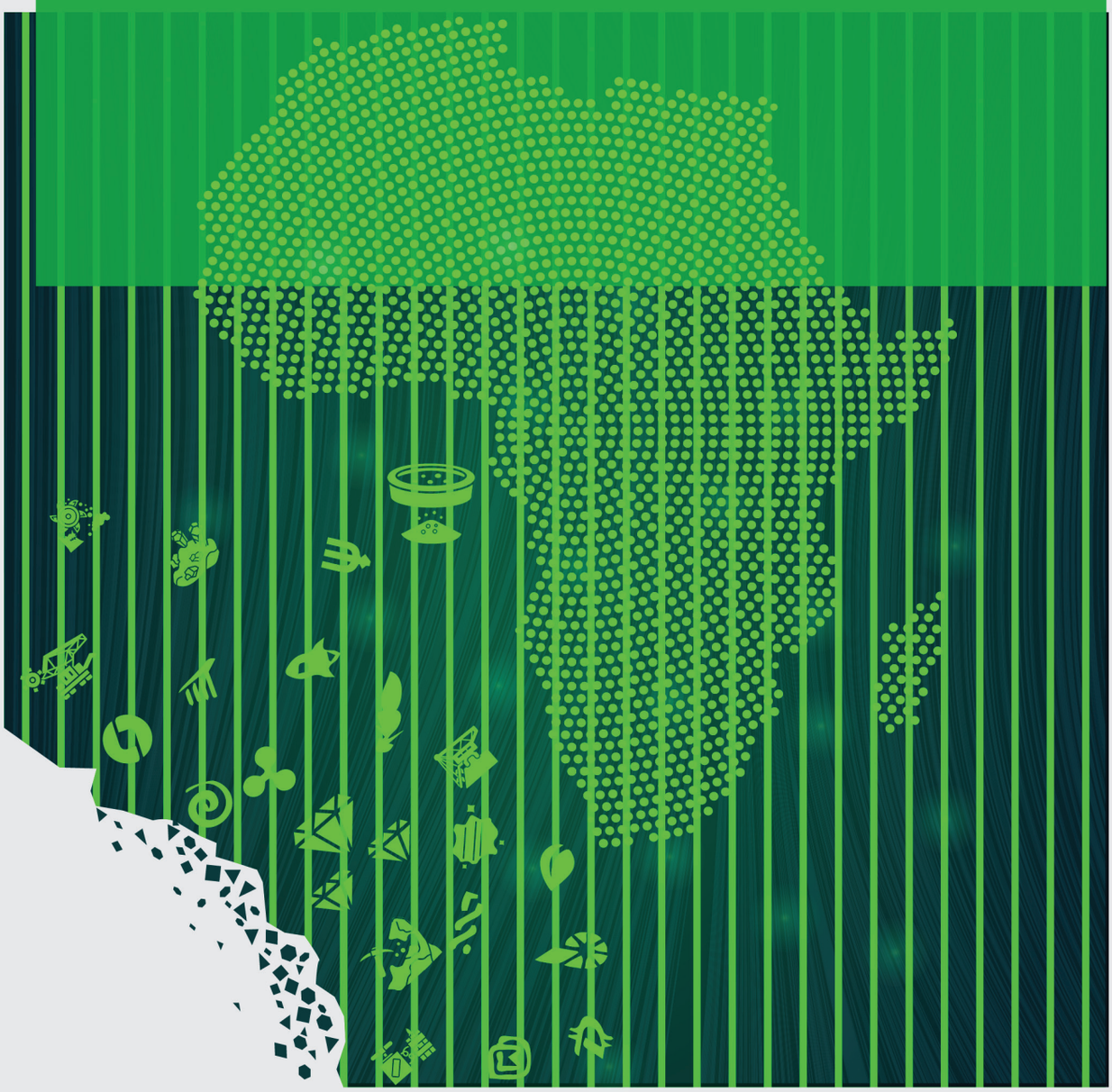
PROCEEDINGS OF THE SPECIAL SYMPOSIUM

Geology and Mineral Information System (GMIS) Strategy to Domesticate The Africa Mining Vision At A Country Level

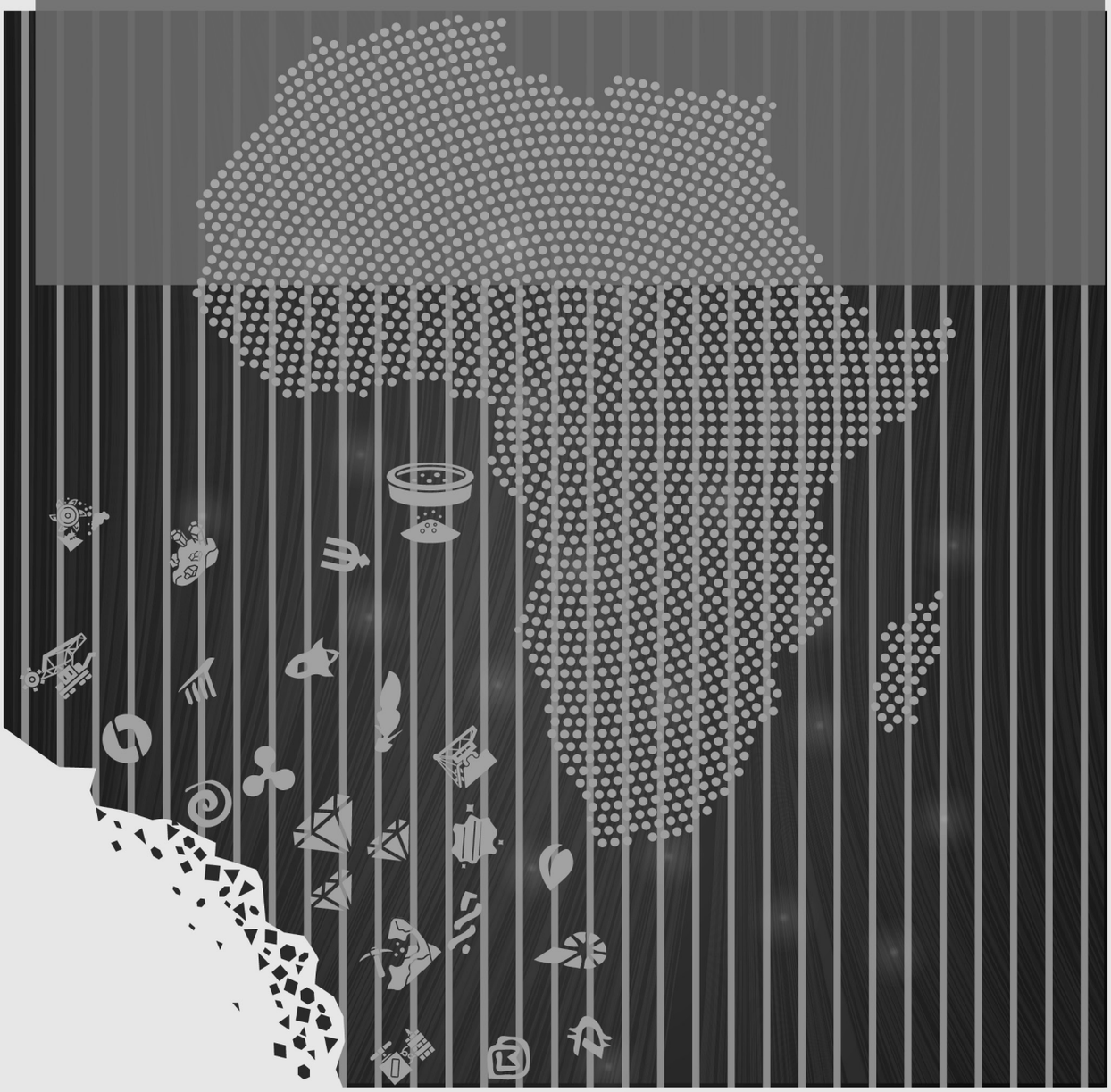


African Minerals Development Centre

United Nations
Economic Commission for Africa

PROCEEDINGS OF THE SPECIAL SYMPOSIUM

Geology and Mineral Information System (GMIS) Strategy to Domesticate The Africa Mining Vision At A Country Level



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FORWARD

The GMIS Strategy was proposed by the African Mineral Development Centre (AMDC) to facilitate the strengthening of the African production, management and dissemination of geological and mineral information (GMI) in connection with the implementation of the African Mining Vision (AMV) and the domestication of the Country Mining Vision (CMV). The Strategy sees geological and geospatial information as crucial for several important legal, economic, social and environmental applications in mining and broad development processes in Africa. It is planned to coordinate, set direction, create alignment, build commitment, promote collaboration, establish trust, mobilize supporters, and facilitate activities from different GMIS initiatives in the continent.

The GMIS coordination meeting as well as the special symposium were conducted during the 35th International Geological Congress (IGC35) held from 27 August to September 4, 2016 in Cape Town South Africa. The International Geological Congress (IGC), originally the International Congress of Geologists, was founded on August 25, 1876. The need of holding international congresses was increasingly felt among the community of geologists in Europe and North America as early as March 3, 1874. Since then 34 Congresses which are visited by a large number of geologists from all continents were organized every 4 years based on a bidding process. Africa had a chance to organize the Congress for the first time in Algeria more than 50 years ago. It was in Oslo, Norway in 2008 that the South African bid won and started preparing the 35th International Geological Congress. Eventhough the meeting was held in Cape Town, South Africa, it was an African meeting which promoted the African diverse geology, society and cutlure. This was an opportunity for the African Minerals Development Center (AMDC) to be involved at this International Congress by organizing a symposium to present and discuss its GMIS Strategy. The activities that were undertaken by the AMDC during the Congress were related mostly to the implementation of the GMIS strategy. They include:

1. A Pre-IGC35 meeting of the GMIS Coordination Committee, as well as the Annual meeting of the Organiztion of Afrian Geological Surveys (OAGS)

2. Organization and convening of a Special Symposium: Geology and Mineral Information System (GMIS) strategy to domesticate the Africa Mining Vision at a country level; and

3. Organization of other meetings and participation in special sessions related to the implementation of the GMIS Strategy

These activities dealt with presentations from initiatives such as the PanAfGeo, OneGeology and others, which are part of the GMIS Functional Structure, introduce the GMIS Strategy to a wider geoscientific audience, provide the large number of African participants information about the Africa Mining Vision (AMV), Country Mining Vision (CMV) and the GMIS Strategy, and engage with Geological Survey Organizations Directors, Leaders of Scientific institutions and project initiatives in the GMIS Strategy.

Based on its mandate the African Minerals Development Center (AMDC) encourges African young geologists to present their research results in geological congresses, participate in workshops etc by provideng full sponsorship. The GMIS Special Symposium organizers invited geologists engaged in GMI programs in Africa and elsewhere to contribute their share and exchange ideas. Among the number of applicants, thirteen African geologists were selected based on the evaluation of their submitted abstracts. The selection of the candidates was made by the AMDC in cooperation with the President of the Geological Society of Africa (GSAf). Oral and poster presentations were made by the sponsored candidates at the GMIS special symposium held during the IGC35 Congress in Cape Town, South Africa. In addition the candidates also got a chance to participate at the International Congress and network with their peers and other earth scientists who came from different parts of the world. The aim was to introduce them to the ideas documented in the Africa Mining Vision and act as an AMV, CMV and GMIS Strategy ambassadors in their respective countries and regions in the years to come.

Kojo Busia

Officer-in-Charge/Coordinator, a.i.
Special Inititives Division/African Minerals Development Center (AMDC)
United Nations Economic Commission for Africa (UNECA)

THE GMIS SPECIAL SYMPOSIUM

The special symposium entitled **"Geology and Mineral Information System (GMIS) Strategy to Domesticate the Africa Mining Vision at a Country Level"** was convened by Kaiser de Souza and Aberra Mogessie of the AMDC, during the International Geological Congress(IGC35) in Cape Town, South Africa, August 2016. The panelists were:

Kaiser De Souza (AMDC): The Geology and Mineral Information System (GMIS) Strategy to implement the Africa Mining Vision

Frank Dixon Mugyenyi (AUC): The Africa Mining Vision and its implementation on a country level using the Country Mining Vision Guidelines (CMV)

Nguno (AMDC): The Functions of the OAGS as member of the GMIS Strategy's Coordination Committee

Daisy Leoncio (AMDC): Communication Strategy of the AMDC

The selected African young geologists who made oral/or poster presentations were:

1. **Lopang Maphale** (South Africa): Towards geospatial information partnerships within the Southern African Customs Union
2. **Eckardt D. F** (South Africa): Using Global Datasets in Local Geomorphic applications: Examples from southern Africa and Makgadikgadi, Botswana
3. **Mudimbu D. and Meck, M.L** (Zimbabwe): Spatial relationships between contaminated mining areas and pathological states around Kadoma, Zimbabwe
4. **Alfredo M. Pontavida** (Mozambique): The application of historical geological and airborne data on Mining Industry-case of coal sector in Mozambique
5. **Rosemary Okla** (Ghana): Importance of Geographic Information Systems (GIS) in mapping the spatial distribution, uses and impacts of neglected development minerals: Case studies in some administrative districts near Accra, Ghana
6. **Ishmael Khalema** (Lesotho): Geoscience Data in Africa
7. **Skalente M. Zoubir** (Morocco): Geoscience Information and data about Geological Survey in Morocco.
8. **Mary Odukoya** (Nigeria): Geochemical Assessment of soil, sediments and water within and around Artisanal mine sites in Southwestern Nigeria
9. **Abdoul Aziz Ndiaye** (Senegal): Real options to value a mining project under 2 uncertainties: A quantitative model for revenue share and mining fiscality.
10. **Winfrida Mtega** (Tanzania): Demographic labour productivity and challenges of mineral wealth to artisanal mining in Lake Victoria mining region, Northern Tanzania.
11. **Mugisho Espoir** (DRC): Geological Control of Au-Cu mineralization in the Neoproterozoic Itombwe formations of Kaziba, South Kivu (D.R. Congo).
12. **Edward Kipkoech** (Kenya): The future of groundwater resources mapping using structural geology for subsurface characterization: A case study of groundwater in Turkana County, Kenya
13. **Yvonne Chasuka Mwalwenje** (Malawi): Geoscience Education in Malawi: The Case of Geography in Secondary Schools.

These geologists were requested to prepare and submit manuscripts based on their abstracts to be published by the AMDC as a Special GMIS Symposium Proceedings. Most of them accepted the call and submitted manuscripts. Among the participants, one did not submit and another one had to be

rejected after the review process. The manuscripts are compiled and reviewed by Aberra Mogessie and Kaiser de Souza, and published by the AMDC in this volume. It is important to note that for most of the authors it was their first time to submit a paper that has to go through an internal review process. As the aim of this publication was to encourage and mentor young African geologists to write manuscripts for publications, we feel we have achieved our objectives. It is important to note that the respective authors are responsible for the accuracy of the data and citation of references and use of figures. The editors of this GMIS proceedings volume thank Gabi Schneider and Marko Komac for facilitating the organization of the Symposium under the Special Theme **"Public Sector Geoscience and Geological Surveys"** of the IGC35.

Kaiser Goncalves de Souza and Aberra Mogessie

African Minerals Development Centre - AMDC

United Nations Economic Commission for Africa – UNECA, Addis Ababa, Ethiopia

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GEOLOGY AND MINERAL INFORMATION SYSTEMS STRATEGY (GMIS)

Kaiser Goncalves de Souza and Aberra Mogessie
African Minerals Development Centre – AMDC/UNECA
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INTRODUCTION

The Geology and Mineral Information Systems "GMIS" consists of Geological Survey Organizations (GSOs), universities, and other national and sub-national agencies with geological functions, the private sector and civil society groups that generate, hold or use geological information, along with Regional Economic Communities (RECs), centres of excellence and other international institutions and initiatives that undertake or support the generation, management or sharing of geological information. Together these entities, their activities and their data form a system.

The **GMIS** Strategy is proposed by the African Mineral Development Centre (AMDC) to facilitate the strengthening of the African production, management and dissemination of geological and mineral information (GMI) in connection with the implementation of the African Mining Vision (AMV) and the domestication of the Country Mining Vision (CMV).

The AMV is a strategy for integrating Africa's mining sector into its broader social and economic development processes. For GMIS, the AMV represents a shift from geological information just for mining development to geological information, which supports broad-based sustainable growth and socio-economic development.

The AMDC was established to support the coordination and implementation of the AMV. It is to become the facilitator of choice to enable AU member States to achieve the AMV.

The CMV Guidebook is especially important as it identifies the AMV goal for GMIS as being "improved geological and mining information systems to underpin investment in exploration and mine development". It sets out the 'problem statement' by noting that Africa lacks sufficient geological map coverage and that Geological Survey Organisations (GSOs), which are the custodians of geological information, are underfunded and poorly resourced. A large proportion of the continent remains unmapped and under surveyed in a systematic manner, at appropriate scales.

The problem statement serves as an important reference for the AMDC and a reference that will be used to guide the development of the GMIS Strategy, including:

(a). Wsustainable and adequate funding of GSOs as well as other geology related institutions such as universities;

(b). improvements in the acquisition and storage of geological information;

(c). the efficient coordination of government geology related activities; and,

(d). the coordination of international initiatives and institutions and their geology related activities.

As such, the goal of all AMV compliant geological initiatives, projects, activities and strategies is "to improve geological and geospatial information and its use in mining and broad development processes in Africa".

GEOLOGICAL AMD MINERAL INFORMATION FOR MINING AND BROAD-BASED DEVELOPMENT IN AFRICA

In Africa geological and mineral information has been dominated by minerals and mining related initiatives, yet geological information has a universal value and is crucial for several other important legal, economic, social and environmental applications. As the goal of all AMV compliant geological initiatives, projects and activities is to improve geological and geospatial information and its use in mining and broad development processes in Africa, different types and applications of GMI should be taken into consideration.

The geological and mineral information is essential for improving transparency of the mining sector. It allows operating in such a way that it is easy for others to see what actions are performed and serve as a marketing window for potential mineral resources of the country. It has an impact on the entire minerals value chain for example the level and types of capital to invest in, the inputs required and the outputs produced. Geological knowledge and information are necessary conditions for African countries to exercise governance over their mineral wealth. It is essential for:

a). Improving the elaboration and the application of policies, regulations and fiscal regimes for mining activities;

b). Providing better decision-making options and improving management capacity of mineral resources and mining sector activities;

c). Better assess the potential of mining projects and designing optimal tenders with the real value of mineral resources;

d). Facilitating price discovery for governments and supporting decision-making in contract negotiations through information on quality and quantity of ores in the subsoil.

e). Providing governments with better options for concession of exploration and mining permits;

f). Establishing judicious taxation rates and ensuring that countries receive a fair share of the mineral related revenues.

g). Allowing a better assessment of environmental impact and sustainability of mining projects and activities;

h). Monitoring licenses of contracts and following up mineral exploration and exploitation projects and activities;

Geological and mineral information is essential to enable African geological institutions to deal with mineral resources in a sovereign manner. In addition, it also reduces the risks for investors and should therefore alleviate investor tendencies to require very favourable tax regimes.

Knowledge of the full extent of the quantity and quality of mineral resources is also a tool for conflict management and confidence building between bordering states.

Geological and mineral information is useful not only for traditional large scale mining projects, which attract the greatest attention from policy makers and investors due to their very high commodity value, but also for assessing industrial minerals, which have low value but very high linkage potential, including:

- agro-minerals to improve agricultural development in Africa that can be used for soil rehabilitation and fertilizers, such as carbonates, potassium and phosphorite;
- minerals that can support African industrialisation as inputs into the manufacturing of cement, ceramics, glass, paints, toothpaste, and many other products;
- aggregate and other materials for construction and infrastructure development in Africa, such as sand and gravels.

It is also critical to support, improve and follow up artisanal and small-scale mining (ASM) activities and to help them to be integrated into local and regional economic development and land-use plans and strategies.

Geological information is also vital for identifying underground water resources and planning for its use and management. It is essential for identifying natural hazards of geological origin, their monitoring and the mitigation of their impacts, such as landslides and rockfalls, collapses, slumps, erosion, sedimentation, earthquakes, natural emissions of hazardous gases, land motion and subsidence, shrinking and swelling clays among others. It is also of great value to highlight characteristics of the ground when planning and performing infrastructure works such as dams, ports, roads, pipelines, transmission lines, bridges, viaducts, roads, development corridors (DCs), etc. Beyond these applications, there are opportunities for geo-heritage for example, through museums and other special institutions, and the development of geo-tourism related to volcanoes, hot pools, spectacular rift landscapes and other geological features. Through it we can make the correct use and occupation of urban and rural land, sustainable urban development and safe construction. It is also important for agriculture. Beyond the identification of areas with potential for agro-minerals, it makes possible the location of favourable areas for different types of agricultural activities. Above all, the geological information is critical for environmental impact assessment and management, as well as for waste management and disposal.

The availability of geological information allows the public and private sectors to take appropriate decisions. The more accessible is that information, lower is the risk of investment in mineral exploration and development and greater is the possibility of its use in areas of social and environmental interest, including territorial planning and management.

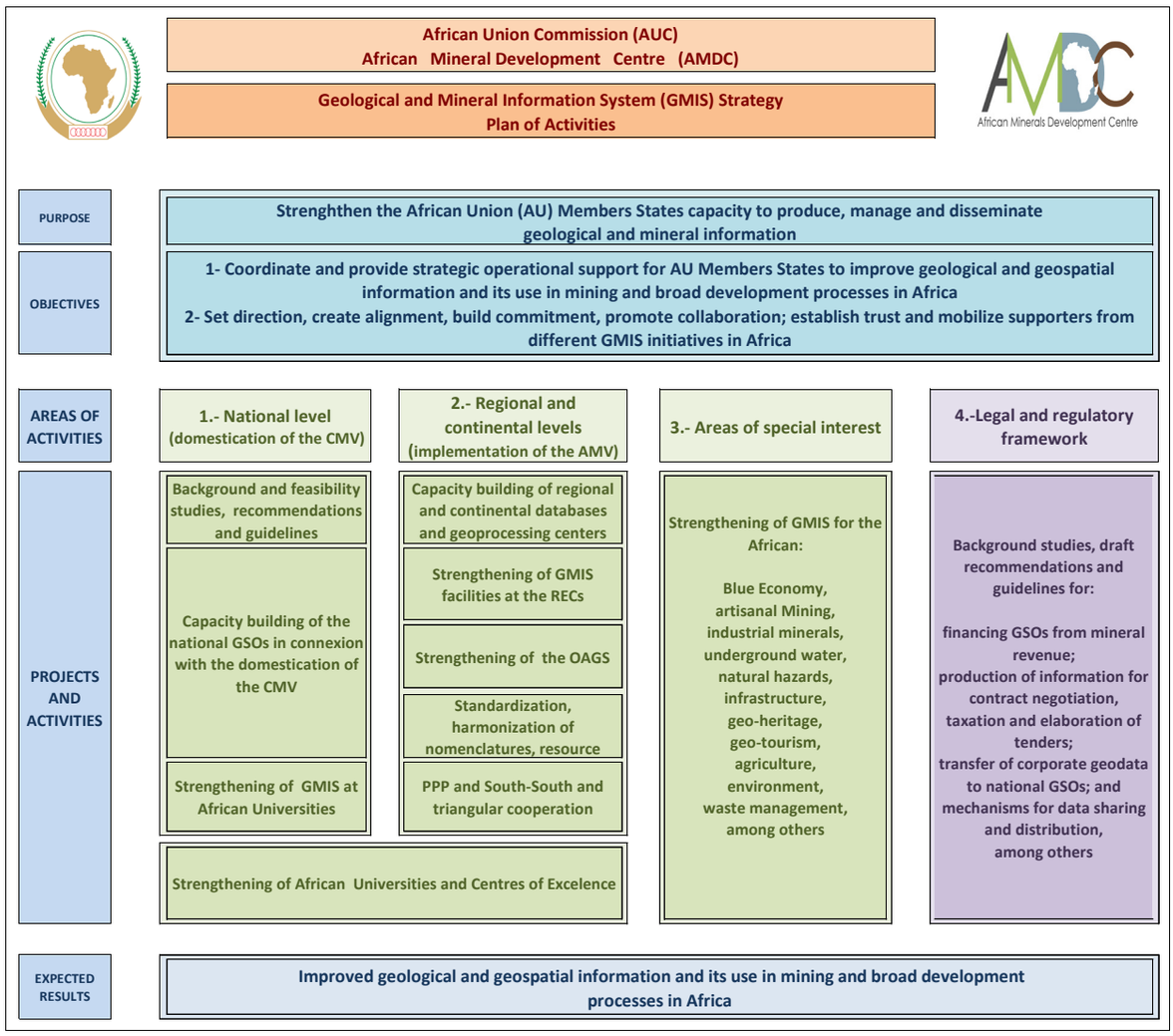
THE GMIS STRATEGY STRUCTURE

The GMIS Strategy is expected to serve as a guide for the AMDC to provide strategic operational support for AU Member States and their Geological Survey Organizations (GSOs) and centres of excellence to improve GMIS, which will encourage investment across the whole Mineral Value Chain, facilitate price discovery for governments, support decision-making in contract negotiation and mining development and facilitate broad development processes.

The GMIS Strategy sees geological and geospatial information as crucial for several important legal, economic, social and environmental applications in mining and broad development processes in Africa. It is planned to coordinate, set direction, create alignment, build commitment, promote collaboration, establish trust, mobilize supporters, and facilitate activities from different GMIS initiatives in the continent.

The Strategy has a general Plan of Activity, to be coordinated in cooperation between the AMDC, its partners and the different African GMIS initiatives. It covers all the areas and activities related to the AMV and the CMV (see table below).

The Plan of activities was designed to allow the permanent and efficient planning, validation, implementation, monitoring, evaluation and updating of its projects and activities at national, regional and continental levels, as well as in areas of special interest. Specific projects and activities may be proposed by the AMDC, its partners and African GMIS initiatives and should be validated by the GMIS Coordination Committee. When validated, projects and activities will become an integral part of the Plan of activities and will be presented as an annex of the GMIS Strategy.



At the national level, activities are proposed to be developed in connection with the AU member States engagement in the domestication of the CMV. This includes both the identification of gaps and areas of need in the member States capability to produce, manage and disseminate GMI, and the assessment of expertise and information resources from a broad range of local and international partners. This takes into account the countries needs of geological and geospatial information to support legal, economic, social and environmental improvement in mining and broad development processes. This also considers the functions of GSOs, universities and other institutions as well as the issues of funding, capacity retention and arrangements of earth sciences functions across government.

At the national level, activities are proposed to be developed in connection with the AU member States engagement in the domestication of the CMV. This includes both the identification of gaps and areas of need in the member States capability to produce, manage and disseminate GMI, and the assessment of expertise and information resources from a broad range of local and international partners. This takes into account the countries needs of geological and geospatial information to support legal, economic, social and environmental improvement in mining and broad development processes. This also considers the functions of GSOs, universities and other institutions as well as the issues of funding, capacity retention and arrangements of earth sciences functions across government.

At regional and continental levels, the GMIS Strategy proposes to guide AMDC and its partners, including the different GMIS initiatives in Africa to support projects, which will facilitate the strengthening of GMIS centres of excellence. This includes the development of Public and Private

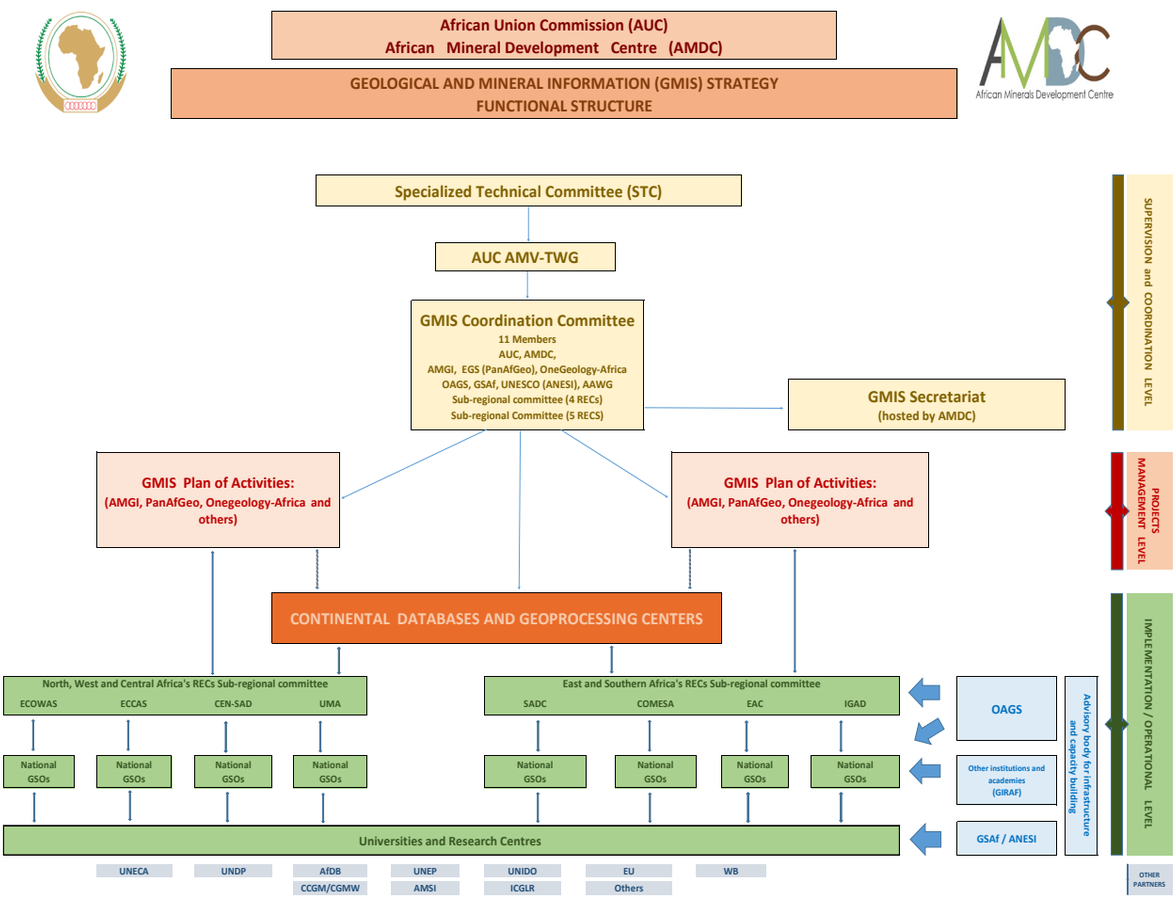
Partnership (PPP), South-South and triangular cooperation, as well as regional and continental data standardization, harmonization of nomenclatures and resource classification.

In areas of special interest, such as the African Blue Economy, the GMIS Strategy aims to support activities and projects related to the delimitation of the African outer continental shelf and the prospecting, exploration and exploitation of marine mineral resources from the African continental shelf and adjacent oceanic areas. Another area of special interest supported by the GMIS Strategy is the artisanal and small mining (ASM), which has high linkage potential to develop agro-minerals, minerals that support industrialization and materials used for construction and infrastructure improvement.

The Plan of Activities takes also into consideration the preparation of legal and regulatory guidelines and recommendations to strengthen African Member States capacity to produce, manage and disseminate GMI and proposes principles for GMIS projects, activities and initiatives in Africa to be aligned and consistent with the AMV and the CMV.

Besides these, the Plan of Activities aims to facilitate training and capacity building and identify mechanisms to finance the production, management and dissemination of GMI by African GSOs, Centres of Excellence and Universities. It also proposes a communication strategy to enable informed participation, promote effective partner's engagement and foster ownership by all partners.

The GMIS Strategy proposes a Functional Structure (see organogram below), which will facilitate joint coordination, provide sustainability and enable regular exchanges between all the partners involved in the implementation of its Plan of Activities. The Functional Structure is a mechanism to support a natural build-up of institutional understanding, which is essential to communicate, revalidate and monitor changing political priorities in GMISs.



The Functional Structure is organized in such a way that it allows permanent and efficient planning, validation, implementation, monitoring, evaluation and updating of its specific activities and projects. It takes into consideration a permanent assessment of issues contained in different documents related to the AMV, as well as consultations with GMIS partners and initiatives in Africa and other continents. It takes also into consideration the feedback and recommendations from related conferences, workshops and meetings, such as the AUC Technical Working Group and the AMDC Technical Committee Meetings (AUC, AfDB, UNDP, UNECA), which provide visibility and transparency of the Strategy.

FINAL CONSIDERATIONS

It is expected that the GMIS Strategy will promote the development of Spatial Data Infrastructure (SDI) among African countries as a tool for GMIS management; provide open access and facilitate data sharing and distribution across various levels of users, including private sector and government agencies; increase regional and national mapping and exploration activities; and support the development of continent-wide mineral inventory.

The sustainability of the GMIS Strategy is significantly anchored on its ability to build, manage and maintain partnerships. Dialogue is the method used to build the AMDC's GMIS Strategy with the final goal of having optimal outcomes from all partners involved in its implementation with the commitment of improving geological and geospatial information and its use in mining and broad development processes in Africa.

FUNCTIONS OF THE ORGANIZATION OF THE AFRICAN GEOLOGICAL SURVEYS (OAGS) AS A MEMBER OF THE GEOLOGICAL AND MINERAL INFORMATION SYSTEM (GMIS) STRATEGY COORDINATION COMMITTEE INFRASTRUCTURE

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INTRODUCTION

The Organization of African Geological Surveys (OAGS) was established in 2007 as an initiative of the New Partnership for Africa's Development (NEPAD) through the African Mining Partnership (AMP). The AMP with all its sub-structures and associated entities was subsequently fully incorporated into the structures of the African Union (AU).

The mandate of the Organization of African Geological Surveys (OAGS) is to foster and sustain geoscience programs and excellence on the African continent in the quest for socio-economic development and poverty alleviation, with special reference to mineral resource assessment, sustainable land use and development, hazard mitigation and environmental protection.

OAGS VISION

The vision of the OAGS is "to be a leader in supporting the Geological Surveys in Africa through provision of information, capacity-building and technology transfer". Its mission is "to provide comprehensive information, support and capacity building to Geological Surveys across Africa. It assists member countries in their development through the establishment of information sources and means of technology transfer for their own use and for the attraction of investment and the establishment of greater public and governmental understanding of the strategic importance and contributions of Geological Surveys."

GOVERNANCE OF THE OAGS

By the fourth quarter of 2016, the OAGS had 41 active member countries participating in meetings, forums and other OAGS related activities. Figure 1 illustrates the OAGS governance organogram. The OAGS governance consists of the General Assembly and the Executive Committee comprises the President, 5 regional Vice-Presidents and the Executive Secretary.

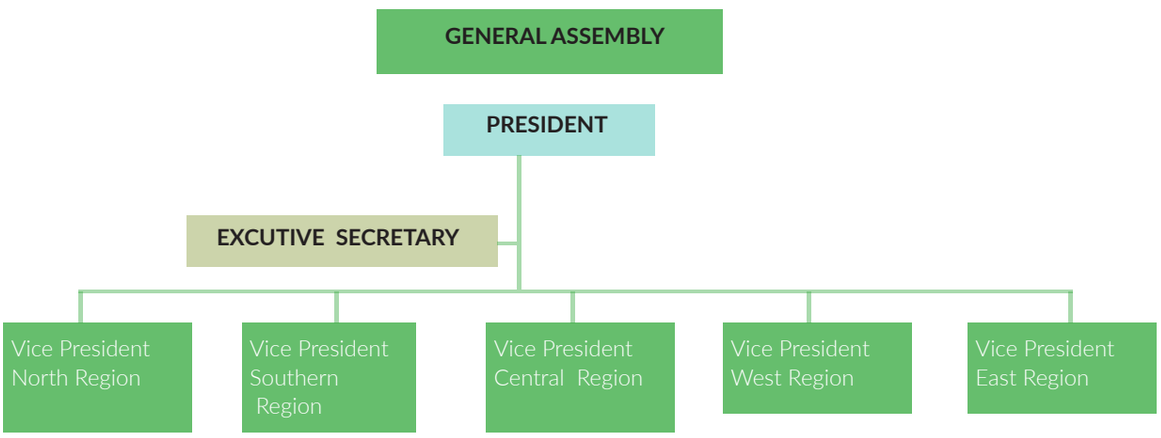


Fig. 1: OAGS Governance

FUNCTIONS AND CHALLENGES OF THE OAGS

OAGS is committed to improving the geoscience resources knowledge infrastructure on the African continent; however, there are many challenges to be addressed and overcome before the organization can fully attain its mandate and mission. The operational structural issues faced by the OAGS are mainly influenced by Geological Surveys on a national level and include - but are not restricted - to the following key subjects:

- ✓ limited communication capabilities
- ✓ limitations in human resources
- ✓ inadequate financial resource

The tasks of a Geological Survey require skilled personnel and specialized technical tools, which several of the OAGS members do not have. Furthermore, there is a lack of consistency in the acquisition, management and sharing of geoscientific data to promote exploration and development of minerals and fuels, the understanding and managing the causes of geological hazards as well as in dealing with the protection of groundwater by the member states.

During the year 2016, the Organization of African Geological Surveys (OAGS) has updated its 2009 strategy document by taking into consideration key trends that will shape its future. The OAGS has five main strategic objectives, i.e.

1). capacity and capability of Geological Surveys in Africa
2). knowledge management and information exchange
3). resource mobilization and sustainability
4). advocacy, advisory and active stakeholder engagement and
5). monitoring and evaluation of OAGS activities (OAGS strategy document, 2016)

STRATEGIC OBJECTIVES

Figure 2 illustrates the OAGS strategic objectives and their respective initiatives. These strategic objectives are defined to ensure the realization of the OAGS mandate. Furthermore, as an affiliated entity to the AU, the OAGS strategy is contributing to some of the aspirations of Agenda 2063 (Agenda 2063, 2015); it also supports the programs and objectives of the African Mining Vision (AMV; Africa Mining Vision, 2009) and the Geological and Mineral Information System (GMIS) Strategy.

The Geological and Mineral Information System (GMIS) Strategy was established by the African Mineral Development Centre (AMDC) in order to facilitate the strengthening of the African Union (AU) member states and their Geological Survey Organizations (GSOs) in the production, management and dissemination of geological and mineral information (de Souza, K. and Mogessie. A., 2016).

The GMIS Strategy consists of a well-defined Functional Structure designed to facilitate the joint coordination of GMIS activities and initiatives in Africa. The Functional Structure of the GMIS Strategy consists of the following interactive levels:

- ✓ Supervision and Coordination
- ✓ Project Management
- ✓ Implementation / Operational

STRATEGIC OBJECTIVES	STRATEGIC INITIATIVES
1 Capacity and Capability of Geological Surveys in Africa	Advancing the Training of African Geoscientists
2 Knowledge Management and Information Exchange	• Collaboration in the creation of regional and continent-wide promotional maps, documents and publications that inform decision-makers in government and industry o matters relating to the applied geosciences • Sharing knowledge and expertise in geosciences, technologies, management and opportunities
3 Resource Mobilization and Sustainability	Ensuring the financial sustainability of the organisation
4 Advocacy, Advisory and Active Stakeholder Engagement	Jointly addressing African geoscience issues of common interest and promoting the contribution of geosciences to African Affairs
5 Monitoring and Evaluation of OAGS Activities	Developing Monitoring and evaluation framework to track progress of activities

Fig. 2: Strategic objectives and initiatives of the OAGS (Source: OAGS strategy document, 2016)

The GMIS Strategy looks at existing stakeholders, organizations, projects and initiatives, with the aim to build synergetic partnerships at the three above-mentioned interactive levels. In relation to the GMIS Strategy Functional Structure, the OAGS will be involved at all the three interactive levels as follows:

- SUPERVISION AND COORDINATION LEVEL:
  - As a member of the African Union Commission - Africa Mining Vision Technical Working Group (AUC-AMV-Technical Working Group (TWG) and
  - GMIS Coordination Committee
- PROJECT MANAGEMENT LEVEL:
  - As one of the project coordinator for instance, “geological knowledge and skills in African Geological Surveys-Pan-African Project (PanAfGeo project - Organization of African Geological Surveys (OAGS) and EuroGeoSurveys (EGS) Partnership project)

- IMPLEMENTATION/OPERATIONAL LEVEL:
  - As an advisory and supporting body for geoscience–related issues and capacity building at national, regional and continental levels

OAGS is considered essential for the implementation of the GMIS Strategy. Consequently, OAGS is amongst the 11 representatives from organizations, initiatives and projects involved in the implementation of the GMIS Strategy and constituting the GMIS coordination committee. The OAGS functions within the GMIS Strategy Coordination Committee include, but are not limited to:

1). providing technical input to the formulation of policies on a continent-wide basis

2). assisting African decision makers to obtain technical advice from the members of OAGS

3). providing a geo-science network between African Geological Surveys

4). providing strong advocacy for geoscience and the value of geological data, information and knowledge continent-wide in order to meet society's demands for natural resources

5). supporting the goal of the GMIS programs by developing a comprehensive knowledge of Africa's mineral endowment

Despite the operational structural issues faced by the OAGS, the body has the capacity to contribute towards realizing the Geological and Mineral Information System (GMIS) Strategy through implementation of its objectives and programs. Recent projects undertaken by the OAGS together with its stakeholders include:

- The role of Geological Surveys in Artisanal and Small-Scale Mining Ghana-Nigeria Experience: OAGS document compiled in 2014.
- OAGS book title "Minerals in our life - A day in the life of Paulus and Paulina" (awaiting publication): this book is aimed at raising awareness of the importance of mineral resources in daily life, by endeavoring to inform the reader about the multitude of mineral resources that go into appliances and other items of everyday use, and hence the importance of mining.
- The Seismo-tectonic Map of Africa: The project was initiated in 2011 by OAGS with the financial support of UNESCO. The first phase of the project has been completed and the map was released to the scientific community at the 35th International Geological Congress in Cape Town, South Africa, 2016. Funds are needed inorder to proceed with the second phase of the project (tittle "Improved Regional Seismo-tectonic Map of Africa: A Key Component for the Seismic Hazard and Risk Assessment') that is undertaken as a collaboration between partners from scientific institutions in Africa and Europe. The project is managed by the Council for Geosciences of South Africa (CGS) in Pretoria and the Institute de Physique du Globe of Strasbourg.
- Geological Knowledge and Skills in African Geological Surveys – Pan-African project – Organization of African Geological Surveys (OAGS) and EuroGeoSurveys (EGS) Partnership (PanAfGeo): A Phase I, three-years continental-scale project entitled 'Geological Knowledge and Skills in African Geological Surveys – PanAfGeo" was launched by the Organisation of African Geological Surveys (OAGS) and EuroGeoSurveys (EGS) during the 35th International Geological Congress, 2016, in Cape Town, South Africa. The crucial objective of PanAfGeo is "to increase African-owned geological knowledge and skills for sustainable mineral exploitation and related infrastructures, natural disaster prevention or mitigation and geoheritage management, by implementing the political commitment to the development of EU-Africa cooperation in this area". PanAfGeo is mainly financed (https://ec.europa.eu/europeaid/sites/devco/files/annex-6-egs-oags_en_0.pdf) by the European Commission's Directorate General for Development and Cooperation (EC DG DEVCO).
- Low-cost surveys for high-technology metals (LoCoSu): - Application of portable field instruments for the mining value chain of high-technology metals in Sub-Saharan Africa (financed by the

Federal Ministry for Education and Research (BMBF), Germany. The LoCoSu project executing Organisation is RWTH Aachen University in collaboration with the University of Namibia, University of Zambia, the Geological Survey of Namibia, and the Organisation of African Geological Surveys. The objectives of the project are:

a). to identify and apply new low-cost approaches to characterize the abundance of strategic metals in Sub-Saharan Africa, and

b). transfer the new knowledge and best practices to current and future mining professionals in Sub-Saharan Africa

- Global-scale geochemical mapping activities on the African continent: OAGS has a councillor on the Governing Board of the International Centre on Global-Scale Geochemistry (ICGG). The OAGS Councillor is responsible for coordinating the global-scale geochemical mapping activities on the African continent through the respective Geological Surveys.

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REAL OPTIONS TO VALUE A MINING PROJECT UNDER TWO UNCERTAINITIES: A QUANTITATIVE MODEL FOR REVENUE SHARE AND MINING FISCALITY

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ABSTRACT

This paper addresses two questions, i) considering two sources of uncertainties on the economic valuation of an open pit gold mining project and ii) evaluating how much the different stakeholders stand to gain from the mining project's revenues.

Geological and technical uncertainties result from gold grades variations inside the deposit and are modelled by geostatistical conditional simulations while financial uncertainties, due to gold spot prices fluctuations are modelled by a geometric brownian motion.

A real option framework was used to consider these two inherent uncertainties and the operating flexibility that is, the possibility for the company to stop mining if the commodity price drops and/or the reserves prove to be lower than that had been envisaged. By this approach, it was possible to envisage scenarios for developing an extension to the main deposit as a function of future values of the commodity prices.

Globally we found that the traditional Discounted Cash Flow (DCF) metrics undervalues the project whilst the Sequential Real Option (SRO) - the metric set up from our real options model - clearly maps and assesses the upside potential and the downside risk of the project. A synthetic case study of a gold mine in West Africa was used to illustrate how this procedure could be applied in practice.

Beyond a better economic evaluation of the project, the purpose is to contribute, by a quantitative approach, to two current problems in the global mining industry: i) determining an equitable split of revenues from mining for all the stakeholders (including the local communities), ii) determining a tool for a conditional mining tax regime (taxes and royalties) when commodity prices are high or low, and when the deposit proves to be richer or poorer than anticipated;

The procedure proposed should provide governments and Non-Governmental Organizations (NGOs) with more objective data for making policy decisions, which is important within the context of a "Social License to Operate".

Keywords: Gold, Open pit, Real Options, Geostatistical simulation, Geometric Brownian Motion.

INTRODUCTION

Low income developing countries, with economies mostly based on mining revenues face problems to fairly assess the value of a mining project and adjust their fiscal taxation policy to many aspects of the project's profitability framework like geological and financial uncertainties. By carefully analyzing the breakdown of the cash flows generated, it was possible to estimate the amounts received by the local community and by the national community (outside the mining area), the taxes and royalties received by the government and the profits made by the mining company.

OBJECTIVES AND METHODOLOGY

This paper has three main objectives:

1. make an overview of economic evaluation techniques of mining projects, highlighting their advantages and drawbacks;
2. propose an application of real options in the economic evaluation of an open pit gold mining project;
3. propose a tool to assess the shares of stakeholders in the mining revenues, which could help States optimize their mining taxation policy.

The methodology used is based on the real options approach. In addition, we considered two sources of uncertainties: geological and financial respectively with gold grades and spot prices as underlying variables.

OVERVIEW OF ECONOMIC EVALUATION TECHNIQUES OF MINING PROJECTS

The practice of valuation in mining projects are mainly based on two kinds of methods:

i). **traditional methods:** are based on Discounted Cash Flows (DCF) techniques which assume that all parameters (reserves, costs, prices ...) are constant over time. The main profitability indicators are Net Present Value, Internal Rate of Return, Payback Period. This approach is a « go-no go » approach. It tells if the project can be started but nothing if expected scenarios doesn't happen, i. e. if prices or reserves change. Other drawbacks could result due to the problem of choosing the right discount rate. To overcome such limitations, the DCF approach is completed by sensitivity study but this is done on "mechanical" and arbitrary variations of key parameters. These facts explain why the DCF approach undervalue a project by ignoring the possible changes that could increase the project value, for example when prices rise. Inversely, the DCF doesn't assess correctly the risk in case of unfavorable change of key parameters in the future.

ii). **numerical methods:** they introduce two main aspects inherent to mineral projects, namely uncertainties and managerial flexibility. Uncertainties are expressed by fluctuations on key parameters like prices for financial aspects and reserves and grades for geological considerations.

These methods are widely based on the Options approach, discussed by Black & Scholes (1973) and Merton (1973) who set the following equations for valuing financial options (Calls and Puts):

$$Call = S_0 * N(d1) - K * \exp(-r\,T) * N(d_2)$$

$$Put = K * \exp(-r\,T) * N(-d_2) - S_0 * N(-d_1)$$

Applications to natural resources (Real Options) had been made by Brennan & Schwartz (1985) on a hypothetical copper mine replicating industry standards. Ndiaye and Armstrong (2013) extended the application to the case of open pit gold mines and added geological uncertainty by the mean of geostatistical conditional simulations of gold grades.

Depending on the kind of decision, a real options model can be built and the suitable mathematical tools could be used to value the project. Two kinds of methods widely used are the Stochastic Partial Differential Equations - SPDE (with the Contingent Claim Analysis and the Stochastic Dynamic Programming, see Dixit and Pindyck (1994)) and the Trees (the Binomial Tree is adopted in this work).

The overview shows that the DCF method doesn't consider the uncertainties in key project parameters. Real Options are desirable in the presence of uncertainty and operational flexibilities (better to base them upon geological features of the deposit). Trees methods are simple and easy to account with geostatistical simulations to combine financial uncertainties with geological ones.

A SIX STEPS MODEL TO APPLY REAL OPTIONS IN MINING PROJECT VALUATIONS

Before applying the model, we built a synthetic open pit gold mine by using the Walker Lake dataset[1] (Figures 1a and b) to obtain gold grades simulating a deposit. Some technical and economic parameters are derived from Kisladag[2] and others are from a compilation of data done by authors on the gold mining sector in West Africa. Finally, the synthetic orebody reproduced realistic values very typical of a mine in this region where several open-pit gold mines have been in operation since the last 10 years. The model is built on six steps to value the real option of the gold mine under two uncertainties (prices of gold and grades of reserves). This allows to assess the shares of Stakeholders which are "STATES", "MINING COMPANIES" and "LOCAL COMMUNITIES".

STEP-1: GEOSTATISTICAL ESTIMATION (MODELIZATION OF GOLD GRADES)

After a transformation on Walker Lake raw data, a geostatistical study had been conducted on gold grades. Kriging and 100 conditional simulations[3] were made. Kriged and simulated gold values on blocs are shown in Figure 1c These simulations are used with the parameters given in table 1 to build the production schedule of the mine and delivers annual mined reserve that will feed the cash flow model.

STEP 2: MODELIZATION OF GOLD PRICES

The Geometric Brownian Motion is the stochastic process chosen to model the average annual gold prices. Figure 2a shows a set of 10 among 120 simulations of annual gold prices over 12 years. The initial price was 800 $/Oz while the implied volatility of 25%/year was computed from ***Société Générale*** gold warrants instead of the historic prices which lead to a too law value of 9%.

Figure 2b presents a tree with an initial price of 800 $/Oz over a 5-year period from year 7 through to year 12. The probabilities of an up-jump and a down-jump are 0.48 and 0.52 respectively. The price changes by a factor of 1.28 in the case of an up-jump, and 0.78 for a down-jump.

STEP 3: BUILDING THE SEQUENTIAL REAL OPTION (SRO) OF THE PROJECT

This step involves two periods:

i). introduction of operational flexibilities

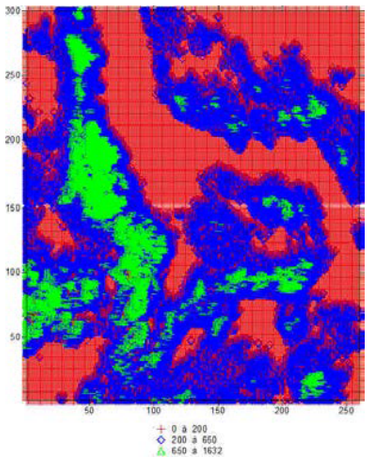
Each project contains a certain number of operational flexibilities, i. e. from the initial schedule, management has several possibilities to adapt to uncertain changes taking place in the future. These flexibilities help to build the real option conform to the project features.

ii). definition of the real options of the project

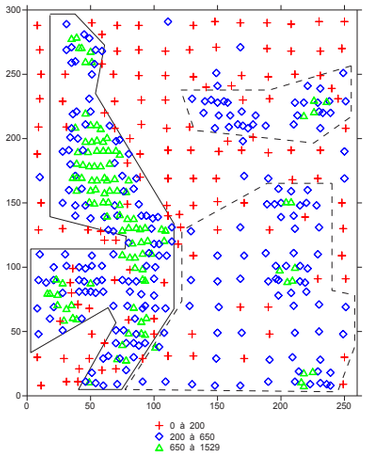
For our case study, we set a Sequential Real Option (SRO) concerning the decision to mine or abandon the eastern part of the deposit. Figure 3 shows the structure of the SRO built from the possibility to separate the deposit into 2 zones. The SRO envisages to:

- Mine the west side in 7 years;
- Have the option « Continue/Abandon » 4 times for years 8, 9, 10 and 11;
- The main deposit will take 7 years to mine; the satellite deposit will take 5 years to mine. Mining on satellite will stop if reserves are not rich enough or if gold price is not high enough.

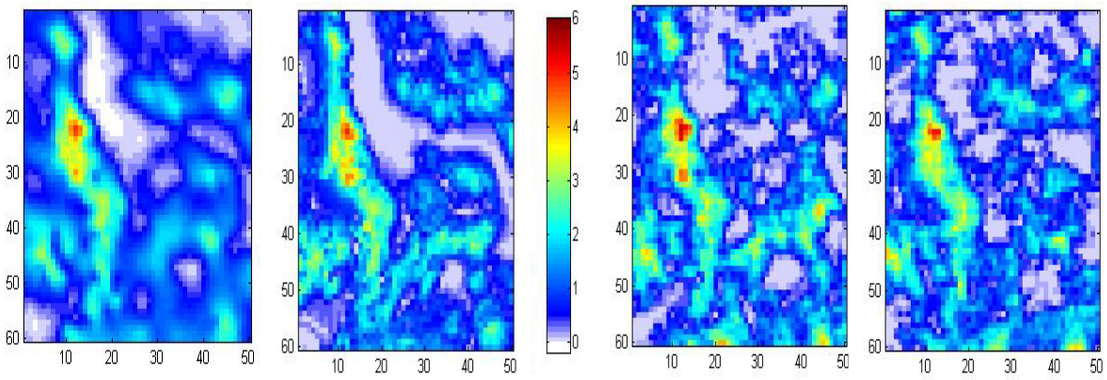
1 The Walker Lake data originally developed by Isaaks and Srivastava (1989) has been widely used by geostatisticians for many years.
2 Gold mine Kisladag of Eldorado Gold in Turkey is taken as reference for mining parameters because detailed feasibility data were available.
3 The Turning Band method was used for the simulations of gold grades.



a-
Mapping the 78 000 data points of Walker Lake



b-
The subset of 470 sampled values (Isaaks & Srivastava (1989)) : mineralized zone in the West and potentials in t



Kriged values | True Values | Simulation N°6 | Simulation N°50

c- spatial distribution of gold grades kriged and simulated over blocs;

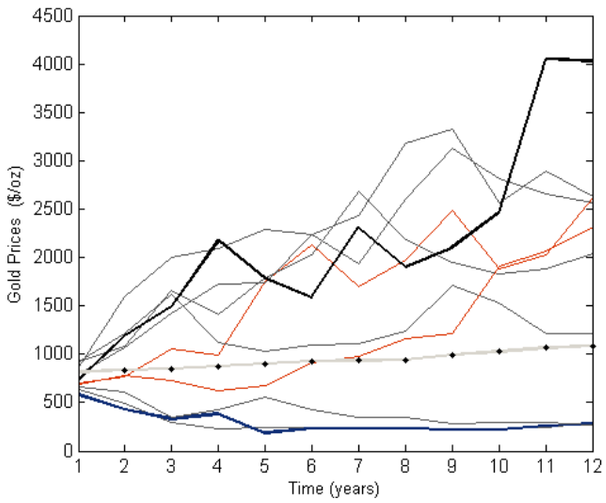
Figure 1: Presentation of raw data and their transformation to kriged and transformed Au grades.

Note the smoothing effect of kriging which cause under-estimation of variability and then of project economics.

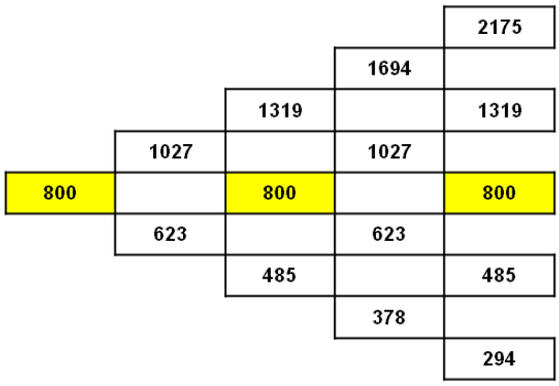
Table 1 Technical Parameters of the synthetic gold mine based on Walker Lake data (Isaac & Srivastava, 1989) and West African parameters (Reference Year is 2012).

Deposit Parameters	Units	Kisladag	Base Case
Mine class (size)		large	large
Resources	MT	214.8	211
Grade	g/T	1.04	1.03
Reserves	MT	135.02	165
Cut off grade	g/T	0.35 (oxides) 0.50 (sulphides)	0.4
Grade above cut-off	g/T	1.16	1.26

Mining Parameters	Units	Kisladag	Base Case
Life of Mine	years	15	15
Mined (ore extracted)	MT/year	16	14
Mill (ore to heap leach)	MT/year	9	11
Recovery from Heap Leach	%	64	64
Metal Recovered	Moz	3.310	4.271



a- *Simulation processes is a Geometric Brownian Motion:* $dS_t = \mu S_t dt + \sigma S_t dz$



b- *Tree calculation parameters: initial gold price is 800 $/Oz; Implied Volatility (from Gold Warrants) is 25% / Year;*

Figure 2: Modelled Gold average annual prices and discretized by a binomial tree.

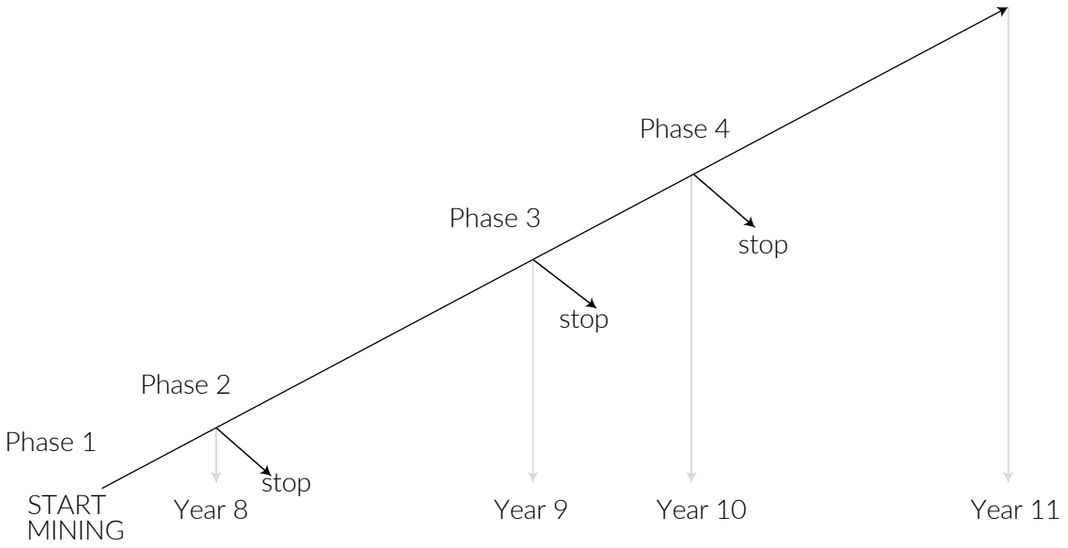


Figure 3: Structure of the Sequential Real Option (SRO): 4 steps of decision.

STEP 4: VALUING THE REAL OPTION OF THE PROJECT

The Real Options valuation procedure needs, like the DCF approach, the value of cash flows at each time-period (here one year). So, a cash flow model must be set using reserves, prices and production parameters defined for the Base Case in table 1.

CASH FLOWS MODEL: BREAKDOWN OF COSTS

The cash flow model is based on some assumptions concerning the production schedule. We also assumed that initial investment was paid for by the main mine. The following cash flow model is then used to focus on the intrinsic economic value of the project:

Revenue	= Gold Price X Gold Recovered
Operating costs	= Mining + Processing + Salaries + General & Administrative costs (G&A)
Cash Flow before tax	= Revenue – Royalties – Operation costs
Cash Flow after tax	= Cash Flow before tax X (1 – tax rate) if Cash Flow > 0

PROJECT VALUATION

The project is valued by the DCF and the Real Options approaches and resulted in the following values:

NO FLEXIBILITY & NO UNCERTAINTY (DCF and Net Present Value)	= 386 M$ with P10 = - 66 M$
REAL OPTIONS METHOD (Sequential Real Option - SRO)	= 510 M$ >> +32% VALUE
REAL OPTION VALUE	= 73,3 M$ (14% of 510 M$)

We see that, by introducing operational flexibility and uncertainties, the real options method increases the value of the project by 32% from 386 to 510 M$. Even better, the P10 risk of 66 M$ obtained from DCF is removed because the real options are exercised only if the cash flows are positive.

ECONOMIC SENSE OF MINING REVENUES

From the historic perspective, a constant fact is the need of African countries to finance their development from natural resources (see Figure 4) as outlined by the Africa Mining Vision (AMV, 2009) guidelines4.

Current analysis on mining risks made by Ernst & Young5 shows that a growing risk in the future remains the access to resources linked to "Resources nationalism" (Figure 5). We can argue that most of the changes on mining laws which will add or increase taxes are much more linked to the need to capture more rents from mining revenues.

WHAT SOLUTION: TAXING OR SHARING? A MAJOR DEBATE?

The efficient solution is optimized mining taxation & sharing of mining rent. There is a need of quantitative tools to optimize the share of states while stabilizing Mining Laws and preserving profitability. In the past years and at present, natural resource discoveries in Africa still feed the debate on «Dutch-Disease» and «Resource Curse». This study aims to develop a quantitative method for evaluating the share of each of the stakeholders, and test it on the context of West Africa. The important questions are:

How to decide the approval of a project?

1. What fiscal policy to adopt?
2. How to do and justify the distribution of revenues and rents?

DEFINITIONS: « STAKEHOLDERS»

Stakeholders are the different groups that are affected by a mining project:

1. mining company: invests the capital required to develop a mine inorder to make a profit;
2. government of a country (the state): earns tax revenue; should provide schools, hospitals, roads, etc.
3. « locals » or « communities »: local government, towns nearby, employees of mining company, senior management (maybe fly-in fly-out), workforce (live nearby) and residents.

ASSESSING THE STAKEHOLDERS´SHARES

We first need to define the way to calculate the share of each stakeholder. The following procedure is followed to assess the shares of the Stakeholders: asses value of net cash flows (the amounts to be shared) and calculate the shares for each Stakeholder (first in % from kriged values and second in probability from simulations).

SPLITTING THE NET CASH FLOWS

The Sabodala gold mine in Senegal was used as a case study. To determine the repartition of net CF considered as the benefits to be shared, we need to know how many workers would be required on a mine like this. O'Hara & Suboleski (1992) developed a method for estimating the number of employees and based on this model we documented 515 persons. The Mine has 1800 employees whereby 62 are expatriates, 453 skilled personnel & 1285 unskilled workers. We assumed the same proportions and came up with the following: 18 expatriates, 130 skilled and 367 unskilled persons. Concerning wages, the current monthly wages in West Africa are estimated at $12000, $2600 and $1000 respectively.

4 see www.africaminingvision.org
5 see www.ey.com/us/en/mining---metals

Figure 6 shows the nodes in the tree corresponding to the scenario where the SRO is exercised, depending on price values and time. In such a project, the SRO is exercised 8 times over 15 possibilities. At each node, we see the shares for the Government (aqua), Mining Company (light blue), the National Communities (purple) and Local Community (pink) given the price of gold (the same as on the binomial tree).



Figure 4: Historical evolution of African countries' mineral policies.

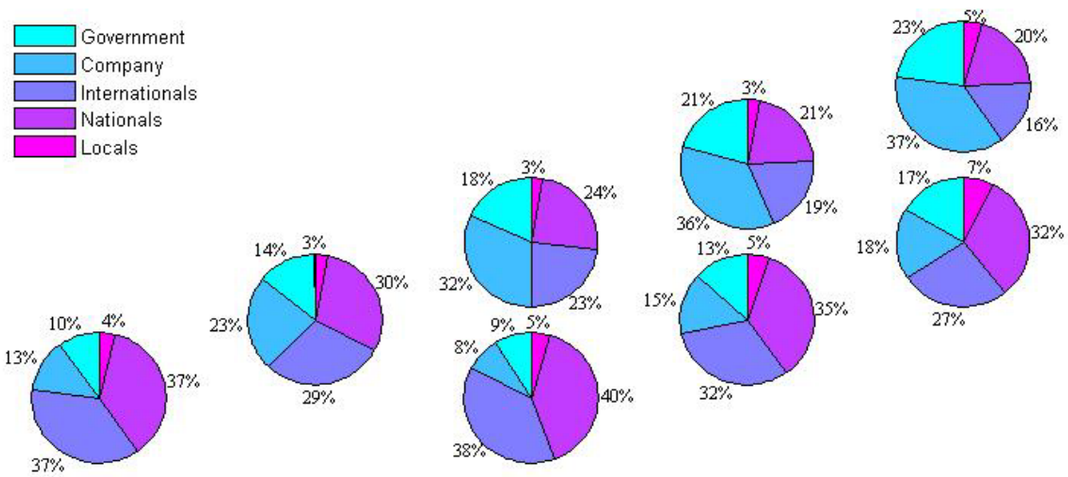


Figure 5: Survey on risks faced by mining sector in 2012. Source: http://www.ey.com

STEP 6: SET PROBABILITIES OF REVENUES BY STAKEHOLDER AND BY SCENARIO

This is another possibility to apply the model to design a quantitative framework of conditional fiscality.

Thanks to the set of 100 conditional simulations of the deposit, it is possible to model the distribution law of Cash Flows at each node of the tree and then, those of the shares.



Initial Gold price is 800 $/oz.

Figure 6: Distribution of Shares of Stakeholders when SRO is exercised (the project is done).

NB: different initial prices could be tested (going back to S0 in the annual gold prices simulations).

VALUES OF SHARES AT EACH TREE´S NODE

Shares are shown in Figures 7, 8 and 9 as distributions of probabilities respectively for State, Mining Company and Locals (from simulations of gold grades).

In Figures 7, 8 and 9, we see that for a given year, the proportion of Cash Flows earned by the local community is greater when the gold price is lower. Then, the units of the Government and Mining Company are increasing from year 8 to year 12 for the prices of the top line of Figure 8.

The distributions of probabilities in the three last figures show that it is possible for each Stakeholder, to forecast its share in terms of probability given a threshold corresponding to its expectation of revenue from the project.

On the first lines of each cell are given successively the gold price (in blue and $ / Oz) and average net cash flow ($ millions).

On the second line are given the types and parameters of the probability distribution laws (in red in the graphic) adjusted on distributions (blue) of Cash Flows obtained from 100 geostatistical simulations of the deposit.

The 95% confidence intervals appear dashed.

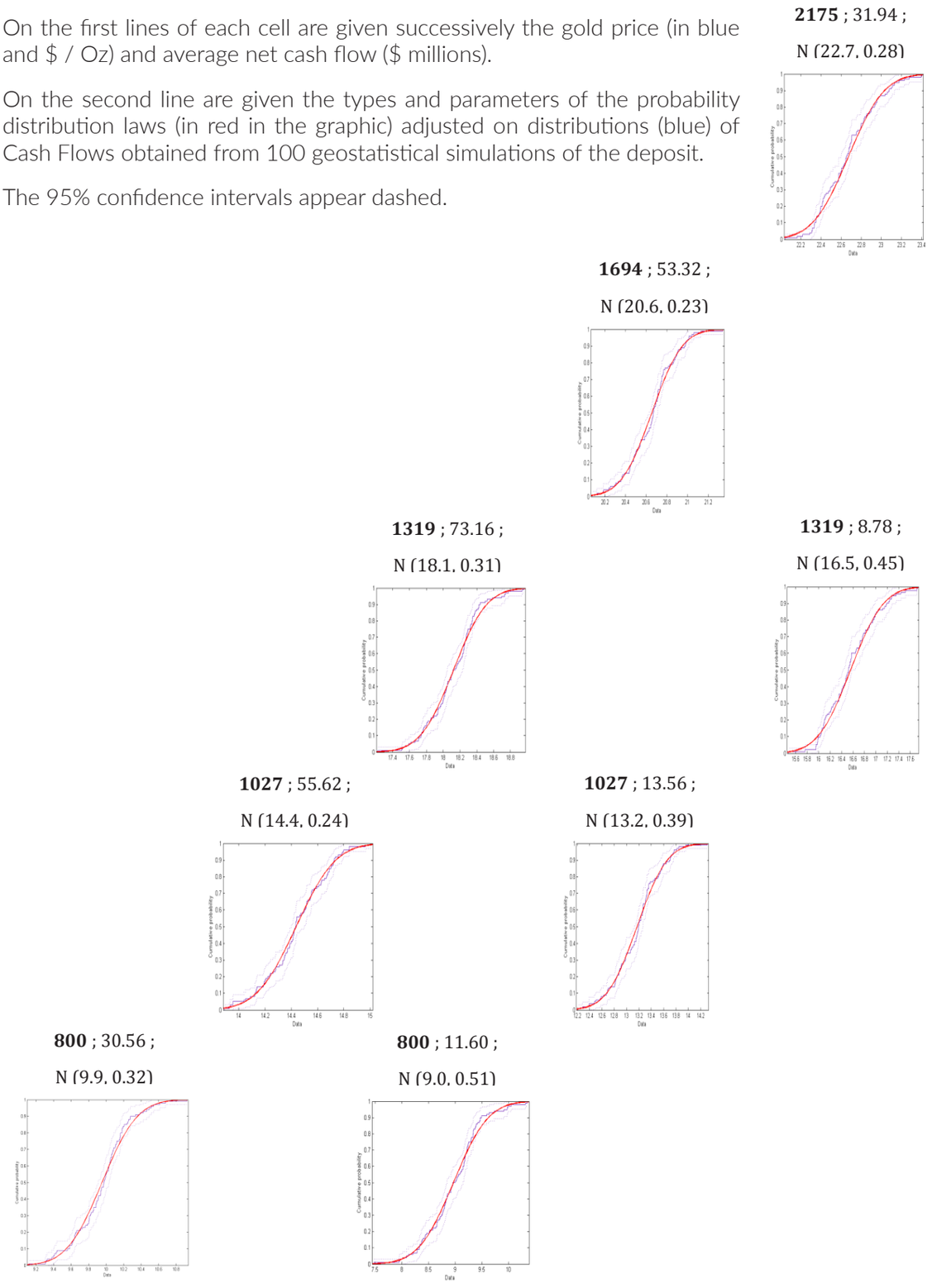


Figure 7: Probability laws of shares for the State at the nodes where the SRO is exercised.

On the first lines of each cell are given successively the gold price (in blue and $ / Oz) and average net cash flow ($ millions).

On the second line are given the types and parameters of the laws (in red in the graphic) adjusted on distributions (blue) of Cash Flows obtained from 100 geostatistical simulations of the deposit.

The 95% confidence intervals appear dashed.

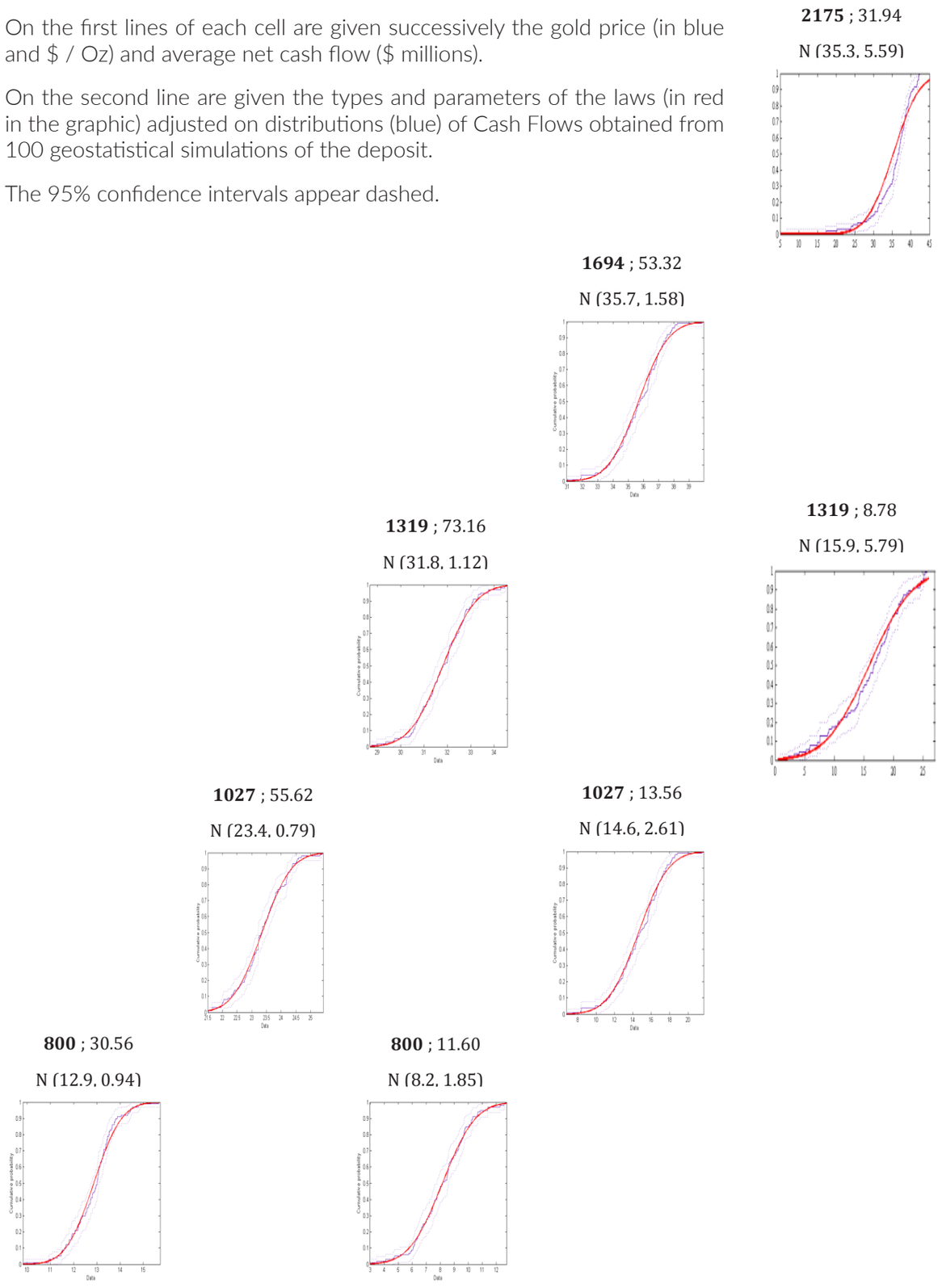


Figure 8: Probability laws of shares for the Mining Company at the nodes where the SRO is exercised.

On the first lines of each cell are given successively the gold price (in blue and $ / Oz) and average net cash flow ($ millions).

On the second line are given the types and parameters of the laws (in red in the graphic) adjusted on distributions (blue) of Cash Flows obtained from 100 geostatistical simulations of the deposit.

The 95% confidence intervals appear dashed.

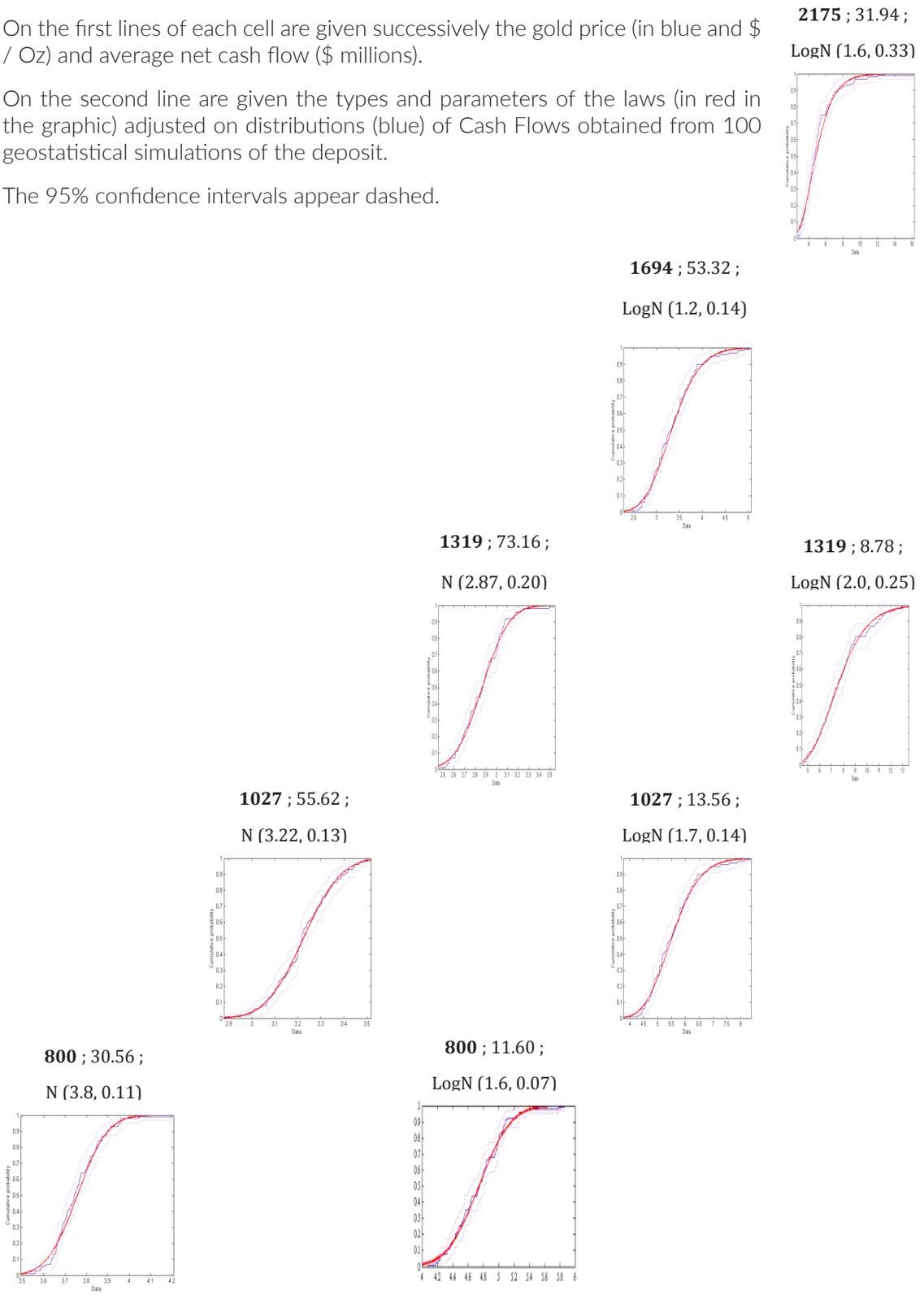


Figure 9: Probability laws of shares for the Locals at the nodes where the SRO is exercised.

GENERAL CONCLUSIONS

The economic value of the whole project is evaluated by a Real Option method combining geological uncertainties (on gold grades) and financial uncertainties (on gold spot prices). A Binomial Tree method was used to evaluate the project`s Sequential Real Option (SRO). The main results of this work are:

1. the Introduction of flexibility and uncertainty in the valuation of a mining project using its geological characteristics;
2. a real options approach to value the mine by combining variations on prices and reserves;
3. a quantitative assessment of shares of each Stakeholder;
4. a possibility to set probabilities on shares and build a contingent tax policy.

CONCLUSION ON THE REAL OPTIONS APPROACH: A NEED OF CHANGE IN THE « ATTITUDES »

The work addressed the question of how much the stakeholders stand to gain from mining a satellite deposit near a larger deposit. When price is low, the local community still benefits from worker's wages and services provided locally. In contrast, government and mining company make much less and might consider abandoning. When gold price is very high, government and mining company stand to gain most; the local community gains the least. As high profits appear in such cases, the government should define rules of taxation in accordance with such events.

This approach can be improved and provides tools to different stakeholders, in particular :

- The "Mining Company", to optimize profitability and profits, must incorporate flexibility and take account of uncertainties on key evaluation parameters impacting profitability and revenues, mainly reserves and prices.

The rule is: the "Mining Company" must optimize Cash Flow Distribution vs. conservative values when doing feasibility studies

- The "State", to optimize its tax policy, must set rates and incentives based on risk measured on key evaluation parameters impacting profitability and tax revenues.

The rule is the "State" must set a conditional taxation vs. automatic or predefined tax rates or tax holidays

- The "Local" and "Communities" should better establish the requirements on the revenues and profits.

The rule is "Communities", NGOs, Civil Society should quantify the benefits from the project vs. CSR expectation or strikes.

CONCLUSION ON THE SENSITIVITY OF THE SRO AND SHARES

The sensitivity analysis shows that the SRO preserves the profitability of the project. SRO is sensitive, at least linearly, to gold prices, volatility and royalties. Our tests show that in such a project, royalty rate should raise 12% without threat on the profitability instead of 3 to 5% widely applied in the African countries.

PERSPECTIVES

The application of real options in mines shall be improved in theory and practice. The DCF approach and NPV are still widely used as standards but most companies know and practice options especially in hedging strategies.

Future research should aim to:

1. Consider other uncertainties like fuel prices, operating costs...;
2. Introduce hedging strategies in the cash flows and SRO models;
3. Enhance geological and geostatistical modeling of reserves;
4. Conform Real Options models to project features;
5. Adjust taxation regimes to project's characteristics.

ACKNOWLEDGEMENTS

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USING GLOBAL DATASETS IN LOCAL GEOMORPHIC APPLICATIONS : EXAMPLES FROM SOUTHERN AFRICA AND MAKGADIKGADI, BOTSWANA

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ABSTRACT

The presentation focused on freely available, global geospatial data sets that are able to deliver appropriate data at the scale of local applications. Particular significance was attached to remotely sensed data, elevation and topographic products with emphasis on geomorphic applications in the southern African domain. The presentation examined its potential and limitation in deciphering surface processes, forms and dynamics with case studies on the Kalahari and Namibia. While the presentation showcased usage of Landsat, SPOT, ASTER, SRTM, GDEM, Icesat and Sentinel data, examples here in this summary and overview will be restricted to Landsat and SRTM data and focus primarily on the landforms and processes associated with the geomorphology and surface rifting and tectonics of the Makgadikgadi basin in Botswana.

INTRODUCTION

The availability of geospatial data is often patchy and limited in coverage due to price, confidentiality or bureaucratic hurdles. Especially geological data has a tendency to be local, national, coarse resolution or fragmented in nature. One of the main limitations in producing global scale geologic data is the need for detailed mapping at ground level. Only recently have we been able to produce African wide soil map (for example Dewitte et al. 2012). At the same time the mapping of vegetation dynamics can be considered routine with numerous online datasets and portals providing information on vegetation state as well as fire. It is precisely the presence of soils and vegetation which covers up much of the geology and obscures lithological and or structural features. There are however free global datasets that have geologic content. In this paper an attempt is made to draw attention to some of these. They include Landsat imagery (Landsat 8, since 2013) and Digital Elevation data (SRTM 1, since 2014).

METHODS

THE LANDSAT AND SCHUTTLE RADAR TOPOGRAPHY MISSION DATA

Landsat data goes back to 1972. The program went from experimental, to becoming operational and briefly turned commercial as outlined by Lauer, et al. (1997). While there have been a number of Landsat-like sensors and products, none match accessibility as provided by the archive at the Global Land Cover Facility, at the University of Maryland, USA which has been an early custodian of global land surface change imagery. The most up to date archive now resides at the US Geological Surveys which features imagery only a few weeks old. It also hosts the Landsat Look Viewer which acts as an image preview tool and features a time slider, basic enhancement settings, and simple export options including the geotif format which allows for accurate spatial placement of small image files within a Geographic Information System (GIS). But first and foremost it acts as the data portal for Landsat 8 imagery around 1TB in size, per scene.

Global elevation or topographic elevation data prior to the SRTM (Shuttle Radar Topography Mission) had a resolution of only 1 to 5 km. SRTM data was made globally available at a resolution of 90m in 2003 and was released in its full 30m resolution 10 years later. Corrected and void filled data is available online at CGIAR-CSI (Consortium for Spatial Information). Other global DEMs derived

from ASTER GDEM data (Advanced Spaceborne Thermal Emission and Reflection Radiometer) are introduced by Tachikawa, et al. (2011) and are also available online. SRTM generally overestimates absolute elevation in southern Africa by approximately 5m, its relative accuracy however is better than 5m (Rodriguez et al. 2004). For additional validation purposes we also compared SRTM elevation data against the ICESat (Ice, Cloud, and land Elevation Satellite) laser altimeter points, which has a much greater absolute vertical accuracy (Schutz et al. 2005). It will be demonstrated that the quality of these two global DEMS (ASTER GDEM and SRTM) varies.

RESULTS

Landsat data is depicted in Figures 1a and b and draws attention to both surface change as well as radiometric fidelity of 16 bit data. Figures 2, 3 and 4 draw attention to the ability for SRTM 1 and 3 data to highlight subtle topographic features not otherwise been mapped or identified previously. In this example here we draw attention to paleo shorelines. Challenges with extracting precise elevation from digital terrain information is illustrated in Figure 5. This is important to consider for example when identifying shoreline features, their elevation and tectonic deformation. Figure 6 quantifies the vertical quality of elevation data for a study area in Botswana. Over and underestimation is most evident when comparing against more precise laser altimetry.

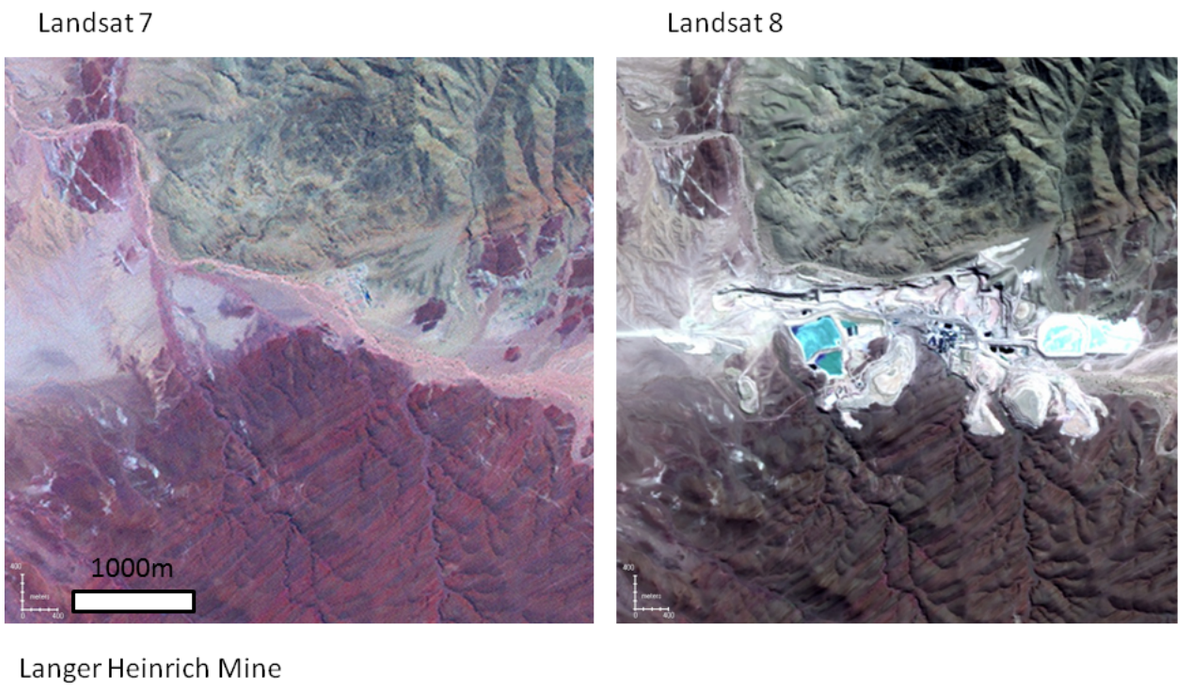


Figure 1a. Landsat Image Examples

Path 179 Row 076, Landsat 7 (2000 April 6th) and Landsat 8 (2013 May 4th) data. In order to achieve maximum contrast and comparability the False Colour Bands 742 (Landsat 7) and 753 (Landsat 8) were selected. Both images were pan sharpened to 15 m. Change depicted features establishment of Langer Heinrich Uranium Mine, Namibia. (Unpublished)

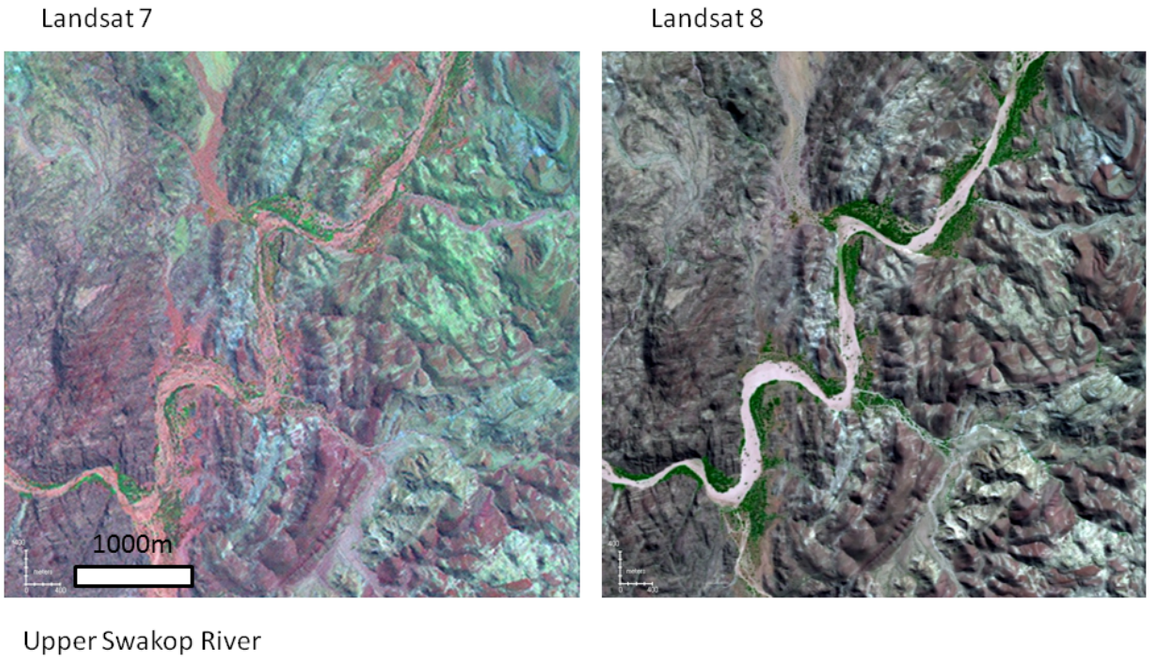


Figure 1b. Landsat Image Examples

Upper Swakop Geology, Landsat 7 (2000 April 6th) and Landsat 8 (2013 May 4th) data.Landsat 7 (8– Bit Data, 255 greyscales) v Landsat 8 (16 – Bit Data, 65,536 greyscales). Note marked difference in contrast and colour depth in Landsat 8 Image. (Unpublished)

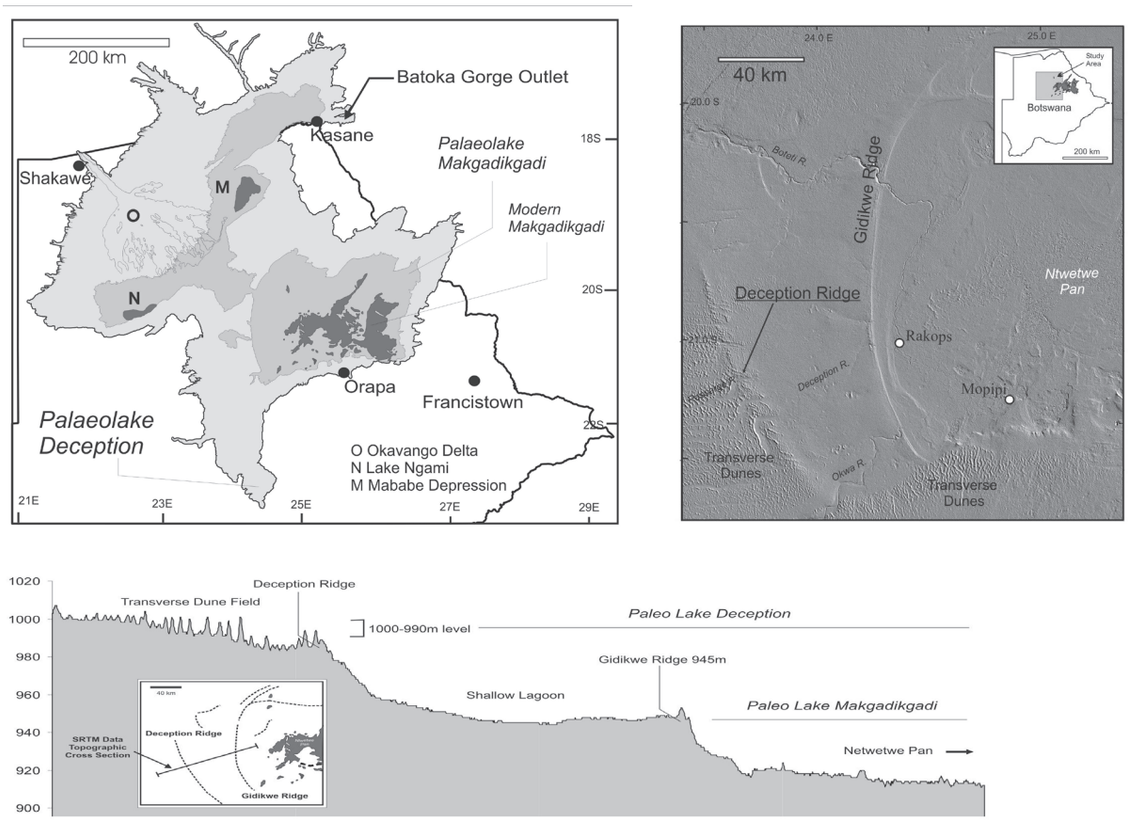


Figure 2. SRTM Data and Surface Geology of Kalahari Palaeolakes

Top Right: SRTM side shaded view of the study area. Bottom: Interpretation of the side shaded view shown using a topographic Crossection. Top Left: Map showing the possible extent of palaeolakes in the Central Kalahari. Paleo Lake Makgadikgadi at 945m and Paleo Lake Deception at 1000m Contour. Source McFarlane, M.J. and Eckardt, F.D. (2008).

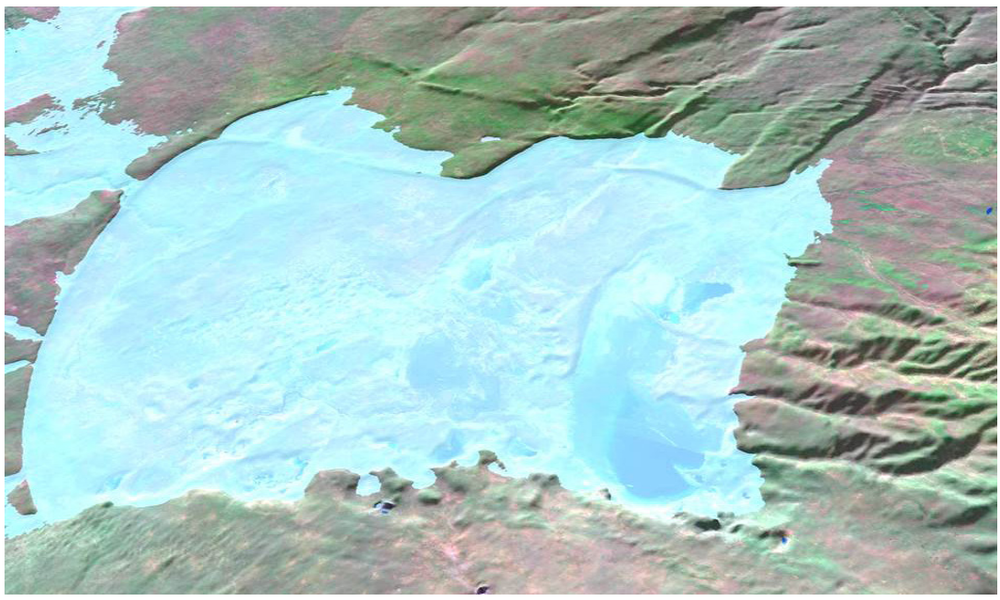


Figure 3. Landsat Drape over SRTM data, Kalahari, Botswana

Terrain visualisation with flooded 945m Makgadikgadi Palaeolake. Note mismatch between lake shore and shoreline surface geology along the northern edge of the lake. (Unpublished)

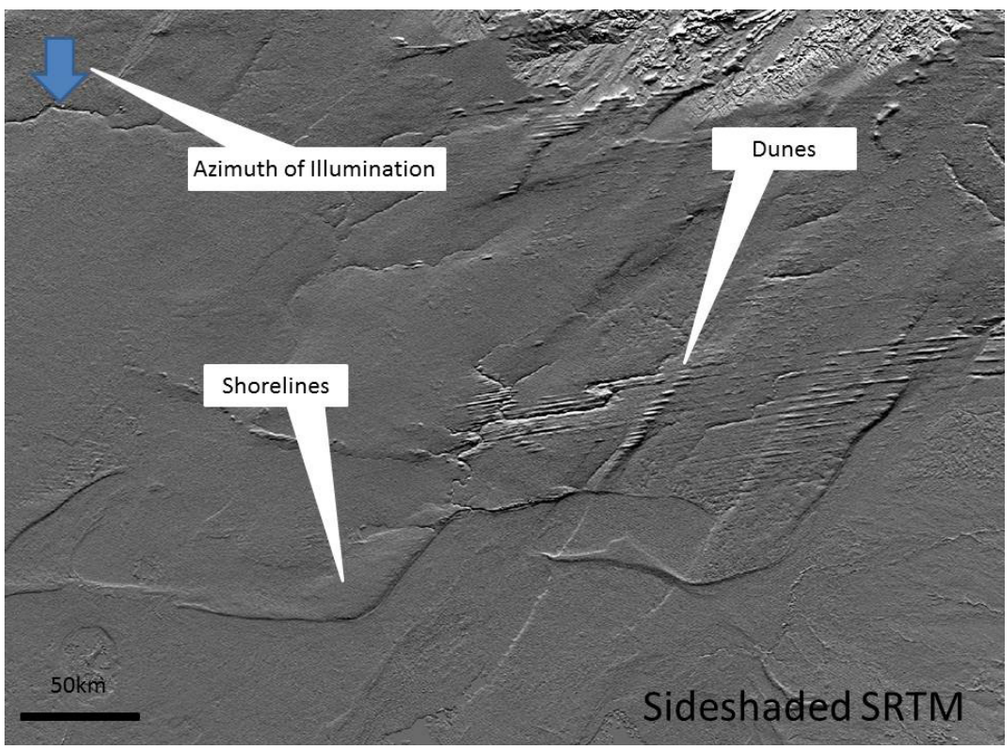


Figure 4. Surface geology in shaded SRTM of northern Makgadikgadi.

This figure depicts the surface terrain of northern NE Botswana and highlights the complex relationship between the shorelines, drainage incision, dune formation and tectonic rifting along normal faults. For the final results and full map, please refer to Eckardt et al 2016.

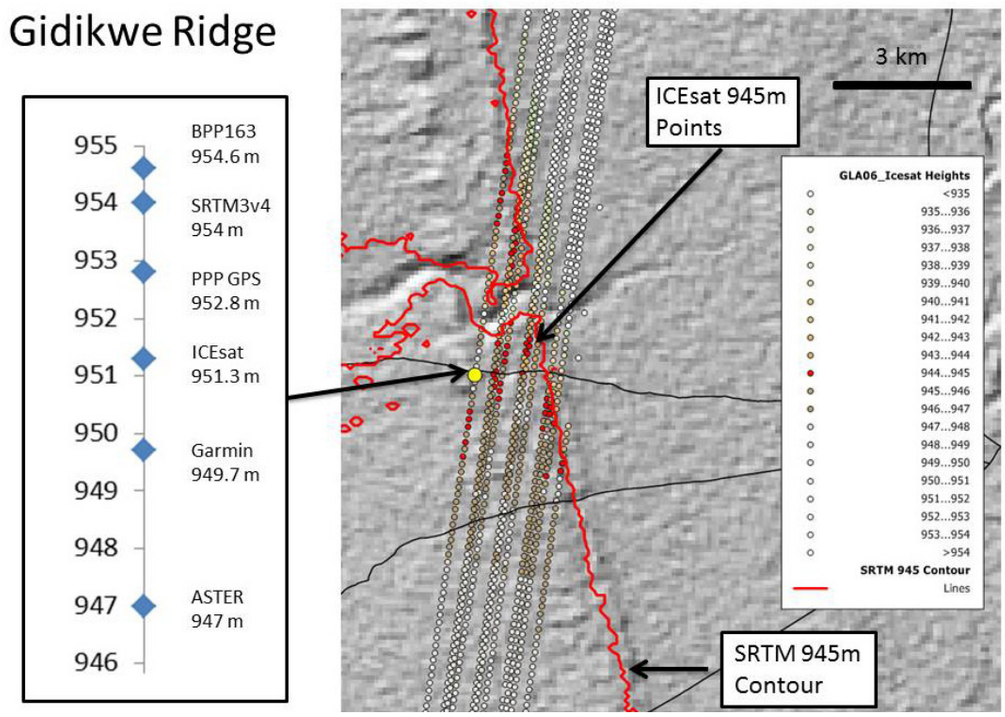


Figure 5. Elevation height for palaeoshoreline in the Makgadikgadi

Close up of 945 m shore along the Makgadikgadi Ridge. Note various height measurements. Red line 945 m contour from SRTM. Coloured points are the Icesat elevation points. Points in red returned 945 m elevation. SRTM clearly overestimates elevation. ASTER GDEM underestimates as can be noted (unpublished).

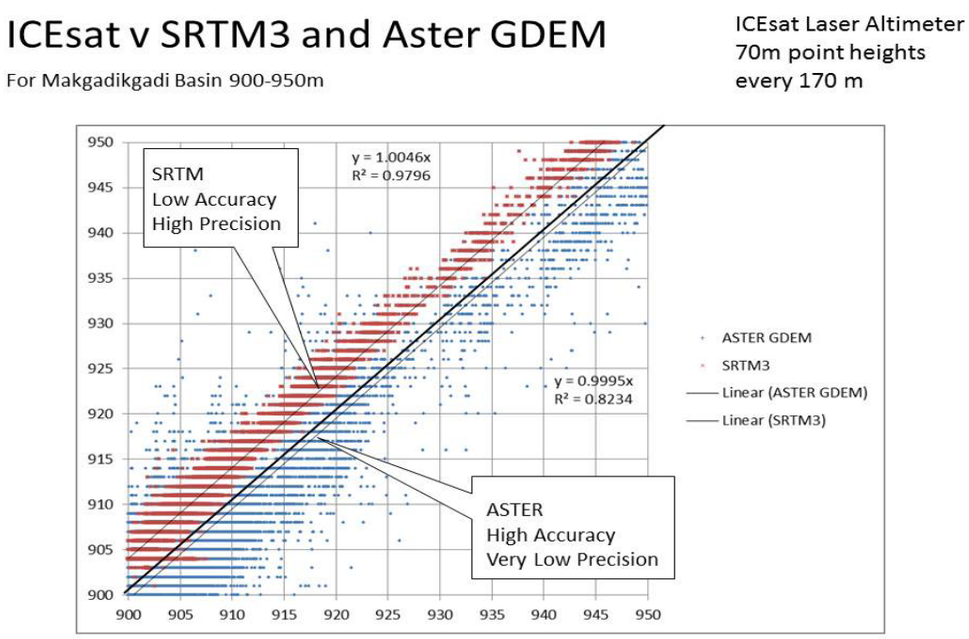


Figure 6. Quality of SRTM and ASTER Elevation data

Comparing ASTER and SRTM elevation data against 65,000 ICEs laser point heights in the Makgadikgadi pan surface and basin (altitudinal range is less than 50 m). Note that SRTM data overestimates height by approximately 4.6m, while ASTER data underestimates by about 2m. Also note wider data spread for ASTER data which is indicative of noise and artefacts (unpublished).

DISCUSSION AND CONCLUSION

Landsat 8 imagery are particularly useful since they cover relatively large areas (180 x 180 km), feature a number of mid and far infrared channels that are ideal for surface feature mapping, including soils and rocks and are both georectified and freely available. The imagery also features 12-bit data scaled to 55,000 greyscales which provides significant contrast and enhancement of spectral subtleties compared to older 8-bit data (255 greyscales). This is significantly different from SPOT and ASTER data and makes Landsat 8 an ideal tool for mapping surface geology in particular in arid and semi - arid Africa. For an area of the size of the Makgadikgadi, 4 full Landsat images were used. The number of SPOT or ASTER imagery would have been about 9 times greater since they cover 60 x 60 km with few of the benefits associated with Landsat 8 data.

SRTM 1 and 3 data is useful as a tool when mapping relative elevation. In this application we were able to identify previously unrecognised shoreline features of the Makgadikgadi and determine the post sedimentary deformation of shorelines by neotectonics processes. When comparing the 90m (SRTM 3) resolution data over the 30 m (SRTM 3) data it is apparent the finer detail adds some noise, which is not necessarily detrimental. However the 9 fold increase in data volume with the higher resolution data may be less desirable since it slows down data processing for large areas

Combining Landsat and SRTM data provides a powerful tool at visualising surface geology, especially in areas devoid of much topography such as the Kalahari. It is however apparent that the actual absolute topography in some instances is crucial and that data accuracy from both SRTM or ASTER is insufficient. SRTM data is more precise and less noisy but tends to overestimate elevation. ASTER data is much noisier, to the point of being useless. It does however fill gaps in areas where SRTM did not return results. Most pronounced are voids in Sand Seas where SRTM failed to retrieve elevation.

ACKNOWLEDGEMENTS

The work here would not have been possible without my co-authors as cited in my papers below. I also acknowledge the Africa Minerals Development Center (AMDC) for facilitating my participation at the GMIS Special symposium during the IGC35 in Cape Town, South Africa.

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GEOSPATIAL DATABASES

Elevation Data

ASTER GDEM data. http://www.jspacesystems.or.jp/ersdac/GDEM/E/2.html

ASTER GDEM data can be downloaded here. It is provided in 1-degree tiles and also comes in geotif format. It also features errors and voids and can be used alongside SRTM. The fact that some roads show up as topographic artifacts is unfortunate.

- CGIAR-CSI SRTM 90m Database. http://srtm.csi.cgiar.org/

This site hosts the latest versions of the SRTM data, which can be downloaded in various formats and resolutions. Individual square data tiles are 5 degrees in size and contain 90-m resolution elevation data. Due to the 58-degree inclination of original shuttle orbit, high-latitude coverage is absent.

Landsat Data

- The Landsat Look Viewer. http://landsatlook.usgs.gov/

This interphase aims to visualize local surface change, drawing on the entire Landsat archive. It features a time slider, basic enhancement settings, and simple export options including the geotif format which allows for accurate spatial placement of small image files within a Geographic Information System (GIS).

US Geological Survey. Earth Explorer. http://earthexplorer.usgs.gov/

This is the home of the entire raw Landsat data archive featuring imagery only a few weeks old. Current Landsat 8 images have a 16-bit resolution allowing for additional contrast and additional bands produce compressed scenes close to 1 GB in size.

SPATIAL RELATIONSHIPS BETWEEN CONTAMINATED MINING AREAS AND PATHOLOGICAL STATES AROUND KADOMA, ZIMBABWE

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ABSTRACT

Toxic elements released from mining activities into agro-ecosystems pose a serious threat to the health of communities that reside in surrounding environments for longer periods of time and the impacts may be felt well after the cessation of mining activities. In Zimbabwe the issues of agricultural land contamination through mining activities, the extent of contamination, toxic element migration pathways and routes of human exposure, are poorly understood. In the present study, soil, stream sediment, water and vegetable samples were collected from around the Kadoma and Hurungwe districts which fall within an extensively mined area, the Sanyati Catchment. Whilst the concentrations of 53 elements that included arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, manganese, nickel, selenium and zinc were analysed in soils, sediments and vegetables, 71 elements were analysed in the water samples. Geochemical maps were produced from the element analytical data through interpolation methods. These maps revealed zones of significant soil and water contamination in the vicinity of the major mining areas with certain locations having levels of toxic elements well above the recommended Food and Agriculture Organization/World Health Organization (FAO/WHO) maximum permissible levels. Most soils around the mines had arsenic values with two digits (96.7, 81.3, 31.1, 91.6, 21.9, 30, 31.6 ppm) compared to a minimum permissible level ranging from 0.4 to 50 ppm. Total chromium values in the soils were up to 406 ppm, well above the minimum permissible level of 230 ppm for residential use. Some streams were found to have high arsenic values (166, 142 and 5847 ppb) compared to the recommended WHO guideline of 10 ppb for safe drinking water. The study also considered the level of element concentrations in common vegetables grown for consumption on these soils and found tomato fruit and pumpkin leaves showing lead levels over 200 times above the FAO/WHO recommendation. Residential areas were identified and digitised from satellite imagery and through field mapping, then used in spatial analyses integrating background geology, geochemical mapping and data from the Ministry of Health on reported cases of chronic illnesses. The results indicated above national average percentage populations with chronic illnesses in the Kadoma district in which the bulk of the densely populated residential areas fall in the zones of the contaminated soils and streams, pointing to a spatial relationship between the geological elements and health which warrants further investigation.

INTRODUCTION

The link between the geological environment and the health of human, animal and plant communities has been known for a very long time and is one that has increasingly gained prominence with more studies being commissioned into the area now referred to as 'Medical Geology'. Dissanayake (2005) explains this link by stating that as the basic building blocks of the Earth are the rocks and minerals, they must, therefore, have a bearing on the health of the human and animal populations that live in such areas. Environmental exposure to heavy metal toxicity from mine waste may be directly or indirectly linked to many human health conditions, including headaches, anger, irritability, depression, and so on, and can contribute to arthritis, asthma, chronic fatigue, diabetes, fibromyalgia, heart disease, arterial sclerosis, multiple sclerosis, Parkinson's disease, ulcers, and many others (Davies & Mundalamo, 2010). Elements such as arsenic, cadmium, chromium, copper, lead, mercury, manganese, nickel and zinc associated with precious and base metal mineralisation, are amongst those potentially harmful elements (PHEs) that have been linked to variety of human health challenges (Bunnell, et al,, 2007; Davies, 2013; Peralta-Videa, et al., 2009), some of which include: cancer of the bladder,

lung skin; negative impacts on female reproductive organs; damage to the kidneys and bones and negative impacts on mental development in children.

Previous studies of environmental pollution through enrichment of toxic elements in Zimbabwe's mining areas have focussed on measuring levels of contaminants in the environment (Ashton, et al., 2001; Meck, 2013; Meck, et al., 2006) but to date a relatively small number of investigations have been conducted that relate the toxic element intake or exposure or uptake by food crops grown by the local communities and the health risk to the consumers (Mamuse, et al., 2003). The study area covers the city of Kadoma which lies within the Sanyati Catchment (Figure 1) and is one of the most mineralised catchments in Zimbabwe, hosting a large number of base metal economic deposits, precious metals, industrial minerals, precious stones and gems that have been mined for several decades. Despite this long history of mining there is neither scientific data nor research that has been conducted to investigate the association between geological materials and human health.

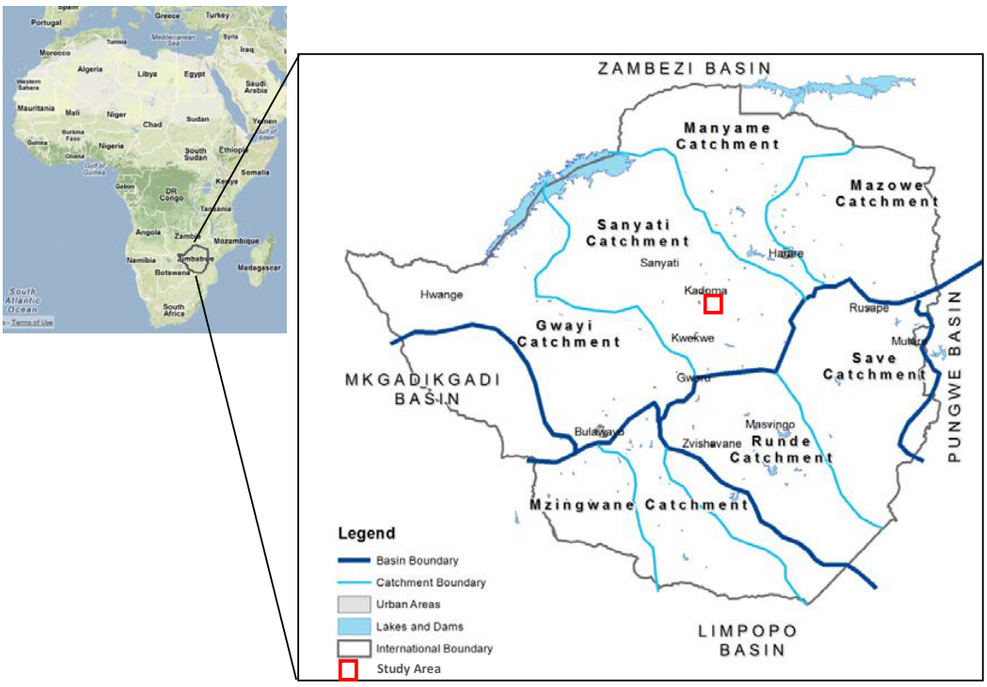


Figure 1. Map illustrating the location of the Kadoma project area within Sanyati catchment in Zimbabwe, adapted from Love, 2006

In 1987 Dunkley produced geochemical maps for the northeastern parts of Zimbabwe and Harare and a national ultra-low density geochemical map for the whole country was also developed by Zhao, et al., (2013). Through the use of the predetermined geochemical background values anomalous element concentrations in a region can be identified and hence contaminated areas can be mapped. In the present paper geochemical mapping at a density of 1 sample per 64 – 100 km2 of an area in Kadoma was undertaken and compared to the patterns of the ultra-low density national geochemical patterns attained by Zhao et al. (2013). The geochemical maps were used to characterise the study site, assessing enrichment or depletion of key elements (As, Cd, Co, Cr, Cu, Fe, K, Hg, Mg, Mn, Mo, Ni, Se and Zn) and to reveal areas of contamination arising from the several abandoned mines in the area (Figure 2).

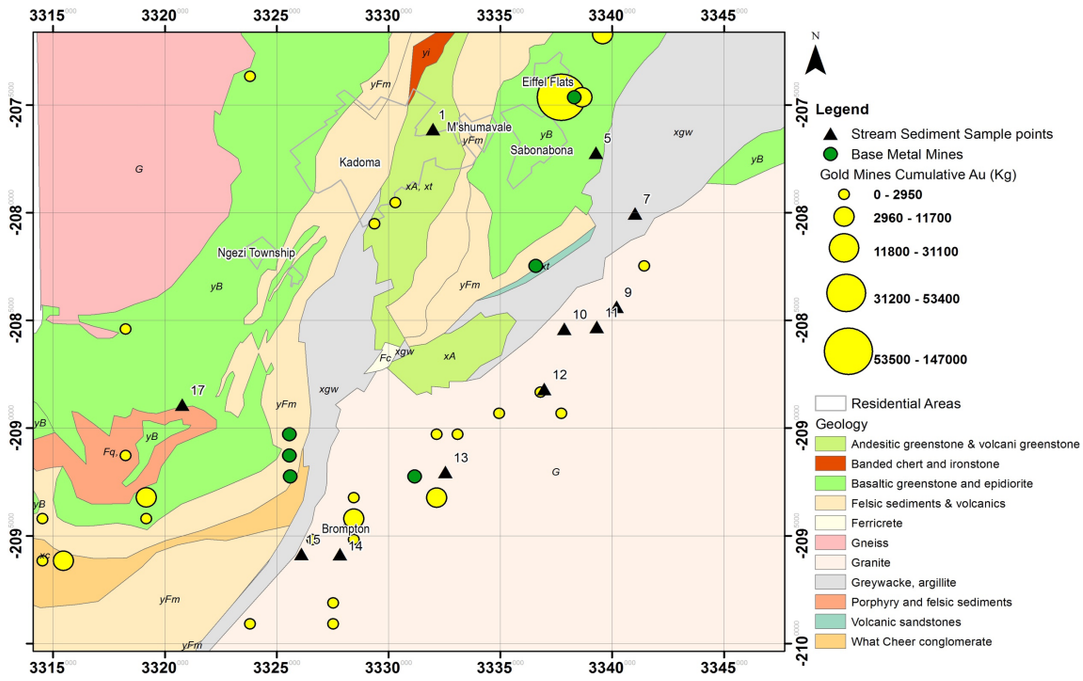


Figure 2. A simplified geological map of the study area with locations of mined gold deposits and the stream sediment sample points

By analyzing the soils, water, vegetables and clinical records, the present project aims at establishing whether past mining activities are contributing to the dominance of certain diseases in the mined areas. Most of the mines in the Sanyati catchment are abandoned and there is no rehabilitation taking place and there are several possible pathways that can transmit toxic elements from the mined areas to the communities living in the surroundings.

METHODS FOR GEOCHEMICAL MAPPING IN KADOMA, ZIMBABWE

SAMPLE COLLECTION AND PREPARATION

Guidelines used in the field sample collection are in accordance with those recommended for international geochemical mapping (Darnley et al., 1995; Johnson, 2005) . The selection of stream sediment and water samples were conducted using a backdrop of the 1:50,000 topographical map sheets, using a 10 km by 10 km grid. All locations of sample collection were recorded using a Global Positioning System (GPS) e-trex 10 unit. This paper focuses on the analysis of the dry season samples collected during a survey conducted in October 2015.

Plastic bottles were used for water sampling. The bottles and their lids were rinsed three times with water from the sampling site and the water samples were kept in a cooler bag until transported to analytical laboratory. Samples were all filtered using 0.45 µm filters, and vacuum filtered on arrival in Harare at Performance Laboratories. Samples were then packed into 250 ml bottles acidified by the addition of 1.0 ml HNO3.

A 2.5cm diameter soil auger was used for collecting soil and stream sediment samples, which were collected after the water samples in wet river beds. Three to five samples along 50-500 m length of the stream were collected for the stream sediments to make a composite sample. From each sampling site, 1 kg of material taken from the 0-25 cm depth to represent the root zone and composite

samples were made for each representative site in the field. The samples were then wet-sieved, oven dried and pulverized in the laboratory and packed into 10 – 15g samples (0.5g required for analysis).

SAMPLE ANALYSIS

All samples were analysed at Bureau Veritas Mineral Laboratory in Canada using ICP-MS. The concentration of 71 elements were assessed for the water samples while the soil and stream sediment samples were digested by aqua regia and analysed for 53 elements. Element analyses included Au, Ag, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, F, Hg, La, Li, Mn, Mo, Nb, Ni, P, Pb, Pd, Pt, Se, Sb, Sn, Sr, Th, Ti, U, V, Y, Zn, Zr, Fe, Mg, Al, Na, and K.

DATA PROCESSING AND MAP PREPARATION

Descriptive statistical parameters and summaries were generated using Microsoft Excel. Spatial analysis was conducted using QGIS Desktop 2.10.1 and ArcGIS 10.1. Geochemical contour maps were produced using the Ordinary Kriging method in ArcGIS 10.1 to produce 100m by 100m grids. The parameters used in the Kriging method were a spherical semi-variogram model with a variable search radius and 12 as the nearest input sample points to produce 12 geochemical maps.

HEALTH DATA COLLECTION

Health data for the period 2008 to 2012 was accessed from the Ministry of Health of Zimbabwe through the permanent secretary. The data obtained was on specific chronic diseases and pathological states by district for the Sanyati Catchment area. Descriptive statistical analyses were done using Microsoft Excel.

RESULTS AND DISCUSSION OF THE GEOCHEMISTRY OF THE AREA AROUND KADOMA

WATER CHEMISTRY PAPRAMETERS

The analysis of the results of the water samples focuses on the key elements that are potentially toxic to humans. Of all elements analysed, average As (arsenic) was found to be above the FAO/WHO and Standards Association of Zimbabwe (SAZ) maximum permissible levels (MPL) of 10 ppm in 4 out of the 14 water samples, with values of all samples ranging from 0.9 ppb to 5.847 ppb (Table 1). The levels of Mg ranged from 0.06 to 317 ppm with an average concentration of 47.46 ppm which is just short of the MPL of 50 ppm. The chart in Figure 3 illustrates the values of element concentrations found.

Table 1. Standards Association of Zimbabwe guideline on maximum permissible level (MPL) of toxic substances in drinking water

Description	As	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Ni	Pb	Se	Zn
MPL(ppm)	0.01	0.003	0.05	1	0.3	0.01	50	0.5	0.02	0.01	0.01	
MPL(ppb)	10	3	50	1000	300	10	50k	500	20	10	10	5k*
Kadoma (ppb)	444.26	0.05	6.04	8.58	145	--	47.46 (ppm)	271.13	2.26	1.64	0.7	9.31

k is '000'* *-- is not detectable*

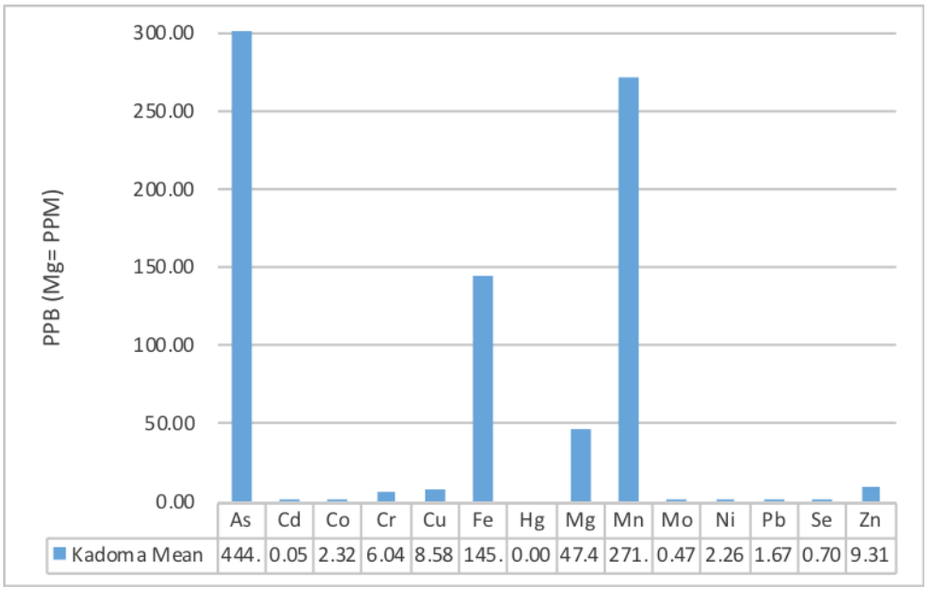


Figure 3. Dry season average element concentration in water samples

STREAM SEDIMENTS AND SOIL GEOCHEMICAL PARAMETERS

The results of the stream sediment sample assays are summarized in Table 2. Mn, Cr, Ni, Hg, Ag, Zn, Au, Cu and As are key ore forming elements typical of greenstone belt terrains. Soil samples show a very similar pattern to the stream sediments. Comparing the element concentrations in stream sediments with Taylor's crustal abundance values (Parker & Fleischer, 1967), an enrichment factor, K (Zhao et al., 2013), was calculated by using the arithmetic mean or geometric mean values of element concentrations divided by the crustal abundance values. Local enrichment of Sb, As, Au, Se, S, Mo, Cr, Ag, Pb, Y and Hg and the depletion of key elements such as Zn, Cu, Mn, Na, K, Ca, P and Mg was observed. Using the same approach, the arithmetic mean of the Kadoma samples was compared to that of the Zimbabwe ultra-low density geochemical mapping.

Table 2. Summary statistics of the stream sediment element concentrations (PPM) and their enrichment factor calculated from Taylor's Crustal Abundance and Zhao et al., background values for Zimbabwe

Element analysed	Min	Max	Median	Standard Deviation	Variance	CV %	Skewness	Arithmetic Mean	Zimbabwe low density arithmetic Mean (Zhao et al 2013)	Crustal Abundance value (Taylor 1964)	K = Arithmetic Mean/ Crustal Abundance	Local K = Arithmetic mean/ Zimbabwe arithmetic mean
As	2.00	90.10	15.00	26.19	686.17	101.30	1.39	25.86	4.22	1.80	14.4	6.1
AgΔ	35.00	463.00	64.00	123.45	15239.74	93.58	1.53	131.92	48.000	70.00	1.9	2.7
Ba	17.70	228.30	89.10	61.69	3805.70	62.66	0.59	98.45	533.00	425.00	0.2	0.2
Cd	0.02	0.15	0.05	0.04	0.00	67.90	0.74	0.07	0.07	0.20	0.3	0.9
Co	4.60	33.40	12.85	9.29	86.22	58.86	0.50	15.78	10.48	25.00	0.6	1.5
Cr	135.70	394.00	231.25	81.45	6633.30	33.16	0.60	245.63	529.00	100.00	2.5	0.5
Cu	12.48	82.05	24.05	20.31	412.48	62.90	1.12	32.29	16.82	55.00	0.6	1.9
Fe*	1.27	4.89	2.55	1.24	1.53	42.46	0.31	2.91	2.75	5.63	0.5	1.1
HgΔ	7.00	304.00	39.00	95.31	9083.35	111.80	1.17	85.25	19.97	80.00	1.1	4.3
K*	0.04	0.26	0.09	0.07	0.00	58.04	1.00	0.11	2.29	2.09	0.1	0.0
Mg*	0.03	0.89	0.14	0.24	0.06	95.95	1.55	0.25	0.99	2.33	0.1	0.3
Mn	86.00	1064.0	299.00	315.38	99462.24	75.83	0.67	415.92	392.70	950	0.4	1.1
Mo	1.05	13.49	2.66	3.83	14.69	89.73	1.12	4.27	0.41	1.50	2.8	10.4
NiΔ	17.20	97.70	48.10	24.76	613.02	46.54	0.30	53.20	41.52	75.00	0.7	1.3
Sb	0.14	11.49	0.97	3.05	9.32	142.08	2.34	2.15	0.52	0.20	10.7	4.1
Se	0.10	0.40	0.20	0.10	0.01	45.07	0.19	0.23	.....	0.05	4.6	.....
Pb	3.91	30.26	13.66	6.99	48.86	51.74	0.72	13.51	17.94	12.50	1.1	0.8
W	0.20	0.80	0.30	0.26	0.07	60.57	0.63	0.43	0.86		.....	0.5
Zn	6.40	75.70	21.30	22.42	502.69	77.89	0.89	28.78	26.10	70.00	0.4	1.1

*Unit in %, Δ Unit in pp

CHEMICAL PARAMETERS OF VEGETABLES SOURCED FROM THE KADOMA AREA

The bulk of vegetable samples had concentrations of As, Cu, Cr, Pb and Zn well above the maximum permissible levels (MPL), with the tomato fruit and pumpkin leaves showing Pb levels of almost or over 200 times above the FAO/WHO and SAZ recommendations as indicated in Table 3.

Table 3. Selected analysed elements measured in vegetable sourced from Kadoma

Samples		Mo	Cu	Pb	Zn	As	Cd	Cr
		Ppm	Ppm	Ppm	ppm	ppm	Ppm	Ppm
	MPL	--	40	0.1-0.3	100	0.1	0.05	--
KAD 001V	Covo	1.35	5.46	29.51	33.8	0.9	0.03	17.4
KAD 002V	Tererini	1.78	5.03	27.88	20.8	0.4	0.04	16
KAD 003V	Cabbage	1.65	6.47	41.67	16.5	6.2	0.01	29.5
KAD 004V	Pumpkin leaves	1.84	14.5	56.86	27.4	0.9	0.01	8.8
KAD 005V	Okra	1.03	18.7	21.81	43.6	1	0.05	23.6
KAD 006V	Tomato	0.65	14.98	82.88	23.9	1.9	0.09	32.2
KAD 007V	Carrot	1.21	9.7	31.15	24.4	0.8	0.05	26.9
KAD 008V	Onion	1.2	15.45	54.96	42.4	1.3	0.07	33.6

Note: Figures in bold (0.01) represent those above the FAO/WHO MPL (Codex Alimentarius Commission, 2011)

GEOCHEMICAL MAPS OF KADOMA

Geochemical maps for As, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Zn, Au and Ag were generated and sample outputs for As and Cr are indicated in Figures 4 and 5. The north-eastern portion of the study area shows concentrations associated with the location of the once largest gold producer Cam and Motor Mine. This area shows levels of As concentration as high as 81 to 90 ppm in some places. The clusters of gold and base metal mines in the study area are associated with the high gold and base metal geochemical areas of the greenstone belt. In particular most mines typically follow the granite greenstone contact areas which are known to be structural controls of the mineralization. The map of Cr distribution indicates a trend of higher concentration in the south-western part where ultramafic rocks outcrop just beyond the boundaries of the study area and considered to be the possible source of these high Cr anomalies.

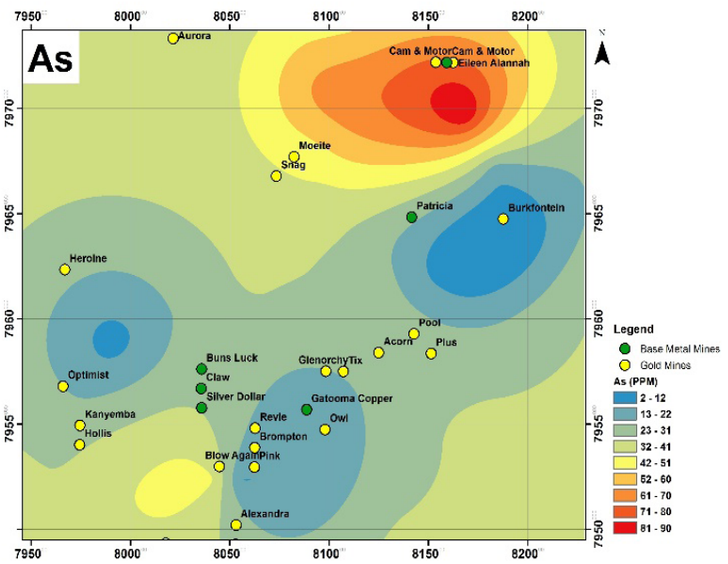


Figure 4. Geochemical map for As concentration obtained from the stream sediment sample results, for the Kadoma area

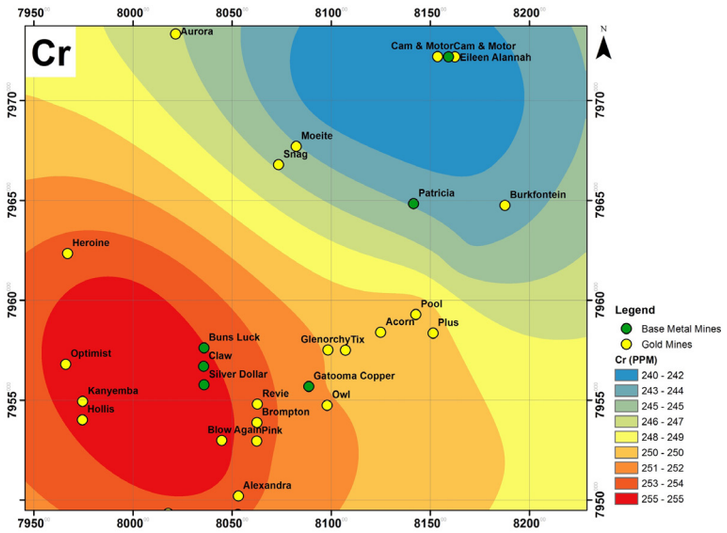


Figure 5. Geochemical map for Cr concentration obtained from the stream sediment sample results, for the Kadoma area.

SPATIAL DATA ANALYSIS AND INTEGRATION

Integrated spatial analysis involving overlaying the mining and residential areas within the Kadoma District onto the geochemical maps for As and Cr, culminated in the map in Figure 6. This map shows that densely populated residential areas of the city of Kadoma and town of Eiffel Flats fall within the zones of high Cr and As enrichment in stream sediments, with concentration levels that are well above the New York State Department of Environmental Conservation (NYS DEC) soil clean up objective values based on removing risks in human health that are set at 0.21 ppm for As, 22 ppm and 36 ppm for Cr (hexavalent) and Cr (trivalent) respectively (Teaf, et al., 2010). The map shows that the residential areas fall within a zone of As values ranging from 4 ppm to 88 ppm and total Cr of 245 ppm to 255 ppm.

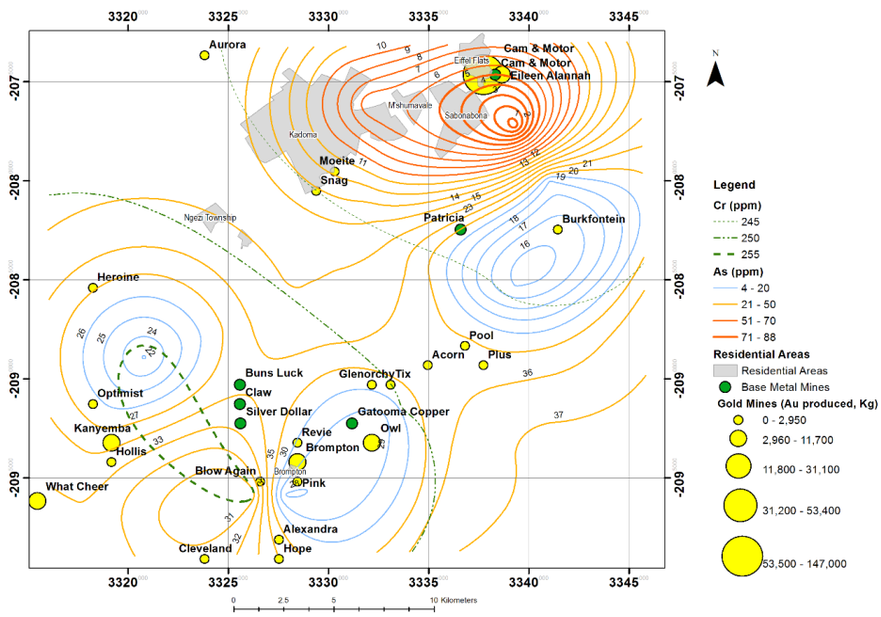


Figure 6. Geochemical map of the Kadoma area indicating contours of the concentrations of Cr and As

A COMPARATIVE ASSESSMENT OF HEALTH RECORDS OF THE KADOMA AREA

A preliminary assessment of the health records of 8 districts in the Sanyati catchment in relation to location, metal and mineral deposits showed that for the period 2008 - 2012 the district of Kadoma had the highest percentage recorded for follow-up cases of chronic renal failure, diabetes, mental illnesses, pneumonia, diarrhoea and still births. Figures 7 and 8 are a graphic representation of the health data. In the cases of prostate and breast cancer, the Kadoma District results were not prominent compared to other districts such as Chirumanzu, Makonde and Gweru which showed higher percentage populations with these conditions.

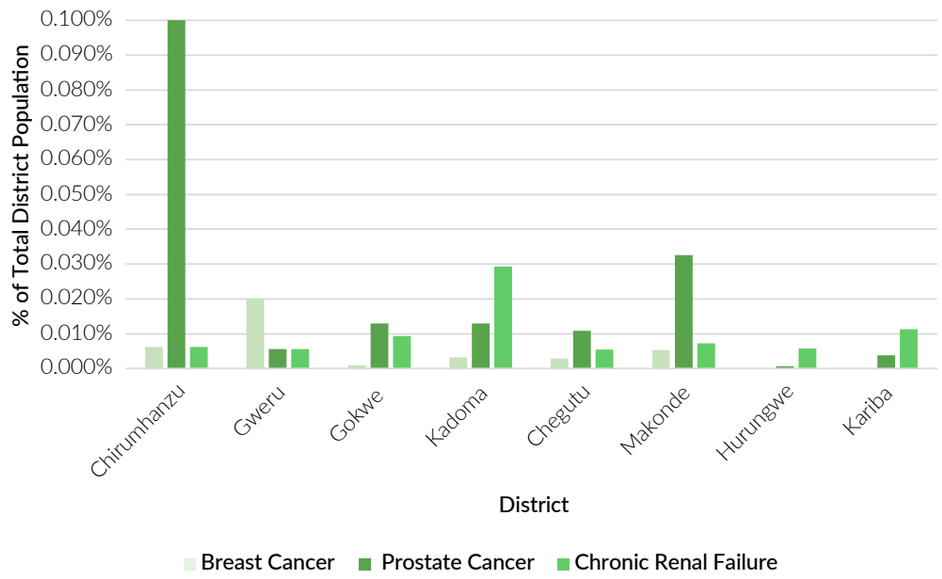


Figure 7. Percentage distribution of follow-up cases in 2012 for cancer and chronic renal failure by district

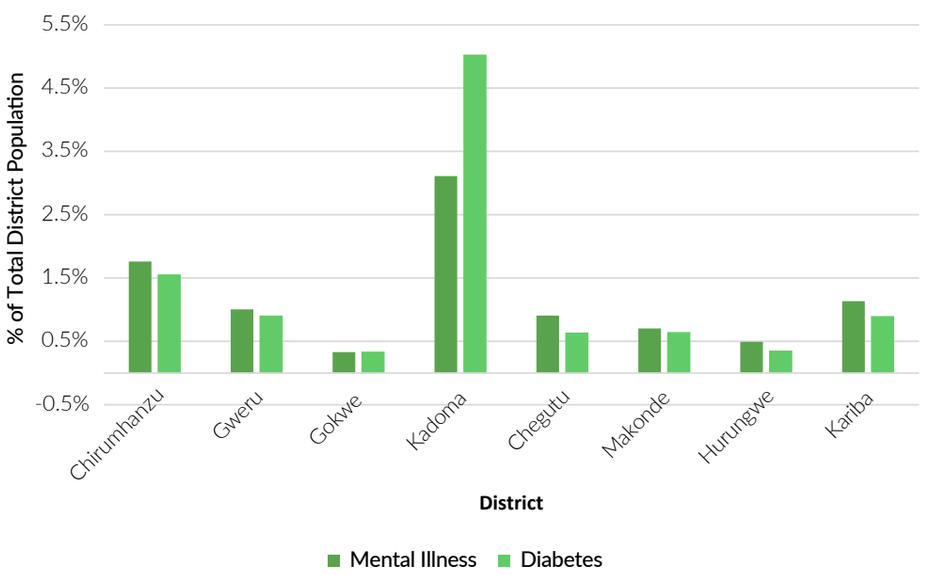


Figure 8. Percentage distribution of follow-up cases in 2012 for diabetes and mental illness by district

CONCLUSION

The study has shown that local enrichment of Sb, As, Au, Se, S, Mo, Cr, Ag, Pb, Y and Hg and the depletion of key elements such as Zn, Cu, Mn, Na, K, Ca, P and Mg provided a basis for the classification of the site and mapping of regions contaminated with PHEs. GIS provided a suitable technique for the identification and mapping of regions of PHE enrichment and analysis of the proximity of residential settlements to these high health risk areas for which further action can be recommended towards a comprehensive human health risk assessment that focuses on specific exposure pathways.

Through comparisons with the MPL for soils and stream sediments, the arithmetic mean for As and Cr (total) was found to be above the MPL for residential purposes and beyond which health risks have been associated as set by institutions such as the NYS DEC in the United States. The absence of locally derived guidelines on MPL for concentrations of PHEs in soils, as well as what Teaf et al (2010) described as a lack of consensus between the regulating and scientific community, poses a challenge in the evaluation of potential human health risks from exposure. Further geochemical analysis of the soils and stream sediments through X-ray Diffraction can aid the investigation of the mobility of potentially harmful elements by identifying their source and occurrence in minerals (whether bound in the crystal structure or not) and natural or anthropogenic processes that may be leading to their release and availability in the environment. Though the utilized health data is course and needs disaggregation to higher densities to be able to allow detailed analysis of spatial relationships, the data analysed indicates that the high ranking of percentage populations with certain chronic illness, such as chronic heart failure, diabetes and cancer may be influenced by the geochemical parameters. This warrants further studies on the health risks that exist for communities within the areas of Kadoma that are enriched with PHEs.

Analyses to determine the species of As and Cr present in the environment is an important component that must be considered in the hazard identification and human health risk assessment. Only through speciation analysis can a better understanding be reached on the link between the geochemical nature of the setting, the exposure pathway and possible toxicity that may lead to chronic illnesses and pathological states that have been presented by members of the communities residing in the Kadoma District.

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GEOSCIENCE DATA IN LESOTHO

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ABSTRACT

Geoscience data dissemination remains to be a limitation towards the development and growth of the mineral infrastructure in African States. A system should be introduced to enhance administrative, exploration and mining activities which will enable the creation of productive interactive platform between the Ministry of Mining and the Public as a whole.

Data availability and accessibility in African states have proved to be outdated, in non-digital format and inappropriately organised. Mineral Resource management without proper facilitation tools and technologically advanced software systems have resulted in indistinct geoscientific information which has resulted in minimal progress in investment in the mining and minerals exploration sector.

The system should aim at proper management and dissemination of geological information and economic minerals data production. Administrative components which include mineral rights acquisition (exploration, prospecting and mining rights) and monitoring of Environmental surface rights should be encouraged. Regulatory frameworks such as Mines and Minerals Act, Environmental Act, Mineral rights guidelines should be introduced into the system to give accessibility and transparency of information to interested parties.

INTRODUCTION

The objective of the project is to introduce the conversion of outdated hard copies of the Geological maps of Lesotho into digital format, with the aim to enable effective editing, and integration of new findings with literature review of projects from previous prospectors (such as Scott, et al., 1978). The Geological Maps were published in 1982 by the collaboration of the UNDP and the Department of Mines and Geology under the Exploration and Minerals project. Digitizing of the material will aid in preservation and improve the access to the collection of information. The focus of the project is based on the Data Collection block in the standardization Geoscience Data Management flow chart (Figure 1).

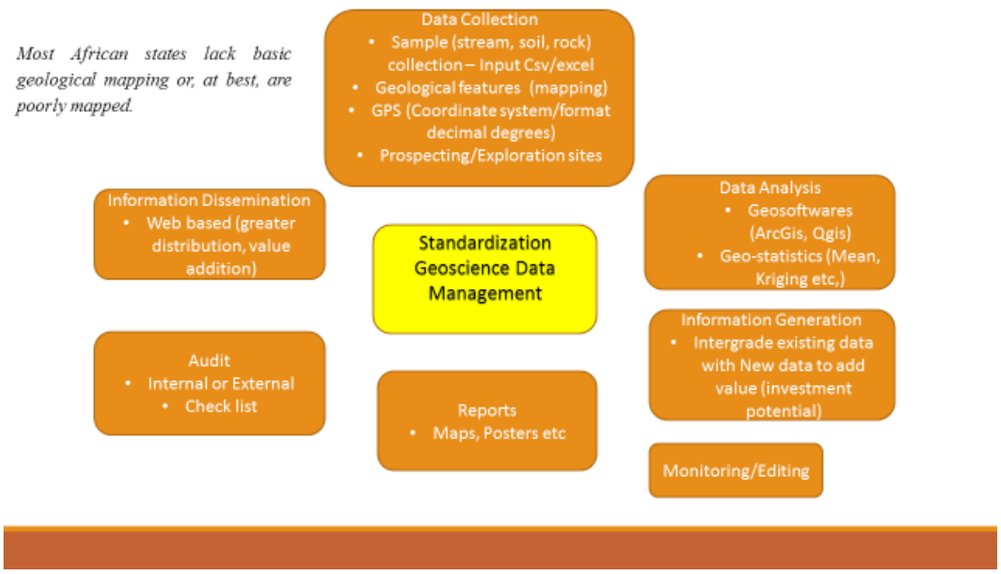


Figure 1 –Standardization Geoscience Data Management

METHODOLOGY

A total of twenty nine 1:50 000 scale and two north and south 1: 250 000 Geological hard copy map sheets covering an area of 33000 Km2 of Lesotho were retrieved from the library archives. The Geological map sheets were scanned and integrated into the ArcGis and QGis Software, to convert the map sheets into digital format.

RESULTS

The scanned map sheet (Figure 2) was georeferenced with spatial reference using coordinate system Wgs (1984), in order to give the raster image spatial definition around the globe. The georeferenced map was digitized (vectorised) and allocated geological attributes which include geological formations (Figure 3) and geological structures (Figure 4). Digitized data was compiled in a standardized format that is compatible with most geospatial media interfaces, and enables the user to edit and change geological features encountered during field work in the simplest and uncomplicated way as possible.

Stream sediment samples were collected and analysed at the geochemical laboratory of the Council for Geoscience in South Africa (CGS). The samples were analysed for 23 elements (Fe2O3, TiO2, MnO, Sc, V, Cr, Cu, Co, Ni, Zn, As, Rb, Sr, Y, Zr, Nb, Sn, Sb, Ba, W, Pb, U, Th) using X-Ray fluorescence spectroscopy. Samples were assigned coordinates in the field during sampling, and tabulated in Microsoft excel where the data is converted into csv (comma delimited) format. The table was imported into ArcGis software where it was converted into shapefile format, in order for the data to appear as points on the map (Figure 5).

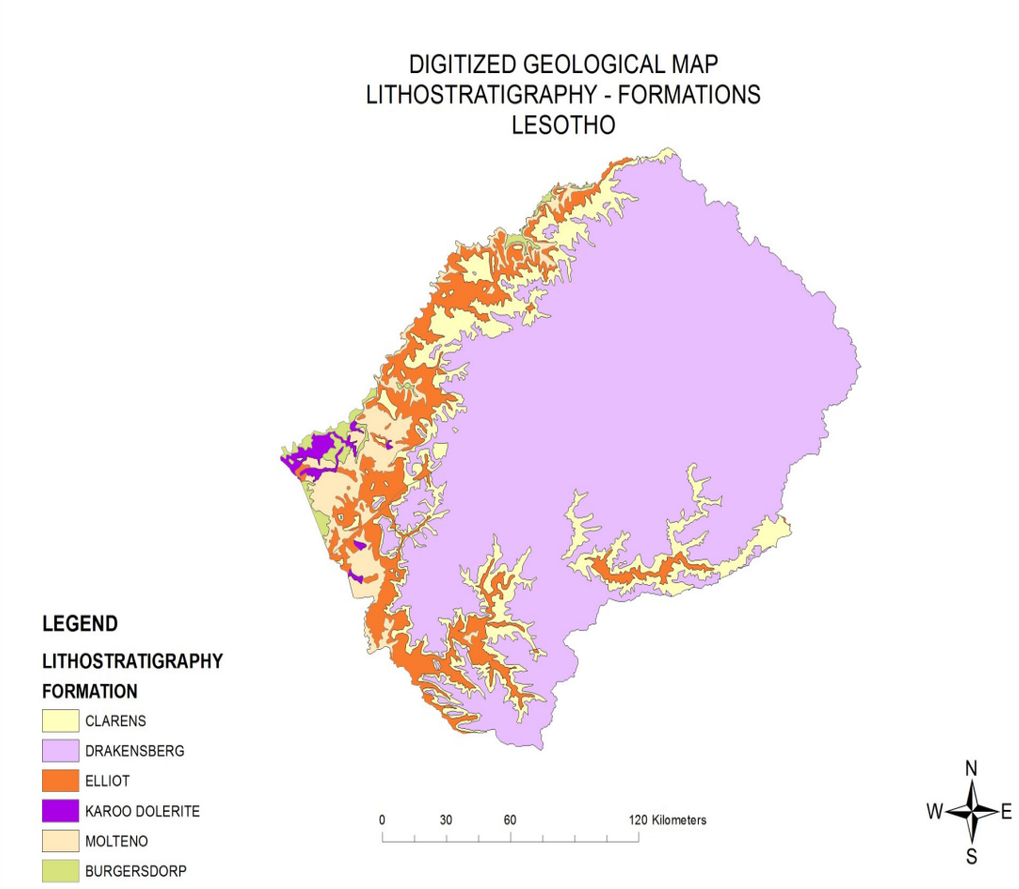


Figure 2–Scanned Geological Map of Lesotho at 1:250 000

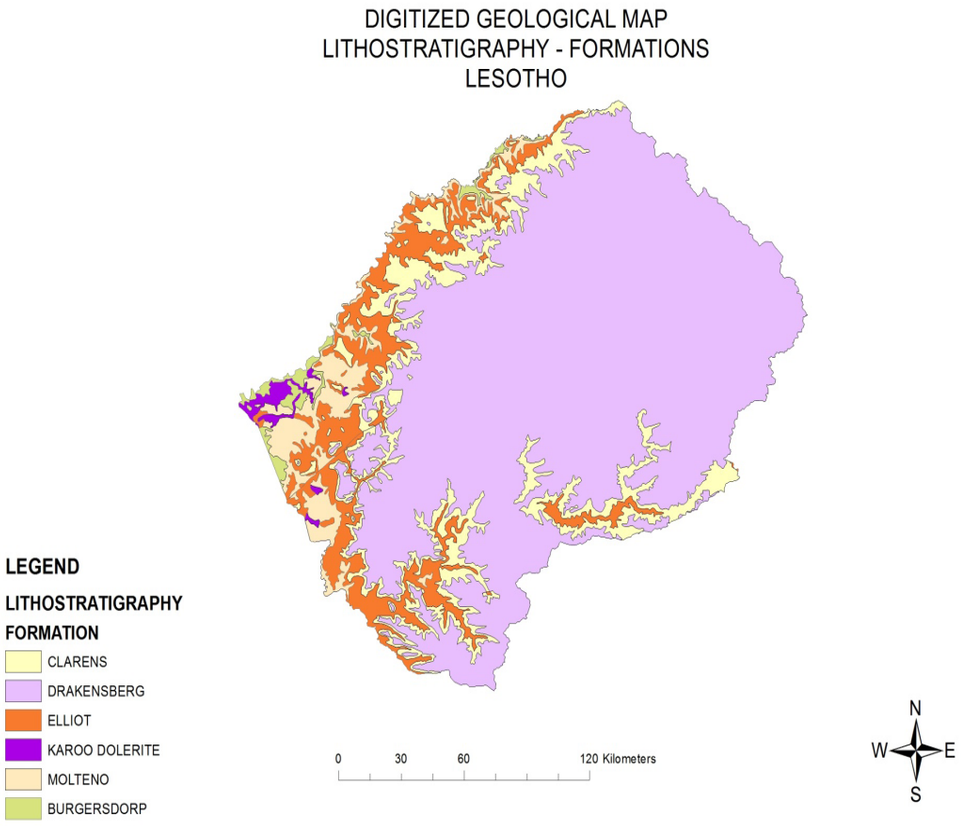


Figure 3- Digitized Geological Map with formations

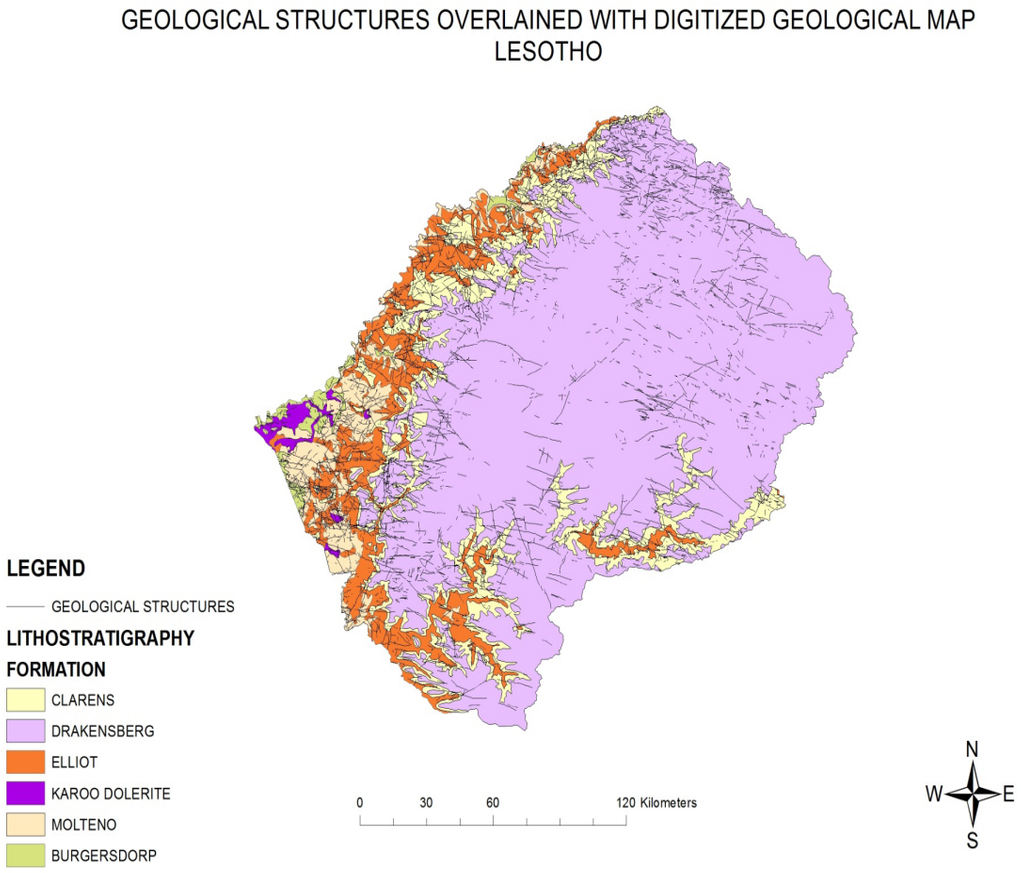


Figure 4- Digitized Geological Map with geological structures

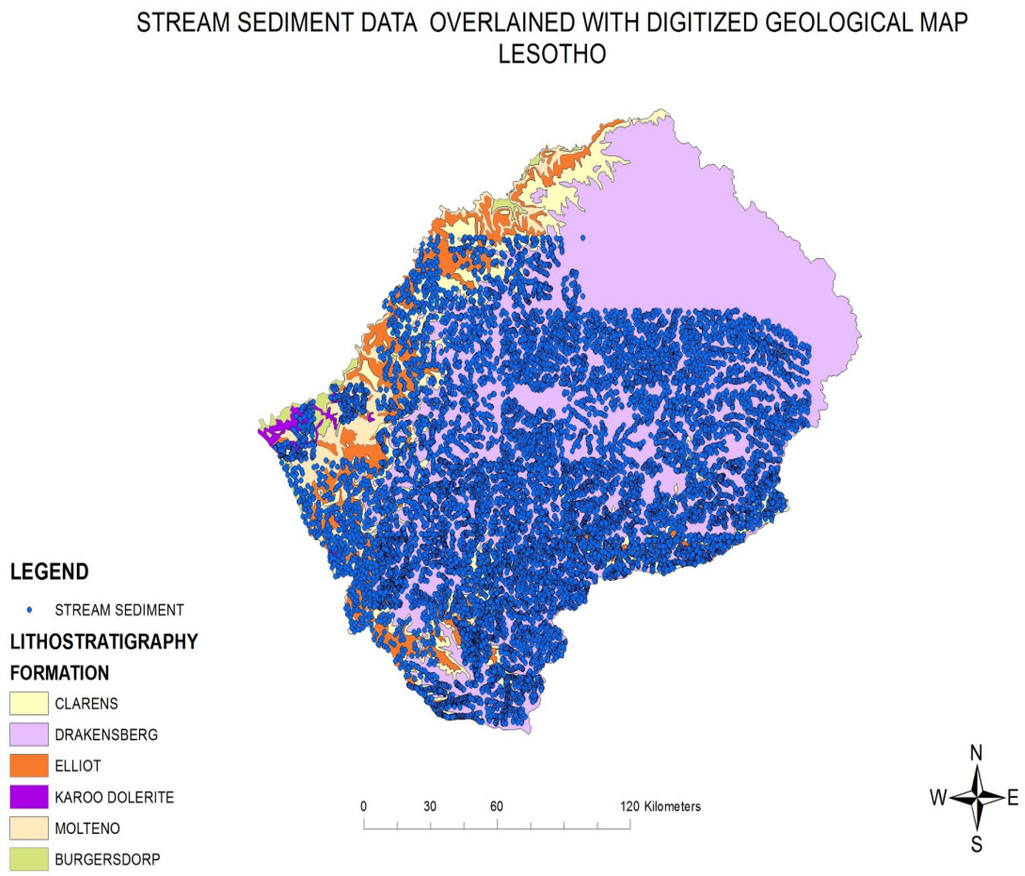


Figure 5- Stream sediments distribution map

CONCLUSION

Fundamental benefits obtained from a standardized Geoscience Data management system include geological information updates, efficient revenue collection, compliance of mining companies with legislation, platform for public to extract mining law and regulations, validation of applications and renewals, and investor confidence.

The project has addressed the statement of geological information collection and updates which include compiling data that is aligned and conformable with the geoscientific data standards. Information generated will be able to ensure that data are discoverable and accessible, that they may be understood and used, and that they are looked after in the long term.

RECOMMENDATIONS

The next phase of the project will include addition of satellite data and geostatistical analysis tools such as kriging and Inverse Distance Weighted to stream sediment data in order to detect and delineate anomalous areas that can be assessed for further detailed investigation for potentially economic viable mineral deposits.

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TOWARDS GOESPATIAL INFORMATION PARTNERSHIPS WITHIN THE SOUTHERN AFRICAN CUSTOMS UNION (SACU)

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ABSTRACT

Geospatial technologies change fast and developing countries continue to strive in adapting them in their geospatial data collection, processing, analysis, regeneration, visualisation, sharing and exchange. These technological advancements have increased the ways in which these processes are executed, for example, GPS enabled smart phones make it possible for anyone to collect spatial data, which in turn increases the pool of those who could be involved in spatial data collection. However, such advancements also bring problems of different data collection methods, data quality issues and unreliability of data. As such, there is a need for a common understanding, streamlining, and adoption of standards in view of accommodating all stakeholders. The management and use of geospatial data can be anchored on partnerships as building blocks for all its various processes stated above. The defining question is whether developing countries have policies to encourage collection, processing, sharing and collaboration on geospatial data and information services. In an attempt to get an answer, this paper aims to suggest that a functional partnership framework on which spatial data can be handled need to be developed and sustained for that purpose by developing countries. This framework is envisaged to be able to guide issues of adaptability analysis, modelling and design in order to meet a developing country's spatial data requirements. The framework should be able to analyse geospatial data adaptability through partnerships in respect of three major tenets i) underlying institutional behaviour, ii) technical issues, and iii) information policy issues. The paper will then further employ comparative analysis between evident geospatial data partnerships in any of the Southern African Customs Union countries (SACU). The emphasis of this paper is handling and coordination of geospatial data and information through functional partnerships in development of Spatial Data Infrastructures.

Key Words: Partnership, geospatial technologies, change, geospatial data, data collection, processing, analysis, visualisation, regeneration, sharing, exchange and infrastructure.

INTRODUCTION

Nations all over the world have recognized spatial data as a buildable infrastructure (Warnest et al., 2003) and with it has come the movement of devolving it from National Mapping Agencies (NMAs) to all stakeholders. Spatial data is now recognized as an important asset in supporting major government, business and private decision-making, (Lipeg, & Modrijan, 2010; Mueller, 2010). It can be defined as information about the location and shape of, and relationships among geographic features, usually stored as coordinates and topology. Technological advancements have increased the way in which spatial data is collected, stored and disseminated. For example, GPS enabled smart phones make it possible for anyone to collect spatial data, which in turn increases the pool of those who could be involved in spatial data collection. However, such increase in stakeholders also bring problems of different data collection methods, data quality issues and unreliability of data. As such, there is a need for a common understanding, streamlining, and adoption of standards in view of accommodating all stakeholders when building geospatial information into a powerful infrastructure.

Spatial data sharing and exchange are now a reality with the current Information and Communication Technologies (ICT). International organizations have shown that spatial information is a commodity that needs foundations anchored on good cooperation and knowledge sharing. Notable organizations involved include:

- Global Spatial Data Infrastructure (GSDI),
  - International Steering Committee for Global Mapping (ISGM)
  - Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP)
  - European Umbrella Organization for Geographic Information (EUROGI)
  - Permanent Committee on SDI for the Americas (PC-IDEA)
  - International Standards Organization Technical Committee (ISO-TC 211) for Geomatics and Geographic Information Systems.
  - Open Geospatial Consortium (OGC)
  - International Federation of Surveyors (FIG)
  - Infrastructure for Spatial Information in the European Community (INSPIRE)

The versatility of geospatial data and information to be shared between diverse environments makes it a good candidate for partnerships. Geospatial information partnerships can be modelled in the development of Spatial Data Infrastructures (SDI). Partnerships are viewed as environments that can greatly advance mandates and functions of organizations involved in geospatial data collection, handling and dissemination. SDIs are very important in aiding geospatial information integration, sharing and exchange leading to an enabling environment for societies and governments in decision-making processes (Lipeg 2010). Further to this Crompvoets et al. (2008) have indicated that spatial information should be treated as multi-stakeholder commodities which can be handled well by developing them into SDIs. The SDIs should then be treated as beneficial on-going processes which can be nurtured to maturity through approaches that are efficient, effective and partner driven.

The intention of this manuscript is to contribute by putting forward a move towards geospatial information partnerships anchored on the development of SDIs in the South African Customs Union (SACU) countries. Partnerships have a very large spectrum and can range from being highly effective and functional to dysfunctional. Between highly effective and dysfunctional, there are a myriad of partnerships which can still fail to deliver SDIs for nations. SDI has been described as ambiguous by Crompvoets et al. (2008) and this can complicate the partnerships that can be associated with its development. It is therefore necessary for a country developing an SDI to properly understand partnerships and be able to settle for those that produce positive results.

Interrogation of partnerships need to be done with the view of deducing effective and functional ones, which could aid in the development of a conceptual SDI framework for developing countries. The role of partnerships in SDI development was captured by Rajabifard (2008, p14) who stated that “aspects identified in developing an SDI roadmap include the vision, the improvements required in terms of national capacity, the integration of different spatial datasets, the establishment of partnerships as well as the financial support for an SDI.” This contribution advances the view that partnerships are the foundation of all the other identified aspects in Rajabifard (2008). A simple but rich definition of partnerships is simply that they occur when two or more people/organizations agree to enter into business together to make profit. Profitability is the motive for most partnerships and in this case, they can come in monetary form, improved decision-making and community information accessibility. It is therefore proposed that the definition of a functional partnership to be cooperation between two or more entities for short or long term profitability.

PROBLEM STATEMENT

Despite the growing awareness of the value of geographic information and applications in developing countries, cooperation and coordination between government and public sector organizations is still limited. In most cases, systems are not designed to ensure smooth data sharing and exchange between organizations. While in other instances, organizations are not interested in investing heavily on spatial databases, but would rather prefer consuming or subscribing to data prepared by other

organizations at reasonable cost. This occurs mainly when spatial data and geospatial technologies are not the core of an organization's operations. SDI current situations in developing countries are that organizations build spatial databases mainly to meet their individual needs. Such databases are often undertaken with little coordination with other organizations in national governments (Sieberitz and Fourie, 2015). Consequently, major duplications and redundancies result from these disjointed activities.

Spatial data and services have capabilities of supporting organizations in their decision-making purposes as outlined above. However, most developing countries do not have policies to encourage sharing and collaboration on spatial data and services. As such, individual organizations develop their own data standards, thus hindering interoperability. Developing countries lack effective national policies, strategies and organizational structures needed for a successful SDI implementation. This is because spatial data collection has been in the past viewed as the responsibility of National Mapping Agencies (Warnest et al., 2003).

Developing countries especially the African countries have experienced a lot of problems in development of SDI from the very beginning. To support this statement (Bishop et al. 2000) identified a lot of challenges these countries faced in building spatial information and suggested solutions by stating; "that simple, low cost, project oriented, easily maintained and user-friendly spatial information technologies have the best chance of success". The question is whether these solutions have been considered, and what is the situation now? There is need to clarify the validity of the views in Bishop et al. (2000) and suggest suitable ways to follow in case of developing SDI in African countries such as those in the SACU region. Studies need to be conducted in order to give insight into the real problems, report on the progress made and suggest new alternatives in terms of effective partnerships in SDI development in the region. Partnerships in an SDI development are a real problem and this is supported by recent reports in (Lipeg & Modrijan, 2010) by indicating that even in Europe the INSPIRE initiative still has its own partnership problems because the NSDI directive fails to explicitly state the role of the private sector.

The foregoing helps to crystallize the idea presented in this short contribution and advances partnerships as vital in SDI development in developing countries and that partnerships can be stumbling blocks or facilitators to SDIs. Partnerships which often take shape when SDI concept is adapted can be suspect and responsible for the failures of SDI development in developing countries. Therefore, there is a need to look deeper at underlying partnerships in SDI development in developing countries. In order to do that countries such as Botswana, South Africa, Namibia, Lesotho and Swaziland collectively known as the Southern African Customs Union (SCU) can be used as a case study to improve our understanding of the partnerships problem.

SIGNIFICANCE OF THE STUDY

The significance of the suggested line of study is to highlight the importance of partnerships in building SDIs and to identify roles in which stakeholders can partake for a successful SDI initiative. In addition, it aims to add valuable literature to ongoing debates with regards to establishing national SDIs as the world moves towards what Rajabifard (2008) calls 'information enabled society'. This contribution is meant to upgrade the concept of partnerships within the realm of a technology-driven discipline of Geomatics focussing on SDI development. Single-handedness of National Mapping Agencies can be a hindrance to the building of SDIs, hence the need for partnerships. Partnerships must not only inform SDI development process but must be functional enough to deliver benefits and opportunities.

The purpose of the suggested line of study has the following objectives:

- To investigate Partnership and Spatial Data Infrastructure concepts and reconcile them,
- To draw on the partnership successes or failures in the SDI development in the study areas,
- To develop a functional partnership framework that can be adapted to the concept of SDI development in the study areas.

Through these objectives research can be carried out which can lead to a conceptual framework that can define and reconcile SDIs and partnerships in order to develop national SDIs in the SACU countries. Several scholars in Crompvoets et al. (2008) have summed up SDI concepts as ambiguous and for them to be understood cross-disciplinary research must be conducted. We believe that studying partnerships in the realm of SDI and their development is a direct cross-disciplinary research in its own right.

THE SACU AS A REGION

The SACU countries started pursuing SDIs as national efforts in early 2000. Examples are the South African Spatial Data Infrastructure Act of 2003, (Sieberitz and Fourie 2015) and Botswana early efforts (Morebodi 2001). Reviews of SDIs in Africa have been done by Makanga and Smit (2010) who have revealed SDI weaknesses across the whole continent, with all the SACU countries included. National efforts reviews have also been done by Maphale and Phalaagae (2012) in case of Botswana and Sieberitz and Fourie (2015) in case of South Africa. In summary, from the forgoing literature the various national efforts are still at their early stages and according to Makanga and Smit (2010) they are slow in relation to the fast-changing technological environment. Among all SACU countries South Africa is the only one which has made significant strides towards formalising its SDI activities through an Act of parliament. Recently, Namibia seems to be gaining momentum in the development of SDIs because of the boost it got in 2011 where the need for SDI development was added to its Statistics Act, (Mudabeti and Longhorn 2016). Further to the literature reviewed, the other three countries Botswana, Lesotho and Swaziland do not seem to be having much going on. To kick start the SACU SDI partnerships the following areas can be explored:

- Regional geodetic framework development
- Regional river system mapping
- Boundary mapping
- Wildlife and conservation Mapping
- Mineral resources

The African Continent has proposed an integrated geodetic reference framework since the early 2000. The suggested framework was to be established based on six regions among them the Southern African Reference Framework, (Combrinck 2010, 2008; and Wonnacott et al. 2015). Up to now these regional reference frameworks have not been operationalised and the concept of regional partnerships in this regard is advanced. Regional geodetic framework will be very useful in geospatial information such as riverine mapping, inter-country boarder mapping, wildlife and general conservation mapping.

Southern African rivers are interconnected and developing a methodology of collaboration in spatial data relating to river system will go a long way in building understanding of that. These are fundamental shared resources in need of mutual management and exploitation by the inhabitants of the Southern African region. The spatial data relating to the rivers can be collected, processed, integrated and shared utilising a common geodetic reference frame. Southern African Customs Union countries share same boundaries which are usually along most major rivers e.g. Limpopo, Nassob, Molopo and Chobe. Inter-country boundary surveys, mapping, geospatial information analysis and dissemination will help the countries towards intelligible handling of their boarders and related activities such as movement of people, goods, services, animals and conservation in general. The areas of partnership collaboration will then be cemented by further developing policies and understanding on issues of wildlife and conservation in the whole area. Wildlife tend to move between these countries and natural disasters such as fire tend to affect these countries across their boarders. In addition to wildlife, Africa is generally endowed with many natural resources such as minerals and through the African Union, partnerships as a way to their sustainable exploitation is encouraged, (AMV, African Union Report 2009). To address all these fundamental issues, partnership frameworks need to be

established based on geospatial information within the auspices of the Southern African Customs Union (SACU).

CONCLUSION

Policies and partnerships can be developed around the proposed themes based on the existing Southern African Customs Union (SACU) framework as a macro platform for the activities. Through national organizations, these countries need to acknowledge and recognize that there is value added in their organizations working together both at national and regional levels in SDIs. In so doing they have to realise that effective partnerships are important even though they take time, hence the need for those involved to establish the right frameworks from the start. If these partnerships are developed, there will be need for regular reviews of the structures and processes of these partnerships on regular basis to measure their successes and shortfalls (World Bank 1998).

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METAL CONTAMINATION ASSESSMENT OF SEDIMENTS WITHIN AND AROUND ARTISANAL GOLD MINE SITES, SOUTHWESTERN NIGERIA

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ABSTRACT

Geochemical assessment of stream sediments within the vicinity of both abandoned and active artisanal mine sites in Southwestern Nigeria were carried out using Inductively Coupled Plasma Mass Spectrophotometer (ICPMS) at ACME laboratories, Canada to determine 56 major and trace elements.

Enrichment Factors (EF) for Th, Cd and Mo were within the background to minimal enrichment in all the samples. Stream sediments could be classified as having background to moderate with Cu, Ni, V, Ba, Sn, Dy, Ag and enrichment to significant enrichment of Pb, Zn, Co, Cr, W, Co, Pr, Nd, Sm, Eu, Gd and Ta. Sediments showed moderate to significant Nb enrichment. Geo-accumulation Index (Igeo) showed that sediments can be classified as unpolluted with all the trace elements except Ta and Nb which fell between unpolluted to moderately polluted group. Contamination degree showed that 52.6%, 15.8%, 15.8% and 63.2% of the sediments fell within low, moderate, high and very high degree of contamination respectively. Pollution Load Index (PLI) also showed that 36.8% of the sediments can be classified as polluted and followed the same pattern with the result of contamination degree where high concentrations were recorded at locations with high active mining activities.

It can be concluded that the sediments of the study area are highly contaminated with Nb and Ta and moderately contaminated with other toxic elements. This could adversely affect the health of the population.

Keywords: Artisanal mine, Sediments, Contamination, Ilesha, Toxic Elements

INTRODUCTION

The activities of miners until recent time has always been on small-scale operations, which is usually very crude in terms of methodology and very dangerous to the health and safety of both the miners and the surrounding environment, nevertheless to a reasonable extent still meet the demand of the society as supplier of materials for production. These activities are carried out by people using manual tools and equipment, usually in an informal sector outside the legal and regulatory framework.

Although most attention in the mining industry is focused on large corporations in many parts of the world, particularly in developing countries, minerals are extracted by Artisanal Small-Scale Mining (ASSM) and illegal miners (Hentschel et al. 2002).

Generally in developing countries, estimations show that 80% to 90% of small-scale mining activities are informal, artisanal and illegal. They may involve only individuals or families, generally between 10 and 50 people. They may or may not obtain mining concession rights. Hence in reality, the activities of artisanal and illegal miners are the same and so are their impacts (Adekeye 2001). Nigeria being a developing country typifies a place where such activities are thriving and blossom with little to no resistance. Their activities include mining of gemstones like tourmaline, beryl, amethyst, aquamarine, garnet and precious minerals like diamond, gold etc. Generally, they extract minerals that have the

advantage of being relatively simple to extract, transport, and sell legally or illegally (Hilson and Potter 2003).

Their activities, have considerable impacts on the environment (Obiora et al. 2016; Warhurst and Insor 1996; McMahon et al. 1999; IUCN 2004). Minerals in their ore forms consist of associated metals, which are washed into the stream at the point of cleaning the mineral or/and erosion of mine tailings. The most important source of trace elements in the environment is from mining operations, grinding, concentration of ores and disposal of tailings. Together with mine waste water they are considered to be the main contamination sources of trace elements in the environment (Adriano 1986). Stream sediments have been found to be contaminated by trace elements from artisanal mining activities and their values have been found to exceed standard safety levels (Ojo and Oketayo 2006; Narley et al. 2011).

Hence, the purpose of the present study is the determination of the implication of the mining activities on the quality of stream sediments and the risk to the health of the population within and around active gold mines and abandoned mines in Ilesha, Southwestern Nigeria.

MATERIAL AND METHODS

STUDY AREA

This study was carried out in Ijesha community, located in Ilesha, Osun State, Southwestern Nigeria (Longitudes 7 30' and 7 35'N and longitude 4 30´ and 4 34'E, Fig. 1). The area is famous for gold mining for decades with Proven reserves of 68,768 ounces of gold hosted by14,104,702 m3 of ore at an average of 0.00488 oz/m3 (NMC 1987). The geology may be broadly grouped into gneiss-migmatite complex, mafic-ultramafic suite (or amphibolite complex), meta-sedimentary assemblages and intrusive suit of granitic rocks (Kayode 2009; Folami 1992; Elueze 1992). The primary gold mineralization comprises a series of auriferous quartz-carbonate veins localized by a subsidiary fault within biotite gneiss and mica schist, presently defined by subparallel old working extending for about 900 m in a NNE direction. Gold occurs with pyrite, pyrrhotite and minor chalcopyrite, galena, sphalerite, magnetite and ilmenite.

STREAM SEDIMENT SAMPLING

3 kg of nineteen stream sediment samples were collected with the aid of a stainless hand trowel which was properly cleaned before and after collection of each sample to avoid contamination. In the laboratory, the stream sediment samples were oven dried at a temperature of 40 °C until a constant weight was attained before dry sieving. Samples were disaggregated and sieved through a minus 80 mesh (177 μm) plastic sieve. The fine-grained (<177 μm) fraction of stream sediment samples were submitted for a multi-elemental analysis in an accredited Canadian laboratory (ACME Analytical. ISO 9002 Laboratories, Canada). 0.5 g split was leached in hot (95 °C) aqua regia (HCl–HNO3–H2O) for 1 hour. After dilution to 10 ml with water, the solutions were analyzed for major and trace elements which are Mo, Cu, Pb, Zn, Ag, Ni, Co, Mn, Fe, As, U, Th, Sr, Cd, Sb, Bi, V, Ca, P, La, Cr, Mg, Ba, Ti, Al, Na, K, W, Zr, Sn, Be, Sc, S, Y, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Hf, Li, Rb, Ta, Nb, Cs, In, Re, Se, Te and Tl.

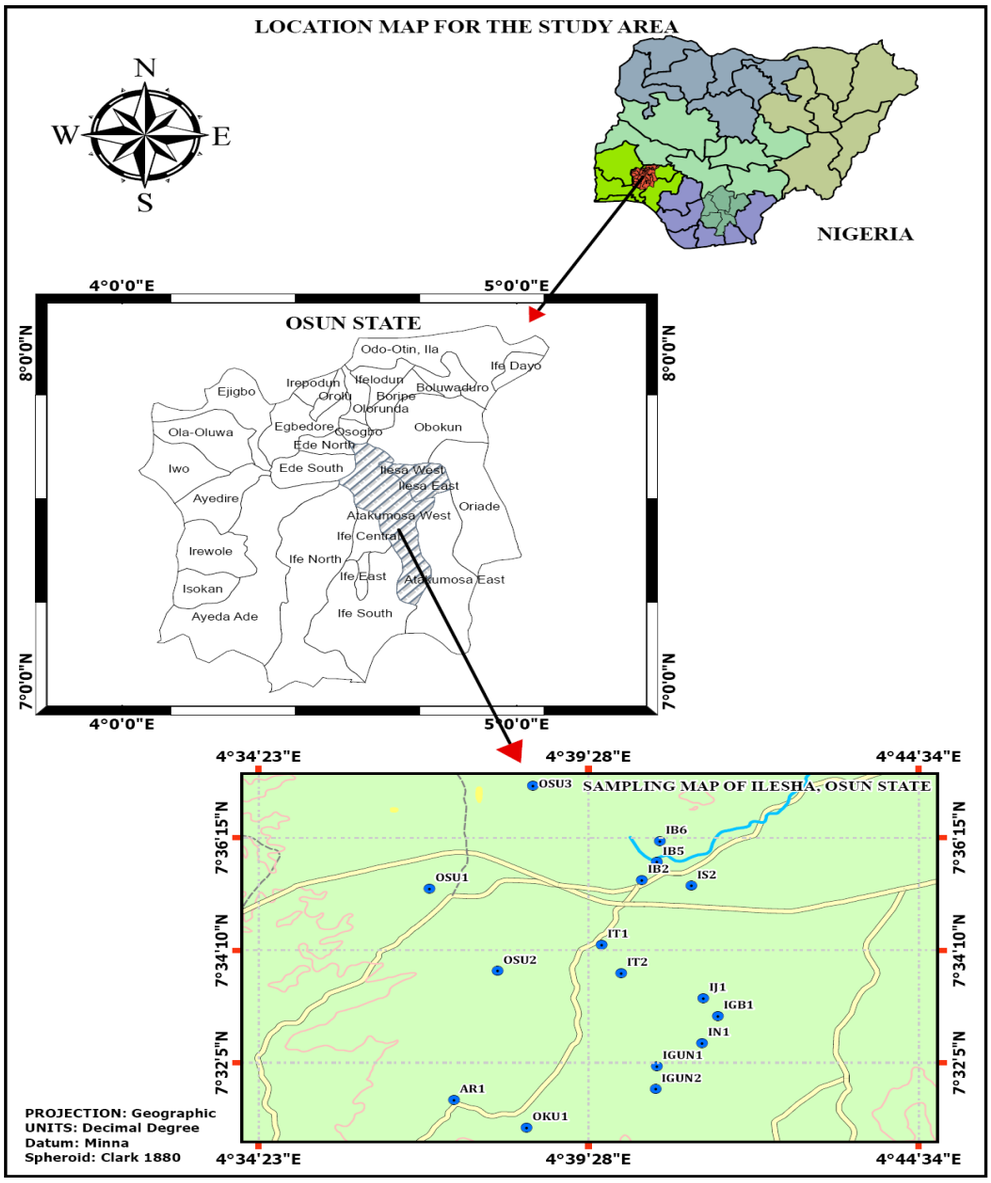


Fig.1 Map of the study area

EVALUATION OF DATA

Some quantitative indices were used to assess the heavy metal contamination. This also allowed for easy comparisons between the determined parameters. These indices included the Enrichment factor (EF) (Simex and Helz 1981), Contamination Factor (CF) and Contamination Degree (CD) (Hakanson, 1980), Geo-accumulation Index (Igeo) (Mueller, 1979) and Pollution Load Index (PLI (Tomlinson et al. 1980). Their various formula and classifications were discussed in Gong et al. (2008), Saha and Hossain (2010), Zoynab et al. (2008), Odukoya et al., (2016) and Odukoya and Akande (2015), among others. The interpretation of the different classifications are presented in Table 1 below.

$$\text{Geo-accumulation Index (Igeo)} = \log_2 \frac{Cn}{1.5Bn} \quad (1)$$

Where: Cn is the measured concentration of the examined metal (n) in the sediment samples

Bn: The geochemical background concentration of the metal (n)

1.5: The background matrix correction factor due to lithogenic effects

Enrichment Factor (EF) = $\frac{CN/CM}{CB/CX}$ (2)

EF is the enrichment factor for the element

CN is the ratio of the concentration of element analysed; CM is the concentration of normalizing element which is Al in this case.

CB is the background value of the element analysed which is Average Shale Concentration (ASC) in this case, and CX is the ASC for Al

Contamination Factor (CF) Cf = $\frac{concentration\ of\ heavy\ metals\ in\ sediment}{concentration\ of\ background\ value}$ (3)

Where, C is the concentration of element "n". In this case, the background value is the average shale concentration (Turekian and Wedepohl, 1961).

Contamination Degree (Cd) = $\sum$ Cf (4)

Pollution Load Index (PLI) = (CF1*CF2*...CFn)1/n (5)

Table 1. Classification of Contamination Indices (Simex and Helz (1981), Mueller (1979) and Hakanson (1980).

Enrichment Factor		Pollution Index (PLI)		Contamination Factor (CF)		Contamination Degree (CD)		Geo accumulation Index (Igeo)	
value	interpretation	value	interpretation	value	interpretation	Value	Interpretation	Value	Interpretation
< 1	Background	PLI = 0	background concentration	Cf < 1	Low contamination factor)	Cd<7	low degree of contamination	<0 Class 1	practically uncontaminated
1-2	Concentration	0 < PLI = 1	Unpolluted	1 < CF < 3	moderate contamination facto r	7<Cd<14	moderate degree of contamination	0-1 Class 2	uncontaminated to slightly contaminated
2-5	depletion to minimal enrichment	1<PLI = 2	unpolluted to moderately polluted	3 < CF< 6	considerable contamination factor	14<Cd < 21	high degree of contamination	2-3 Class 3	moderately to highly contaminated
5-20	moderate enrichment	2 < PLI = 3	moderately polluted	CF > 6	high contamination factor	Cd > 21	very high degree of contamination	4-5 Class 4	highly to very strongly contaminated
20-40	significant enrichment	3 < PLI = 4	moderately to highly polluted					>5 Class 5	very strongly contaminated
>40	extremely high enrichment	4 < PLI = 5	highly polluted						

Table 2: Descriptive Statistics major element concentration in the sediments

Major Elements (%)	Min	Max	Std. Deviation	Mean	Detection Limit	Background (ASC)
Fe	0.87	8.11	2.03	4.31	0.02	4.72
Ca	0.03	0.86	0.26	0.26	0.02	1.6
P	0.005	0.176	0.04	0.03	0.001	0.007
Mg	0.04	0.66	0.18	0.23	0.02	1.5
Ti	0.3	3.364	0.77	1.58	0.001	4.6
Al	0.98	8.09	1.68	3.16	0.02	8.8
Na	0.017	0.698	0.18	0.15	0.002	0.591
K	0.08	2.22	0.62	0.62	0.02	2.66
S	<0.04	<0.04	0	<0.04	0.04	2.4

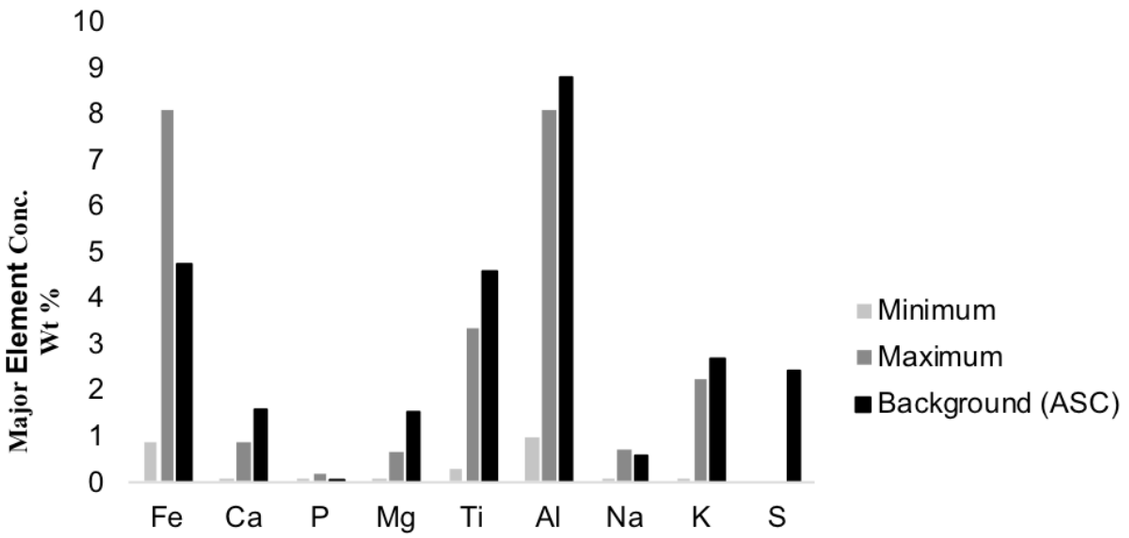


Fig 2. Major Elements against ASC

RESULTS AND DISCUSSION

GEOCHEMICAL ANALYSIS OF SEDIMENTS

Nineteen (19) stream sediments samples were taken from ten different communities in Ilesha, Southwest Nigeria. Fifty-Four (54) elements which included Mo, Cu, Pb, Zn, Ag, Ni, Co, Mn, Fe, As, U, Th, Sr, Cd, Sb, Bi, V, Ca, P, La, Cr, Mg, Ba, Ti, Al, Na, K, W, Zr, Sn, Be, Sc, S, Y, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Hf, Li, Rb, Ta, Nb, Cs, In, Re, Se, Te and Tl were analysed using ICPMS.

The results of major elements are presented in Table 2. Fe, Ca, P, Mg, Ti, Al, Na, K and S ranged from; 0.87 – 8.11 %, 0.03 - 0.86 %, 0.005 – 0.176 %, 0.04 – 0.66 %, 0.3 – 3.36 %, 0.98 – 8.09 %, 0.017 – 0.698 %, 0.08 – 2.22 % and <0.04 % respectively (given in weight %) and showed the following descending order of concentration; Fe >Al >Ti >K >Ca >Na >Mg >P >S (Fig. 2). The concentrations of Ca, Mg, Ti, Al, K and S in the sediment samples were all below the Average Shale Concentrations (ASC) (Taylor, 1964) which were used as background values while Fe, P and Na exceeded the ASC (Fig 2).

The result of the trace element analyses showed that Bi, Be, Re, Se and Te are below the detection limit while Mo, As, U, Sr, Cd, Sb, Zr, Sn, Hf, Li, Rb, Cs, In and Tl were below ASC values. Cu, Pb, Zn, Ag, Ni, Co, Mn, Th, V, La, Cr, Ba, W, Sc, Y, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ta, Nb and In are above their respective ASC values which are 45, 20 95, 0.1, 50, 19, 850,12, 130, 43, 90, 580, 1.8, 13, 26, 82, 9.8, 33, 6.2, 1.2, 5.1, 0.8, 4.7, 1, 11and 0.1 ppm respectively in some of the sediments (Figs 3A-C).

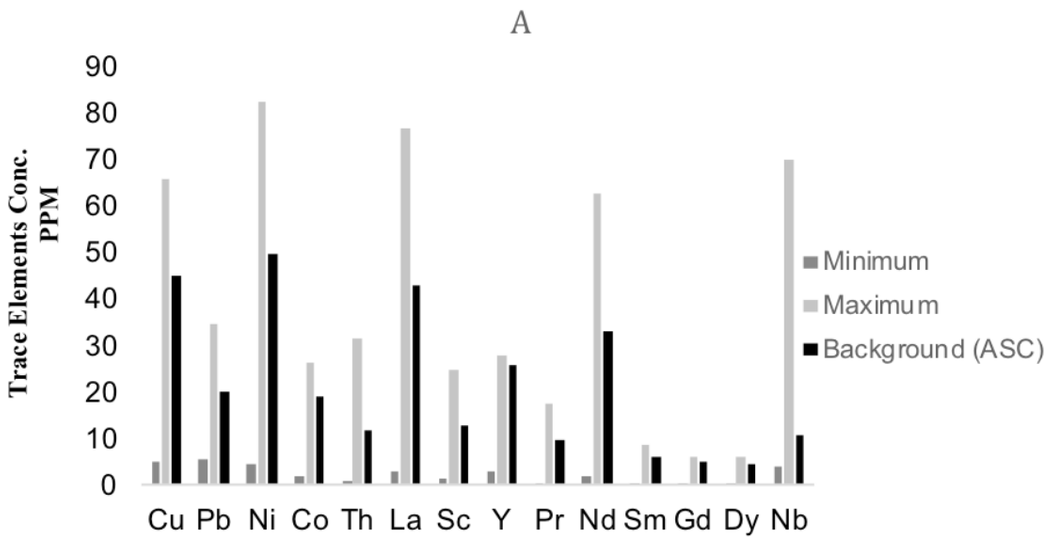


Fig. 3A. Trace Elements concentration versus ASC

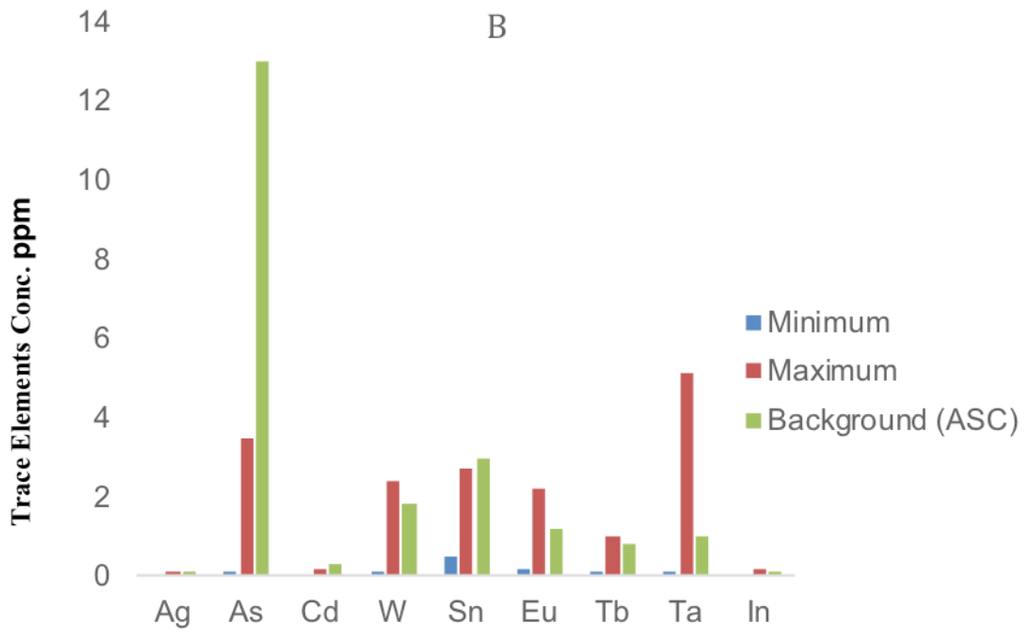


Fig. 3B. Trace Elements concentration versus ASC

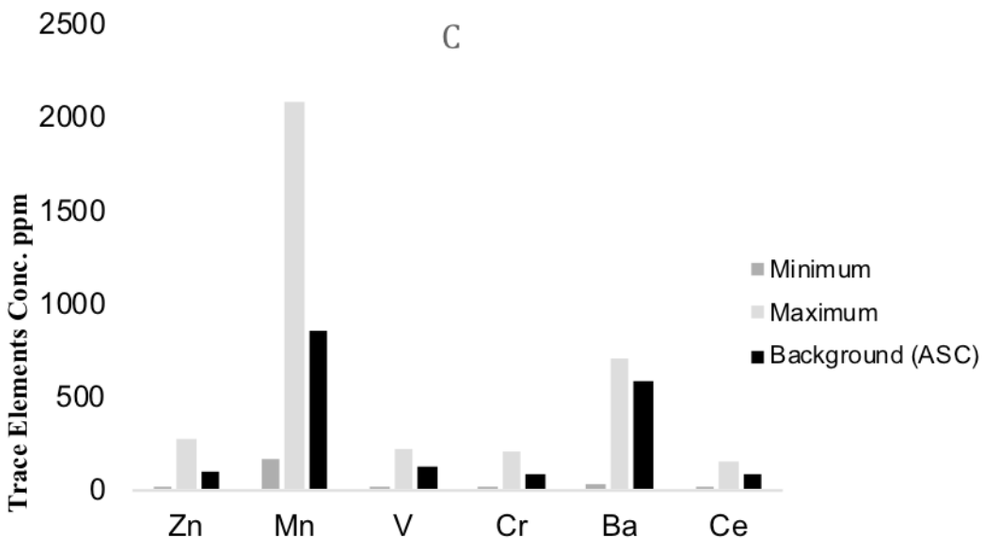


Fig. 3C. Trace Elements concentration versus ASC

CONTAMINATION OF ASSESSMENTS

ENRICHMENT FACTORS (EF)

Generally, the enrichment factors for Th, Cd and Mo are within the background to minimal concentrations in all the stream sediment samples. All the stream sediments could be classified as having background to moderate enrichment for Cu, Ni, V, Ba, Sn, Dy, Ag and background to significant enrichment for Pb, Zn, Co, Cr, W, Co, Pr, Nd, Sm, Eu, Gd and Ta. The sediments showed moderate to significant enrichment for Nb (Table 1). The average values of EF for the different analysed elements are shown in Fig 4.

GEO-ACCUMULATION INDEX (IGEO)

The results of the geo-accumulation index showed that the sediments can be classified as unpolluted based on all the trace elements except Ta and Nb which fall between unpolluted to moderately polluted according to Muller (1979) as displayed in Table 1.

CONTAMINATION FACTOR AND CONTAMINATION DEGREE

The result of the contamination factor also showed that sediments in the study area have different levels of contamination ranging from low to moderate for all the trace elements except Nb and Ta which display high contamination in some samples where active mining is still going on (Table 1). Based on contamination degree, 52.6% of the sediments can be classified as being low contaminated and 15.8% can be classified as being moderately contaminated, another 15.8% highly contaminated while 63.2% can be grouped as very highly contaminated with toxic elements (Fig 5).

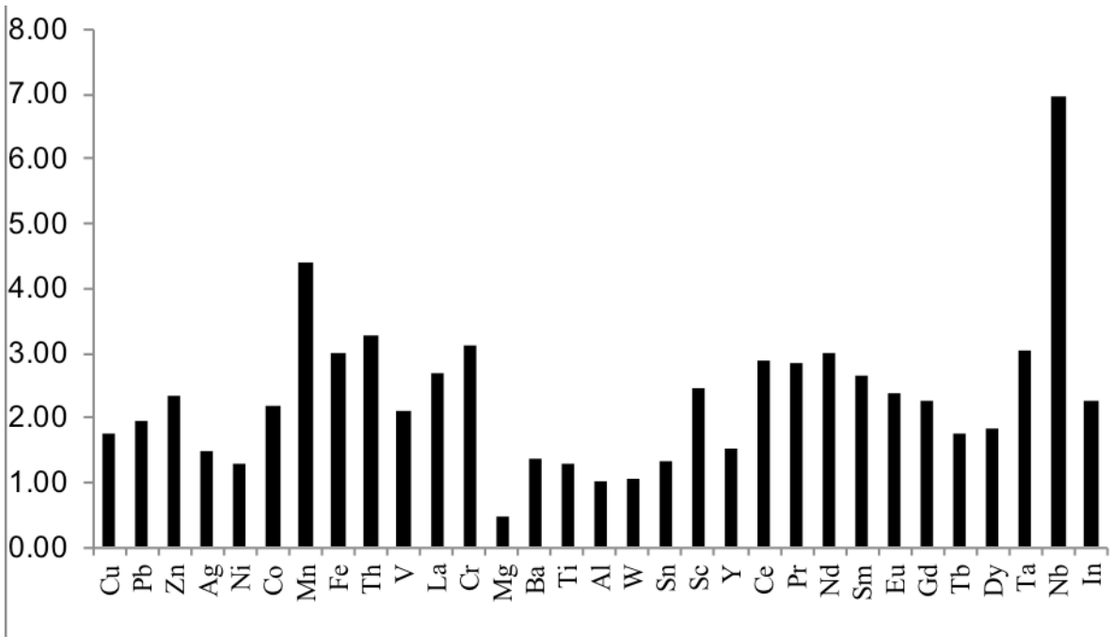


Fig. 4. Average EF in the sediments of the study area

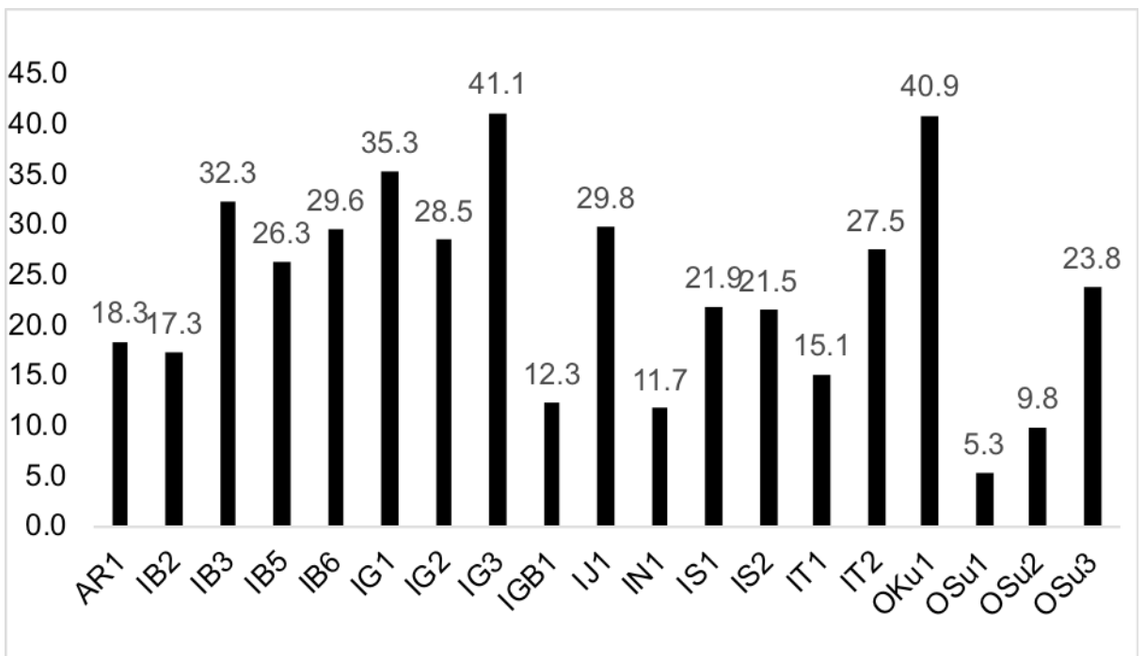


Fig. 5. Contamination degree versus sample locations

POLLUTION LOAD INDEX (PLI)

The Pollution Load Index (PLI) results for the study area are shown in Fig. 6 based on the methods of Tomlinson et al. (1980). PLI value greater than1 signifies pollution, while PLI value less than 1 indicates no pollution. The PLI values recorded range between 0.25 – 1.95. 36.8% of the sediments can be classified as polluted. PLI showed the same pattern with contamination degree with high values recorded at locations of high active mining activities.

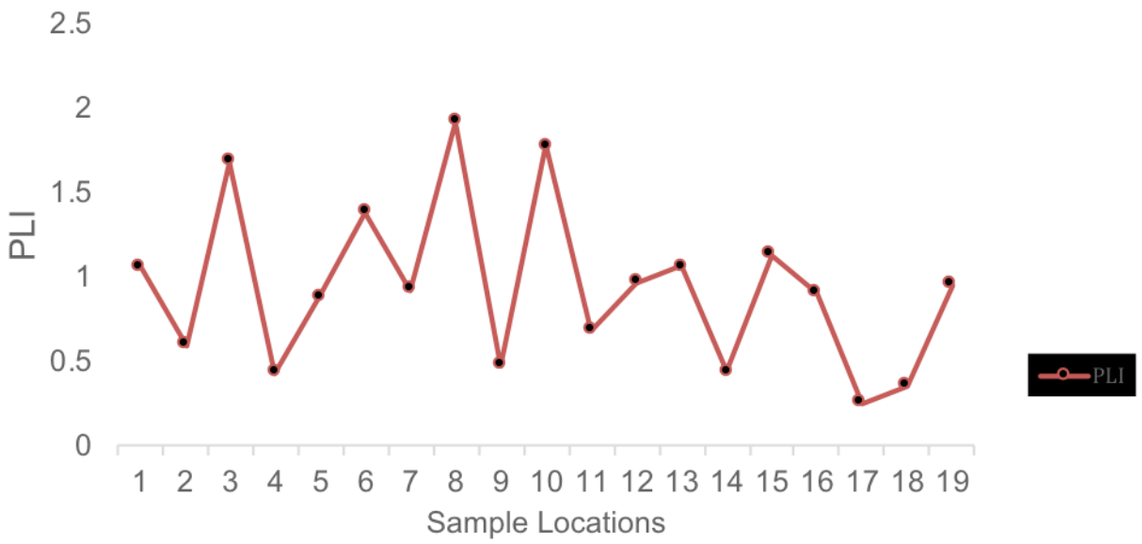


Fig. 6. PLI against Sample Locations

CONCLUSION

It can be concluded that the activities of small scale artisanal miners in Ilesha, Southwest Nigeria have led to low to moderate contamination of stream sediments for most of the analysed heavy metals except Nb and Ta which caused high contamination in the sediments

The moderate risk may be due to mining method employed in the area which are not expected to introduce additional toxic elements to the environment unlike other mine sites in the country. Active mining are still going on at the locations which fall under moderate and high contamination.

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THE APPLICATION OF HISTORICAL GEOLOGICAL AND AIRBORNE DATA IN MINING INDUSTRY – CASE OF COAL SECTOR IN MOZAMBIQUE

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ABSTRACT

An exploration company's initial decisions to invest are directly dependent on historical data availability in the country, mostly based on Geological Surveys. The database with range of data from geological maps, topo-sheets, aerial photography, satellite imagery and airborne-geophysical data can provide very useful information to the first step of knowledge of identified deposits. In the case of Moatize basin, these datasets support the first assessment of the area concerning the extension of the basin and delimitation of potential areas prone to occurrence of coal deposit. The geological structures interpreted from airborne geophysics were used to provide an assessment of the distribution (and volume) of intrusive which can affect the quality of coal, in addition to building an understanding of the basin structures/zones which are considered to have significant potential for enhanced coal development. From the aerial photography, information such as roads, tracks, vegetation areas, inhabited areas, water courses and streams as well as built infrastructure around the planned mining area could be extracted. With the processing of hyperspectral data, with advanced image processing software, it is possible to automatically identify the location and condition of features that display specific spectral signatures, such as the analysis of vegetation and thus, produce hyperspectral maps. The Digital Elevation Model-DEM data in sedimentary basin will help to distinguish between sandstone environment from mudstone and alluvial systems, and clearly show the flat lands from high lands.

INTRODUCTION

This short article intends to highlight some of the application and importance of historical dataset, remote sensed data and airborne geophysics when exploring coal basins. First the historical datasets archived under the geological surveys, if well managed can play very important role towards initial exploration of any mineral and non-mineral deposits. Such data vary from 250000 to 50000 scale geological maps, regional geochemistry, Landsat imagery, topo sheets and airborne geophysical maps. When digitized and superimposed they result in powerful tool to discriminate different geological features and delineate preliminary extension of target areas for mineral exploration. Recent advances in technology and the integration of multiple geophysical data-sets including aeromagnetic, radiometric and gravity surveys help provide useful information on lithology and structure in the coal mining industry.

In the case of Moatize basin (Fig 1), these datasets support the first assessment of the area concerning the extension of the basin and delimitation of potential areas prone to occurrence of coal deposits. High resolution satellite data are used for regional geological mapping as well as for locating the potential coal bearing area for detail exploration. The geological structures interpreted from airborne geophysics were used to provide an assessment of the distribution (and volume) of intrusive rock which can affect the quality of coal, in addition to building an understanding of the basin structures/zones which are considered to have significant potential for enhanced coal development. The DEM data in sedimentary basin will help to distinguish between sandstone environment from mudstone and alluvial systems, and clearly show the flat lands from high lands.

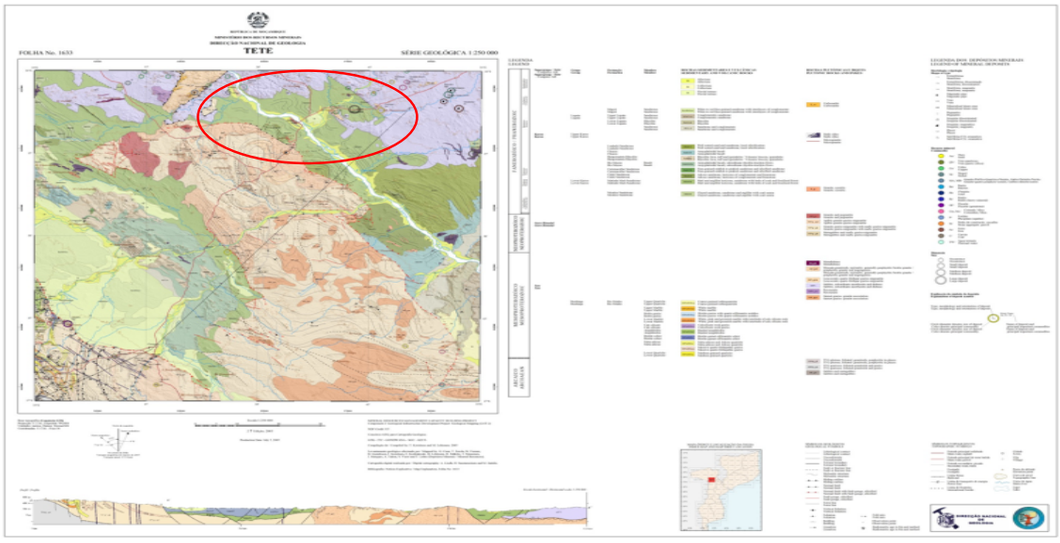


Fig. 1 – Location of Moatize basin in light green cycle area (GTK)

METHODS/RESULTS

HISTORICAL DATA

Historical data used for coal exploration under the Riversdale (Rio Tinto) tenements rang from:

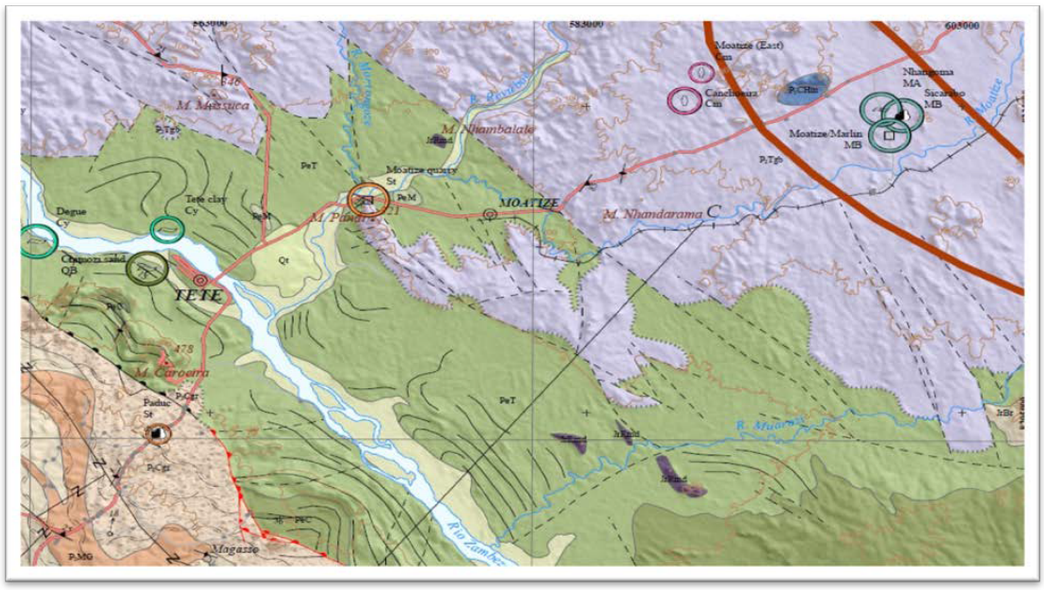


Fig. 2 – Geological map sheet 1633 showing the Moatize Coal basin

- Regional geological and mineral deposit one million scale map;
- Published geological maps at scale of 1:250000 (Fig.2);
- Magnetic and gamma-ray reprocessed data from Hunting survey;
- Landsat TM imagery including the following processed spectral combination bands (753, panchromatic band 8, 742 pan, 532 and 321 pan).

All available and relevant geological, topographical, Landsat and airborne geophysical data were assembled into MapInfo and ArcView Geographical Information Systems.

LANDSAT-7 TM SATELLITE IMAGERY

Interpretation is based on hard copy false colour composites of Landsat-7 TM satellite imagery band 7 (Red), band 4 (Green) and band 2 (Blue), merged with the high resolution panchromatic Band, prepared by Southern Mapping. The imagery is of high quality and entirely cloud free although there is some active burning in progress in places.

Geological interpretation was carried out directly on to transparent overlays to the three images (or sheet areas), at 1:100 000 scale. Topographic and topo cadastral control was provided from Mozambique Government 1:250 000 scale maps, the relevant portions of which were merged, georeferenced and enlarged to 1:100 000 scale to fit the three sheets of satellite imagery. Geological control was provided by the 1:1000 000 Carta Geológica da Moçambique (1987), prepared and published by the Instituto Nacional de Geologia, Maputo, the 1:1 000 000 Geological and Mineral Deposits Map of the Mozambican Phanerozoic (2004) prepared by the National Directorate of Geology in Maputo in collaboration with the Council for Geoscience of South Africa, Pretoria, and merged 1:50 000 and 1:100 000 scale geological mapping of Karoo areas in parts of the Moatize Coalfield by Swede Coal Development AB (1982) as part of their Minjova Project.

On completion of the initial interpretation, titles, surrounds and an explanation were designed

and drafted to AutoCAD. The interpretation was then scanned and merged with the explanation to form a set of three sheets on AutoCAD.

RESULTS

In mapping the area geologically from the satellite imagery without field control, only a simple five-fold subdivision of the

stratigraphy was possible, namely (Fig.3); pre-Karoo basement (B), Lower Karoo, mainly shales, thin sandstones and coal measures (KL), Upper Karoo, thick sandstones, overlain in places by basalts and rhyolites (KU), major Karoo dolerite intrusions (Kd), and extensive areas of Quaternary to recent alluvium and transported soils (Q), mainly along the Zambesi and Moatize Rivers but also in the Ncondeze tenement. Possible gabbroic intrusions (gb) and Cretaceous alkaline intrusions (ornamented and labelled) were also mapped at a few places within tenements 935L and 945L. In the Ncondeze tenement it was possible to subdivide the Quaternary-Recent into sandy soils (Qs) and clayey soils (Qc) (Aquila Resources Ltd).

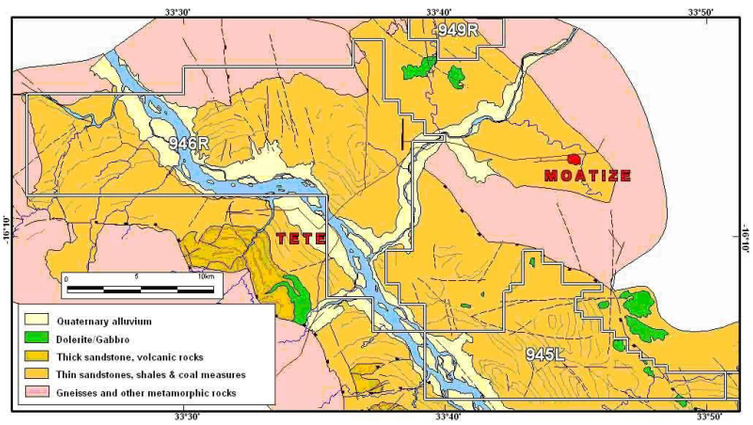


Fig.3 – Geological Interpretation map based on Landsat TM7 satellite imagery

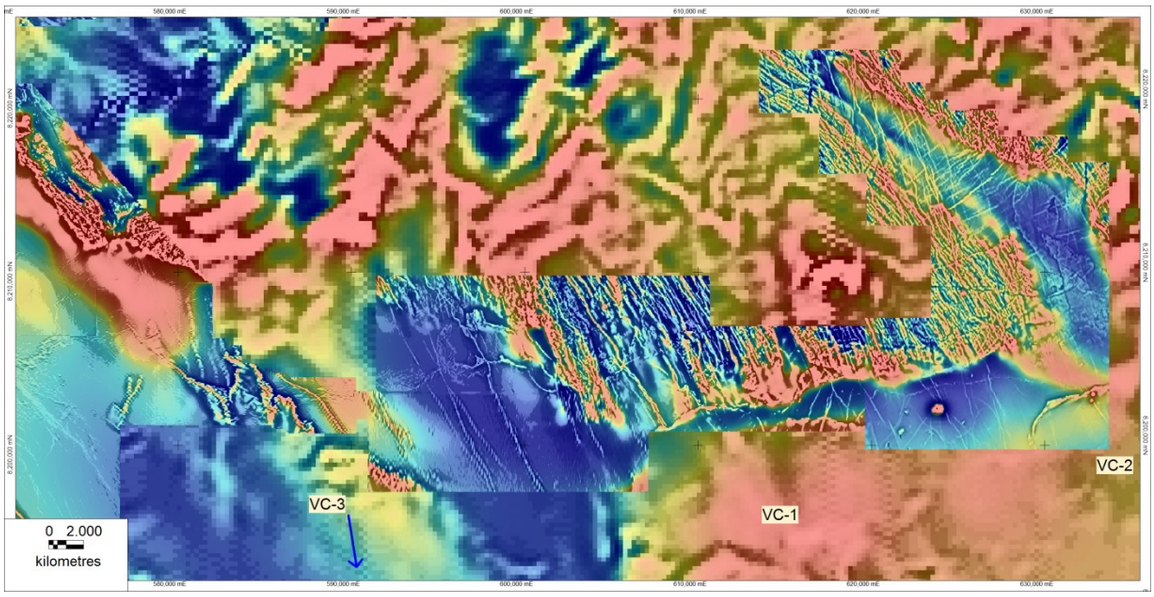
Normal faults can also be frequently mapped, over quite long distances in some instances, often forming the contact between Karoo and basement, and subdividing parts of the area into grabens and half grabens, e.g. the well-established Moatize graben and the Ncondeze half graben. Some dykes can also be recognized and there are many undifferentiated lineaments, some of which could be faults or dykes. The strike and dip of bedding within the Karoo has been inferred in some places. This is based mainly on the configuration of traces of bedding or “form lines” and may not be reliable.

Even with the benefit of stereoscopy, which was not available to us in this case, errors can be made in dip directions based on form lines.

AIRBORNE GEOPHYSICS

A range of enhancement techniques were also applied to the data to improve resolution and delineate the lateral distribution of sills at depth as well as anomalous features associated with vertical/sub-vertical dyke deposits that may or may not reach the surface.

High-resolution aeromagnetic survey data represent a rich source of detailed information for mapping surface geology as well as for mapping deep tectonic structure. Traditional enhancement techniques, such as first vertical and horizontal derivatives 1VD (Fig.4),



reduction and high-pass in - line or grid filters are used in enhancing magnetic anomalies from near-surface geology. There are a number of linear features that can be identified on the magnetic datasets that are interpreted as possible dykes or sills including intrusions. The RTP-1vd magnetic data - the stitch includes both the regional and detailed grids. Note that the first vertical derivative process significantly narrows the magnetic anomaly associated with the magnetic rocks, and highlights shallow - level geology and edges (at the expense of deeper-seated magnetic sources). The difference in geological resolution between the regional and detailed surveys is well represented in this image (Rankin, 2012).

Airborne radiometric surveys similarly are used to measure variations in the mineral composition of the surface geology and are used to map lateral lithological changes. From the single total count and uranium channel it was possible to discriminate between the basements and the sedimentary basin, and from ground follow up the blue area were the target for drilling exploration program.

CONCLUSION

From Landsat TM and Quick Bad satellite images interpretation it was possible to identify thick sequences of lower Karoo buried underneath the surface deposits which assisted for identification of possible target areas. This was confirmed and supported with preliminary interpretation of airborne magnetic and radiometric data acquired from the same area.

Results from the airborne geophysical survey were successfully used to target and define a number of dykes in the area and subsequently resulted in modifications to the proposed mine plan.

ACKNOWLEDGEMENT

The author would like to acknowledge the African Development Center (AMDC) for financial support; the International Coal Venture Lda & Direcção Nacional de Geologia for the data. Thanks to Mrs. Anna Nguno & Prof. Aberra Mogessie for supporting the submission and review of this article.

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MAPPING THE SPATIAL DISTRIBUTION, USES AND IMPACTS OF DEVELOPMENT MINERALS USING GEOGRAPHIC INFORMTION SYSTEMS (GIS): CASE STUDIES IN GREATER ACCRA METROPOLITAN AREA, GHANA

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ABSTRACT

Information on natural resources available in other parts of the world is abundant as compared to Africa, thus affecting Africa's economic development. The availability of natural resources is the biggest asset for the rapid development of most African countries. There is, therefore, the need to provide public geological information to enhance socioeconomic development. Recently, an attempt is made to provide geological information for precious minerals such as gold, silver, and bauxite compared to development minerals, i.e. industrial minerals (construction materials; dimension stones; and semi-precious stones etc.). The neglect of development minerals has important implications for the sustainable development of a country.

The development minerals, especially those extensively used as bulk construction materials e.g. sand and quarry stones, have for decades helped the rapid transformation of cities and many metropolitan and urban areas in some developing countries. The phenomenal growth we observe recently, in infrastructure such as housing, office complexes and road construction have all benefited from extensive exploitation of such materials which are transported and used in the construction and allied industries from mainly semi-urban and rural communities. Exploitation of these materials undoubtedly provides employment, livelihoods and income to many low-income households and women in particular. Inspite of their increasingly socio-economic importance, however, not much research has been done to systematically map and document the spatial distribution of such materials which are worth exploiting. Few studies have been conducted to know their likely effect, over time, on the physical landscape or on the health and safety of the people directly engaged in and the communities populating the nearby mining areas.

This project aims primarily to utilize GIS (Geographic Information System) to spatially map the relative distribution and spread of the exploitation of development minerals that are extracted from the Greater Accra Metropolitan Area. The project provides relevant data that will be significant for policy planning and implementation. It will maximize the benefits derived from development minerals and its uses in the metropolitan area, and also highlight the possible environmental impacts of mining these minerals in the area.

Keywords: Development minerals, construction materials, Geographic Information System (GIS)

INTRODUCTION

Natural resource has direct impact on an economy. The fastest-growing economies in the world are in resource-rich countries like China, India and Brazil, making mineral resource an important source of economic growth in this century (McMahon, et al. 2014). Since mineral resource is a vital commodity for rapid development of a nation this has caused most nations to search for available mineral resources in their countries. Information on natural resources in other parts of the world is higher compared to Africa, thus affecting Africa's socioeconomic development. There is, therefore, the need to provide public geological information related to mineral resources.

According to Kesse (1985) over 2000 kinds of minerals are presently known but only about 100 of these minerals are common. This proves that more research should be done to identify the various mineral resources in a country. In recent times, geological information has been made available for precious minerals such as gold, bauxite and silver etc. but less or no information on development minerals such as industrial minerals (construction materials; dimension stones; and semi-precious stones etc.) due to the low fiscal returns.

Development Minerals are materials which are useful for economic, social and human development. They are natural resources that are of low value to the international commodity market but rather provide essential domestic commodity for construction, infrastructure and manufacturing etc. According to Franks (2015) development minerals are "the hidden bedrock of our society", it has helped nations to attain sustainable development and created employment opportunities to its citizenry which has boosted the livelihoods of millions of people.

ECONOMIC CONTRIBUTION OF PRESIOUS AND DEVELOPMENT MINERALS

Comparing the economic contribution of precious minerals to development minerals in the area of foreign direct investment (FDI) as shown in Figure 1, one recongnizes that it is high for precious minerals but very low for development minerals. In the case of government revenues, precious minerals contribute about 3 – 20 % whereas development minerals contribute < 3%, and are considered as secondary revenue. The Government generates 3-10% of the national income from precious minerals but development minerals contribute largely to domestic value addition by feeding local industries. Regarding employment, only a small percentage of about 1–2% of the total employees in a country are engaged in the precious mineral mining sector whereas in development minerals a large number of unskilled labour are employed.

The comparison between precious and development minerals indicates that both contribute to a nation's economy in diverse ways. Therefore, if governments provide the needed attention to development minerals, especially rich-resource countries will not depend only on precious minerals for their revenues but on development minerals during the mineral bust and their economy will not be seriously affected.

Since Ghana is among the top twenty (20) countries in terms of production value (ICMM, 2012) in precious minerals, less attention has been given to development minerals despite their significance as the "hidden bedrock of our society" (Franks, 2015). Therefore, this paper seeks to address the spatial distribution, uses and the impacts of development minerals in the Greater Accra Metropolitan Area, Ghana.

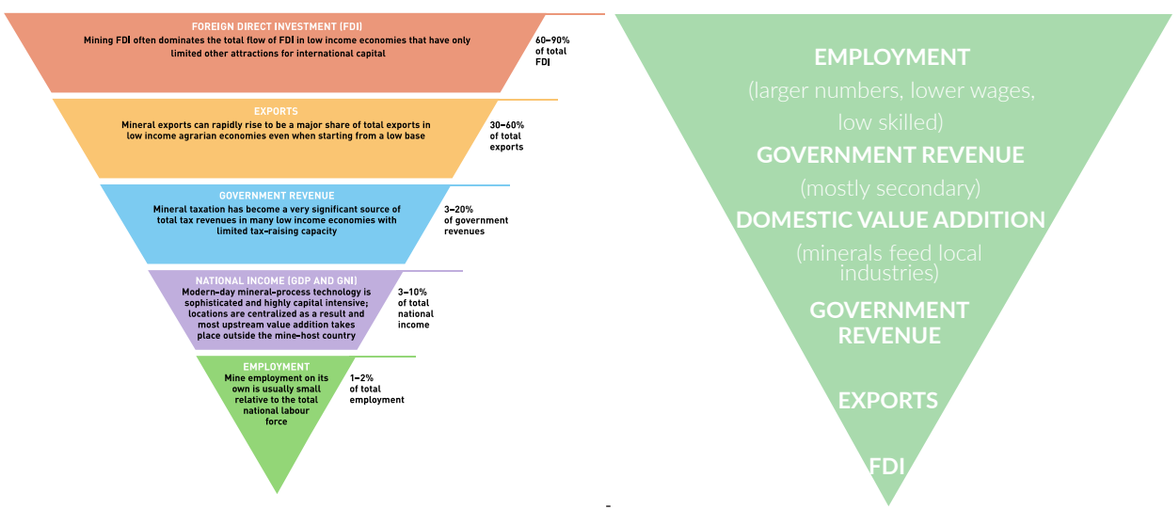


Figure 1. Diagram showing the comparison between Precious and Development Minerals (ICMM, 2012) The role of mining in national economy

DEVELOPMENT MINERALS IN GREATER ACCRA METROPOLITAN AREA AND THEIR USES

The development minerals within the Greater Accra Metropolitan Area are construction materials e.g. sand and gravel etc., industrial minerals e.g. salt, gypsum and dimension stones like slate. Construction materials are aggregates produced from bedrocks used in their natural form. Granite, boulders, pebbles, gravels, sands and clays are examples of such materials. Sand and gravel are essential components for the construction industry. According to Goldman (1994), 97% of gravel and sand is consumed in the construction industry. These materials are used in concrete for bridges, apartment structures and road construction etc.

Industrial minerals are “any rock, mineral or other naturally occurring substance of economic value, exclusive of metal ores, mineral fuels, and gemstones” (Bates, 1975). Salt and gypsum are examples of industrial mineral. Salt has more than 14000 uses (Kesse 1985) such as seasoning for food, an additive in chemical feedstock, softening and conditioning of water, in fertilizers and insecticides, in the manufacture of chlorine and caustic soda, etc. Gypsum is also used in making wall boards, casts and in the building industry as a binding material.

Dimension stone is a natural rock material quarried for the purpose of obtaining blocks or slabs that meet specifications as to size (width, length, and thickness) and shape (Barton, 1968). It is used as a building material.

Despite the uses of these development minerals, without locating where these materials are, it will be irrelevant talking about their socioeconomic importance and value. Thus identification of the location of these minerals is very critical. They have to be mapped since maps have influence on our daily activities; they help us to understand our world as well as the minerals that are deposited in specific areas. Geographic Information System (GIS) helps to visualize, analyze and interpret data and to understand the spatial relationships between the data (Clarke, 1986). In this project GIS was used to visualize the spatial distribution of development minerals in the Greater Accra Metropolitan Area in Ghana

STUDY AREA

The study area (Greater Accra Metropolitan Area - GAMA) was chosen because it is within the nation’s capital where lots of infrastructure, construction and industries are springing up and there is high demand for development minerals.

Ghana is one of the West African countries with Accra as the capital city. GAMA lies within the southern part of Ghana along the coastal plain. It covers an area of about 1400km2 from longitude 0° 30’W to the longitude 0° 05’E and stretches from the coastline to latitude 5° 45’N. It is the hub of Ghana where most governmental agencies, the major seaport and industrial areas are located.

GEOLOGY OF STUDY AREA

The study area consists of Precambrian, Lower Paleozoic, Devonian and Quaternary or Tertiary geological units. The Precambrian rock units within the Accra area are Birimian and Dahomeyan systems and the Togo Series. The Birimian and Togo rocks occur mainly in the North West, the Dahomeyan rocks occur in the North East and the Accraian, unconsolidated, poorly consolidated sediment and soils are within the central part as shown in Figure 2.

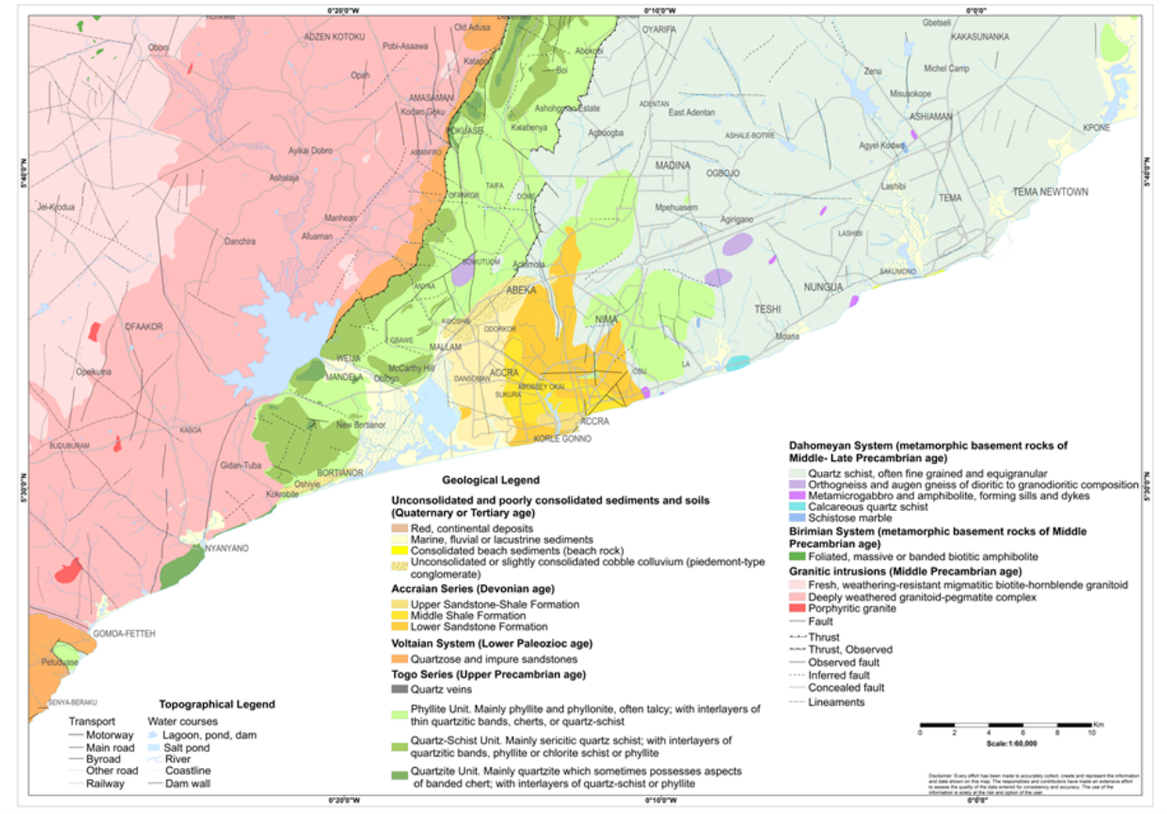


Figure 2. Geology of study area. Modify from Geological Survey Department (2006)

METHODOLOGY

The flowchart of the method used to illustrate the various steps and procedures is shown in Figure 3. The topographic base, field and geological data were gathered. Topographic base and the geological data were acquired from the Geological Survey of Ghana at a scale of 1: 10000 and 100000, respectively, with Ghana National Grid projection. A desk study of construction materials was done with information collected from the Mineral Commission of Ghana and the Geological Survey of Ghana which gave a rough idea about where the materials were located. The locations of these construction materials were determined using GPS (Geographic Positioning System). The field data was organized and loaded in ArcGIS 10.1 and converted into shapefile. Field data shapefile was projected from the geographic coordinate systems to the Ghana National Grid which was overlaid by the base data. The geological data of the area was also overlaid to ascertain the underlying geology.

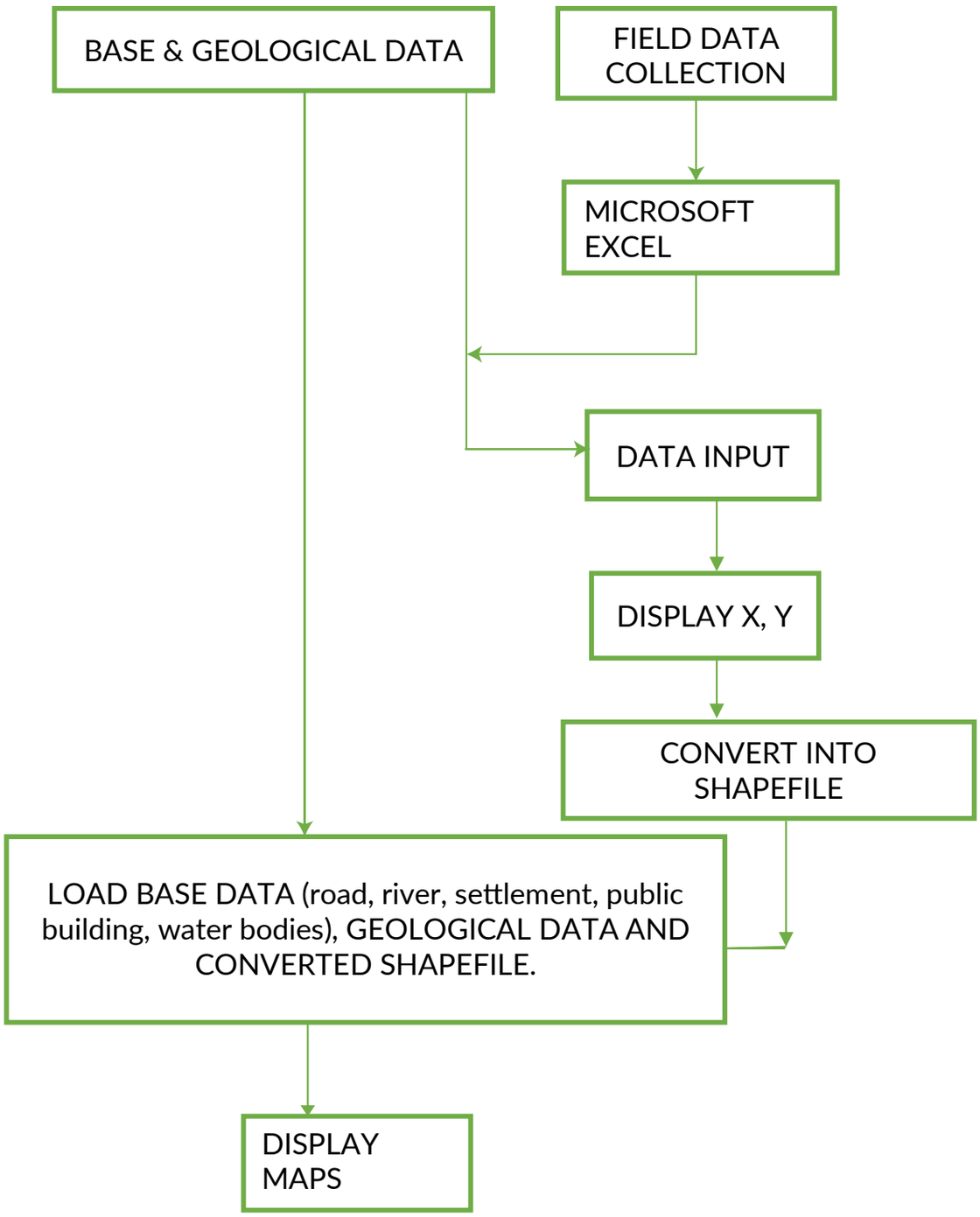


Figure 3. The flow chart of the methodology

RESULTS

The results of the spatial distribution are shown in Figure 4. It is observed that most of the development minerals are located along the Akwapim range with a height of about 365m above sea level and 3 to 6 km in width and mostly made up of quartzite, phyllite, sandstone, shale and schists. The map of the overlaid geology is shown in Figure 5. It is also observed that most of the construction materials and dimension stones fall within the Upper Precambrian age.

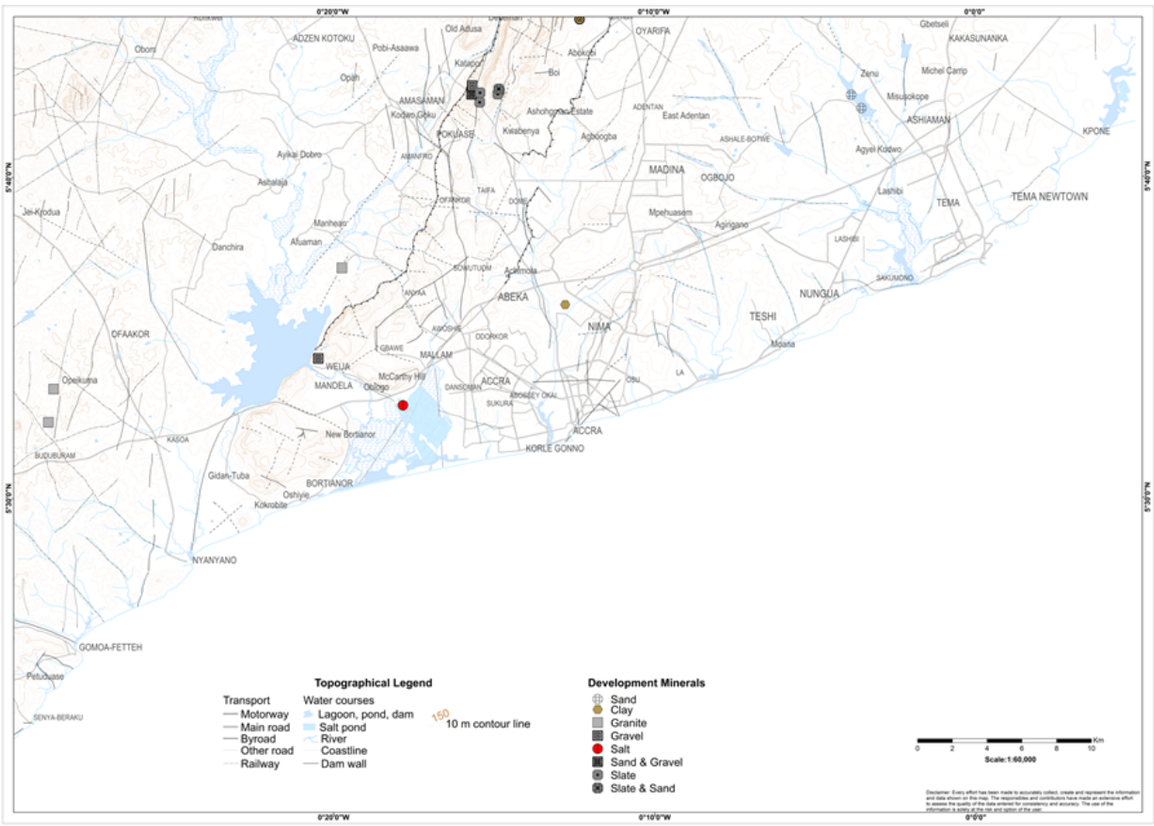


Figure 4. Map showing the Spatial Distribution of Development Minerals in the Greater Accra Metropolitan Area.

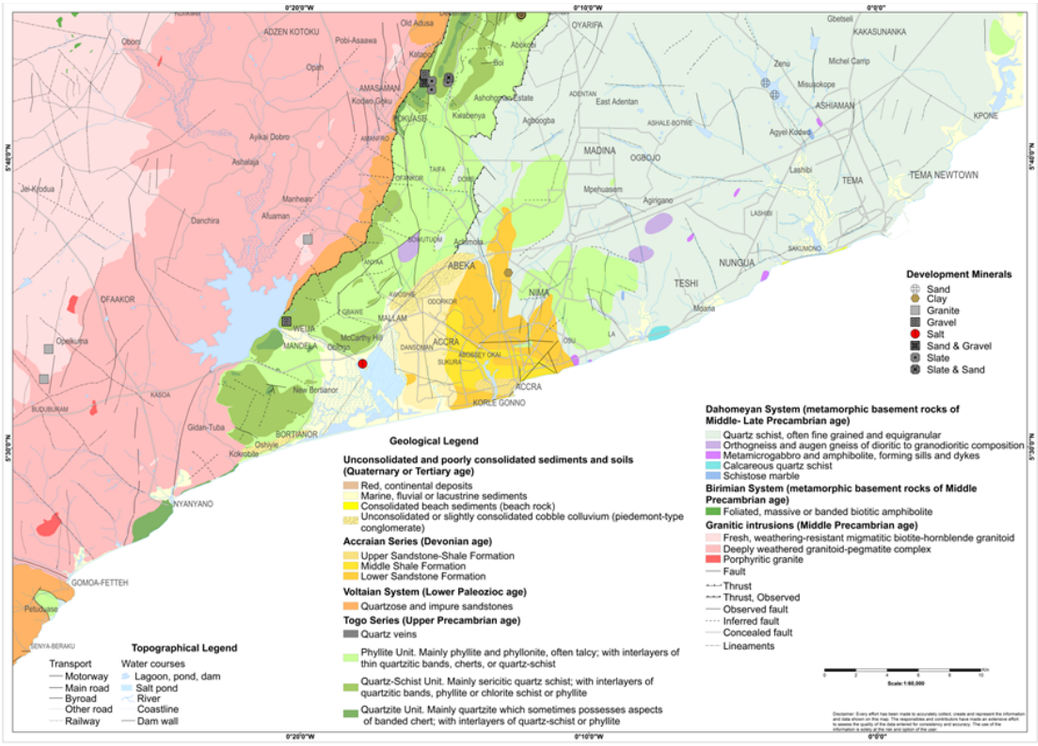


Figure 5. Map showing the Geological Map and Development Minerals in the Greater Accra Metropolitan Area, Modified from Geological Survey Department (2006)

ENVIRONMENTAL IMPACTS

Mining has the potential to release harmful substances into the atmosphere, soil and water bodies. Some environmental impacts of mining activities were observed at the quarry sites. The following are the impacts of mining of development minerals on the surrounding area:

Air pollution: At the mine sites drilling, blasting, excavation, crushing operation, pile storage of sand and gravel activities generate noise and dust particles which are harmful to both workers and the surrounding communities with greater potential of causing health hazards, e.g. respiratory diseases such as asthma.

Water pollution: the dust pollutes the surface water which changes the water quality thus affecting its aquatic life, wildlife and other uses of the surface water; it would ultimately pollute the groundwater.

Topographic modifications: the removal of top soil and overburden to have access to the material causes damage to landscapes. The excavated sites are also left and filled with rain water which would serve as breeding grounds for mosquitoes.

CONCLUSION

The spatial distribution map of development minerals that is produced through this project will help developers to have easy access to locate such construction materials in the GAMA and as well as update Ghana's geoscientific database. Eight development minerals and materials were identified, i.e. clay, granite, salt, slate, sand, laterite, gravel and shale. Even though gypsum occurs within the area, it has no economic occurrences thus was not included. All the quarry sites fall within the Upper Precambrian age, specifically the Togo series.

Some quarry sites adhered to the Environmental Protection Agency policies whereas a few did not, thus affecting the environment. There were more female workers in the salt mines as compared to

those working in the quarries. It was observed that some quarry sites used manual operation which impeded productivity even though there was a high demand for the materials.

The commitment and assistance from the government would greatly promote the exploration of development minerals and improve the mining activities and attract investors for the sector which will boast Ghana's domestic direct investment for economic and infrastructure growth.

ACKNOWLEDGEMENT

The following are highly acknowledged for their contributions in this project: Special thanks to Dr. K. Boamah (Director, Geological Survey of Ghana), Anna Nguno (Deputy Director, Geological Survey of Namibia), Prof. Aberra Mogessie (President of the Geological Society of Africa (GSAf)), African Mineral Development Center (AMDC, sponsors), Mr. R.S. Nartey (Head of Applied Science, Radford University –Ghana), Mr. Seth Okla (Husband), Nhyira & Adom (Children) and my reviewers for their support, contribution and dedication to the success of this paper.

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THE FUTURE OF GROUNDWATER RESOURCES MAPPING USING STRUCTURAL GEOLOGY FOR SUBSURFACE CHARACTERIZATION: A CASE STUDY OF GROUNDWATER IN TURKANA COUNTY, KENYA

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ABSTRACT

Characterizing the permeability structure in groundwater exploration requires collection and integration of structural geological data as well as background geology and present-day stress field. A combination of methods involving field based structural geology with lithological formation plays an important role in identifying the groundwater geological controls on permeable zones, thus the overall flow pattern.

The Turkana region is generally formed of largely metamorphic formations whose groundwater occurrence is mostly controlled by geological structures. A proper mapping of these structural controls has and would lead to discovery of huge reservoirs that can play an important role in regional water supply.

Boreholes in the Turkana are largely drilled on geological structural controls mainly fault zones. These happen to be the same zones that control the surface water flow. As a result, most of the boreholes are dug near rivers. It is important to note that the recently discovered major aquifers in the Turkana area are basically on lithological formations.

This study shows that the Turkana County presents all types of the major lithologic formations ranging from the basement mostly of metamorphic rocks; both volcanic and plutonic and sedimentary rocks. It is important to note that with this kind of geology supported by structural controls; all types of groundwater potential can be documented. This ranges from high to moderate to low and even poor groundwater potential. It is fundamental to equally note that groundwater in the basement system is highly dependent and controlled by geological structural occurrences and orientations.

INTRODUCTION

BACKGROUND INFORMATION

Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment. The world's freshwater resources are under increasing pressure; so, many still lack access to adequate water supply for basic needs. Growth in population, increased economic activity and improved standards of living lead to increased competition for, and conflicts over the limited freshwater resources.

Only a certain proportion of renewable water can be used (known as the safe yield), while the remainder is either technically inaccessible or required to safeguard environmental and ecological processes. Even though all water up to the safe yield can be tapped, it can only be accessed at a steeply increasing cost. The safe yield for surface water is estimated to be on the order of 7.4 billion m3/yr, while the estimated safe yield from groundwater is on the order of 1.0 billion m3/yr (Onchoke W., 2010).

Groundwater has considerable potential for boosting water supplies. Kenya's geology and hydrogeology favor economic exploitation of groundwater resources with an estimated annual safe yield of 1.0 billion m3 per year. This is good news especially for the Arid and Semi-Arid Lands (ASALs) of Kenya, where the Turkana County is located.

It is estimated that less than 10% of Kenya's available groundwater resource is currently used (MOWI, 2006). The advent of technology has made the quest for water for all purposes in life to drift from ordinary search for water to prospecting for steady and reliable subsurface or groundwater. While available groundwater resources must be used for economic growth, at the same time it is important to avoid creating undesirable impacts on groundwater leading to a decline in the value of the resource. This calls for proper management, both to ensure resource sustainability and to maintain quality.

Groundwater is one of the major sources of fresh water supply for the Turkana County pastoral community and sustains a number of urban centers in the area. The survey of groundwater is significant for the County of Turkana, which is considered to be one of the country's poorest and driest areas.

OBJECTIVE OF THE RESEARCH PROJECT

The potential volume of the surface water resources is highly declining leading to increased dependence to a higher degree on groundwater resources. Deforestation, land fragmentation, cultivation of wetlands and rapid increase in human settlements compounded by the effects of climate change have had negative impacts on water resources resulting in reduced stream flows and ground water. Groundwater is one of the major pre-requisites for a decent life and indeed any form of life.

The distance to and from the nearest water points in the County are varied depending on the areas but on average it is between 5-10 kilometers. Considering this, there is need to try and understand the groundwater regime of the County to ease access to water resources.

Structural geology studies have come up with incontrovertible evidence pertaining to the physical characteristics of the subsurface and their comparison to Stratigraphic correlation, monitored from the geologic logs and geophysical surveys which are practically excellent (Mogaka 2010). This study has tried to establish the geological structures of Turkana which will form a basis for the future understanding of the groundwater regime of the area in its various aspects like recharge, discharge, pollution and effectiveness in groundwater development.

LOCATION

The county of Turkana, one of the largest in Kenya is situated in Northwestern region of the country in the former Rift Valley province. It borders Uganda to the West, South Sudan to the North West and Ethiopia to the North East with an area coverage of approximately 77,000 Km2. It consists of six districts namely, Turkana North, Turkana West, Turkana South, Loima, Turkana Central and Turkana East. The region has 17 divisions, 56 locations and 156 sub locations and classified as Arid and Semi Arid Lands (ASALs). It lies between latitude 35° 45‘ -36° 20‘ E and longitudes 00° 38‘ - 33° 29‘ N (Figure 1).

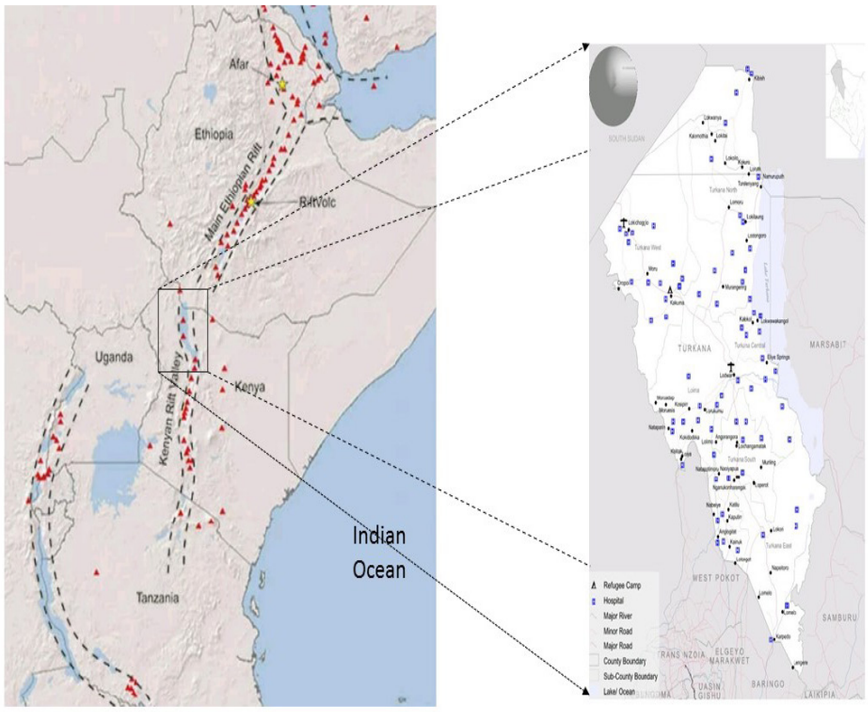


Figure 1: Geographic map showing the study area. (maps.google.com)

PHYSIOGRAPHY

Physiographic features in the County include low lying open plains, mountain ranges and river drainage patterns. Lake Turkana is at an elevation of 360 meters (1,181 feet) while the surrounding basin is anywhere from 375-914 meters (1,230-3,000 feet).

The main mountain ranges of the County are Loima, Lorengippi, Mogila, Songot, Kalapata, Loriu, Kailongol and Silale mountains. Because of their high elevations, the mountain ranges are normally green, covered with dense bushes and high woody cover. Important economic activities like honey production, grazing during the dry season, wood and charcoal production can be documented. There are also water catchment sources thus supporting gum Arabica growing and small household shambas. The hills in the County consist of Tepes in Kibish Division, Lokwanamor and Lorionotom in Kaikor Division, Pelekech in Kakuma Division and Loima Hills in Loima Division which are characterized by large forests.

Open lying plains consist of the Kalapata and Lotikipi Plains. These form part of the arid area in the County and receive the lowest amount of rainfall of around 180 mm per annum. They are dominated by dwarf shrub and grassland, which provide forage for livestock during and shortly after the rainy season. However, this forage dries rapidly at the onset of the dry season. Tarach, Kerio, Kalapata, Malimalite and Turkwel are the major rivers in the County with significant potential of supporting agricultural activities for producing large amounts of food, if properly utilized.

CLIMATE

Turkana County is arid and semi-arid and is characterized by warm and hot climate. The temperatures ranges between 20°C and 41°C with a mean of 30.5°C. Rainfall pattern and distribution is erratic and unreliable with respect to time and space. There are two rainfall seasons: the long rains usually occur

between April and July and the short rains between October and November and range between 52 mm and 480 mm annually with a mean of 200 mm. Dry periods are January, February and September. Rainfall is distributed on an east-west gradient with more rainfall in the western parts and other areas of higher elevation, with brief violent storms resulting in flush floods. The surface runoff and potential evaporation rates are extremely high.

JUSTIFICATION AND SIGNIFICANCE

Main water sources in the County are hand dug shallow wells, boreholes, piped water and river water. Access to quality water is still a big problem for the County although through the GOK/UNICEF WASH Programme (UNICEF Kenya, 2009), the community has largely benefited from water dug for school children because of the high yields found in some areas.

The distance to and from the nearest water points are varied depending on the localities, but on average is between 5-10 kilometres. In urban centers and some market centers, different water users associations have managed to pipe water closer to settlements, thus reducing the distance to the nearest water points. However, in far flung areas like Kibish, Lorengipi, Lomelo and Mogila, distances covered are much higher ranging from 10-20 kilometres. These distances are in line with the groundwater sources, which are considered the most reliable permanent source. This qualifies the argument that development of groundwater will go a long way in serving the human race in this part of the world and the Turkana County in particular.

The aim of the project is to document the significance of geological structural mapping as an aid to groundwater surveying, mapping and extraction and to determine the correlation between geological structures and operating boreholes in the Turkana County.

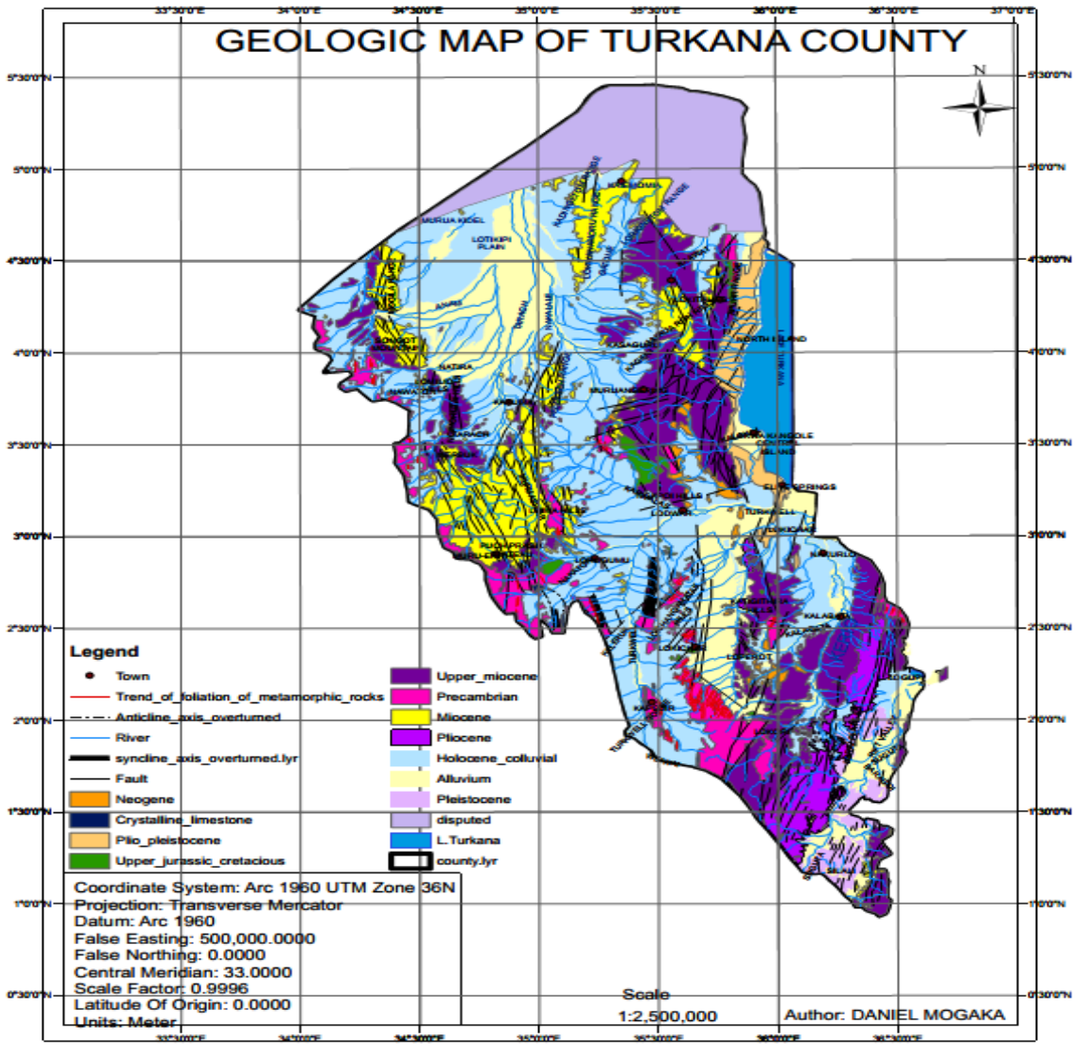
GEOLOGY AND HYDROGEOLOGY

GEOLOGY

The geology of the study area is as shown in Figure 2, and discussed below.

BASEMENT

The crystalline rocks of the Basement System cover wide areas of the country, and are particularly extensive in the eastern half. They comprise principally various types of sediments-grits, sandstones, limestone and shale that have been metamorphosed into gneisses, schists and marbles as a result of having been subjected to various grades of metamorphism as well as impregnation by pervading fluids. The metavolcanics are derived from lavas and volcanic fragmental rocks. Igneous rocks are relatively scarce and consist of granite sheets and dykes, and sills of epidiorite and amphibolite derived from originally doleritic or allied rocks, and some ultrabasic rocks.



Some are apparently of later date than the metamorphism of the sedimentary hosts, but are probably Precambrian in age.

The variety of rocks in the metasedimentary units is extensive and includes, besides widespread mica- and mica-hornblende schists and gneisses, such types as graphite schists, kyanite gneisses, garnet gneisses and schists, sillimanite gneisses, pyroxenite granulites, quartzites and crystalline limestones. Other and rare kinds include actinolite schists, anthophyllite schists, and gneisses. In some areas, there are considerable developments of migmatites, which have arisen by the injection of granitic magma into the gneisses and schists, or permeation by granitic fluids. Several granites of northern and northwestern Kenya are considered to be the products of granitization of metasediments due to anatexis. Pegmatites of various types are frequently associated with the Basement rocks; particularly where metasomatic reaction has been prominent.

Crystalline limestones form notable bands and lenses, often of considerable thickness and length, though some are small. A series of outcrops extends discontinuously through the central part of the County.

VOLCANIC

These formations are explicitly represented in the geological map (Fig. 2), and includes augite, olivine and analcime basalts, rhyolites and patches of phonolites and nephelinites.

AUGITE AND ANALCIME BASALTS

These are the oldest volcanic rocks which are generally fine-grained basalts and overlie the Turkana Grits and tend to weather fairly rapidly by mechanical breakdown on joints and fractures, which reduce much of the mass of the exposed rock to small boulders and cobbles due to surface weathering and alteration. For this reason the topography of the outcrops of the lower basalts is generally a series of low rolling hills.

PHONOLITES AND NEPHELINITES

A typical phonolite rock found in the area is medium grey in colour with no visible phenocrysts. In thin section it contains rare microphenocrysts of nepheline, partly altered to sodalite, and turbid anorthoclase felspar set in a fine-grained groundmass of green aegirineaugite, anorthoclase and nepheline.

The nephelinite is medium grained, with the groundmass generally consisting of nepheline and replaced by sodalite in some cases, enstatite-augite and green aegirine-augite and small amounts of sphene and magnetite. The other type of nephelenite found in the area is a black coarsely porphyritic rock, which in thin section shows phenocrysts of purple-grey titanaugite with sphene and magnetite, in a groundmass rich in euhedral crystals af nepheline with laths and grains of green pyroxene and subhedral magnetite. The rock is stained with red-brown iron oxide.

OLIVINE BASALTS

These types of rocks are widespread in the northern part of the area and the outcrops are generally coarsely porphyritic. Regular and well-marked jointing is locally a feature of the olivine basalts. It is believed that these basalts represent a locally developed basic phase occurring towards the end of the extrusion of the older basalt series, and were locally extruded on an already eroded surface of the lower basalts. The olivine basalts are of medium to coarse texture, dark blue-grey or black in colour, with phenocrysts of pyroxene, olivine and plagioclase up to 0.5 cm in size. .

RHYOLITES

These are acid lavas which tend to be more resistant to local conditions of erosion, with the result that they often form protective caps on hills of basalt and pyroclastics. Fault scarps in rhyolitic lavas tend to be vertical or near-vertical due to the breaking away of sheets of rock at strong vertical joint planes. Rhyolites of the study area are found in the north and central regions capping all the major mountain ranges. They have a light colour, in shades of buff, yellow or pale grey, sometimes stained red-brown by iron oxides. Alteration of the lavas in the form of iron ore replacement of much or all of the mafic minerals is widespread. In some instances in thin section the mafic minerals of the groundmass are completely altered to a black or dark chocolate brown iron mineral in mossy aggregates.

TERTIARY AND YOUNGER SEDIMENTS

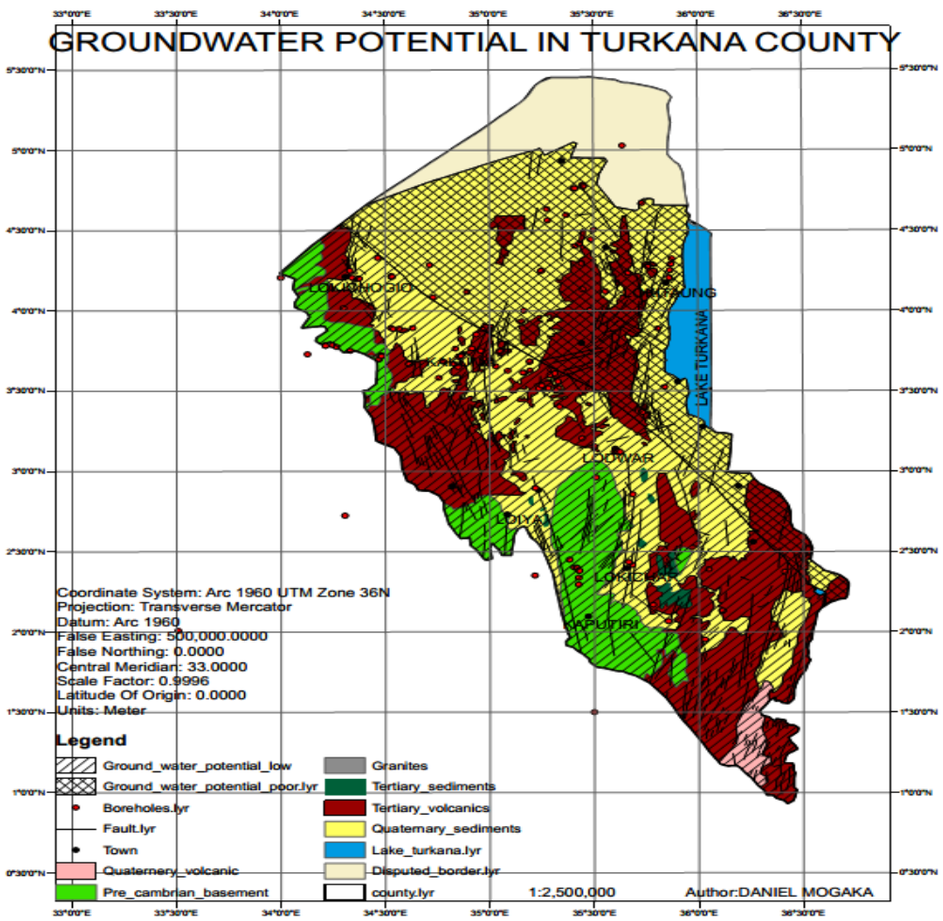
LAKE BEDS: These rock formations are found in the eastern part of the County, but were not covered during the sampling time. These are sediments of the Lake Rudolf basin (Lake Turkana) and according to Walsh and Dodson (1969) they comprise a series of lacustrine deposits dating from the Pleistocene and continuing into the recent period.

SUPERFICIAL LIMESTONE: Various localities flanking the Lodwar-Lokitaung road ideally from Kanukurdio to Kaeris are broad flat expanses of nodular pea-sized kunkar limestone of varying shades of white and pink, sometimes with a heavy admixture of soil and sand but more often virtually pure limestone.

SANDY SOILS: These deposits are divided into two main groups, deep red, often well compacted, sandy soils derived wholly from basement rocks, and generally buff to grey, occasionally light red, fine-textured and powdery sandy soils derived mainly from lavas.

HYDROGEOLOGY

Turkana County presents all types of the major geological formations ranging from basement and igneous rocks of both volcanic and plutonic source. It is important to note that with this kind of geology (see Figure 2) several types of groundwater resource potential are expected (see Figure 3). This ranges from high, moderate to low and even poor groundwater potential.



METHODOLOGY

In view of the aims and the objectives of this study, the following secondary data were collected;

- Borehole data (including water rest levels, water stike levels, yield and total depths of the boreholes) in the study area.
- Geological map of Turkana which covers the study area.

- Hydrogeological data (groundwater potential map of Kenya).
- Literature on geology and hydrogeology.

The methods that were employed in the collection of the aforementioned data included reviewing of existing groundwater data from the Ministry of Water and Irrigation and its subordinate institutions, geological maps and reports from the Ministry of Environment and Natural Resources, Mines Department, and topographic maps from the Survey of Kenya. Other data was received from the water partners in the County including the Catholic dioceses, the Ministry of water within the County Government. The datasets had geographical coordinates and altitudes are taken at the point of collection using a Geographical Positioning System (GPS).

It is important to understand that with the advent of GPS and associated softwares, well location surveys have become easier and more accurate. Using the GPS receiver, one can locate wells and other objects within 2 to 5 meters of their actual position. Well locations are used in maps, cross-sections, and ground water flow models produced by the Section. Water level data is useless unless we can accurately fix the position of the monitoring well under consideration. For this purpose, we used GPS to determine accurate coordinates of our monitoring well locations. GPS works by triangulating locations on the earth using three to five GPS satellites.

The methodology adopted for the present study consists of the following steps:

1. In the first step, all the existing geological maps (as mentioned above) (including thrusts, axial traces of folds, lithological contacts and drainage lines) were converted to digital format.
2. Georeferencing of all geological maps from the different scales and coordinate systems, that is all maps being brought to same coordinate system as base map through georeferencing technique.
3. The groundwater plotted using Arc GIS software.

DATA PROCESSING AND INTERPRETATION

DATA PROCESSING

The data collected was individually processed depending on the original format and the expected format of presentation as discussed below.

a). Borehole data, including water rest levels, water stike levels, yield and total depths of the boreholes in the study area. These data were tabulated in an excel sheet indicating ID, Name of water point: BH, Latitude, Longitude, District, Division, Depth of borehole (m), Depth of pump (m), Pumping test maximum yield (m3/hr.).

b). Geological map of Turkana covering the study area, which includes the northern and southern parts, presented in Tiff format.

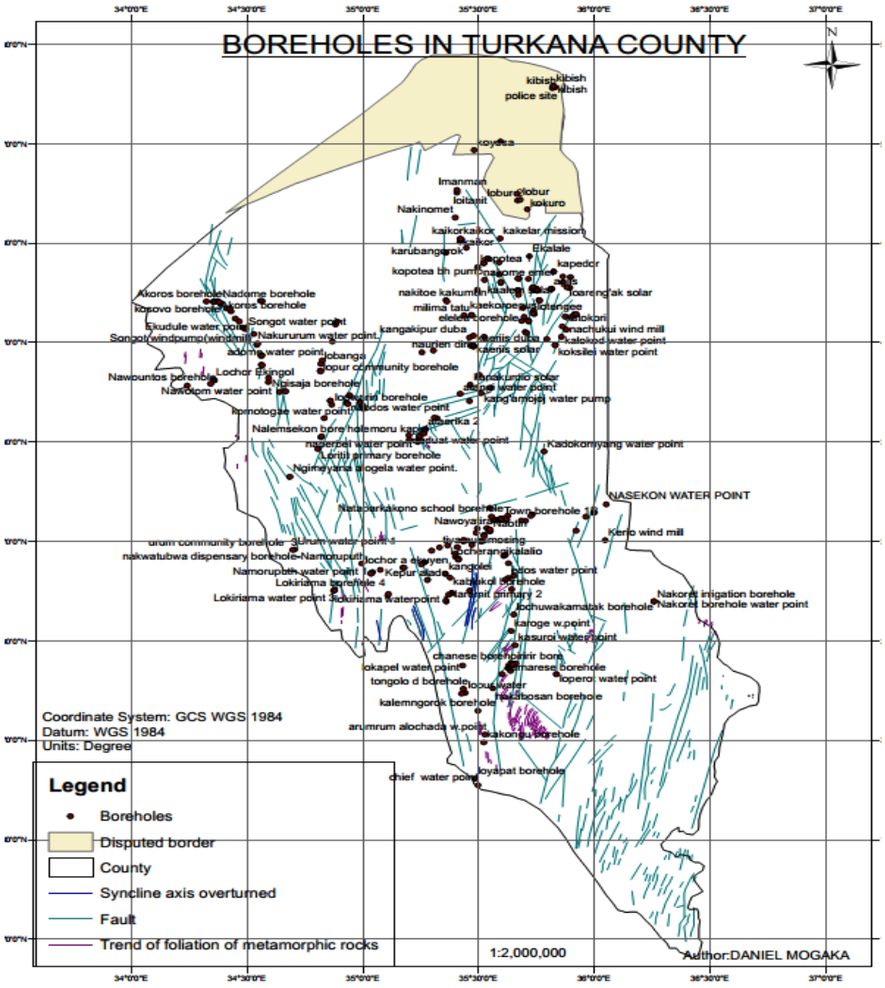
c). Hydrogeological data (groundwater potential map of Kenya). The groundwater potential map in Tiff format.

d). Literature on geology and hydrogeology. This was data and information from geological, hydrogeological reports as well as unpublished reports and journals.

The processing of the data included conversion to digital format of all the existing geological maps with thrusts, axial traces of folds, lithological contacts and drainage lines; georeferencing of all geological maps from the different scales and coordinate systems, so that all maps are brought to the same coordinate system as base map, and plotting groundwater data using Arc View.

INTERPRETATION

The above exercise of well and borehole locations enables one to understand and project the groundwater resources accessibility in the County. The groundwater abstraction of the County through the use of shallow wells and boreholes is mainly guided by geological structural orientation (see Figure 4 distribution of boreholes), where most of the boreholes in the County are drilled in areas highly affected by faulting.



CONCLUSIONS

From the present study, it can be concluded that geological/structural mapping, if employed judiciously, can be a very important tool for groundwater mapping. Undoubtedly linear features of geological importance do occur, and significance of these features can be attributed only after field work. Mapping of geological features could easily direct surveying activities in groundwater mapping or assessment.

ACKNOWLEDGEMENT

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WOMEN IN SMALL SCALE MINING IN TANZANIA: A CASE STUDY OF SMALL SCALE SAND AND AGGREGATE MINING IN THE CITY OF DAR ES SALAAM, TANZANIA

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ABSTRACT

According to the 2011 census, Artisanal Small Mining (ASM) in Tanzania directly engages 680,000 people, of which mining of gold amounts to 58.2% followed by building /construction 23.6%. The rest are engaged in colored gemstones (12.0%), copper (1.5%), diamonds (2.5%), salt (2.1%) and other minerals 1.0%. The percentage of women miners range between 25% and 40%, of which the highest number are engaged in low value minerals and materials (LVMM) mining activities. This sub sector, small scale aggregate and sand mining is the most important segment engaging women in the urban and semi-urban areas of Tanzania. Conservative estimates document 50000 - 100000 women miners engaged in LVMM and responsible for producing 30 - 40% of the minerals in the construction and building industry in the country. With their families, this means 300000 to 600000 people are directly dependent on this activity.

Women working in artisanal and small-scale mining dealing with LVMM in Tanzania face a huge array of issues, challenges and threats. This paper briefly reviews the socio-economic challenges facing women in aggregate and sand mining in Tanzania.

INTRODUCTION

Tanzania is among the developing countries with abundant mineral resources such as gold, diamond and varieties of gemstone like tanzanite, ruby, garnet and building minerals and materials as well as salt and other minerals. Recently ASM has increased in number from 550000 in 1996 (Tan Discovery 1996) to 680000 in 2011. Statistically gold mining ranks first with 57.5% of the total small scale miners, followed by building materials 23.6%, then colored gemstone 12% and the rest diamond, salt and copper making up 6.1%. The total number of artisanal small scale miners engaged in building materials is 160744 of which 68% are males and 32% are females. According to the 2011 census, the general population of small scale miners in Tanzania is around 680000 (Bryceson et. al., 2012). This trend was also reported by other researchers (Mdee, 2015). According to the World Bank 1995 definition, artisanal small scale mining refers to those who employ manual, low technology and mining conducted on small scale. Artisanal small scale mining can play an important role in poverty eradication and rural development as it employs a large number of people without gender bias. However, the general observation is that artisanal and small-scale miners remain trapped in a life of poverty because of a combination of community and institutional problems. This paper briefly discusses some of the socio-economic challenges faced by women miners engaged in aggregate mining in Tanzania.

OBJECTIVE OF THE STUDY

As a starting phase of the project, the area that was selected for intervention is the Dar es Salaam Region and the commodity is the mining of limestone for aggregates and boulders for the construction industry. The objective was to assess the immediate socio-economic challenges faced by women miners at Mji Mwema in Kigamboni area in the outskirts of the city of Dar es Salaam.

STUDY AREA

The city of Dar es Salaam has several small scale aggregate quarries, but the major active ones include Mji Mwema, Kunduchi and Mtongani quarries (Figure 1). The area of study, Mji Mwema Quarry in Mtongani area is shown in Figure 2. This quarry produces aggregates and rips raps for construction materials. According to URT 2012 Population and Housing Census, the population of Kigamboni is around 30500 people.



Figure 1: Location area showing some of the aggregate quarries in Dar es Salaam City.

METHODS OF DATA COLLECTION

Mining of limestone rocks for aggregates and boulders for the construction industry are conducted in the coastal regions of the city of Dar es Salaam. The data collected is based on activities conducted at Mji Mwema in Kigamboni in Dar es Salaam city, which has about 100 women engaged in mining and crushing of limestone aggregates. The satellite imagery in Figure 2 shows the location at 37M 538480E and 9242600N, 20m above sea level.

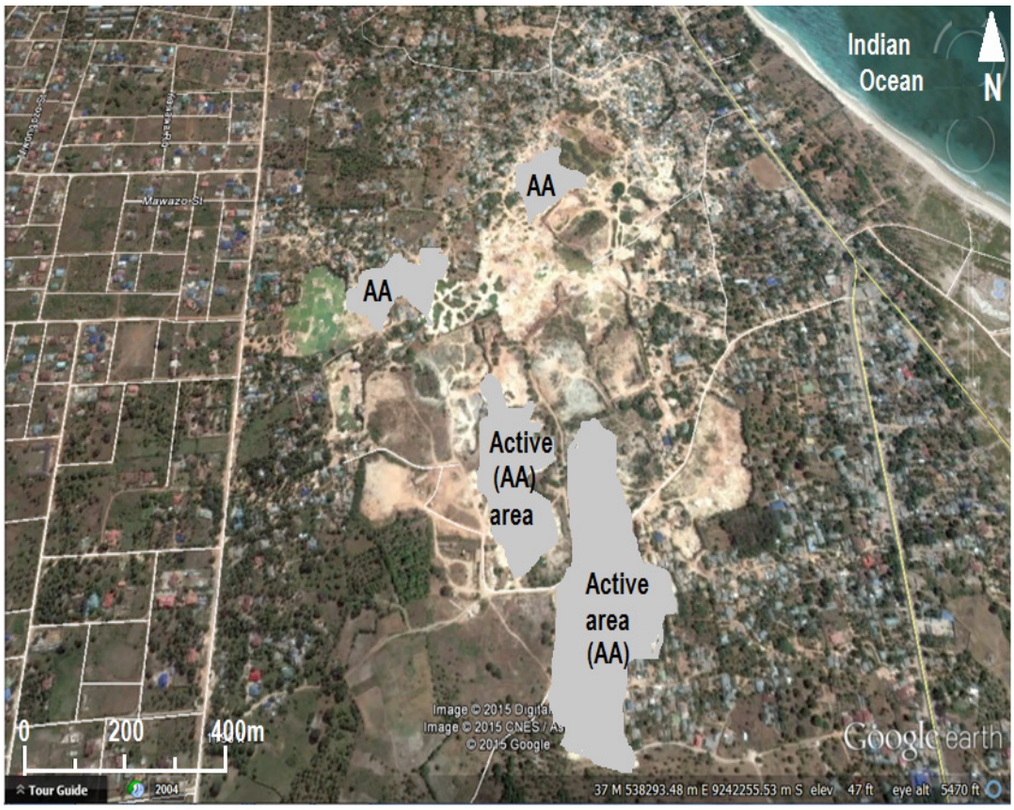


Figure 2. Mji Mwema Dar es Salaam showing aggregate and sand mining active quarries (AA)

The information regarding women artisanal small scale miners was acquired by interviews, structured questionnaire, as well as literature reviews. It was necessary to personally discuss with the women miners at the mining site about challenges they face in the working area. During the execution of the activities, 20 women miners were selected for interview and questionnaires were completed which led to address some of the socio-economic and environmental challenges that they face during mining operations.

RESULTS

DISTRIBUTION OF QUARRIES

Using remote sensing technology, it was revealed that there are several quarry areas in the city of Dar es Salaam, mining limestone aggregates and sand for construction purposes. Among the active quarries are Mji Mwema in Kigamboni area. This area was selected for initial intervention with the small scale women miners (Figure 3).

SOCIAL AND HEALTH CHALLENGES

In general, women in artisanal and small-scale mining (ASM) in Tanzania face a huge array of issues, challenges and threats. ASM, as it is practiced in the country today, is partially unregulated, hazardous, controlled by middlemen traders which increasingly marginalize the socio-economical activities of women in the sector. The women and children who carry out this work are grateful, exploited and manipulated for political and financial purposes. Whilst everyone in the sector faces challenges, the security, health, and social risks posed by women are particularly acute. Figure 3 shows some women engaged in aggregate mining in Kigamboni area at the outskirts of the city of Dar es Salaam. The activities involve women of all age groups, some were pregnant while others were breast feeding young babies. They face several problems such as:

a). Sexual violence and abuse in the quarries, particularly where young women are caught mining in restricted areas such as registered claims, private restricted areas etc.

b). Health risks due to lack of sanitation in work places, malnutrition, and physical trauma from the difficulty of the manual labor. Women in mining camps suffer a high rate of miscarriages due to injury and stress;

c). The risk of HIV/AIDS and other STDs due to forced sex in order to get permits to mine in some restricted areas mentioned above;

d). Gender discrimination whereby women do not receive equal pay or opportunities, and are often required to surrender high value products



Figure 3: Conducting interviews with the women miners using structured questionnaire

e). Family break-up, child labor and abandonment of family members due to unequal distribution of income within a family. Women are frequently obliged to bring their children with them to the quarries, which play in harsh and dusty environment. This exposes them to hazards and health risks, and frequently prevents them from going to school, thereby limiting their future options and the hope for transition to a better life.

f). About 100 women who were engaged in small scale mining of aggregates at Kigamboni area in the City of Dar es salaam, between 18 and 25 years old were forced to undertake aggregate mining after being divorced from or abandoned by their husbands.

ECONOMIC AND TECHNOLOGICAL CHALLENGES

All interviewed women miners had no knowledge of rock materials or geology. Miners lack geological knowledge to establish appropriate rock materials that can be used as building materials. They also lack geological knowledge to distinguish different minerals and rocks which influence quality of their product and assess available resources in terms of quality and quantity.



Figure 4. Poor Working tools for aggregates crushing

It was noted that the population of women miners exceed 100, children and toddlers are excluded. They are divided into two groups – i) those directly engaged in aggregate crushing earning max 2 dollars a day; and ii) those middle women buying crushed aggregates and sell it to the truck owners, of which they pay 8 dollars/day (4 dollars for haulage; 4 dollars for revenue) Therefore, poor women end up cashing 5 to 10 dollars for the bulk assignment which can be sold for 100 US dollars at the market.

Technologically, the sector remains unattended. The miners use rudimentary tools as shown in Figure 4. In addition to poor infrastructure, they lack proper technology and equipment to mechanize their mining and crushing operations. Artisanal women miners have poor skills in marketing and selling of the raw aggregate materials, which on actual market can earn up to 100 dollars a day.



Figure 5: Women crushing aggregates in a poor working environment

SOCIAL AND LABOUR ISSUES

Airborne silica dust generated from stone crushing can result into silicosis, source of cancer and other lung diseases due to lack of dust cover and other safety gears.

As presented in Figure 5, the women miners are engaged in crushing of rocks without proper working gears. The largely affected groups are women and children miners as they work in less conducive environment like exposure to sunlight, lack of first aid kit for immediate treatment in case of injury or any accident. All in all as working environment is not well regulated and there is a lack of mining knowledge this can cause land degradation and erosion.

DISCUSSION

While it is widely accepted that mining causes environmental damage at a local level, some have argued that on a national level, the environmental consequences of ASM are not as widespread as most of the literature suggests. Scott (2002) evaluated two small-scale mining sectors in Zimbabwe (small-scale brick making and gold mining), and noted that these practices contributed to deforestation, river and dam siltation as well as mercury pollution and land degradation. However, the chemical pollution due to gold mining was much more serious as compared to brick making. The same applied to aggregate mining where the impact can be controlled by rehabilitation of the area, so long as the volume and number of miners is limited. As stated above, the sector suffers from insufficient skills and poor skilled miners and lack of geological knowledge. Hence mining has often led to the implementation of inappropriate equipment and mining methods, which, have resulted in environmental and associated socio-economic problems. The inability or unwillingness of the local governments to collaborate with research institutions, build capacity among miners has led into mining-unfriendly technologies which in addition increase environmental pollution.

As noted by Mwaipopo et al. (2004), gold mining communities in Geita, Tanzania could be both a family livelihood strategy, mining being considered part of a particular life style and a good opportunity for young people. But she noted that it could also be taking place where there is extreme impoverishment caused by family breakdown, with for example divorcees or elderly relatives depend on their children for the family income. Both issues could be dealt with at local government levels, if the sectors policies, laws and regulations are properly implemented.

At national level, Tanzania, unlike other countries, could effectively use its human resources to implement technologies and support services for artisans. The Government in collaboration with international donors has undertaken the census for the ASM. This data together with geological information on hand can be used to deduce which options are most suitable for target mining populations.

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GEOSCIENCE EDUCATION IN MALAWI: THE CASE OF GEOGRAPHY IN SECONDARY SCHOOLS

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ABSTRACT

In Malawi geoscience concepts are covered under geography as a subject. The concepts are taught in primary schools for 8 years, secondary for 4 years and in tertiary education for another 4 years. This presentation argues for a comprehensive and multi - dimensional understanding of geoscience education, (simultaneously referred to as geography education) to come up with a curriculum that is relevant to the national policy goals. The study is motivated by the disparity in the status quo where despite introducing the subject at primary level, the pass rate in geography at the Malawi National Examination in the 2015 class in secondary schools has been worrisome. It is a disturbing development as data shows that the pass rate has been falling sharply in the past twenty years reaching as low as 19% in 1995 prompting the Subject Specialist at the Ministry of Education Headquarters to call for stakeholders' conference to reflect on the dismal performance. These stakeholders meeting recommended curriculum review (All Africa, 1999) which was done in a way that the content of the curriculum was reduced with the vision to contribute to the Millennium Development Goal of Education for All (Masperi, 2008).

Based on empirical data collected through qualitative research design, this study establishes that regardless of imploring such a huge intervention, there are still indicators that students continue to fail in geography. The paper also reveals that lack of proper and effective instruction materials such as books, textbooks and journals have been cited as the main challenges to the failing of students. Other factors such as competition with other related subjects have also contributed to the status hence making the subject to become less popular among the students. This has increased the failure rate in geography at national examinations.

The study concludes that the Government needs to take extra steps on curriculum review to comprehensively understand geosciences education and find out if the education system is to make sense in Malawi. The approach by the Government should be consultative and deep enough to capture voices that will inform policy debates that will assist in coming up with a curriculum that generates interest in the students whilst at the same time contributing to the sustainable development of the nation.

Key words: Malawi, Geography, Learner, Geoscience, Ministry of Education, Malawi National Examination

INTRODUCTION

Malawi's (Figure 1) key interest in geosciences related concepts dates back from its colonial education system designed by the British before independence in 1964. The geosciences education concept in Malawi is a multidisciplinary field that is introduced at nursery, primary, and continues to be taught at secondary and tertiary stages. These are included in subjects such as geography, agriculture, chemistry, physical sciences, mathematics and biology. Geography covers different topics that are related to the earth systems. The topics include astronomy, oceanography, geomorphology, geology

and environmental sciences. Quite often, advanced core concepts of geosciences education including climate change, human and economic study, geology, astronomy, hydrology, lithosphere and social aspects are taught under a broad discipline of geography as stated above. In general, Malawi has an 8-4-4- system consisting of primary school, secondary school and university education (Malawi Government, 2001). This paper deals with the geosciences education especially the case of geography in secondary schools. The analysis focuses on three interconnected aspects of i) methodology, ii) content and iii) the challenges that Malawi faces during the teaching and learning of the subject. In this paper, as it is the case in the Malawi primary and secondary school education, geography is used synonymously with Geosciences.



Figure 11. Map of Malawi

PRIMARY SCHOOL GEOGRAPHY EDUCATION

Primary school education takes eight years from standards 1 to 8. The official primary school age group is 6-13 years. However, it is very common for students of varying ages up to 18 years to attend primary school. Distances to nearby school, repetition of classes, food insecurity, disabilities, poor infrastructure and poverty are some contributing factors to age variance of the students in primary school.

Common concepts introduced at this stage are physical geography of the learners' environment and its surrounding. In the primary schools, geography is integrated in social studies which also includes history and civics. At the end of 8 years, the students take the national Primary School Leaving Certificate Examination in five subjects, namely English, Chichewa (Malawi Native language), Mathematics, General Science and Social studies. The examinations are jointly administered (set, conducted and marked) by the Ministry of Education and the Malawi National Examinations Board.

Regarding the performance of the students in geography education, Lusungu Msowoya, a teacher at Mwenilondo primary school in Karonga in the northern part of Malawi, noted that primary school students perform quite well in geography during the primary national examination as compared to languages and pure science subjects. Basic education sector analysis report. (2014) affirms that the

performance of learners in geography education has been very good. One of the reasons Msowoya put forward was that students learn and the lessons become real when the teaching process includes practical examples by showing the students what is significant in their immediate environment.

For a student to be selected for public secondary schools, he/she should have passed with excellent grades at the Malawi National Examinations and get selected to attend public secondary school. If a student is to attend private school, he/she can just enroll if one has the potential to pay the tuition fee.

SECONDARY SCHOOL

Unlike in primary school where geography is integrated in the social studies, in secondary schools, the subject is stand alone at all levels of junior as well as senior classes. However, at senior level, the subject has become optional since 2000. According to the Malawi National Examinations Board (2015), many candidates have not been successful in the national geography examinations at the secondary school level and this is documented to be very drastic over the recent years as compared to languages and science subjects.

Secondary school education takes 4 years from Form 1 to Form 4. The official secondary age group is defined as 14- 17. However, ages vary drastically as many students leave primary school when they are much older. As such students in the age bracket of 14 to 25 may be found attending secondary schools. Students can attend secondary school education in public (run by the government) or in private schools (run by the private sector and individuals). The quality of secondary education varies widely in both sets of schools. In general, tuition fee in private schools is more than 50 times than in public schools ranging from $20 USD to $150 USD in public schools to $1000 USD in private schools per year (British Council, 2001). For a long time, secondary education was very restrictive in Malawi but this situation is changing positively due to rapid expansion of private schools as well as government run community day secondary schools. Generally, the subject is taught three times per week with forty minutes per period in Junior secondary classes and four times per week of forty minutes per period in senior secondary schools.

Advanced Geography education such as the solar system, hydrology, geomorphology and geology are taught in secondary schools in Malawi. The students have to sit for two examinations, a Junior Certificate Examination ([JCE) at Form 2 and a Malawi School Certificate Examination (MSCE) at Form 4. They cannot progress to Form 3 without passing JCE in Form 2 and cannot graduate from secondary school without passing Form 4. Both examinations are coordinated by the Malawi National Examinations Board but jointly administered with the Ministry of Education. MSCE is considered an adequate credential to be selected for university entrance. However very few students are admitted to a university due to inadequate space in public universities and the expensive costs in private ones.

It is documented that the performance of Earth Science at MSCE has been failing over the years reaching as low as 58.64 % in 2010 from 73.34% in 2006 (Malawi National Examination Board 2015). There is a clear-cut boundary between private and public schools. Private schools excel over public schools because of good teaching materials and good incentives

Secondary education lasts four years. It consists of two cycles -junior (Forms one and two) and senior (Forms three and four) with national examinations after each cycle. Currently, the secondary schools can only absorb 30% of the eligible primary school students. University absorbs only about 4% of the eligible secondary school graduates (The Malawi Nation Newspaper, September 23 - 29, 2014). Selection takes place at Form 4 for the various colleges including vocational colleges, technical colleges and the four universities, namely; University of Malawi, Lilongwe University of Agriculture Natural Resources, Malawi University of Science and Technology and the University of Mzuzu.

TERTIARY EDUCATION

At the university level, which takes 4 to 5 years, very few practicing teachers are enrolled in geography courses. Apart from education departments, further graduates come from geology, hydrology and

soil science, meteorology and astronomy departments thereby increasing the number of geosciences alumni in Malawi.

To raise students´ interest and public awareness in the geosciences as well as to enhance geosciences learning among students, the Government has been revising the geography curriculum to be at par with the world geosciences contemporary issues. As such the curriculum was overhauled again in the year 2000, and some topics were incorporated while others which appeared to be archaic and irrelevant to the society were dropped. This paper explores the geoscience education and the case of geography in secondary schools in Malawi.

METHODS AND RESULTS

The study was conducted with the qualitative research paradigm method though quantitative research was partially used mainly to substantiate the descriptive results. The population of interest for this study was secondary school students from all the regions across Malawi during the end of 2015 and early 2016. Random sampling was conducted. Through observations, questionieres and interviews. All respondents were sampled from 6 secondary schools, the criteria being that they all have attended school up to July 2016. Another inclusion criteria in the study was that students would have taken geography course some times during their secondary education. Due to the large number of secondary schools in Malawi, sampling was done to come up with the desired number. Accessibility to school, mainly a location near the main road played a significant role in the sampling process. A total of six schools (2 international, 2 national private schools and 2 public schools) were chosen for inclusion in the study. This implies two schools from each of the 3 regions. However, the number of schools sampled rose to ten because of proximity to neighboring schools. For instance, four schools were added from the central region because the researcher came from this region and it was easy to do the study at very little or no transport costs.

In addition, the study adopted key informant technique where some teachers and head teachers were interviewed. This resulted in a sample size of 142 persons over the one year course of the study.

The sampling for this study may not be considered true representative of the original population of interest. However, considering the limited resources and long distance to cover the whole country, the findings were more representative as similar learning conditions were experienced by Malawian students and teachers. In addition, a country wide study of girls' attendance in basic literacy education including challenges of teaching and learning in Malawi was conducted, and the findings were similar to this study.

The responses from all the schools showed reliability and validity. Validity was examined by looking at the correlations of the learners' answers while reliability was measured by consistence of the results. There were 142 participants in the final sample for this study and two drop-outs from the sample group, leaving a total of 140. The following are the findings of the study.

RESULTS

The study observed that learners who are most successful in geography education are those from the international schools. Empirical data in the past five years shows a 75% lead of private schools over public schools (Malawi National Examinations Board). In 2011, the private schools pass rate constituted 75 %. This percentage remained stable in 2012. In 2013, it became 100 % and the trend has been the same over the past two years with private schools being always at the top. This is due to mainly inadequate and poor resources, lack of teaching and learning materials, as well as library and laboratory facilities in the public schools.

From the national examinations performance, the study revealed that international private schools have the best resources for teaching and learning compared to the rest.

Therefore, this paper reveals that the teaching of geography in Malawi secondary schools, especially the public ones need a very big improvement. Unless the government, stakeholder s, teachers and

learners from public schools join hands, the students of the Malawi secondary school education will continue to fail the national examinations.

DISCUSSIONS AND CONCLUSIONS

In a bid to meet the country's education goals, poor infrastructure, inadequate teaching resources, government policies and the perception of learners towards the subject are contributing factors challenging the learners' performance and have to be dealt with.

Although, the study focused on secondary schools and the challenges were more pronounced, it was documented that some of the challenges had their basis in the primary school education. For instance, one of the underlying root causes that has negatively impacted the education sector was the multiparty politics and policies which began in 1994 and introduced free primary education in Malawi.

The free primary education has seen a large increase in the number of students attending primary school. For instance, in 1995, primary school enrollment tripled from 1.6 million to over 3 million (RIPPLE Africa, 2012). This increase in enrollment caused major infrastructural damage in the countrywide. In some primary schools' poles and thatch roofs (Figure 2) were used to construct temporary classrooms. Teaching had to be conducted outside due to lack of infrastructures. In case of rainfall and strong sunshine, the situation was bad that teaching became impractical. In the worst-case, students must be sent back home without having classes. It should be noted that drastic weather such as rainfall and hot season in Malawi can last for a longer time of more than six months. This has been and is a frustrating situation for the students and teachers.

In the secondary schools, as also outlined above lack of infrastructure like laboratory present lots of challenges. The Japan International Cooperation Agency and International Development Center for Japan (2012) argue that teaching of certain subjects such as biology, physical science, chemistry and geography require special facilities and are not available in many government secondary schools compared to many private schools that do have such infrastructures. It is important to note that students from both private and public schools should take the same national examinations, even though the students from the public schools are at a disadvantage. There is no equal playing field., Therefore, the successful students come from Private Schools.



Figure 2. Poles, Mud and bottle Glass Thatched Classroom

Lack of qualified teachers also poses a challenge in secondary school education. The government trains teachers specialized in geography every year and yet it may take time to employ them. For example, out of the 400 practicing teachers who graduated from various public Universities of Malawi in 2014, no one was employed by the Malawi government, although the government is a major employer in many sectors. The market cites economic meltdown as the cause. However, the government seems to offer employment for graduates from other fields of specialization rather than geography.

Tuition fee was cited by many respondents as another blow to secondary education. Students should pay tuition fees which vary greatly from $20 USD per year at a local community day school run by the government, to $3,000 USD or higher for private schools. The fees, even at a lower amount pose a huge burden to most families earning less than $1 USD a day and struggle to raise enough money to send their children to secondary school at these rates. As such, only 13 % of secondary school aged children attend school due to financial challenges. Prohibitive tuition fees coupled with long distance means that students must walk great distances, for example 15 kilometers one way to attend classes each day.

One should also note that the abrupt increase in the number of students has been constraining the government‘s education budget making it impossible to meet the education demands. The ministry has been failing to buy the resources for teaching. In some cases, some schools may not have basic resources like a simple globe, maps, and textbooks. Thus, traditional instruction has been primarily theoretical, whereby teachers use methods based on memorization and repetition of facts year in and year out. Such style of teaching makes learning unsuccessful.

Thus, even if the Malawi government has a minimum of 3 secondary schools per district, private owned secondary schools are better resourced while government secondary schools still suffer from poor resources, such as little access to teaching and learning materials. For instance, a class of 60 students may share one book and quite often it is the teachers copy.

In addition to what has been stated in the foregoing sections, for a long time since independence, there has been a restriction in the secondary schools that Geography be taught as one of the core subjects. Nevertheless, in 1994, this restriction was changed due to government policy allowing the students to have freedom of choice to learn the subjects they are interested in. This resulted in making geography as one of the elective subjects in the curriculum.

However, many students did not choose geography as part of their study program. In short, the study revealed that, the teaching of the subject was at the mercy of the head teacher. For instance, if the head teacher had no interest in geography, no one would query him or her. Against such background, some students could finish senior secondary education without learning a single geography concept. It is during this era in education system that geography received very little attention.

Lack of teaching resources coupled with overcrowded classrooms has resulted into many teachers shunning learner centered approaches as they are time consuming and the teacher may not achieve the intended outcomes. Resources aid in learning whereas learner centered approaches encourage critical thinking. If these conditions are not met the education goals for teaching geography are far from reached.

Another point of contention has been pointed to the government policies itself and its readiness and way to implement it. In the year 2000, the government of Malawi conducted curriculum review in which the geography curriculum was revised; other topics were dropped while other new topics were introduced to make the geography subject more relevant. Some of the key topics in the areas of geology, astronomy and environmental sciences, and hydrology were added in detail. At the same time, mining topic which was a pure geological topic was removed.

The curriculum fix was indeed well timed considering the government´s interest to revamp the education sector. In a bid to achieve this, the government had employed fresh graduate teachers from various universities whose major subject was geography to beef up and assist the senior staff in delivering the new content. It should be noted that, qualified primary and secondary school teachers in Malawi are responsible for the teaching of geography. The assumption is that trained teachers are more likely to produce successful students hence, making geography a successful subject.

Despite such a huge curriculum overhaul and compounded by enriched human resource capital through deployment of geography teachers, geography did not enjoy the new status assigned to the subject. Many students did not like the subject. One of the frequently raised reason put forward by the students for not opting for geography was because it was alleged that it presented a lot of challenges as it was perceived a more scientific subject and yet it was branded as a humanity subject. In addition, the subject faced opposition from related subjects within the same humanities department.

By extension, students noted that as compared to geography that has been taught since Malawi got its independence in 1964, in recent years after multiparty politics in 1994, good grades have been scored in newly introduced subjects like Social Studies and Life Skills. As such, learners prefer the new subjects to geography as it is believed that the new subjects are simple, relevant and address the needs of the society (Kadzamira, 2009). According to Banda (2010), the students further contend that if someone is good at life science skills, one may work as a counselor in various organizations dealing with Human Immune Deficient Virus (HIV) and AIDS issues while geography has very few openings in Malawi apart from teaching.

It should be noted that teaching is perceived a very low grade profession in Malawi (personal communication Fidelis Mgowa). Therefore, students are not inspired to pursue geography amid very narrow career chances.

On the part of teachers, the study reveals lack of incentives by both government, various administrations and different stakeholders regarding the welfare of teachers especially for those from the humanities. For instance, it is only science teachers who are sent for in service courses during holidays. In addition, some development partners provide money to the government especially for strengthening the career path of science teachers. Such developments have not inspired geography teachers who feel sidelined. Therefore, this affects the teaching and learning process.

Some school administration has specific policies which systematically put humanity teachers in a fix. For instance, provision of accommodation for a teacher in some schools is one of the major incentives a school can retain its staff members. With limited institutional houses for teachers, to get accommodation is yet a nightmare in Malawi secondary schools. Amid such type of stiff competition, geography teachers have been the losers most of the time for in some schools, a science teacher has a priority over a humanity teacher to get accommodation at the school compound.

Lastly, Geography education in Malawi is equally affected by student's poor accessibility to safe and drinking water. Despite Malawi having a total of up to 80 % of its land covered with fresh water from Lake Malawi and other rivers water security remains a challenge. Malunga (2001) argues that the main challenge is the degradation of water resources due to siltation that blocks the water sources during the rainy season, while in the dry season the water level in the reservoirs goes down. If the trend continues, the education sector in general and school attendance will be largely affected by water security. Many schools have low attendance when water supply is low. Girls are more affected as water shortage affects their health. Consequently, girls cannot attend classes when there is no water in schools. This has affected their academic performance. Sometimes, the school can be closed prematurely as a preventive measure because lack of water access may result in the spread of water borne diseases. The study recommends that an investment in environmental education today is an investment in peace building on a longer-term basis in Malawi because environmental education will promote stewardship of scarce natural resources which would be a cause for conflict when depleted.

In a twist of events, from 2009 onwards a significant group of students had to sit for geography national examination when it became apparent that it was a requirement for many universities to enroll a student if he or she had good grades in specific subjects including Malawi Government Ministry of Education, Science and Technology (Education Sector, Policy and Investment Framework, 2015). Because of this requirement, many students started learning the subject once more because they wanted to be selected for universities and not because they have the passion for the subject. However, the geography option policy has since changed and in effect since 2015 geography has assumed its old status of being a core subject. It is everyone's excitement that things will work out and many are looking forward to the success of the program.

CONCLUSION

In summary, Malawian Geography education is not appealing to both teachers and students. However, if students, teachers, government and stakeholders can work together and make commitments to the failing human capacity and infrastructure, the situation is reversible. Learners need to remove that perception of complacency if they are to excel in their geography studies, while teachers' commitment need to be revamped by giving them incentives. On the other hand, the government needs to go back to its drawing table. One factor contributing to this status quo is the revelation by the study that the status of geography in the education curriculum during the colonial rule in Malawi has a negative effect on the subject. The subject was placed in humanities department instead of science. Not only is the humanities department the most neglected section by the society, but the subject is a pure science discipline.

Therefore, to improve the teaching of geosciences and bring the subject in the lime light, there should be a combination of approaches that deal with the problems outlined above and lessons should be learned from world-wide approaches.

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