

BGS/CBU-ACESM Exchange Visit, Zambia

BGS International Geoscience Research & Development
Programme

Open Report OR/22/048



BRITISH GEOLOGICAL SURVEY

BGS INTERNATIONAL GEOSCIENCE RESEARCH & DEVELOPMENT
PROGRAMME

OPEN REPORT OR/22/048

BGS/CBU-ACESM Exchange Visit, Zambia

EM Hamilton, CJ Mitchell & KK Maseka

Keywords

CBU; Zambia; Kitwe; ACESM;
Black; Mountain; Graphite;
Critical Raw Materials.

Front cover

Nkana slag dump, known locally
as 'The Black Mountain', Kitwe,
Zambia.

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British Geological Survey offices

**Environmental Science Centre, Keyworth, Nottingham
NG12 5GG**

Tel 0115 936 3100

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BGS Sales

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Tel 029 2167 4280

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OX10 8BB**

Tel 01491 838800

**Geological Survey of Northern Ireland, Department of
Enterprise, Trade & Investment, Dundonald House, Upper
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Foreword

This report summarises an exchange visit carried out by the British Geological Survey (BGS) to disseminate previous research findings and discuss future opportunities and collaborations with the Copperbelt University's "Africa Centre of Excellence for Sustainable Mining" (CBU-ACESM) in Kitwe, Zambia during May 2022.

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- Dr Michael Watts from the BGS
- Dr Moola Mutondo, Mrs Womba Mwanza, Dr Mwansa Chabala, Dr Nelly Chunda Mwango from Copperbelt University

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Summary

The Copperbelt Province in Zambia is a world-renowned mining centre that is responsible for a significant proportion of the global copper (Cu) and cobalt (Co) production. Over the last 100 years the mineral processing and refining operations in the Copperbelt have produced large volumes of mineral and slag waste. Past research collaboration between the British Geological Survey (BGS) and the Copperbelt University Africa Centre of Excellence for Sustainable Mining (CBU-ACESM) has focused on the environmental impact of Potentially Harmful Elements (PHEs) associated with this waste material, and the subsequent human health risk for proximal subsistence communities.

In May 2022 a small team from the BGS visited the CBU-ACESM as part of an exchange visit to disseminate the findings of the past research (an exercise delayed due to the Covid-19 pandemic) and to explore the potential for future research collaboration. The week-long visit included workshops with CBU-ACESM stakeholders and small-scale miners, discussions with CBU-ACESM staff, field excursions to the copper refinery slag stockpile (the ‘Black Mountain’) in Nkana West and a silica sand operation near Kalulushi and lecture sessions for CBU students.

The recent (at the time of writing) acquisition of nearly 50% of the ‘Black Mountain’ slag stockpile (approximately 10 million tonnes) by a cooperative of small-scale miners has led to significant disruption and transportation of slag material throughout Nkana West and surrounding towns, creating large quantities of fugitive dust in the process. Assessment of the human health risk (HHRA) and adoption of better practices for reworking tailings material is essential to improve the sustainability of the cooperative’s processing; the CBU-ACESM PhD student, alongside the BGS’ International Geoscience Research & Development (IGRD) programme, are well-placed to address these issues.

The relationship between the BGS and CBU-ACESM has been strengthened by the exchange visit, through direct engagement and discussions with new and established contacts. It builds on a research collaboration dating back to 2013, with potential for future research collaboration via two CBU-ACESM funded PhDs focusing on the environmental contamination posed by the copper refinery slag stockpiles ‘Black Mountain’ in the Kitwe area. There is also potential for research collaboration to be explored further on battery raw materials, particularly graphite, for Electric Vehicle battery manufacture and on sand mining.

1 Introduction

The Copperbelt Province of Zambia has been the site of extensive mining operations for over 100 years (Weissenstein and Sinkala, 2011), which had led to an increase in surface concentrations of Potentially Harmful Elements (PHEs) such as chromium (Cr), arsenic (As), cobalt (Co), lead (Pb) and zinc (Zn) (Křibek et al., 2010). Numerous studies have evaluated the mobility of these PHEs (Ettler et al., 2011) (Kaninga et al., 2019) and the risk to human health through consumption of groundwater (von der Heyden and New, 2004) and staple crops grown in contaminated soil (Křibek et al., 2014). Despite this, a comprehensive evaluation of the soil geochemical processes governing PHE mobility and transfer into staple crops has not been undertaken in tropical soils, resulting in a significant knowledge gap which has led to the implementation of insufficient agriculture and public health policies.

The “Strengthening African capacity in soil geochemistry to inform agriculture and health policies” project, led within the British Geological Survey (BGS) by Dr Michael Watts (Inorganic Geochemistry Facility (IGF)), was funded by the Royal Society & Department for International Development (RS-DFID) Africa Capacity Building Initiative between 2015 and 2020. The aim of this initiative was to facilitate soil geochemistry capacity strengthening in each of three African countries (Zambia, Zimbabwe and Malawi) through PhD projects to support agricultural and public health policies aligned with UN Sustainable Development Goals (SDGs). One such PhD project was undertaken in Zambia, with Dr Belinda Kaninga (Zambian Agricultural Research Institute) researching the mobility of metal bioavailability from tropical soils within close proximity to tailings storage facilities (TSF) near Kitwe, the second largest city in Zambia and the central hub of mining activity within the Copperbelt Province. An additional Royal Society International Exchange grant enabled an MSc student from the Copperbelt University (CBU-Lukundo Nakaona) to undertake a health focussed study at the adjacent village to include food and water intake, as well as biomonitoring samples to assess human health risk and pathways for exposure to PHEs. At the same time, Elliott Hamilton (BGS IGF staff) undertook a part-time PhD aligned with Belinda’s research; all three had completed their studies by 2020, but were unable to disseminate findings of their work to stakeholders due to the onset of the COVID-19 pandemic.

In August 2019, an MoU was signed for the BGS to collaborate with the Copperbelt University (CBU) through their World Bank funded Africa Centre of Excellence for Sustainable Mining (CBU-ACESM). At the time of signing, the intention was for BGS to participate through staff exchanges, PhD co-supervision, provision of training and development of teaching modules for postgraduates through to 2024; however, these activities were significantly delayed due to the COVID-19 pandemic.

This report outlines the exchange visit undertaken by the BGS to the CBU-ACESM in May 2022, to disseminate research findings from the aforementioned RS-DFID, Royal Society international exchange and PhD/MSc research projects to stakeholders for BGS’ International Geoscience Research & Development (IGRD) programme, and alongside training provision in environmental geochemistry using practical examples for undergraduate students.

2 Exchange Visit

2.1 EXCHANGE VISIT INTRODUCTION

An exchange visit was carried out between the BGS and the Copperbelt University under the auspices of the Africa Centre of Excellence in Sustainable Mining (CBU-ACESM). The exchange visit took place from Sunday 15th to Saturday 21st May 2022. The primary participants were:

- Elliott Hamilton, Clive Mitchell (BGS)
- Kakoma Maseka, Moola Mutondo, Womba Mwanza (CBU)
- Patson and Barnabus (CBU Drivers)

The objectives of the exchange visit to CBU-ACESM were as follows:

- Disseminate previous findings from the Royal Society Department for International Development (RS-DFID) Africa Capacity Building Initiative PhD/MSc student projects to a group of invited stakeholders.
- Discuss future opportunities for research and collaboration in the scope of BGS' International Geoscience Research & Development (IGRD) programme.
- Deliver talks to students within the School of Mines and School of Mathematics and Natural Sciences.
- Visit large- and small-scale mining areas to have a better understanding of operations and avenues for future research.
- Leverage additional funding from World Bank through CBU-ACESM for future visits and research.

2.2 EXCHANGE VISIT ITINERARY

The exchange visit itinerary was as follows:

Date	Activity
14 th to 15 th May 2022	Travel from the UK to Kitwe (3 flights; Birmingham to Dubai; Dubai to Lusaka; Lusaka to Ndola)
16 th May 2022	BGS / CBU-ACESM open day, Garden Court Hotel, Kitwe.
17 th May 2022	Discussions on research collaborations between CBU & BGS
18 th May 2022	Field excursion to mining sites in the Copperbelt- Black Mountain and associated sites. Session with CBU students.
19 th May 2022	Small scale mining workshop and field excursion.
20 th May 2022	Session with CBU students and excursion to Chimfunshi.
21 st to 22 nd May 2022	Travel from Kitwe to the UK (3 flights; Ndola to Johannesburg; Johannesburg to Dubai; Dubai to Birmingham)

2.3 EXCHANGE VISIT DAY 1 - MONDAY 16TH MAY

The BGS team arrived at the Edgar Chagwa Lungu (ECL) Convention Centre, situated at the Garden Court Hotel in Kitwe, for the CBU-ACESM/BGS Open Day registration at 08:30. The day was formally opened with addresses by Dr Mwansa Chabala (CBU-ACESM Centre Leader) and Prof Paul Chisale (CBU Vice Chancellor), before the RS-DFID dissemination presentation session led by Elliott Hamilton. Prof Kakoma Maseka (Dean, School of Mathematics and Natural Sciences, CBU) presented on behalf of both Belinda and Lukundo, followed by a talk from Womba Mwanza (CBU Laboratory Technician).



Figure 1. Clive Mitchell (left) and Elliott Hamilton (right) presenting during the BGS/CBU-ACESM Open Day

The second half of the Open Day started with presentations from CBU researchers; Patrick Hayumbu presented early results from occupational health surveys at large-scale mines, and Charles Mulenga gave an account of his PhD work on the impact of mining pollution on trees.

A stakeholder group exercise was facilitated by the BGS team to explore how best to develop the research collaboration between the BGS and CBU-ACESM. A wide-ranging discussion focused on the concept of a buffer zone around mine waste tailing sites particularly where there is concern regards environmental contamination. Research aspects could include the impact on communities, the application of GIS for land use management, monitoring by Remote Sensing, the role of government and regulators and the impact on mining policy. The creation of “Managed Agricultural Zones” was proposed. These could be supported by agricultural extension officers funded by the mining companies as part of their Corporate Social Responsibility (CSR) commitment and in line with “polluter pays” principles.

The Open Day concluded with a number of poster presentations from CBU students, encompassing a wide range of topics from occupational exposure to silica and subsequent risk of silicosis at Mufulira Mine (Lubinda Nabiwa), to assessing the role of microbial ecosystems in the bioremediation of lead-contaminated sites in Kabwe (Annette Lombe). The day generated interesting discussions on the importance of interdisciplinary approaches to improving the sustainability of mining operations whilst allowing for translation of research findings to cooperatives and communities at risk of deleterious health effects resulting from mining activities. The event was attended by 25 participants from academia and industry, including representatives from Mopani Copper Mines and Zambia Environmental Management Agency (ZEMA).

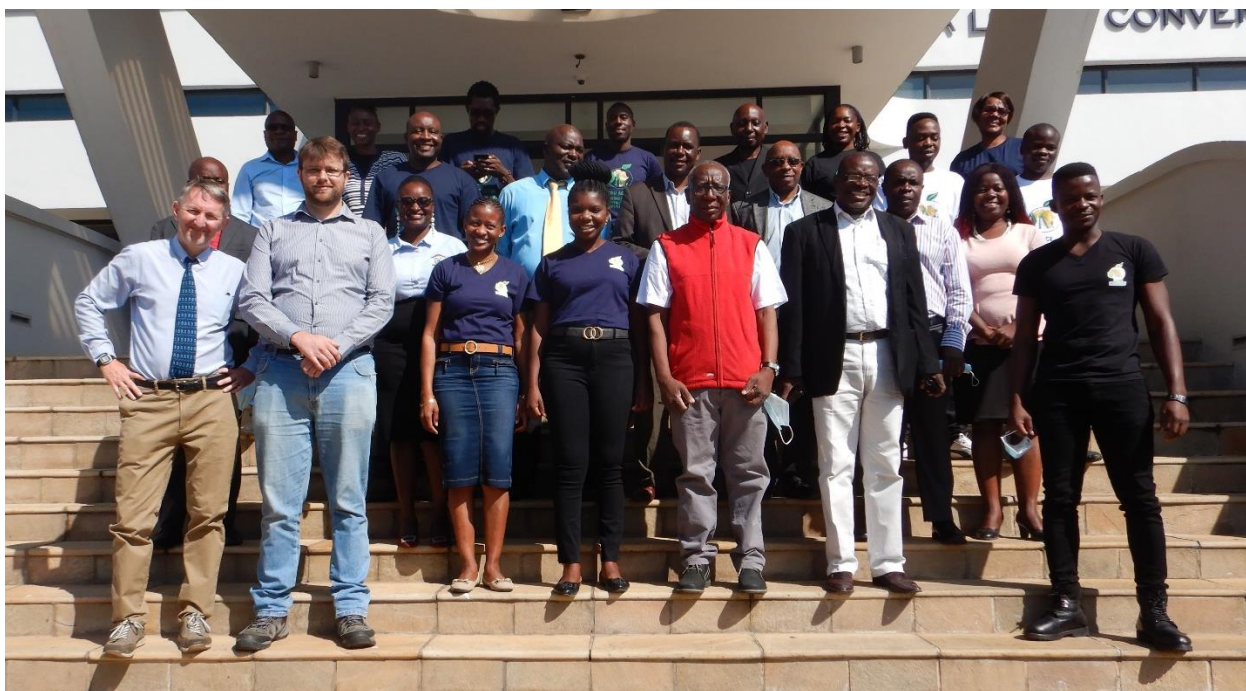


Figure 2. Clive Mitchell and Elliott Hamilton (far left, first row) with attendees for BGS / CBU-ACESM Open Day

2.4 EXCHANGE VISIT DAY 2 - TUESDAY 17TH MAY

The BGS team arrived at the School of Mathematics and Natural Sciences at CBU where discussions were held with CBU ACESM & Ministry of Mines staff regards future IGRD collaboration with the BGS. As well as the BGS team, those present during the discussions included: Edward Chisakulo (CBU Geology), Mwenzimutimbwa Phiri (Inspector of Environment, Ministry of Mines), Sitembile Ncube Kaseka (CBU Mining Engineering), Misozi Makangila Daka (CBU Environmental Engineering), Womba Kaumba Mwanza (CBU Chemistry), Moola Mutondo (CBU Geneticist) and Francis Bwalye (CBU Mining Engineering). The BGS team gave presentations on Zambian research and the scope of the IGRD programme. This was followed by a tour of the laboratories at CBU including X-Ray Fluorescence (XRF), Scanning Electron Microscope (SEM), mineral processing, mineralogy and Atomic Absorption Spectrometer (AAS).

After lunch a meeting was held with Dr Mwansa Chabala (CBU-ACESM Centre Leader) at the CBU Graduate School (where approximately 1000 PhD and MSc students are based). The scope for PhD students to enable the continuation of research collaboration between CBU ACESM and BGS was discussed. Two PhD students fully funded by ACESM were agreed; both to focus on the copper refinery slag waste at the ‘Black Mountain’.

In addition, there was a discussion regards research on Zambian battery raw materials. This was of interest due to the signing on the 29th April 2022 of the “Zambia and Democratic Republic of the Congo (DRC) Cooperation Agreement on the Establishment of a Value Chain in the Electric Vehicle and Clean Energy Sectors”. The aim being to manufacture electric vehicle batteries using the mineral resources of Zambia and the DRC (Nachalwe-Mbao, 2022). CBU and other universities in Zambia have been tasked to create a research programme to address the challenge posed by the cooperation agreement. In addition, there is potential for a third PhD student fully funded by ACESM to focus on Zambian battery raw materials with an emphasis on graphite resources, which mainly occur in the Eastern Province of Zambia.

2.5 EXCHANGE VISIT DAY 3 - WEDNESDAY 18TH MAY

The morning of the third day consisted of field excursions, starting at the Nkana West slag dump ('Black Mountain') and tracing its movement to reprocessing sites following the decision earlier in the year to allow a cooperative to rework the TSF. Local community cooperatives have been granted 45% of the slag dump with the aim of excavating 'crome' or 'chrome', a colloquial term for nuggets of mineralised material believed to contain Cu and/or Co. They are currently excavating and relocating the waste material to other sites including several large sites in the Kalulushi area; the cooperatives earn ZMK 200 per tonne of excavated material.



Figure 3. Clive Mitchell, Elliott Hamilton, Kakoma Maseka and Nelly Mwango in front of the 'Black Mountain' copper refinery slag pile, Nkana West, Kitwe, Zambia.

In the afternoon, the BGS team presented on “Novel methods for the assessment of Chromium species bioavailability” and “Graphite in Africa” to 12 students from the School of Chemistry.

2.6 EXCHANGE VISIT DAY 4 - THURSDAY 19TH MAY

The BGS team arrived at the Edgar Chagwa Lungu (ECL) Convention Centre, Garden Court Hotel in Kitwe, for the CBU-ACESM/BGS Small-scale Miners workshop. There were 25 delegates, mostly small-scale miners and co-operative group leaders as well as the Mines Safety Department, BGS and CBU. The morning session was formally opened with addresses by Dr Mwansa Chabala (CBU-ACESM Centre Leader) and Prof Kakoma Maseka (Dean, School of Mathematics & Natural Sciences, CBU). Two presentations were given by the BGS team, the first on ‘Sand Mining’ and the second on ‘Artisanal & Small-scale Gold Mining (ASGM) in Migori, Kenya’. A debate ensued that mostly focused on the business aspects of small-scale mining and the financial

support that could be provided by the Zambian government. The latter part of the morning session was taken up by completion of a ‘Questionnaire for Small Scaler Miners’ facilitated by CBU.

After lunch the workshop delegates were taken by bus to an artisanal silica sand mining site, Gerntina Mines Ltd, in Lufwanyama (part Chief Lumpuma’s area) to the west of Kalulushi (12° 50’ 36.6” South 28° 04’ 11.0” East). This mining operation was working coarsely crystalline quartz veins and quartzite. The vein quartz was being extracted and crushed manually. The quartzite was friable and easily broken down into sand sized particles. The quartzite sand was dug and sieved manually using an A-frame screen. The quartz sand appeared to be pure silica. The mine manager claimed it was 99.5% SiO₂. The silica is sold to Mopani Copper Mines for use in copper refining. Copper ore is heated in a furnace with silica. The iron in copper bearing minerals such as chalcopyrite is removed to form an iron silicate slag.



Figure 4. Manual screening of silica sand at Gerntina Mines, Kalulushi, Zambia

The mine site is listed on the Zambia Mining Cadastre Map Portal (<https://portals.landfolio.com/zambia/>) as active Small-Scale Mining Licence 8552-HQ-SML owned by Dickson Sinyangwe and registered to exploit silica.

The Kitwe-Mufulira Area 1:100,000 scale geological map shows that the mine is working quartzites of the Muva Supergroup (Meso-Proterozoic, 1600 to 1000 million years old). These are described as medium- to coarse-grained, friable quartzites and micaceous quartzites (Marjonen, 2000). These quartzites occur in several bands running from the mine for approximately 27km to the south east.

2.7 EXCHANGE VISIT DAY 5 - FRIDAY 20TH MAY

The BGS team arrived at the School of Mines at CBU. Presentations were given to students from the School of Mines (17) and School of Geology (17). The BGS team gave two presentations, the first on the current trends and future perspectives for analysis of Chromium and the second on graphite resources in Africa. In the afternoon there was an excursion to Chimfunshi Chimpanzee orphanage.



Figure 5. Presentation to CBU students.

3 Conclusions and Outlook for Future Research with CBU-ACESM

The potential for future research collaboration between the BGS and the CBU-ACESM was consolidated by the exchange visit in May 2022. The primary objective, to disseminate research findings from the RS-DFID PhD studentships, was successfully achieved, and stimulated discussion amongst key stakeholders that will be integral to the coalesced IGRD research project “Mineral Waste: Whole System Approach”.

The past research collaboration focus on the environmental contamination posed by the copper refinery slag stockpiles in the Kitwe area will continue through a CBU-ACESM funded PhD studentship (one of the 16 scholarship students currently registered within the CBU-ACESM), who will investigate spatial and temporal changes in human health risk assessment (HHRA) at two tailings storage facilities (Nkana Slag Dump/’Black Mountain’ and a site in Luanshya). This will incorporate bioaccessibility extractions, mineralogical analyses and leaching tests to fully characterise the distribution, behaviour and fate of PHEs in the tailings material, alongside remote sensing to plan fieldwork, monitor and identify land use change resulting from movement of tailings material around Kitwe, and produce multiscale maps to spatially assess human health risk and critical raw material (CRM) extraction potential of the waste to allow for more sustainable approaches to be implemented in the reworking of waste heaps in Zambia.

An additional PhD studentship is also being discussed, to focus on a potential new area of research collaboration on battery raw materials, particularly graphite resources in Zambia, for Electric Vehicle battery manufacture. Supplementary funding for both students will be sought through BGS’ University Funding Initiative (BUFI), alongside targeted funding calls from the Royal Society (RS) and the Royal Society of Chemistry (RSC).

Another potential area for research collaboration is sand mining, particularly in the context of the information obtained during the afternoon of the fourth day of the exchange visit.

Overall, the exchange visit strengthened existing partnerships and allowed direct engagement with new contacts to diversify the research portfolio between BGS and CBU, leading to a bright outlook for continuing research with the CBU-ACESM.

4 References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: <https://envirolib.apps.nerc.ac.uk/olibcgi>.

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Appendix 1: BGS staff CVs

Elliott Hamilton

Biography

- PhD: 'Novel methods for the assessment of chromium species bioavailability' (School of Biosciences, University of Nottingham: 2014-2020 (part-time)).
- Environmental Chemist- Inorganic Geochemistry Facility, British Geological Survey, UK.
- MChem in Chemistry (Department of Chemistry, University of Surrey: 2008-2012).
- Research Interests:
 - Development of analytical techniques (ICP-QQQ, HPLC) for the measurement of potentially harmful elements (PHEs) in environmental and biological matrices.
 - Microspatial analyses of soils using novel sampling techniques (microdialysis) to assess the mobility and bioavailability of essential micronutrients and PHEs.
 - Elemental speciation methods for water and soil.
 - PHE mobility, availability and fractionation in contaminated soils using chemometric and isotopic testing methods.
 - Laboratory innovation to streamline workflows and improve resource deployment (data processing macros, efficiency gains), laboratory quality control and quality assurance.



Relevant Past Work

- ORCID ID: <https://orcid.org/0000-0002-9437-5238>
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Future Opportunities for Collaborative Research in Zambia

- International Geoscience Research and Development (IGRD)
 - Recipient of internal BGS grant to undertake research in Copperbelt Province, Zambia.
 - Project aim: to better understand environmental impact, potential public health risk and valorisation of legacy mine tailings.
 - For discussion: PhD project with CBU-ACESM to assess spatio-temporal changes in potentially harmful element (PHE) geochemical speciation, mobility and oral/inhalation bioaccessibility at worked and non-worked tailings sites. Opportunity to capitalise on World Bank investment and BGS IGRD funding to enable co-supervision, exchange visits for laboratory training and data interpretation.

Clive Mitchell

Senior Industrial Minerals Geologist, British Geological Survey (BGS)

British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK

BGS staff profile <https://www.bgs.ac.uk/people/mitchell-clive/>



Main work experience and expertise

Clive is responsible for developing business opportunities and leading BGS industrial minerals research projects including mineral resource evaluation, institutional capacity building, training, workshops and mineral promotion. Current research on Artisanal and Small-scale Gold Mining in Kenya, graphite battery raw materials in Africa and Brick Clay in the UK. Clive is the author of the bestselling book 'The Pebble Spotter's Guide' (National Trust).

Clive's industrial minerals experience includes: brick clay, aggregate, dimension stone, dolomite, feldspar, graphite, gypsum, kaolin, limestone, mica, mineral sand, marble, perlite, phosphates, silica sand and talc. Projects in Afghanistan, Angola, Botswana, Costa Rica, Ethiopia, Gambia, Ghana, Indonesia, Ireland, Kenya, Malawi, Malaysia, Mozambique, Myanmar, Namibia, Saudi Arabia, Sudan, Thailand, Trinidad, Uganda, Ukraine, United Arab Emirates, United Kingdom, Zambia and Zimbabwe.

Clive is an experienced geoscience communicator and active participant in community & public engagement activities, science events, social media channels, filming programmes, media interviews and other opportunities to engage the public with geoscience. Presented at over 60 conferences/workshops, recently on 'Strategic critical metals and battery raw material resources and supply chain development' as part of the 16th Arab International Mineral Resources conference (UAE Feb 2022).

Selected publications

Full publication list & downloads can be found here: <http://nora.nerc.ac.uk/view/author/2827.html>

Mitchell, C.J. & Deady, E. 2021 [Graphite resources, and their potential to support battery supply chains, in Africa](#). British Geological Survey OR/21/039.

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Future Opportunities for Collaborative Research in Zambia

Graphite (Critical Raw Material)

Graphite is a critical raw material of growing economic interest. In Zambia, there are flake graphite occurrences in the Proterozoic metasedimentary rocks (gneiss and schist) in the central and eastern parts of the country. There is potential for the development of economic graphite deposits in Zambia.

Sand Mining

Globally sand is in high demand for construction. Poorly managed extraction has severe environmental and social impacts, including erosion, increased flooding risk, habitat loss, pollution and soil degradation. BGS research aims to develop methodologies for quantifying the flow of sand through its lifecycle. This will be done via remote sensing and primary data gathering. The results will be used to assess impacts, compile good practice and governance advice for sand production and use.

Appendix 2: Graphite in Zambia

Clive Mitchell, Industrial Minerals Geologist, British Geological Survey email: cjmi@bgs.ac.uk

Graphite is an industrial mineral that is highly valued for its unique properties. It is a commodity of growing economic interest, as it falls into the category of so called ‘critical raw materials’. These are raw materials that are vital for modern technology and therefore have high economic importance, but have a high risk of supply shortage, frequently due to concentration of their production. Many countries are seeking alternative sources of these raw materials supply.

Graphite is an allotrope of carbon and has unique physical properties that makes it a valuable raw material in many modern technology applications. It occurs in either amorphous, flake or vein graphite deposits. Coarse-grained flake graphite (>500 microns in diameter) with a graphite content of at least 94% is the most valuable. This is extracted by open pit mining methods and concentrated by froth flotation. Currently, its use in steel production accounts for over half of graphite produced with the remainder used in a range of applications from lithium-ion batteries and energy storage technologies to high temperature lubricants and pencils. In Africa, there are currently 7 operational flake graphite producers (in Madagascar, Mozambique and Tanzania). However, there is great interest in the development of other graphite resources in Africa particularly in east Africa.

Geological setting and known occurrences

Zambia is underlain by Proterozoic Basement Complex rocks in its Central, Northern and Western provinces. Metasedimentary and metavolcanic rocks occur in Central, Copperbelt, Southern and Northern provinces and metamorphic rocks of the Mozambique Belt in Eastern province. The Katanga Supergroup sedimentary rocks occur in Northwestern and Western provinces. The Karoo Supergroup sedimentary rocks occur in the eastern rift valleys and in the western plateau where it is overlain by the Kalahari Group sandstone and windblown sand (Schlüter, 2006) (Figure 1).

In Zambia, there are flake graphite occurrences in the Proterozoic metasedimentary rocks (gneiss and schist) mostly in the central and eastern parts of the country. Graphite principally occurs in the Mkushi Gneiss and Mvuvye Gneiss, which are part of the Basement Complex in Zambia. These are dated at 2049 ± 19 Ma and probably formed during the Ubendian Orogeny. There are 28 occurrences of graphite reported in Zambia (Coats *et al*, 2000; Drysdall, 1960a; Drysdall, 1960b; Reeve, 1963; Simpson and Drysdall, 1965; Mitchell, 1993).

The Njoka graphite deposit occurs approximately 53 km west-north-west of Lundazi on the lower part of the Lundazi River. The deposit is hosted in garnet-biotite gneiss containing bands of leucogranite. Flake graphite occurs in lenses of medium grained, dark graphitic gneiss up to 366 m in length by 8 m wide. Three deposits are recorded at this location that have graphite contents of up to 20 per cent and average 10 to 13 per cent. A further deposit, comprising flake graphite in gneiss (15 per cent graphite), occurs immediately north of the Lundazi River. Processing trials produced concentrates grading 77 to 95 per cent graphite with recoveries from 90 to 97 per cent. The non-compliant resource estimate is approximately 10 000 tonnes of graphite (Drysdall, 1960b; Mitchell, 1993).

The Mkonda graphite deposit occurs 12 km west of Petauke and 16 km west-southwest of Sasare. Flake graphite occurs in leucocratic granodiorite-gneiss that forms a series with paragneiss and subordinate crystalline limestone and amphibolite. Graphite flake size reaches up to 1.2 mm, with an average of about one mm, and the graphite content averages 6–7 per cent. Graphite rarely occurs in outcrop, although where associated with biotite it forms harder “reefs”. Mica minerals intergrown with graphite pose an issue, as separation is difficult, leading to low recovery and an impure final product (Drysdall, 1960b).

The Mvuvye graphite deposit is located in the basin of the Mvuvye River, south of Petauke, and stretches over an area of 260 square kilometres. Flake graphite occurs in a variable sequence of biotite-gneiss and granulite. The flake size varies considerably with graphite contents ranging from approximately 6 to 12 per cent. The extreme north-east part of the Mvuvye paragneiss outcrop, south-east of Sasare, hosts a graphite deposit that is very similar to the rest of the Mvuvye graphite and has a graphite contents of up to 17 per cent (Drysdall, 1960b).

Other published information on graphite deposits is as follows:

- Graphitic schist occurrence in Serenje, Central Province (Guernsey, 1952);
- Graphitic shale, described as a ‘minor’ occurrence and assaying 16 per cent graphite, on the east bank of the Lunga River, Northwestern Province (Coats et al, 2000);
- Graphitic schist, in Walamba Siding, between Kapiri Mposhi and Ndola, Copperbelt Province. The occurrence comprises lenticular bodies of graphite schist in the Basement Complex that contain up to 25 per cent amorphous graphite (Drysdall, 1960a);
- Kayumba (Kajumba) graphite, 34 km north-east of Chama, Eastern Province. “Massive” graphite occurs in a grey gneissic granite. It takes the form of a lenticular body, estimated to contain 3 000 tonnes with a graphite content of 40 per cent (Coats, et al 2000);

Past and current production

Zambian mineral production is dominated by copper and cobalt. Other mineral production includes bismuth, building material, cement, gemstones, gold, manganese, silver and sulphur (Trimmer, 2015). There is no publicly available information on past or current graphite production in Zambia.

Recent exploration and development activity

There is no ongoing graphite exploration in Zambia.

Graphite resource development potential

The online portal “Zambian Mining Cadastre Portal” lists two active licences for graphite occurrences: 1) Mwilwa Investments & Minerals Zambia Ltd - Active ‘Large Scale Exploration Licence’ between Kapiri Mposhi in Central Province and Mpongwe in Copperbelt Province; and 2) Zamgraphite Resources Ltd - Active ‘Large Scale Exploration Licence’ for graphite deposits between Eastern and Muchinga provinces between Chama and Lundazi. Based on known occurrences and the geology, which is favourable for the development of graphite mineralisation, there is moderate potential for the development of economic graphite deposits in Zambia.

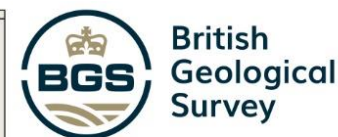
Zambian graphite references & recommended reading

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: <https://envirolib.apps.nerc.ac.uk/olibcgi>.

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Zambia: geological map and graphite occurrences

(map compiled by Clive Mitchell & Kathrine Linley, BGS; Basemap & data use covered by Creative Commons <https://doi.pangaea.de/10.1594/PANGAEA.788537>)



ZAMBIA

Rock type

- Unconsolidated sediments
- Siliciclastic sedimentary rocks
- Mixed sedimentary rocks
- Carbonate sedimentary rocks
- Evaporites
- Metamorphic rocks
- Acid plutonic rocks
- Intermediate plutonic rocks
- Basic plutonic rocks
- Acid volcanic rocks
- Intermediate volcanic rocks
- Basic volcanic rocks
- Water body
- No data

Coordinate system: GCS WGS 1984
Datum: WGS 1984
Units: Degree
Basemap: GLIM Lithological Map of the World
Original scale: 1:35 000 000
©CCGM-CGMW 2015

Graphite site status	ID	Locality	Graphite site status	ID	Locality
●	122	Chikola Plumbago	●	135	Numbu
●	123	Chikoti	●	136	Njoka
●	124	Chitambo	●	137	Nkonda
●	125	Chinkombe	●	138	Old Mkushi
●	126	Chipunga	●	139	Sakulwe
●	127	Fitete	●	140	Sasare
●	128	Kachanga	●	141	Serenje
●	129	Kajumba	●	142	Walamba
●	130	Kalindawalo	●	143	West Lunga
●	131	Kalinku			
●	132	Lusiwazi			
●	133	Makonda			
●	134	Mvuvye			

