are attracted to and ASM area in search for an income. These areas can be characterised by poverty, by lack of regulation and absence of government support. There lies at the same time an opportunity in reaching many people with the efforts of support and development.

Decision-making and regulation of LSM is complex and multi-layered. Decision-making and regulation in ASM is very different. Decision-making and regulation should be supported by a government representative or professional present in an ASM area. Presence is key and the professional could be a geologist, social- or environmental scientist, an agriculture extension officer, a medical doctor, or a teacher. Most importantly presence by and support from resources other than the ASM practitioner is essential. This can change timelines, introduce alternative incomes, and support regulation and decision making for the betterment of the ASM sector.

ASM training in Zambia

# SYNOPSIS FOR GROUP WORK

*By Enatfenta Melaku Gebre, African Deputy Co-lead*

## Introduction

ASM activities are prevalent in several African countries. The minerals operated by ASM operators include gold, tantalum, iron ore, gemstone (emerald, sapphire, opal, citrine, obsidian, agate, morganite, garnet, ruby, jade, tanzanite, quartz, jasper, aquamarine, serpentine, malachite, tiger eye, peridot, etc.), industrial minerals (kaolin, dolomite, diatomite, silica sand, talc, clay, bentonite, mica, tin, tantalum, lithium ore, etc.), dimension stones (marble, granite, basalt, limestone, etc.), and quarry materials (selected materials, gravel, sand, basalt, ignimbrite, rhyolite, etc.).

Despite experiencing its share of environmental and health related problems, which adversely impact the quality of human life, the potential of the ASM sector to significantly contribute to social-economic development and alleviate poverty in these African  is substantial.

The workshop on ASM, under the scope of the PanAfGeo-2 Project, held in Dar es Salaam, Tanzania, on 13-16 November 2023 comprised trainees from 17 countries of the Northern and Eastern African region, six co-trainers and four guests in total.

The trainees were split into four groups to discuss two topics each related to ASM in the aforementioned region, namely:

1) Challenges in establishing and developing an ASM operation;
2) Challenges for women and children in ASM operations;
3) Challenges in formalising ASM operations;
4) Conflict minerals and any challenges with armed actors profiting from ASM supply chains;
5) Geophysical methods used by the respective national geological survey and the benefits of using geophysical methods in the work carried out;
6) Challenges for a geological survey to be involved in the national groundwater mapping;
7) Environmental challenges related to ASM;
8) Opportunities for ASM and LSM to co-exist and the challenges;

Each group was mentored by a co-trainer and had selected a moderator and a secretary.

Upon completion of the group discussions, each group had to present its findings at a plenary session moderated by Dr. John Tychsen thereby allowing everyone to share views and practices from their respective country.

## Group A

Group A represented nine African countries (Kenya, Zambia, Sudan, South Sudan, Somaliland, Tanzania, Rwanda, Libya and Eritrea) and one world resource forum expert.

FIGURE 94 | GROUP A

Source: Enatfenta Melaku

### Challenges in Establishing and Developing an ASM Operation

Group A identified the following challenges in establishing and developing an ASM operation:

- Transforming the informal ASM sector to a legal and formalised industrial sector;
- Limited training available for ASM operators;
- Lack of capacity building programs for staff at the national geological survey;
- Limited access to mining equipment for ASM operators;

- Low technology application;
- Limited information on the availability of mineral resources to ASM operators;
- Lack of geoscience skills and knowledge by ASM operators;
- High level of participation by uneducated people;
- Lack of trust between the ASM operators and the government officials;
- No laws to address or recognise ASM operators;
- Limited or no access to credit finance for ASM operators;
- Political instability; and
- Low or no value additions.

Given the above wide range of challenges identified, Group A concluded that without government intervention and support for the international mining community it will prove difficult to overcome the stated challenges and to further develop and improve the ASM sector overall.

An ASM development package should include access to finance, training and capacity building in geosciences, environmental rehabilitation and proper mining tools and equipment.

Challenges for Women and Children in ASM Operations
A substantial number of women work in the ASM sector. Women are involved in direct mineral production activities and in mining settlement-related activities. Although taboos and socio-cultural factors, financial and economic capacity, and technological and organisational aspects often curtail their entry into direct production, their numbers have been increasing in many countries. The growth of women's participation is often a necessity rather than choice, due to their lack of alternatives. The increase in retrenchments from public employment as a result of structural adjustment programs, low commodity prices, prolonged droughts, and other factors can be linked to this growth.

Group A identified the following challenges for women and children in ASM operations:

- Lack of organisation/association;
- Cultural/traditional barriers, e.g. customary laws ban women from owning mines and or operating a mine. There are also myths and taboos associated with women in mining;
- Unavailability of a national gender strategy and gender mainstreaming policy, which should be addressed in ASM regulations;
- There are several health, safety and environmental issues, which directly and indirectly impact women and children, e.g. use of mercury for amalgamation of gold, exposure to dust and noise during mining and crushing of gold;

- Undeveloped and reinforced shafts are at risk of collapse and physical accidents;
- No proper sanitary facilities for women in mining in ASM areas;
- Women tend to be vulnerable to lending institutions because they lack trust on women working independently;
- Women in some communities are seen as the property of men, forced to work and return earnings to their spouses;
- Women tend to risk sexual harassment in exchange for minerals;
- Exposure to prostitution, divorces and spread of sexually transmitted diseases;
- Alcoholism and drug substance abuse; and
- Children easily participate in artisanal mining to earn money instead of going to school.

Given the above listed challenges for women and children in mining, Group A suggested that gender sensitisation on existing regulatory mining frameworks should be undertaken to better cater for women and to protect children. Better and more awareness campaigns on the adverse effects of exposure to hazardous chemicals, use of proper PPE and equipment, and general health and safety measures should be implemented by national authorities and mining interest groups, such as the national geological surveys.

## Group B

Group B represented seven African countries (Zambia, South Sudan, Eretria, Somaliland, Tanzania, Libya, and Rwanda) and one world resource forum expert.

FIGURE 95 | GROUP B

Source: Enatfenta Melaku


**Challenges in Formalising ASM Operations**

Group B discussed the challenges in formalising ASM operations for each country represented in the group.

- **Zambia**: ASM operators do not clearly know the difference between a legal and an illegal mining operation. There is also a cultural and traditional practice of undertaking individual mining without a permit. License fees are also too high, and miners prefer not to pay royalties and taxes on revenue. The bureaucratic process to formalise an ASM operation is also a challenge. Furthermore, if formalised it is more difficult for ASM operators to move around, i.e. from mining site to mining site;
- **Rwanda**: There is no partnership or collaboration between LSM and ASM, which makes it difficult to formalise ASM, since the latter lacks skilled man-power and access to finance;
- **Libya**: The primary focus in Libya is on the oil and gas sector; hence, little if no focus on ASM and the formalisation of this sector;

- **Somaliland**: Overall, the country lacks knowledge, skills and finances to formalise and organise the ASM sector. The country also struggles with internal conflicts and an influx of foreign illegal miners;
- **South Sudan**: The country lacks a geological database and proper law enforcement. There is also a cultural miss conception and conflict between LSMs and ASMs, which hinder formalisation of the ASM sector; and
- **Tanzania**: The country lacks geological information and market data. There are also problems with land rights and access to finance, but steps to provide funds for ASM operations have been taken lately.

### Conflict minerals and Challenges with Armed Actors Profiting from ASM Supply Chains

Group B found conflict minerals present in South Sudan and Rwanda, but identified no issues or challenges with armed actors profiting from ASM supply chains, except for a few smuggles in Somaliland, ref. Table 16.

TABLE 16 | PRESENCE OR ABSENCE OF CONFLICT MINERALS AND ARMED ACTORS

| Country Name | Conflict Mineral | Armed Actors |
|---|---|---|
| Zambia | No | No |
| South Sudan | Yes | No |
| Eritrea | No | No |
| Somaliland | No | No, but Smugglers |
| Tanzania | No | No |
| Rwanda | Yes | No |
| Libya | No | No |

Source: Group B

## Group C

Group C represented six African countries (Egypt, Ethiopia, Uganda, Malawi, Tanzania, and Guinea- Bissau).

FIGURE 96 | GROUP C

Source: Enatfenta Melaku

### Geophysical Methods Used by National Geological Survey and their Benefits

Group C identified and discussed the benefits of each geophysical method employed by national geological surveys, ref. Table 17.

TABLE 17 | GEOPHYSICAL METHODS AND THEIR BENEFITS OF USE

| Geophysical Methods | Benefit |
|---|---|
| Magnetic | ▪ identifies all bodies with magnetic properties;<br>▪ Shows geological structure, e.g. fold, void, fault and other from the subsurface; and<br>▪ Helps delineate the zone of mineralization along the orientation of a geological structure. |
| IP | ▪ Identifies a zone of conductivity, such as sulphide, water, salt etc. |
| Gravity | ▪ Detects high density contrast, such as void, fault and caves. |
| Radiometric | ▪ Identifies bodies with radioactive behaviour; and<br>▪ Identifies lithological contrast in geological mapping used for EIAs. |
| Resistivity | ▪ Identifies the locations of groundwater and mineral deposits, determine targets for new drilling programs and select suitable locations for tailings dams. |
| Seismic | ▪ Provides high-resolution images of geologic structures hosting mineral deposits and, in a few cases, can be used for direct targeting of mineral deposits. |

Source: Group C

Ethiopia, Egypt, and Tanzania are using geophysical instruments for mineral exploration and mapping, but list the following challenges in their use:

- Lack of internal knowledge and skills to maintain equipment, i.e. if an equipment shows an error or fails it has to be shipped back to the manufacturer and is thus out of commission for quite some time; and
- Lack of internal knowledge and expertise to use equipment, obtain and interpret data acquired.

**Challenges for a Geological Survey Involved in National Groundwater Mapping**
Group C discussed the challenges for geological surveys involved in groundwater mapping for each country represented in the group.

- **Tanzania**: The issue of groundwater is managed by the Ministry of Water; hence, the national geological survey is not much involved in the mapping and exploration of groundwater;
- **Ethiopia**: Until 2021, groundwater mapping was carried out by national geological survey, but since then all groundwater mapping is undertaken by the Ministry of Water;
- **Uganda**: The Ministry of Water and Environment conducts ground water surveys and acquires geological data from the national geological survey if and when needed;
- **Seychelles**: In some cases Petro-Seychelles, the public utilities corporation, is consulted to provide maps on groundwater and other information needed by the Ministry of Water. In the absence of geological survey mapping some islands are over-pumping their aquifer and causing saltwater incursion;
- **Malawi**: Groundwater mapping falls under the Ministry of Water; hence no involvement by the national geological survey. However, there is need for better linkages and sharing of information between the departments so that issues of ground water are better addressed; and
- **Egypt**: Remote sensing is being used thoroughly in ground water mapping by the Ministry of Water Resources and Irrigation. The national geological survey is not involved in groundwater mapping as it is mainly concerned with mining related studies.

Group C suggested that ground water/hydrogeological mapping should be done in coordination with the national geological surveys because the geological mapping expertise lies within the national geological surveys. Furthermore, data should be shared between relevant stakeholders.

## Group D

Group D represented nine African countries (Malawi, Tanzania, Egypt, Mauritius, Guinea Bissau, Ethiopia, Seychelles, Kenya, and Uganda).

FIGURE 97 | GROUP D

Source: Enatfenta Melaku

### Environmental Challenges Related to ASM

Group D identified the following main environmental challenges related to ASM:

- Deforestation;
- Loss of habitat due to deforestation;
- Water pollution due to the use of mercury and cyanide in mining operations;
- Soil pollution due to the use of mercury in mining operations;
- Air pollution in connection with blasting and mercury amalgamation;
- Breeding of mosquitos in the abandoned well-logs;
- Change in landscapes;
- Soil erosion; and
- Siltation or sedimentation due to soil erosion.

Group D underlined that provision of environmental awareness through various platforms is necessary, e.g. information campaigns (leaflets), training sessions, information and training in alternative mining technologies, environmental control mechanisms, law enforcement, and formalisation of the ASM sector.

However, enacting regulations for improving health and safety standards and environmental management without improving access to technology, finance, information, and support services might have little long-lasting impact.

**Opportunities and Challenges for ASM and LSM to Co-exist**

Group D also discussed the opportunities and challenges for ASM and LSM to co-exist.

Group D agreed that both ASM and LSM are equally important for the socio-economic development of a country with mineral resources.

ASMs enable job creation and help alleviate poverty in rural areas, whereas LSMs offer transparency and accountability of mining operations.

LSMs, given easier access to finance and capacity building, can offer skills and knowledge transfers to surrounding ASMs on mining technology, and health, safety, and environmental issues. LSMs can also offer apprenticeships and other social community benefits to ASMs. LSMs, given their size and output, can offer a better and more organise platform for ASMs to market and sell their mineral products.

The challenges and conflicts occur when ASMs and LSMs mine for the same minerals.


Shop in ASM village in Zambia

Children in ASM village in Zambia

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