



AfricaMaVal

Coordination and Support Action (CSA)

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Health and Digital Executive Agency (HADEA). Neither the European Union nor the granting authority can be held responsible for them.

Start date : 2022-06-01 Duration : 42 Months



Pan-African inventory of existing ore processing and refining capacities

Authors : Mrs. Carla FORTES (LNEG)

AfricaMaVal - Contract Number: 101057832

Project officer: Victoria Leroy

Document title	Pan-African inventory of existing ore processing and refining capacities
Author(s)	Mrs. Carla FORTES
Number of pages	19
Document type	Deliverable
Work Package	WP1
Document number	D1.3
Issued by	LNEG
Date of completion	2023-09-25 22:22:13
Dissemination level	Public

Summary

The inventory of industrial mineral processing units operating in Africa, stored in conveniently structured datasets and, if possible, with economic information on the involved markets, will be designed to be an instrument to assess the extension of the value chain of each type of ore, installed on the African continent. Where the information is available, each mineral processing unit will be characterized in detail, taking into consideration the adopted technological solutions and its potential for flexibility concerning the processing of different ores of a certain type. Depending on the geographic proximity and regional metallogeny, the possibilities of using existing industrial units to carry out preliminary pilot tests, enabling the development of new processing projects, will be evaluated.

Approval

Date	By
2023-09-25 22:24:55	Dr. Daniel OLIVEIRA (LNEG)
2023-09-25 22:56:57	Mr. Jean-Claude GUILLANEAU (BRGM)



Horizon Europe Framework Programme (HORIZON)

D1.3 – Pan-African inventory of existing ore processing and refining capacities

WP1 - Task 1.3

Sept. 2023

Daniel de Oliveira¹, Carla Fortes¹, Pedro Patinha¹, Maité Le Gleuher², Herman Cornelissen³, Nikolaos Christou³, Jürgen Vasters⁴, Philip Schütte⁴

¹Laboratório Nacional de Energia e Geologia (I.P.), LNEG

²Bureau de Recherches Géologiques et Minières, BRGM

³DMT GROUP: Engineering & Consulting Services

⁴Bundesanstalt für Geowissenschaften und Rohstoffe, BGR



Funded by
the European Union

Disclaimer

The content of this deliverable reflects only the author's view. The European Commission is not responsible for any use that may be made of the information it contains.



Document information

Grant Agreement / Proposal ID	101057832
Project Title	EU- Africa Partnership on Raw Material Value chains
Project Acronym	AfricaMaVal
Project Coordinator	Guillaneau, Jean-Claude (jc.guillaneau@brgm.fr) - BRGM
Project starting date (duration)	1st June 2022 (42 months)
Related Work Package	WP1
Related Task(s)	Task 1.3
Lead Organisation	Laboratório Nacional de Energia e Geologia (I.P.)
Contributing Partner(s)	BRGM, DMT, BGR
Due Date	September 2023
Submission Date	July 2023
Dissemination level	Public

History

Date	Version	Submitted by	Reviewed by	Comments
17/07/2023	Draft	LNEG	Jürgen Vasters - BGR	Comprehensive data collection with high degree of relevance and quality
07/08/2023			Carol ZAMMIT	Data collection had been done but a synthetic table is requested. Analysis and perspectives are missing.
21/09/2023		LNEG		Reviewed
25/09/2023		LGI	Mathilde Videlo	Table of contents to be updated



Table of Contents

1	Introduction statement for WP1	7
1.1	The concept of ECRM	7
1.2	Objectives of Task 1.3 of WP1	8
2	Source of data used	8
2.1	Type of data	8
3	Data confidentiality	9
3.1	Data management and visualization	10
3.2	Analysis of results	10
4	Overview of the final database	15
4.1	Database view	15
	Conclusions	17
	Bibliography	18

List of Figures

Figure 1.	Percentage of processing facilities by country	11
Figure 2.	Total number of main types of processing facilities	12
Figure 3.	Percentage of ECRM processed in African processing facilities	12
Figure 4.	Overview of AfricaMaVal GIS geodatabase showing the Processing Facilities distribution	16

List of Tables

Table 1.	The complete attributes reference table for AfricaMaVal - Processing Facilities database	9
Table 2.	Processing facility: Plant data	13
Table 3.	Processing facility: Smelter data	14
Table 4.	Processing facility: Refinery data	14
Table 5.	Processing facility: Concentrator data	15



Abbreviations and Acronyms

Acronym	Description
CRM	Critical Raw Materials
ECRM	Extended Critical Raw Materials
WP	Work Package
USGS	United States Geological Survey
WMS	Web Map Service
WFS	Web Feature Service
GDS	Geographic Data Services



Executive Summary

Work Package (WP) 1 is designed to show the current African Critical and Strategic Raw Materials (CSRMs), the available sites for mining and mineral processing and placing this information in the hands of the European political and industrial decision makers to focus on diversifying EU supply chains. The WP deals on an Africa-wide scale while also addressing the regional and local levels via its identification of possible and existing mineral and mining clusters (Task 1.1), ore processing and refining capacities (this task; Task 1.3), as well as artisanal and small-scale mining and processing developments (Task 1.4).

This report aims to provide an AfricaMaVal GIS geodatabase showing the Processing Facilities distribution in Africa. The data is divided into plants, smelters, refineries, and concentrators.

The final geodatabase is released as a WMS (Fig. 4) containing the attributes deemed necessary for the information being delivered (Table 1).

The distribution of the various processing facilities in Africa are mostly concentrated within the mining and mineral producing countries (e.g., South Africa, DRC, Zambia, Morocco and Zimbabwe; Fig. 1).

Keywords

AfricaMaVal geodatabase, Extended Critical Raw Materials, mineral processing facilities, mineral refining facilities, WMS.



1 Introduction statement for WP1

This work package is designed to unravel the current knowledge about African ECRM, the available sites for mining and mineral processing and placing this information in the hands of the European political and industrial decision makers. This will contribute to several anticipated project outcomes, with a focus on diversifying EU supply chains while also outlining possible sustainability. The WP deals on an Africa-wide scale while also addressing the regional and local levels via its identification of possible and existing mineral and mining clusters, ore processing and refining capacities, as well as artisanal and small-scale mining and processing developments.

WP1 is divided into four tasks, namely:

- Task 1.1 - provides the base for the subsequent work in this WP, constructing a database of existing known CSRM deposits in Africa - Completed.
- Task 1.2 - acknowledges the heterogeneity of some of the datasets and will perform a predictive assessment to reveal hidden trends – Task underway.
- Task 1.3 - will perform an analysis of the existing ore processing and refining capacities to understand the outlet points of pre-concentrates of the ECRM – the focus of this report.
- Task 1.4 - integrates and combines the findings of all previous tasks into one final report. Dialogue with African and EU partners is variably integrated into individual tasks and supplements dialogue and outreach activities performed in other work packages (WPs 3, 5, 7) as well as through individual country case studies – Task underway.

1.1 The concept of ECRM

Minerals and metals defined as strategic to be addressed by the AfricaMaVal project comprise the ones included in the European Critical Raw Materials (CRM) list, the minerals that are used in the Li-battery manufacturing and electric mobility society in general, the minerals needed by the decarbonization targets of the Energy Intensive Industries (EII), the minerals and metals which energy transition and low-carbon technologies are dependent on, and the metals required by the electronics and high-tech industry (Frame, 2018).

This extended critical raw materials (ECRM) to be included and targeted in the AfricaMaVal project are: Antimony (Sb), Baryte, Bauxite, Beryllium (Be), Bismuth (Bi), Borate, Cobalt (Co), Copper (Cu), Fluorspar, Gallium (Ga), Germanium (Ge), Hafnium (Hf), Indium (In), Lithium (Li), Magnesium (Mg), Manganese (Mn), Natural graphite, Nickel (Ni), Niobium (Nb), Coking coal, Phosphate rock, Phosphorus (P), Silicon metal (Si), Scandium (Sc), Strontium (Sr), Tantalum (Ta), Tin (Sn), Titanium (Ti), Tungsten (W), Vanadium (V),



HREEs-Heavy Rare Earth Elements: (Dysprosium-Dy, Erbium-Er, Europium-Eu, Gadolinium-Gd, Holmium-Ho, Lutetium-Lu, Terbium-Tb, Thulium-Tm, Ytterbium-Yb, Yttrium-Y),

LREEs-Light Rare Earth Elements: (Cerium-Ce, Lanthanum-La, Neodymium-Nd, Praseodymium-Pr, Promethium, Samarium-Sm),

PGM-Platinum Group Metals: (Iridium-Ir, Palladium-Pd, Platinum-Pt, Rhodium-Rh, Ruthenium-Ru).

1.2 Objectives of Task 1.3 of WP1

The aim of task 1.3 within WP1 is to, where possible, extract the inventory of industrial mineral processing units operating in Africa, stored in conveniently structured datasets and, if possible, with economic information on the involved markets.

2 Source of data used

All data was compiled from freely available on-line datasets (e.g., USGS; Padilla & al., 2021 and other bibliography presented at the end of the report), mining company websites and “in-house data” from the various contributing consortium partners. Verification and validation were undertaken using S&P Global data (S&P Capital IQ Pro DB, 2023). Additionally, internal consortium intelligence on the subject was used.

2.1 Type of data

The data displayed in this data set consists of the following items (Table 1).



Table 1. The complete attributes reference table for AfricaMaVal - Processing Facilities database

Current Layer		Processing Facilities						
<input type="checkbox"/> Visible	<input checked="" type="checkbox"/> Read Only	Field Name	Alias	Data Type	<input checked="" type="checkbox"/> Allow NULL	<input type="checkbox"/> Highlight	Number Format	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	OBJECTID	OBJECTID	Object ID	<input type="checkbox"/>	<input type="checkbox"/>	Numeric	
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Shape	Shape	Geometry	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input type="checkbox"/>	<input type="checkbox"/>	Id	Id	Long	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Numeric	
<input checked="" type="checkbox"/>	<input type="checkbox"/>	LatYY	Latitude	Double	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Numeric	
<input checked="" type="checkbox"/>	<input type="checkbox"/>	LongXX	Longitude	Double	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Numeric	
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Country	Country	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	<input type="checkbox"/>	ECRMproces	ECRM Processed	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Processing	Processing Facility Name	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Processi_1	Processing Facility	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Status	Status	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Location	Location	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Owner	Owner	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Operator	Operator	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Technology	Technology or Process	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Processi_2	Processing Capacity	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	<input type="checkbox"/>	FeedstockT	Feedstock Type	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	<input type="checkbox"/>	WasteProdu	Waste Production	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Production	Production Statistic	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	<input type="checkbox"/>	EnergySour	Energy Source	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	<input type="checkbox"/>	PortAndRai	Port and Rail	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Comments1	Comments 1	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Comments2	Comments 2	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input type="checkbox"/>	<input type="checkbox"/>	NameOrgani	NameOrgani	Text	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
<input type="checkbox"/>	<input type="checkbox"/>	Date	Date	Date	<input checked="" type="checkbox"/>	<input type="checkbox"/>		

3 Data confidentiality

All data used is considered non-confidential by all contributing partners.

For this reason, the AfricaMaVal team agreed that there are two possible ways to make this data available:

- **Web Feature Service (WFS)** – A WFS service is a specification of a format that provides geographic data in vector format, i.e., information is communicated in the form of vectors and attributes that describe them. These Geographic Data Services (GDS) can be used using a GIS program or application (Geographic Information System) compatible with these standards, free (e.g., Quantum GIS, gvSIG, uDig), or commercial (e.g., ArcGIS, Geomedia, AutoCAD Map). In this format, the dataset can also be used to update and manipulate the data. Hence, a more secure method, namely WMS was used to display and deliver the data.
- **Web Map Service (WMS)** - The WMS specification is a standard that makes it possible to provide geographic information in the form of georeferenced images over the Internet. The

WMS

for a mineral occurrences map is typically read-only, meaning that it can only be used to view the data specified before.

3.1 Data management and visualization

Managing and visualising the AfricaMaVal data can be undertaken using, for example, a geological data portal such as LNEG's Geoportal.

LNEG's GeoPortal (<https://geoportal.lneg.pt>) is LNEG's integrated services infrastructure to support the management and visualization of spatial data, which aims to provide, in a web environment, the georeferenced information related to the different institutional activities of the National Laboratory of Energy and Geology.

This tool also allows implementing and securing data services (WMS and WFS) in accordance with internationally established technical specifications by organizations related to spatial data.

The GeoPortal consists of four main components:

- **Metadata Catalogue:** a service for research and consultation of institutional metadata, which allows to know the existence and availability of the geographical information of the LNEG;
- **Online Databases:** a set of applications that allow access and consultation of information on various institutional themes;
- **Map Viewer:** LNEG mapping and spatial information visualization and analysis service, which also allows the overlay and spatial analysis of geographic data from different sources (maps, geoscientific data, orthophotomaps, etc.).
- **Cartography Download:** Space for the provision of cartography following the open data policy.

These four components allow the user to search for spatial information made available by the Institution, to consult and analyze them (as queries or map services) or to download official maps.

3.2 Analysis of results

In the obtained database a total of 215 entries are available. An Analysis by country indicates that South Africa contains the largest number (27.44%) of processing facilities (*s.l.*; Concentrator, Plant, Refinery and Smelter; see below) and the least are spread through Mozambique, Algeria,



Ghana, Liberia, Mali, Nigeria, Rwanda and Togo (0.47%). Figure 1 shows the statistical representation of the number of African processing facilities.

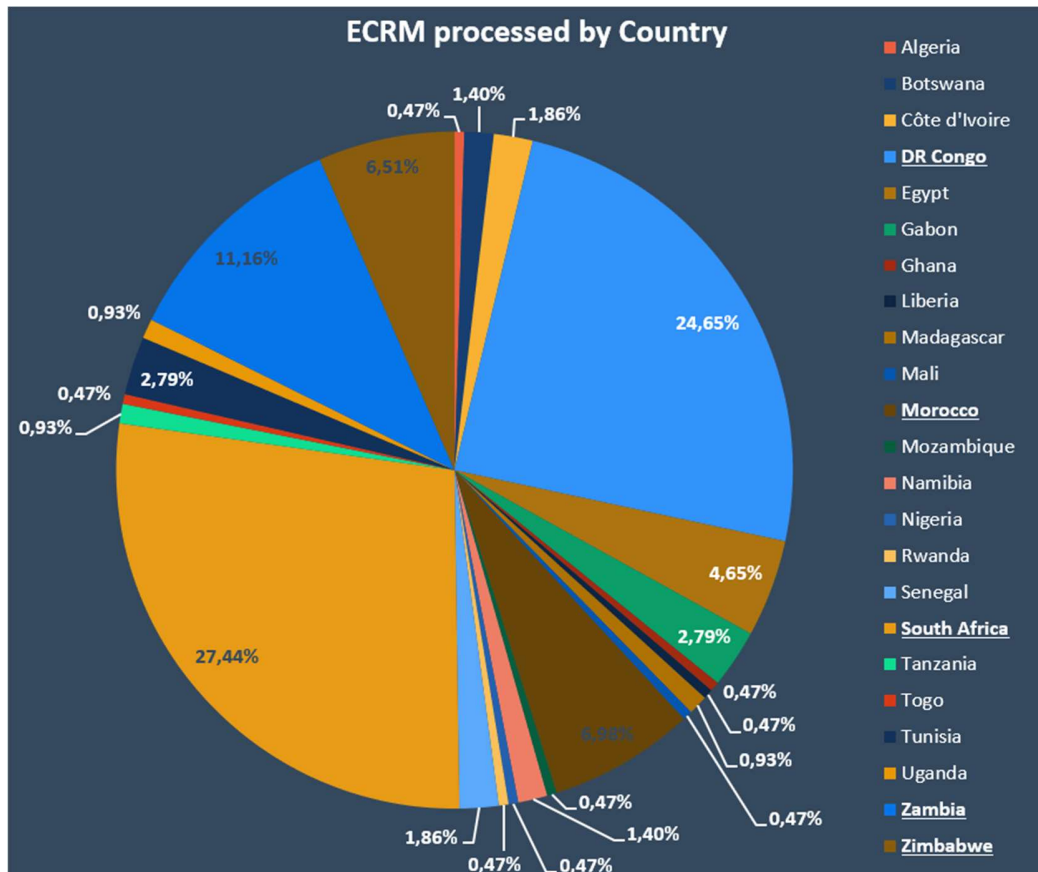


Figure 1. Percentage of processing facilities by country

The types of processing facilities are divided into 4 main types (Fig. 2):

- 6 Concentrators (2.82%),
- 117 Plants (53.99%),
- 45 Refineries (21.13%), and
- 47 Smelters (22.07%).

In general, the main differences between these processing facilities lie in their specific functions and industries of application. A "plant" is a general term for various industrial facilities, while a "smelter" focuses on extracting metals, a "concentrator" enhances the concentration of valuable minerals within raw ore and a "refinery" mostly deals with refining petroleum or chemicals.

However, the term refinery is the location where the concentration of metal/s and purity is increased.

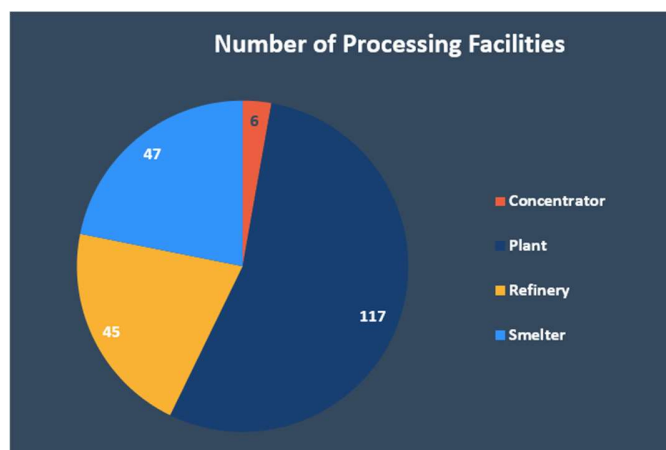


Figure 2. Total number of main types of processing facilities

Of the total elements processed, copper (37.21%), phosphate rock and cobalt (12.56%), manganese (10.70%) and PGM (8.84%) lead the way (Fig. 3).

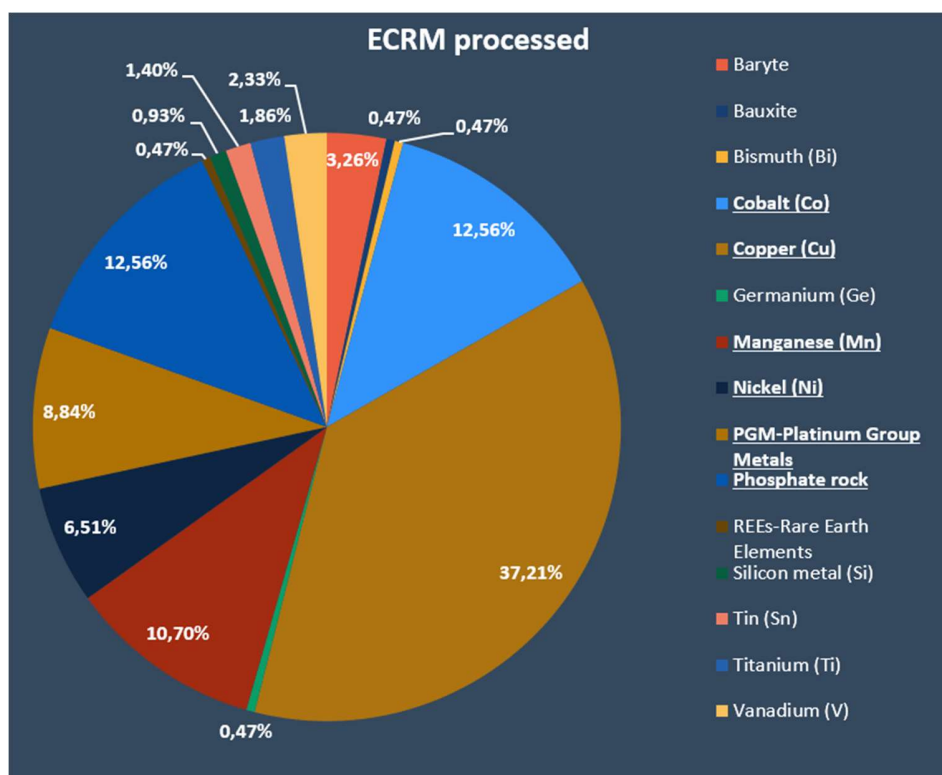


Figure 3. Percentage of ECRM processed in African processing facilities

In terms of processed elements by processing facility Tables 2, 3, 4 and 5 show the variation of processed elements per country obtained within the African countries’ dataset. The table is divided into the main processing facilities and the subsequent ECRM processed by country.

Table 2. Processing facility: Plant data

Country	ECRM processed	Count by Country
Algeria	Copper (Cu)	1
Côte d'Ivoire	Manganese (Mn)	4
DR Congo	Cobalt (Co)	11
	Copper (Cu)	21
	Germanium (Ge)	1
	Tin (Sn)	1
Egypt	Baryte	1
	Copper (Cu)	2
	Manganese (Mn)	1
	Phosphate rock	6
Gabon	Manganese (Mn)	6
Ghana	Manganese (Mn)	1
Liberia	Baryte	1
Mali	Phosphate rock	1
Morocco	Baryte	5
	Cobalt (Co)	1
	Nickel (Ni)	1
	Phosphate rock	7
Mozambique	Bauxite	1
Nigeria	Copper (Cu)	1
Senegal	Phosphate rock	4
South Africa	Cobalt (Co)	1
	Copper (Cu)	1
	Manganese (Mn)	6
	Phosphate rock	1
	Silicon metal (Si)	2
	Titanium (Ti)	1
	Vanadium (V)	4
Tanzania	Nickel (Ni)	1
Togo	Phosphate rock	1
Tunisia	Phosphate rock	6
Uganda	Cobalt (Co)	1
Zambia	Cobalt (Co)	2

	Copper (Cu)	6
Zimbabwe	Cobalt (Co)	1
	Nickel (Ni)	2
	PGM-Platinum Group Metals	2
	Phosphate rock	1

Table 3. Processing facility: Smelter data

Country	ECRM processed	Count by Country
Botswana	Cobalt (Co)	1
	Copper (Cu)	1
	Nickel (Ni)	1
DR Congo	Cobalt (Co)	1
	Copper (Cu)	9
	Tin (Sn)	1
Namibia	Copper (Cu)	1
Rwanda	Tin (Sn)	1
South Africa	Copper (Cu)	5
	Manganese (Mn)	2
	Nickel (Ni)	2
	PGM-Platinum Group Metals	8
	Titanium (Ti)	3
	Vanadium (V)	1
Tanzania	Copper (Cu)	1
Zambia	Bismuth (Bi)	1
	Cobalt (Co)	1
	Copper (Cu)	6
Zimbabwe	PGM-Platinum Group Metals	1

Table 4. Processing facility: Refinery data

Country	ECRM processed	Count by Country
DR Congo	Copper (Cu)	7
Madagascar	Cobalt (Co)	1
	Nickel (Ni)	1
Morocco	Cobalt (Co)	1
South Africa	Cobalt (Co)	2
	Copper (Cu)	5
	Manganese (Mn)	3
	Nickel (Ni)	5

	PGM-Platinum Group Metals	6
Uganda	Cobalt (Co)	1
Zambia	Cobalt (Co)	1
	Copper (Cu)	6
Zimbabwe	Cobalt (Co)	1
	Copper (Cu)	3
	Nickel (Ni)	1
	PGM-Platinum Group Metals	1

Table 5. Processing facility: Concentrator data

Country	ECRM processed	Count by Country
DR Congo	Copper (Cu)	1
Namibia	Copper (Cu)	2
South Africa	REEs-Rare Earth Elements	1
Zambia	Copper (Cu)	1
Zimbabwe	PGM-Platinum Group Metals	1

4 Overview of the final database

4.1 Database view

The final AfricaMaVal Mineral processing facilities geodatabase web service (Fig. 4) will be disseminated via:

- **WMS** - List of Web Map Services (WMS) that allow the visualization of maps dynamically. The address made available must be consumed in a GIS application compatible with the integration of WMS services.
- The WMS of the AfricaMaVal Database can be found at the following address:

<https://sig.Ineg.pt/server/services/Projects/AfricaMaVal/MapServer/WMSServer?>



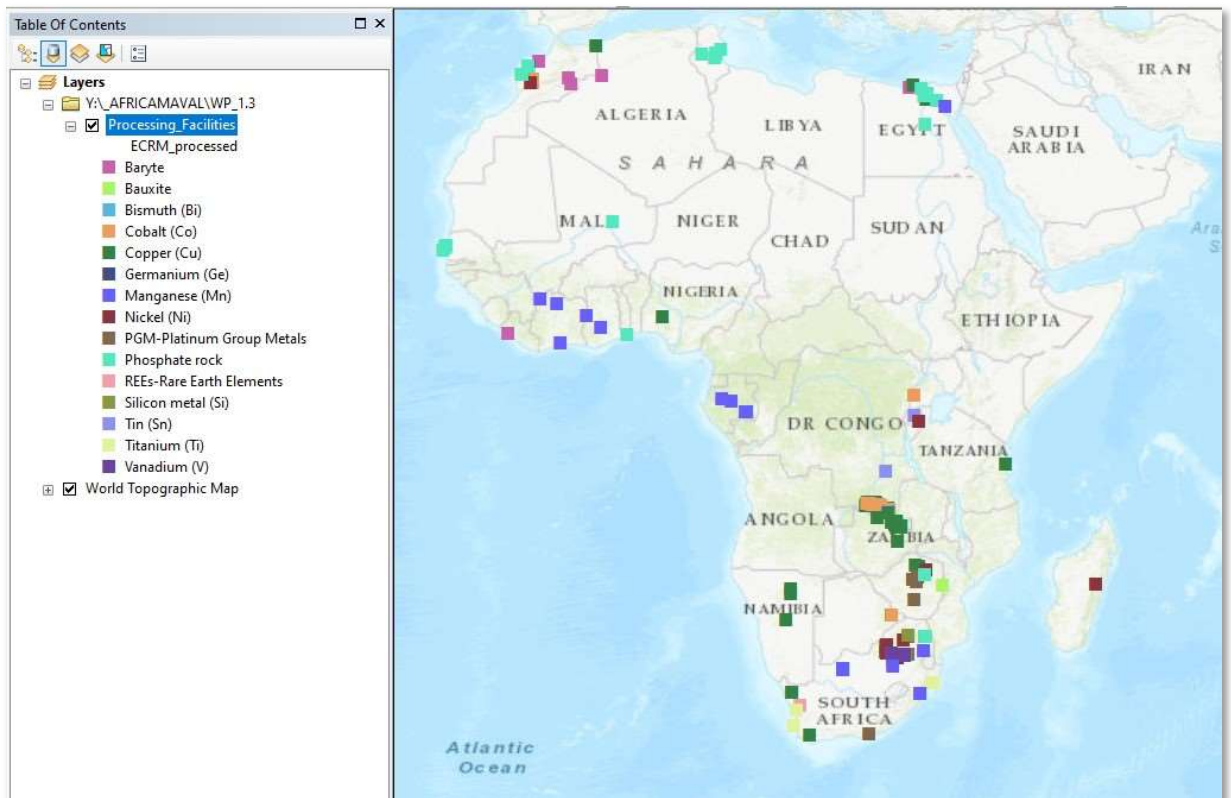


Figure 4. Overview of AfricaMaVal GIS geodatabase showing the Processing Facilities distribution

Conclusions

For ease of management, the AfricaMaVal GIS Mineral processing facilities geodatabase is presented as a WMS that can be easily updated should new data become available.

The distribution of the various processing facilities in Africa are mostly concentrated within the mining and mineral producing countries (e.g., South Africa, DRC, Zambia, Morocco and Zimbabwe; Fig. 1). New potential mineral extraction projects will benefit from a closer proximity to the processing facilities within each country. Therefore, depending on the geographic proximity and regional metallogeny, the possibilities of using existing industrial units to carry out preliminary pilot tests, enabling the development of new processing projects, will need to be evaluated on a case-by-case basis. Additionally, the type of processing facility and the mineralurgical and metallurgical processes active in each processing facility needs to be similarly evaluated depending on the type of deposit, main mineralogy, accessory mineralogy, grain size and mineral liberation factors.



Bibliography

(Padilla & al., 2021) - Padilla, A.J., Otarod, D., Deloach-Overton, S.W., Kemna, R.F., Freeman, P.A., Wolfe, E.R., Bird, L.R., Gulley, A.L., Trippi, M.H., Dicken, C.L., Hammarstrom, J.M., and Briocche, A.S. Compilation of Geospatial Data (GIS) for the Mineral Industries and Related Infrastructure of Africa. [DOI: <https://doi.org/10.5066/P97EQWXP>]

(Algeria, 2018) - USGS 2018 Minerals Yearbook, Vol. III, Algeria Country Chapter - <https://d9-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/atoms/files/myb3-2017-18-Algeria.pdf>

(Botswana, 2018) - USGS 2017–2018 Minerals Yearbook, Botswana Chapter. <https://pubs.usgs.gov/myb/vol3/2017-18/myb3-2017-18-botswana.pdf>

(Congo Democratic Republic of, 2018) - USGS 2017–2018 Minerals Yearbook, Congo- kinshasa Chapter. <https://pubs.usgs.gov/myb/vol3/2017-18/myb3-2017-18-congo-kinshasa.pdf>

(Egypt, 2018) - USGS 2018 Minerals Yearbook, Vol. III, Egypt Country Chapter. <https://pubs.usgs.gov/myb/vol3/2017-18/myb3-2017-18-egypt.pdf>

(Gabon, 2018) - USGS 2018 Minerals Yearbook, Vol. III, Gabon Country Chapter. <https://d9-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/atoms/files/myb3-2017-18-gb.pdf>

(Madagascar, 2018) - USGS 2018 Minerals Yearbook, Vol. III, Madagascar Country Chapter. <https://pubs.usgs.gov/myb/vol3/2017-18/myb3-2017-18-madagascar.pdf>

(Mali, 2018) - USGS 2018 Minerals Yearbook, Vol. III, Mali Country Chapter. <https://d9-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/atoms/files/myb3-2017-18-ml.pdf>

(Morocco, 2018) - USGS USGS 2018 Minerals Yearbook, Vol. III, Morocco Country Chapter. <https://pubs.usgs.gov/myb/vol3/2017-18/myb3-2017-18-morocco-western-sahara.pdf>

(Mozambique, 2018) - USGS USGS 2018 Minerals Yearbook, Vol. III, Mozambique Country Chapter. <https://pubs.usgs.gov/myb/vol3/2017-18/myb3-2017-18-mozambique.pdf>

(Namibia, 2018) - USGS 2018 Minerals Yearbook, Vol. III, Namibia Country Chapter. <https://pubs.usgs.gov/myb/vol3/2017-18/myb3-2017-18-namibia.pdf>

(Nigeria, 2018) - USGS 2018 Minerals Yearbook, Vol. III, Nigeria Country Chapter. <https://pubs.usgs.gov/myb/vol3/2017-18/myb3-2017-18-nigeria.pdf>



(Rwanda, 2018) - USGS 2018 Minerals Yearbook, Vol. III, Rwanda Country Chapter. <https://d9-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/atoms/files/myb3-2017-18-rw.pdf>

(S&P, 2023) - Capital IQ Pro Database 2023. S&P Global Market Intelligence, a division of S&P Global Inc. S&P Global Market Intelligence, 55 Water Street, New York, NY 10041

(Senegal, 2018) - USGS 2018 Minerals Yearbook, Vol. III, Senegal Country Chapter. <https://d9-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/atoms/files/myb3-2017-18-sg.pdf>

(South Africa, 2018) - USGS 2018 Minerals Yearbook, Vol. III, South Africa Country Chapter. <https://pubs.usgs.gov/myb/vol3/2017-18/myb3-2017-18-south-africa.pdf>

(Togo, 2018) - USGS 2018 Minerals Yearbook, Vol. III, Togo Country Chapter. <https://d9-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/atoms/files/myb3-2017-18-to.pdf>

(Tunisia, 2018) - USGS 2018 Minerals Yearbook, Vol. III, Tunisia Country Chapter <https://pubs.usgs.gov/myb/vol3/2017-18/myb3-2017-18-tunisia.pdf>

(Zambia, 2017) - USGS 2017 Minerals Yearbook, Vol. III, Zambia Country Chapter. <https://pubs.usgs.gov/myb/vol3/2017-18/myb3-2017-18-zambia.pdf>

(Zimbabwe, 2018) - USGS 2018 Minerals Yearbook, Vol. III, Zimbabwe Country Chapter. <https://d9-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/atoms/files/myb3-2017-18-zi.pdf>

(Sustainability report, 2021) – <https://ambatovy.com/en/wp-content/uploads/2022/10/Ambatovy-Sustainability-Report-2021-EN.pdf>

(Press release, April 11, 2023) - La Société pour le Traitement du Terril de Lubumbashi (STL) <http://stlgcm.com/>

