The environmental impact of small cap mineral exploration companies: A review of African activities and legislation.

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DECLARATION

I, the undersigned, hereby declare that the work contained in this dissertation is my own original work and that I have not submitted in previously in its entirety or in part to any other university or intuition.

Signature: 

Date: 21 November 2016

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This work is dedicated to my family, for their support and understanding.

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ABSTRACT

In recent decades, the extractive minerals industry's impact on the environment has, for numerous reasons, been the object of intense scrutiny. Operating mines are under constant pressure to reduce the impact their operations have on the environment. Consequently, they are compelled to conduct their operations with environmentally and socio-economically sustainable approaches. Countries that have a history of mining are frequently faced with issues relating to environmental degradation. The level of degradation they face is difficult to mitigate and near impossible to restore to its former state. Current research, focussing on operating and closed, defunct or abandoned mines, attempts to address these issues. However, this research addresses the potential impact caused by neglectful exploration practices that are not covered by current environmental research and legislation. Moreover, research on the extractive minerals industry's current practices, specifically regarding the impact on the environment, focusses very little on the initial stages of mineral exploration which may, or may not, lead to new mining operations.

Anecdotal evidence from the industry and role players suggests that mineral exploration activities have a limited impact on the environment, both in terms of duration of exploration activities and of the severity that exploration activities have on the environment.

The aim of this research was to investigate the impact of mineral exploration activities on the environment. By utilising literature reviews, questionnaires and site visits, this study reviewed these activities' impact on the environment. The focus was on small capitalised (or junior) exploration companies that conduct exploration activities for solid minerals on the African continent. Due to the mineral potential of the African continent, this study reviewed the reason(s) why exploration companies conduct business on the continent, as well as some of the risks they face.

In order to better understand these companies' practices, the study also reviewed the impact that the global macro-economy has on the extractive minerals industry. This review was necessitated by the cyclical nature of the extractive minerals industry, which have various impacts on small cap exploration companies' funding and staffing. This aforementioned impact on funding and staffing, ultimately affects how these companies approach decisions regarding environmental matters.

Mineral and environmental legislation is an additional aspect that influences, or should influence, these companies' approaches to environmental matters. Therefore, selected legislation was reviewed in terms of effectiveness regarding environmental concerns and, subsequently, selected companies' compliance or non-compliance to the legislation was reviewed.

The literature review showed that limited research has been conducted on the environmental impact of exploration activities. Furthermore, quantitative and qualitative data about the environmental impacts, if any, are unknown or limited. Certain responses from the questionnaires were in line with information obtained from the literature reviews. As was expected, however, other responses indicated areas of shortcomings that were not forthcoming from the literature. The observations made during the site visits indicated various exploration activities' impacts on the environment, along with some varied responses and attempts made by selected companies to mitigate the impact on the environment.

The study concludes with a summative overview of exploration companies' impact on the environment and then proceeds to make recommendations regarding the impact of mineral exploration activities on the environment.

Keywords: environmental impact, global macro-economy, legislation, mineral exploration (and activities), small cap companies.

Definitions:

Deposit:

A concentration of minerals in or on the Earth's crust. Includes both uneconomic and economic deposits (Reserves and Resources).

Greenfield(s) exploration:

Mineral exploration that targets mineral occurrences in previously unexplored areas, where information regarding mineralisation is limited or where mineral occurrences are not known to exist.

Mineral exploration:

The action of searching for minerals.

(Ore) Reserve:

The economically mineable part of a Measured and/or Indicated (Mineral) Resource.

(Mineral) Resource:

The concentration or occurrence of minerals of economic interest in or on the Earth's crust in such form, grade and quantity that there are reasonable prospects for its eventual economic extraction. The characteristics of a Resource are determined from geological evidence and knowledge.

Small-capitalisation (small cap, junior) company:

A company whose market value is less than USD 1 million.

Solid minerals:

Minerals that occur naturally in a solid form or state in the earth. Exclude oil and gas minerals.

Units of measure:

All units of measure are according to the *Système international d'unites* (International System of Units).

OPSOMMING

Tydens die afgelope dekades het die impak wat die ontginning en herwinning van minerale op die omgewing het, vir verskeie redes, die onderwerp van intensiewe ondersoeke en navorsing geword. Operasionele myne is onder gedurige druk om die impak van hul bedrywighede op die omgewing te verminder. Gevolglik is hulle verplig om hul bedrywighede uit te voer met omgewingsvriendelike en sosio-ekonomies volhoubare benaderings. Lande met 'n geskiedenis van mynbou het dikwels te make met kwessies rakende die agteruitgang van die omgewing. Die vlak van agteruitgang wat hulle in die gesig staar is moeilik om te ontken en haas onmoontlik om te herstel tot die oorspronklike natuurlike staat. Huidige navorsing, met die fokus op operasionele en geslote, ontbinde of verlate myne, probeer om hierdie kwessies aan te spreek. Hierdie navorsing daarenteen, fokus op die moontlike impak wat veroorsaak word deur nalatige eksplorasie praktyke wat nie gedek word deur huidige omgewingsnavorsing nie. Verder het navorsing oor die huidige praktyke in die ontginning en herwinning van minerale, spesifiek met betrekking tot die impak op die omgewing, min fokus geplaas op die eerste fase van die mineralebedryf, naamlik op mineraal-eksplorasie.

Anekdotiese bewyse uit die industrie en vanaf rolspelers dui daarop dat mineraal-eksplorasie aktiwiteite 'n beperkte impak op die omgewing het, beide in terme van tydsduur en die intensiteit van eksplorasie-aktiwiteite.

Die doel van hierdie navorsing is om die impak van mineraal-eksplorasie aktiwiteite op die omgewing te ondersoek. Deur gebruik te maak van literatuuroorsigte, vraelyste en terreinbesoeke sal hierdie studie die moontlike impak van hierdie aktiwiteite op die omgewing ondersoek en bepaal. Die fokus sal wees op klein gekapitaliseerde (of junior) eksplorasiemaatskappye wat gemoeid is met vaste minerale op die Afrika-kontinent. As gevolg van die minerale potensiaal van die Afrika-kontinent, sal hierdie studie ook die rede(s) waarom eksplorasiemaatskappye besigheid onderneem op die vasteland, asook sekere van die risikos wat hulle moet oorkom, hersien.

Ten einde die praktyke van hierdie maatskappye beter te verstaan, sal die studie ook die impak wat die wêreldwye makro-ekonomie het op die minerale bedryf hersien. Die hersiening word genoodsaak deur die sikliese aard van die minerale bedryf, wat onder andere 'n impak het op die befondsing en personeelkapasiteit van eksplorasiemaatskappye met beperkte kapitaal. Die bogenoemde impak op befondsing en personeelkapasiteit beïnvloed hoe hierdie maatskappye besluite neem ten opsigte van omgewingsake.

Minerale- en omgewingswetgewing is 'n bykomende aspek wat maatskappye beïnvloed oor die hantering van, en die aandag wat aan omgewingsake geskenk word. Toepaslike wetgewing word dus hersien in n poging om die doeltreffendheid met betrekking tot omgewingskwessies, en daarna die nakoming van maatskappye aan die vereistes van wetgewing, te hersien.

Die literatuuroorsig dui daarop dat beperkte navorsing gedoen is oor die omgewingsimpak van eksplorasie-aktiwiteite. Verder is kwantitatiewe en kwalitatiewe data oor die omgewingsimpak, indien enige, onbekend of beperk. Sekere antwoorde van die vraelyste stem ooreen met die inligting wat verkry is uit die literatuuroorsigte. Ander antwoorde egter dui gebiede van tekortkominge aan wat nie in die literatuur aangedui word nie. Die waarnemings wat tydens die besoeke gemaak is dui die impak van verskeie eksplorasie-aktiwiteite op die omgewing aan, tesame met verskeie aanslagte en pogings wat deur die geselekteerde maatskappye gebruik word om die impak op die omgewing te verminder.

Die studie word afgesluit met 'n samevattende oorsig van die impak op die omgewing deur eksplorasiemaatskappye, en aanbevelings wat die impak van mineraal-eksplorasie aktiwiteite op die omgewing kan verminder.

Sleutelwoorde: omgewingsimpak, wêreldwye makro-ekonomie, wetgewing, mineral eksplorasie (en aktiwiteite), kleinkapitalisasie-maatskappye.

Definisies:

Afsetting:

‘n Konsentrasie van minerale in of op die Aarde se kors. Sluit in beide nie-ekonomiese en ekonomiese afsettings (Hulpbronne en Reserwes).

Braakland-eksplorasie:

Mineraal-eksplorasie wat mineraalvoorkomste teiken in gebiede waar geen eksplorasie vantevore onderneem is nie, waar inligting aangaande mineralisasie beperk is, of waar mineraalvoorkomste nie bekend is nie.

Eenhede van mates:

Alle eenhede van mates is volgens die *Système international d’unites* (Internationale Sisteem van Mates).

(Minerale) Hulpbron:

Die konsentrasie of voorkoms van minerale met ekonomiese vooruitsigte in of op die Aarde se kors in so ‘n vorm, samestelling en hoeveelheid dat daar ‘n redelike moontlikheid is vir latere ekonomiese herwinning. Die eienskappe van ‘n Hulpbron word bepaal deur geologiese bewyse en kennis.

Klein-kapitalisasie (kleinkap, junior) maatskappy:

'n Maatskappy met ‘n markwaarde van minder as een miljoen Amerikaanse dollars (VS$ 1 mil).

Mineraal-eksplorasie:

Die optrede vir die soek na minerale.

(Erts) Reserwe:

Die ekonomiese mynbare deel van ‘n Gemete en/of Aangetoonde (Minerale) Hulpbron.

Vaste minerale:

Minerale wat natuurlik voorkom in 'n vaste vorm of toestand op die aarde. Sluit olie en gas minerale uit.

ABBREVIATIONS

CE	**Common Era (Alternative to AD, has the same numeric value as AD dates)**
BCE	**Before Common Era (Alternative to BC, has the same numeric value as BC dates)**
bn	**billion**
CAD	**Canadian Dollar**
CEN-SAD	***Communauté des États Sahélo-saharies*** **(Community of Sahel-Saharan States)**
EAC	**East African Community**
ECOWAS	**Economic Community of West African States**
EIA	**Environmental Impact Assessment**
EIS	**Environmental Impact Statement**
EITAA	**Extractive Industries (Transparency and Accountability) Act 16 pf 2015 of the United Republic of Tanzania**
EITI	**Extractive Industries Transparency Initiative**
EMA	**Environmental Management Act 20 of 2004 of the United Republic of Tanzania**
EMP	**Environmental Management Plan**
EPA	**The Environment Protection Act 2 of 2000 of the Republic of Sierra Leone**
JORC	**Joint Ore Reserves Committee (an Australian professional code of practice that sets minimum standards for Public Reporting of Mineral Exploration Results, Mineral Resources and Ore Reserves)**
JSE	**Johannesburg Stock Exchange**
M&A	**Mergers and Acquisitions**
Ma	**Mega Annum (a period of 1 million years)**
MA	**Mining Act 14 of 2010 of the United Republic of Tanzania, as applicable to Tanzania Mainland**
MMA	**Mines and Minerals Act 17 of 1999 of the Republic of Botswana**
MMA	**Mines and Minerals Act 12 of 2009 of the Republic of Sierra Leone**
MPRDA	**Mineral and Petroleum Resources Development Act 28 of 2002 of the Republic of South Africa**

MPRDAA	**Mineral and Petroleum Resources Development Amendment Act 49 of 2008 of the Republic of South Africa**
NEMA	**National Environmental Management Act 107 of 1998 of the Republic of South Africa**
NEMAQA	**National Environmental Management: Air Quality Act 39 of 2004 of the Republic of South Africa**
NEMWA	**National Environmental Management: Waste Act 59 of 2008 of the Republic of South Africa**
NI 43-101	**National Instrument 43-101 (Canadian standards of disclosure for mineral projects)**
NWA	**National Water Act 36 of 1998 of the Republic of South Africa**
SADC	**Southern African Development Community**
SAMREC	**South African Code for Reporting of Exploration Results, Mineral Resources and Mineral Reserves**
TSX	**Toronto Stock Exchange**
USD	**United States Dollar**

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1 CHAPTER 1 - INTRODUCTION AND CONCEPTUALISATION

Globally, producing mines (both underground and surface) number in the thousands and, in addition, a multitude of additional mines are planned for and developed annually. These mines extract the materials needed by the manufacturing, construction and chemical industries. Furthermore, some also produce the energy minerals our society is completely dependent on (Whiteway & Loree, 1990:2). Moreover, minerals from developing countries, including several African countries, are exported in exchange for foreign currency and thus forms part of the vital international trade between countries. It is thus clear that producing mines are important for the global economy.

In general, the positive contribution of mining activities, i.e. the extraction of raw materials, economic growth, employment and social improvement are considered to be common knowledge. However, its negative impacts are frequently downplayed, ignored or are unknown.

The resulting reality, concerning how to balance all forms of development with the potential negative impacts on the environment, ultimately lead to the implementation of sustainable development in mining operations (Whiteway & Loree, 1990:56). Consequently, Whiteway and Loree (1990:57) noted that, in order to ensure sustainability, environmental protection need to be initiated in the earliest stages of exploration.

Sustainability in mining can however be viewed as a contradiction, and it can be said to be an oxymoron, especially when using the term sustainable mining (Mudd, 2007:1). However, when considering sustainability in mining related activities such as mineral exploration, factors such as the environmental footprint and environmental impact of exploration activities, water usage, greenhouse gas emissions, fossil fuel or other energy usage are critical and have to be considered (Mudd, 2007:20).

1.1 Background to the research

The extractive minerals industry is intrinsically interrelated with the global macro-economic environment and, consequently, should be understood as a cyclical industry (Schodde, 2013b:14) that follows the cycles of the global macro-economy. Periods of high investment and intense industry activities are followed by converse periods of non-investment and low activity. When the minerals industry experiences an upswing, a proliferation in the number of mineral exploration companies occur. Consequently, resources – which include qualified and experienced staff (Sillitoe, 2010:12) and time – become limited and the subsequent achievement of corporate goals gets hampered, viz. the urgency to discover a major mineral deposit (Dougherty, 2013:340). Adding to the pressure of urgency, financial investors require timeous and worthwhile returns on their investments.

This limitation of resources and the pressure of urgency could force small cap mineral exploration companies to make improper decisions. Firstly, small caps might decide against employing the most qualified or experienced staff to undertake the required operations. Secondly, they might potentially downplay the importance of environmentally friendly and sustainable operations. Thirdly, small cap companies might seek out jurisdictions with poor legislation to conduct business in. Lastly, driven by corporate goals, the possibility exists that only limited or restricted capital is made available for environmentally sustainable and compliant activities (Groves & Trench, 2014:11). Since the minerals industry is dominated by large multinational companies, focused research conducted on small cap mineral exploration companies have been notably lacking (Botas, 2015). Africa has not escaped the scourge of a rich endowment of mineral resources, and faces similar environmental concerns as the rest of the world.

Africa, as a geographic region, has tremendous mineral wealth, which includes some of the largest mineral deposits discovered in the world. Consequently, mineral exploration companies will continue to focus their business activities on Africa, since such deposits are continuously being discovered and developed throughout the continent (Schodde, 2013a:31). To some extent, the view that barriers to entry in African countries are less prohibitive than in other regions is still held. This view results from mineral and environmental legislation that is either non-existent or not as strictly enforced and, consequently, the environment is not necessarily regarded as important (Dougherty, 2013:339). The implication is that the impact on the environment is considered inconsequential when compared with economic and social development. Lastly, levels of corruption in African countries' public sectors are well documented and only serve to strengthen the views discussed above (Transparency International, 2014).

Therefore, the possibility that small cap mineral exploration companies might be encouraged to conduct business in Africa, precisely due to the perceived regulatory negligence, still exists.

1.2 **Problem statement**

In Africa, limited research has, or is being conducted regarding the environmental impact(s) of small cap mineral exploration companies and their various activities. Current research on the environment in the extractive minerals industry tends to focus on operating, decommissioning and defunct mining operations. Consequently, this study aims to address the research gap that currently exists regarding, not only the regulation of, but also the environmental impact of mineral exploration.

The focus of this research will be on small cap (also referred to as junior) mineral exploration companies that operate in the extractive minerals industry in Africa.

1.3 Research aims and objectives

Given the problem statement described above, the aim of the study is to review the potential environmental impact of small cap mineral exploration companies operating in Africa, and of their exploration activities.

The following research objectives are to be considered:

- Identify the major exploration activities employed by mineral exploration companies to locate mineral resources.
- Identify and ascertain the environmental impacts that mineral exploration activities have on the environment.
    - Produce a table to link specific mineral exploration activities to specific, or general, environmental impacts.
    - Produce a table to identify potential environmental impacts when exploring for specific minerals or general mineral groups.
- Determine whether small cap mineral exploration companies have the resources (i.e. suitable equipment, qualified and experienced staff, processes and corporate culture) to ensure that mineral exploration activities are conducted in environmentally friendly and sustainable ways.
- Compare South African legislation to those of selected African countries.
    - Analyse and review the various relevant mineral and environmental legislation that is applicable to mineral exploration activities

1.4 Structure of the dissertation

The dissertation is structured according to the following chapters:

Chapter 1: Introduction and conceptualisation

This chapter serves as an introduction to and conceptualisation of the study, and includes a preamble, the problem statement, research – and sub-research – aims and objectives of the study. The research methodology is addressed, as well as possible limitations of the research and the study.

Chapter 2, 3, 4 and 5: Pure literature review

Chapter 2 provides a literature review based on existing research and information regarding small cap mineral exploration companies. The definition of small cap mineral exploration companies is formulated, along with the need for, and the source of mineral resources. The reasons concerning why small cap mineral exploration companies operate in Africa is addressed, as well as the impact of the global macro-economy on small cap mineral exploration companies. The consulted literature sources include peer reviewed articles, books, guideline documents, reports, and articles.

Chapter 3 focusses on mineral exploration and related activities. Firstly, mineral exploration is defined according to how it will be used in this study. Secondly, the source of geological information is identified as an outcome of mineral exploration. Thirdly, mineral exploration activities are described and, lastly, related activities that are associated with mineral exploration are discussed. The consulted literature sources include peer reviewed articles, books, guideline documents, reports, and articles.

Chapter 4 reviewed the environmental impact of mineral exploration activities. The review focused on existing literature, field and site observations and also tacit and explicit knowledge in the mineral exploration field. Information obtained from existent research will be reviewed. In addition, results from this study will be tabulated according to the impact of exploration activities, mineral occurrences and common associations, as well as the impact of potentially deleterious constituents on the environment.

Chapter 5 addresses the legal aspects concerning mineral exploration and related activities. An overview of the legal systems used in Africa is provided. A subsequent review of four countries' mining and environmental legislation, viz. South Africa, Botswana, Tanzania and Sierra Leone is conducted. The consulted literature sources include Acts and legislation, peer reviewed articles, books, guideline documents, reports and articles.

Chapter 6 focusses on the questionnaire and its resultant feedback, as well as the site visits and related observations are reviewed and examined. Both the questionnaire and the site visits are crucial aspects of the study, since they are utilised to confirm and verify the baseline data and literature reviews.

Chapter 7 concludes the research by summarising the results, drawing conclusions and making recommendations based on the findings and observations that may be considered for future research.

The conceptual research design of the study is schematically summarised in Figure 1-1.

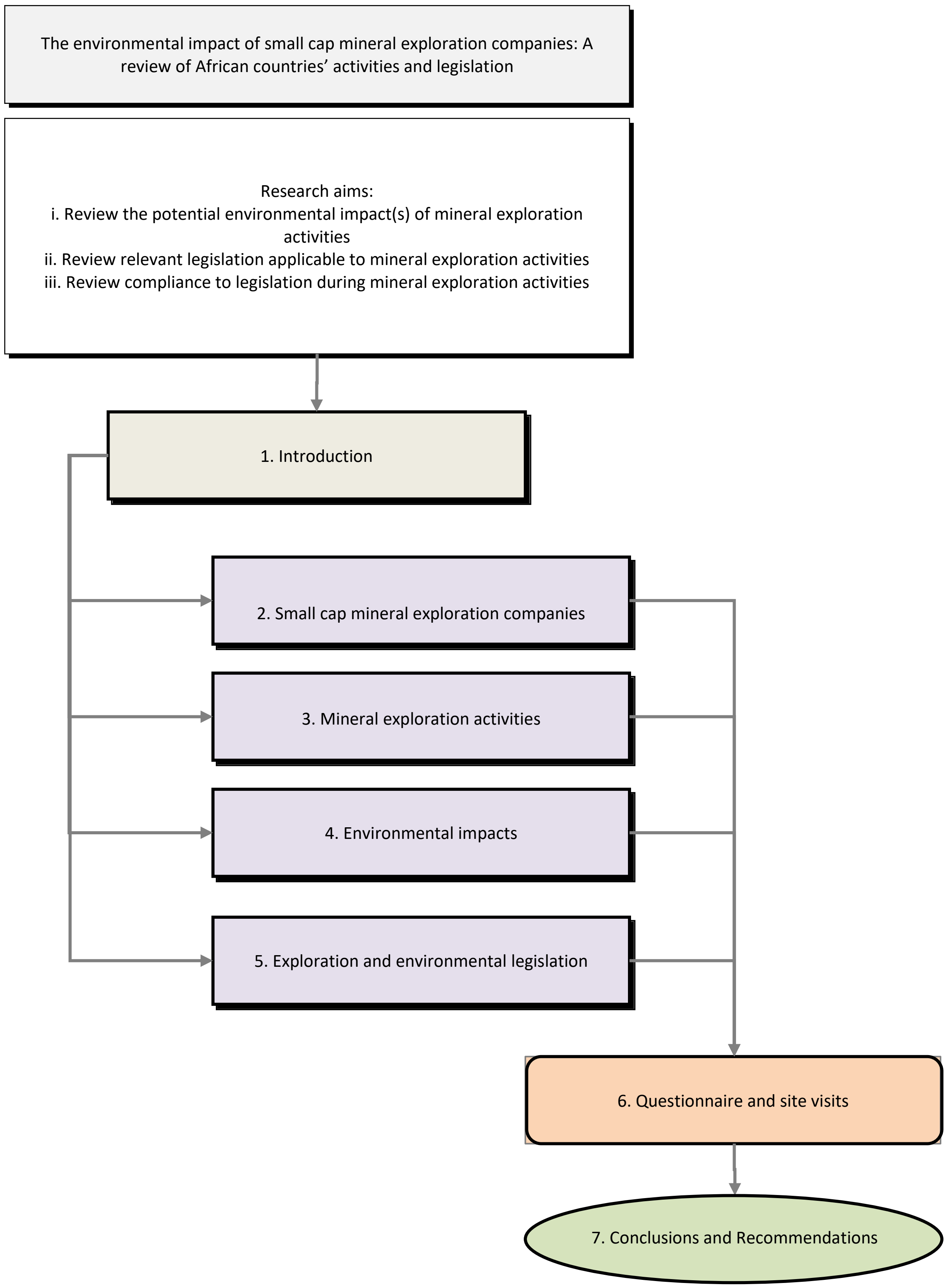

Figure 1-1: Conceptual research design

1.5 **Research methodology**

1.5.1 Literature research

Available relevant literature, i.e. textbooks, journal articles, magazine articles, e-books, legislation, published and unpublished company reports, and conference proceedings were identified and reviewed. The literature review provided insight into, and an understanding of small cap mineral exploration companies; how they are impacted by the global economy; their mineral exploration methods and activities; legislation that is applicable to mineral exploration and the environment and, lastly, the environmental impact of mineral exploration.

1.5.2 Empirical research

Applied research were utilised in order to investigate the environmental impact of small cap mineral exploration companies. Forming part of the empirical basis of this study, a quantitative approach was taken in order to obtain data and to provide an objective baseline aimed at meeting the study's proposed objectives.

In order to quantitatively describe and assess the trends, attitudes and practices of small cap mineral exploration companies, specifically regarding their adherence to selected countries' legislation, data collection methods included the following two practices:

- A survey questionnaire to ascertain whether small cap mineral exploration companies are aware of, and adhere to environmental legislation. The results served as a baseline for subsequent site visits.
    - Data collection process of the questionnaire:
      The electronic collection of data by means of a questionnaire that was distributed digitally via the Internet and electronic mail. The questionnaire used checklists, rating scales and open-ended questions to quantify the behaviour of small cap minerals exploration companies.
- Site visits to small cap mineral exploration companies conducting exploration activities in: South Africa, Botswana and Republic of Congo:
    - Structured observation and interview schedules to confirm and/or verify baseline data.

The objectives and outcomes of the study are tabulated in Table 1-1.

Table 1-1: Objectives and outcomes of the study

Objective		Outcome
Objective 1	Identify the major exploration activities utilised by mineral exploration companies to explore for minerals.	A list of the major exploration activities in use.
Objective 2	Identify and determine the environmental impact(s) of mineral exploration activities on the environment.	A table to link specific mineral exploration activities to specific or general environmental impacts. A table to identify potential environmental impacts when exploring for minerals.
Objective 3	Determine whether small cap mineral exploration companies have the necessary resources to ensure that mineral exploration activities are conducted using environmentally friendly methods.	
Objective 4	Compare South African legislation to that of specific African countries' legislation.	Identify strengths and weakness of the countries' environmental legislation.

1.6 **Limitations of the study**

Available literature and research regarding the environmental impact caused by mineral exploration activities are limited. The impact of operating, defunct and decommissioned mines on the environment is well researched and documented and consequently, this research was to an extent utilised to direct the current study.

The effect of the current global macro-economy on the extractive minerals industry in general, and particularly on solid minerals exploration, impacted this study. Small cap mineral exploration companies currently conducting active operations in Africa have been significantly reduced in numbers or their operations have been curtailed. For these reasons the target population for this study was much smaller than would have been the case otherwise.

Although the participants of the questionnaire will remain anonymous, participation was entirely voluntary. Potential respondents might have been reluctant to participate due to failed or non-adherence to legislation. Corporate policy and non-disclosure agreements might further have inhibited valid responses.

The willingness of companies to allow site visits could prove to be a major obstacle for the study. Companies might have been unwilling to allow researchers to visit operating sites due to their health and safety requirements. Not only the latter applies here, since these companies might also have wished to protect their corporate image in cases where negligent environmental practises were followed.

Many African countries do not have English as an official language. Consequently, legislation might not have been available in a language familiar to the researcher. If this was the case, legislation might needed to be translated, or unofficial translations could have been used that could be inaccurate.

No financial assistance or bursary funding was available to conduct this study. The consequent lack of funding impacted on the potential number of site visits, as well as the locations visited.

2 CHAPTER 2 - SMALL CAP MINERAL EXPLORERS

2.1 **Introduction**

The aim of this chapter is to investigate the role of mineral exploration, while taking into consideration the reasons for such exploration to exist. This need stems from various aspects, which include population growth, per capita metal usage and what the sources of natural resources are. Moreover, these aspects will be considered along with the reasons behind small cap explorers' motivations regarding exploration, corporate goals and the resources they have available to minimise business-related risk.

Lastly, specific motivations driving these exploration companies' decision to conduct business on the African continent are addressed, which is then followed by a review of the impact that global macro-economic cycles have on them.

2.2 **Need for exploration**

Ever since the Palaeolithic Age approximately 2.5 Ma ago, and possibly even earlier, when hominins first began making and using tools for purposes as varied as the construction of stone shelters to creating hunting equipment or weapons, *Homo sapiens* and their ancestors' existence have been intrinsically driven by the need to obtain raw materials from the environment (Guiseppi, 2000).

As *H. sapiens* developed and adapted, their needs changed from using simple tools such as stone or bone-based items to tools that have consistently increased in sophistication, ultimately resulting in the present era, where humanity's need for natural resources have reached peak demand. These resources include metals for construction, fuel minerals for providing energy, construction minerals for building, agri-minerals to increase crop yield, special alloys for use in speciality tools and equipment, precious metals as a store of their labour's wealth, gemstones to adorn them, and speciality metals for use in high technology industry, (Bridge, 2004:206).

Numerous accounts exist that recount the importance of minerals in literature and history:

- In ancient Saones, river deposits included gravel that contained gold, which was then passed over sheep's fleeces to extract the precious metal. These fleeces were hung on trees to dry and then beaten, in order for the gold to be recovered. The tale of Jason and the Argonauts' search for the Golden Fleece near the shore of Euxine could be based on these activities (Jensen & Bateman, 1981:3).
- The Romans were drawn to Britannia partly due to the mining of metals such as tin, iron, silver and gold (Wake, 2006).

- Similarly, the Spanish Conquistadores were drawn to the New World by riches of gold and silver. The Argentine Republic's name was derived from the Latin name of silver "argentum" (New World Encyclopedia contributors, 2016).

Durucan *et al*. (2006:1057) confirms that extraction and utilisation of natural resources through mining is still a corner stone of the current economy. Therefore, the continued survival and development of humanity will remain linked to the exploitation of natural resources, although possibly with different and more efficient methods.

2.2.1 World population

The solid minerals extractive industry forms the basis of modern 21st century society and, despite the onset of modern technologies, newfound environmental sensitivities, and social resistance against the extractive industry, extraction of materials from the earth will continue. This is true even though humanity is already looking to space for potential mineral extraction from celestial bodies (Planetary Resources, 2015).

According to the United Nations Department of Economic and Social Affairs, the human population currently stands at an estimated 7.349 $x10^6$ and is expected to grow to 9.725 $x10^6$ by the year 2050 (UN Department of Economic and Social Affairs, 2015). The growth in human population will require continued extraction of natural resources to sustain the expected 30% growth in population. With the increase in the global population, an increase in the extraction of natural resources is expected (Graedel, 2010:52).

Furthermore, life expectancy has increased from 46.9 years in the 1950's to 71.0 years during the period 2015 - 2020 and is expected to be 81.8 years for the period 2095 - 2100 (UN Department of Economic and Social Affairs, 2015). Moreover, according to the United Nations Population Fund (UNFA, 2012), the world population aged 60 years and older, will overtake the world population aged 0 - 14 between 2045 and 2050. This data indicates that, besides the fact that the world population is increasing, the world population is also ageing. Consequently, urbanisation and industrialisation is especially prevalent in "Chindia" (China and India) (PricewaterhouseCoopers, 2013:3).

2.2.2 Per capita metal usage

In conjunction with an expected increase in the world population, Graedel (2010:9) states that as a country develops so does the demand for metals. His research showed that the per capita metal stocks in more developed countries are approximately five to ten times higher than in developing countries.

In his findings he notes that as more countries become better developed, the demand for metals will increase. Although not addressed in his study, the question arises whether this holds true for other commodities such as energy minerals, agri-minerals, construction materials and other commodities?

To further substantiate Graedel's research, Schodde (2013b:24) found that metal production doubles every 20 - 25 years, by using primary copper production as a basis for his study. He estimates that global cumulative primary copper production (ranging from 1000 BCE to 2012 CE) stands at 611 Mt. He forecasts that production for the period 2013 - 2037 will be 638 Mt copper. According to Schodde (2013b:24), the global cumulative primary copper production in 2012 was 17 Mt, and he estimates that it will increase to 35.6 Mt in 2037, an increase of 209.4%.

When considering Graedel's (2010) and Schodde's (2013b) research, it can be concluded that the expected population explosion, urbanisation, industrialisation and human longevity, can in future only be supported through food production, construction of infrastructure, development of current and new technology and other growing demands, that will only be possible through significant increases in our use of, and dependence on natural resources.

2.3 **Source of mineral resources**

Natural resources can be derived from two sources, i.e. recycling of "old" or used material, or the exploitation of newly discovered material extracted directly from the earth.

Recycling of material occurs when "old" material is recovered and reused, such as aluminium from packaging, or copper recovered from demolished buildings. According to the United Nations Environment Programme the recycling cycle or life span of materials differs. For example, aluminium used in packaging has a life span of 0.3 - 0.8 years, while copper in a building has a life span ranging between 25 and 40 years (Graedel, 2010:31). However, not all materials that are mined can be recycled. Consider, for instance, coal which is destroyed when burnt to generate heat, or when used in chemical factories.

An alternative, which does not form part of this study, is the substitution of certain types of materials with others (Graedel, 2010:23). Substitution will occur when a higher priced raw material is substituted with a lower priced material, or where a more readily available material substitutes a less available material. Furthermore, as technology develops, a substitute material may be used for various reasons. An example is carbon fibre replacing metals and alloys in several applications.

The search for, or discovery of naturally occurring materials is referred to as exploration. Exploration is intrinsically connected to mining and, therefore, the economy. Consequently, without exploration there cannot be a mining industry. The drawback, however, is that with an increasing world population, exploration will more and more affect and impact communities and the environment in every corner of the planet.

2.4 Mineral exploration companies

Various companies, each fulfilling a specific function in the value chain, operate in the natural resources industry. However, this study will focus specifically on the exploration sector. Exploration companies can broadly be classified into three groups: major, mid-tier and small cap (or junior) companies (Dougherty, 2013:341). Although these classifications are not accurately defined, the size of the company, in terms of number of operating sites, infrastructure, and sources of income, level of capitalisation and geographic distribution of operations across the globe can be considered as definitive parameters. For the purpose of this study the definition of a junior company (also referred to as a small cap company), will be in line with Natural Resources Canada’s (2015) definition, which defines small cap companies as companies that do not have access to sales revenue to fund activities (Schodde, 2013a:9).

Companies that focus solely on exploration activities are usually small cap companies, with no operating or production sites that generate income. They further tend to have very limited finances and other resources and they derive their revenue from equity placements on, mostly, venture capital markets. Although the expenditure of individual small cap exploration companies are much lower than mid-tier and major companies, the combined total expenditure of this part of the exploration sector shows that small caps dominate the market. The spending of small cap explorers from 1998 to 2007 increased from USD 1.6 billion to USD 5.3 billion, while the combined total spending of major and mid-tier companies were only USD 4.1 billion (Dillion, 2007:6). Therefore, it is evident that small cap explorers play just as significant a role in the exploration industry as mid-tier and major companies.

2.4.1 The small cap mineral exploration companies

Based on corporate decision-making structures, major and mid-tier companies focus on taking low-risk, viable projects into production, thus leaving the high risk exploration industry to the small cap exploration companies (PricewaterhouseCoopers, 2015:4). Consequently, small cap exploration companies attempt to fill the void left by mid-tier and major multi-national companies, that either do not want to conduct exploration or, during an economic downturn, reduce their exploration spending to reduce overall costs (Sillitoe, 2010:11). Small cap exploration companies advance viable projects to a stage where enough exploration work has been conducted and encouraging results have been obtained, and then “passing” the projects on to more senior companies for further development. Consequently, there are notable differences, but also links, between the different sized companies that operate in the extractive minerals industry.

2.4.2 Corporate goals of small cap mineral exploration companies

Any listed company, be it private or public, has as primary goal the creation of profits, either for the owners, the operators, or the shareholders. Therefore, exploration is strongly incentivised, in a free market, capitalist environment, by profit or rent seeking. Henderson (2008) compares rent seeking with “privilege seeking”, where a company or individual gets to benefit from special privileges such as tax exemptions, reduced import tariffs and special financial dispensations. Rent extraction is thus critical to the existence of small cap exploration companies (Dougherty, 2013:340).

According to Kaplinksy (1998:16 - 28), nine different rent categories are available to a company: resource rents, policy rents, technology rents, human resources rents, organisational rents, relation rents, product and marketing rents, infrastructural rents and finance rents. Depending on where a company is situated along the value chain or curve, it will access, or target, certain types of rent (Dougherty, 2013:342). Small cap exploration companies predominantly access resource rents and finance rents as part of their business.

To access resource rents, exploration companies target geological, mining and metallurgical settings that favour and enable low cost capital expenditure and low cost production. To access finance rents, these companies incorporate in territories that incentivise small cap companies through policy and legislation. Canada, for example, attracts small cap exploration companies with incentives that include more lenient corporate governance, which could lead to small cap explorers to be less focussed on social and environmental issues (Dougherty, 2013:342).

Consequently, a number of small cap explorers are listed on Canada’s Toronto Stock Exchange (TSX), while their managerial and operational offices are situated in other locations. This strategy by small cap explorers clearly illustrates their preference to seek out lenient corporate governance requirements, which also highlights the possibly questionable ethical standards to which some might subscribe (Dougherty, 2013:349). Dougherty (2013:349) does not indicate whether this attitude is applicable to all small cap explorers, or just to a selection of these companies. The question arises then, to what extent does this apply to small cap explorers in general? Moreover, Dougherty (2013:350) points out that the TSX does not review and audit assessments and reports as closely as other exchanges are known to do.

Due to the rent opportunities that exist in the mineral exploration industry, small cap explorers are increasing in numbers and, consequently, the competition with one another also intensifies (Dougherty, 2013:345), and this is particularly the case during periods of global economic growth. Furthermore, with improvements in exploration related technologies, the opportunities for small cap explorers to seek and capture rents increase (Dougherty, 2013:345). Consequently, the rent seeking behaviour of companies is important to understand and also, as competition increases, why companies have to strategically differentiate themselves from their competitors in order to become more attractive to investors (Dougherty, 2013:347, 351). To be successful then, small cap exploration companies seek mineral occurrences and deposits that potentially favour low cost exploration activities, have potential low extraction costs, and which occur in geographic areas that have favourable (and possibly questionable) laws and policies (Dougherty, 2013:347).

2.4.3 Requirements of successful small cap mineral exploration companies

Some (if not all) small cap exploration companies presumably do not have access to equivalent resources that major and mid-tier companies have. In other words, the most notable difference between small cap explorers and larger companies boils down to the amount of capital each has available (Dougherty, 2013:343). It is thus imperative to understand where and how the limited capital available to small caps are applied.

In small cap companies, capital is applied to the most important aspects that will impact the success of the company. Capital allocation is prioritised between high impact and low impact activities. Moon *et al.* (2006:54) states that two key prerequisites for success of a mineral exploration company are to have the best available staff, and adequate finance.

2.4.3.1 Availability of technical board and management staff

As with most industries, employing the best suited staff is key for success. Stone (2015:12) indicates that junior mining companies are usually headed by technically competent and experienced professionals, such as geologists, metallurgists and mining engineers. These professionals focus on getting the product out of the ground, processing it, and selling it. Groves and Trench (2014:11) state that serious exploration companies further appoint board members with the required technical expertise on their boards and management. Since they are driven by success, this across-the-board level of professional competence ultimately enables them to raise the necessary funds to advance exploration work. Many small cap explorers employ industry veterans who have experienced the cyclical nature of the industry and who have the experience to survive future cycles (PricewaterhouseCoopers, 2014:3).

However, a major problem facing small cap explorers, and to some extent the larger companies, is the fact that the experience and expertise of the geological teams is not properly appreciated. This was evident during the 2008/2009 financial crisis when several exploration teams were dismissed (Sillitoe, 2010:12). The short term savings achieved by these dismissals were overshadowed by the massive long-term losses of institutional memory which would be needed when exploration eventually resumed (Sillitoe, 2010:12). This decision, made in the name of reducing overheads and cutting back on expenditure, was ultimately short-sighted and can only be blamed on poor long term vision.

The increasing demand to document and verify facts and issues leads to the unfortunate reality that technical staff, such as geologists, spend significantly less time in the field and, therefore, not doing what geologists were trained for, and intended to do, i.e. to work with rocks (Sillitoe, 2010:12). This is particularly true for small cap explorers, who oftentimes do not have the required administrative, logistical and other support staff available.

2.4.3.2 Availability of capital

Despite the fact that they have suitable staff that oversee the geological and financial aspects of operations, other aspects such as environmental and social compliance are often reduced in significance (Dougherty, 2013:342), or even ignored, due to funding rather being spent on the technical aspects of the business, i.e. drilling and resource calculations that will have a greater impact on the financial success of the small cap explorer.

Frequently, due to limited financing and the dependence on global macro-economic cycles, small cap explorers are compelled to operate with less qualified and experienced technical staff, resulting in frequent services by consultants. This is particularly true during slowdowns in global markets (Groves & Trench, 2014:11). Consequently, the current global economic downturn requires companies in the extractive industries, mines and exploration companies alike, to be highly diligent in ensuring that they continue to be profitable (Stone, 2015:13).

Due to the limited capital available to small cap explorers, these companies are under constant pressure to maintain expedient or even immediate exploration successes (Sillitoe, 2010:11). This remains true, despite the expected timeframe of approximately five years that is normally required for greenfields exploration to present proper results.

2.4.4 Risk small cap mineral exploration companies face

Since very few exploration projects ultimately become a producing mine, small cap explorers have to absorb most, if not all, of the risks associated with exploration. As a consequence of this high risk, small cap explorers frequently have difficulty in obtaining financing, especially during global economic downturns (PricewaterhouseCoopers, 2014:3). When small cap explorers do access capital funding, the use of the funds has to be tightly controlled to ensure that funds are spent where it will have the largest impact. Securing capital to fund exploration projects are one of the most important challenges faced by a small cap explorer (Stone, 2015:12).

2.4.4.1 Geological and project related risk

Harwood, (2015:6) states that the life of a mining project can broadly be divided into two major phases, i.e. the exploration and production phases, which can then further be subdivided. The post-mining phase of decommissioning, closure and rehabilitation forms a major additional phase of the mining project (Groves & Santosh, 2015:390). The risk associated with the project is reduced as each sub-phase is successfully completed. The reduction in the project risk is simply a reflection of the increase in project knowledge as the different sub-phases are completed.

The risk, expenditure profile, and decision points from the conceptual stage of a project through to the closure stage of a mining operation is indicated in Figure 2-1 below.

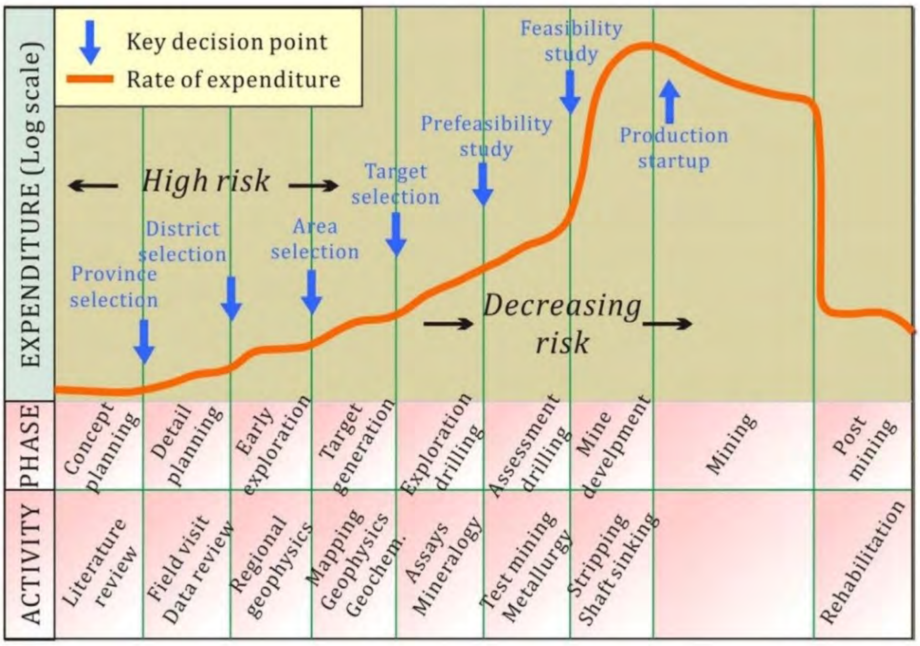

Figure 2-1: Project development phases indicating risk, expenditure and decision points (Groves & Santosh, 2015)

The sub-phases of the exploration phase include the concept planning phase, followed by the detailed planning phase, early exploration phase, target generation phase, and the exploration drilling phase. The risk during these five phases are high, with an increase in expenditure as the exploration drilling phase is approached. During these phases there is no certainty of success, or that the capital expenditure will ever be recouped. This is the risk that small cap explorers, as well as their investors, are willing to take.

When the risk profile of exploration is reviewed (Figure 2-2), it is clear that the risk of failure (blue line) reduces as the activities are moved along the X axis (time and funds spent) from conceptual planning to mine development. At the same time, the number of exploration targets along the Y axis, reduces. An exploration company usually starts off with numerous conceptual targets, which are reduced in numbers to fewer follow-up targets, and ultimately to only a few drilling targets.

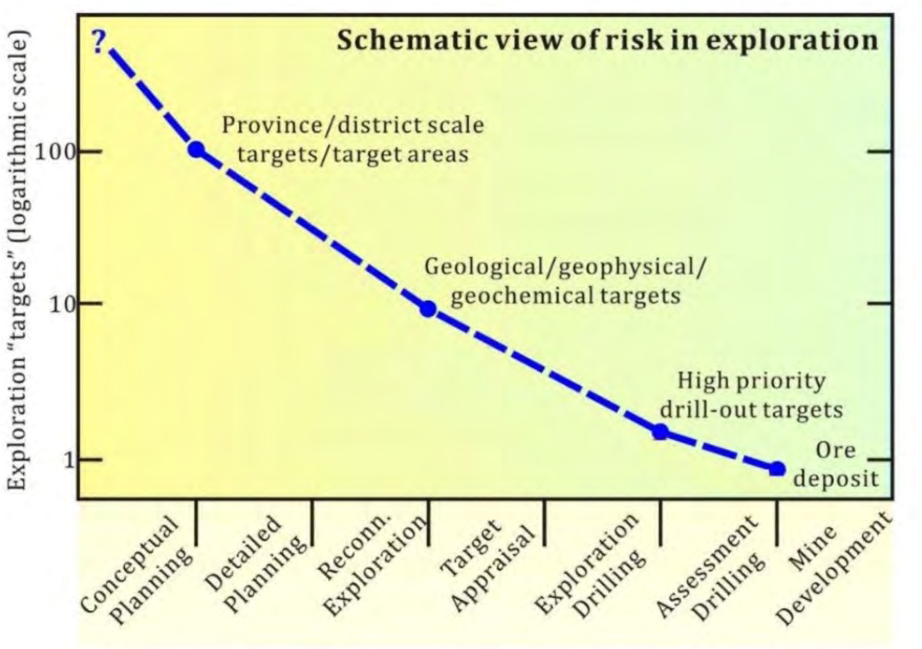

Figure 2-2: Risk profile during exploration phases (Groves & Santosh, 2015)

Exploration, especially greenfields exploration, is a high risk, high reward industry where unnecessary delays cannot be sustained and where financing is obtained via specialised risk markets. Baillie (2013:11) summarises the following aspects as critical for successful exploration:

- Explorers should have quality professionals, i.e. be suitably experienced and qualified,
- Should have multiple targets to reduce the risk of failure,
- Ensure that delays are minimised, and
- Reduce overhead costs.

Due to their corporate strategies, large and mid-tier companies, avoid the high risk phases of exploration (Sillitoe, 2010:11). This leaves small cap explorers to vie for this high risk, but high reward, segment of the industry (Dougherty, 2013:343, 351).

2.4.4.2 Geopolitical risk

Besides the geological and project related risk associated with exploration, companies also have to face geopolitical risks, which are summarised by Schodde (2013b:40) in Figure 2-3 below. Schodde further summarises global government actions (since 2011) that impact on two aspects:

- Increase of taxes and royalties and
- Nationalising of assets.

As can be observed in Figure 2-3 below, all the countries except one, Guinea, either increased taxes or royalties, or introduced nationalising-type laws.

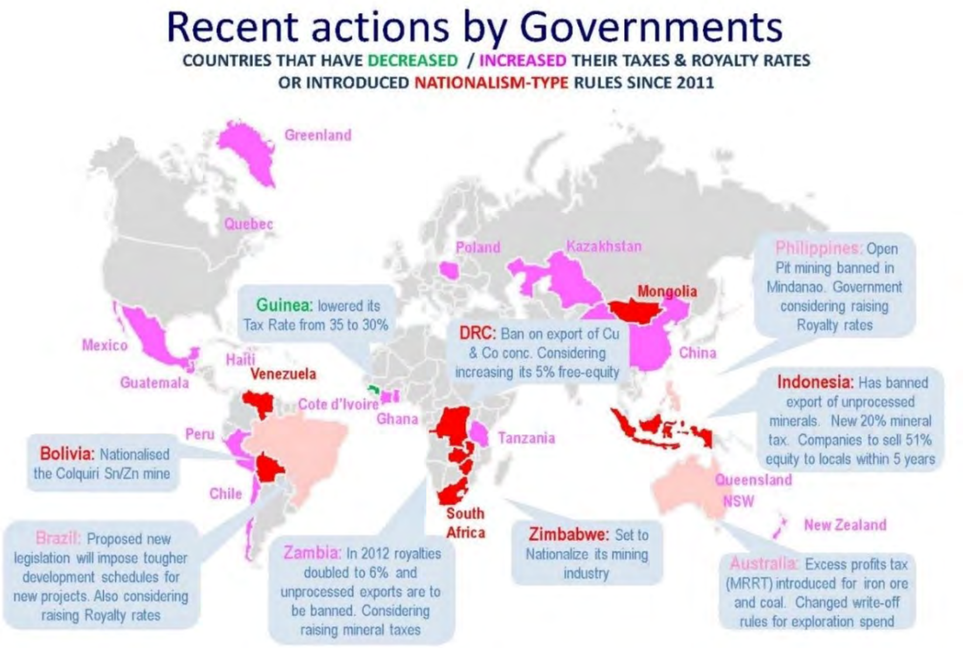

Figure 2-3: Global geopolitical risk facing exploration companies (Schodde, 2013b)

Besides the political risks that companies in the extractive industry face, there is also the problem of corruption. Transparency Internal annually publishes its Corruption Perceptions Index which measures the perceived levels of public sector corruption, and for sub-Saharan Africa, 92% of countries scored less than 50 out of 100, and the average score obtained was 33 out of 100 (Figure 2-4).

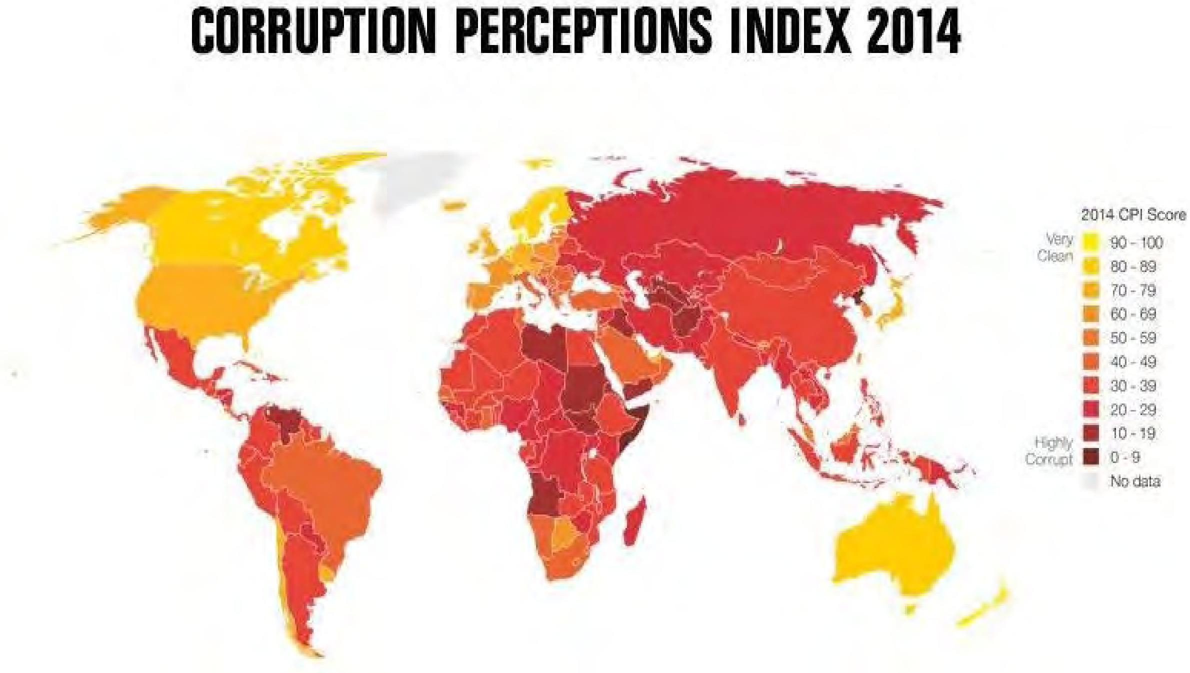

Figure 2-4: Global corruption perception (Transparency International, 2014)

2.5 **Small cap exploration companies in Africa**

According to Adams and Morall (2008:14) certain small cap exploration companies make deliberate corporate decisions to conduct their business in Africa. For a number of reasons, the African continent remains a prime target for exploration companies. Reasons why companies conduct business in Africa are discussed below.

2.5.1 Mineral potential of Africa

According to the World Bank's Extractive Industries Overview (2015), Africa accounts globally for approximately 30% of the mineral reserves, 10% of oil and 8% of the natural gas. When compared with the fact that Africa covers approximately 20.4% of the earth's total land area, it is evident that Africa is a geographic region that cannot be ignored by any company that operates in the extractive industry.

Referring to Figure 2-5 below, Schodde (2013a:31) highlights two areas in Africa that, from 2000 - 2013, were significant in terms of major mineral discoveries globally. These areas are located in West Africa, where mostly gold discoveries were made. The other is Central Africa, where significant gold and base metal discoveries have been made, and also some other lesser discoveries as well.

Figure 2-5: Recent global mineral discoveries (Schodde, 2013a)

2.5.2 Potential exploration value

Schodde (2013a:45) takes his research even further, by comparing the amount of funding spent between 2003 and 2012 within certain regions of the world versus the number of discoveries. The comparison includes Tier 1 and 2 discoveries, the estimated value of the discoveries made, and a value spend ratio. Reviewing Schodde's (2013a) Table 2-1 below, it shows that, for Africa, the exploration spend was CAD 16bn, or 14% of global expenditure, placing Africa fourth on the list. This expenditure resulted in 124 discoveries, or 22% of the global figure, for a second place position. Even when only reviewing Tier 1 and 2 discoveries, Africa accounts for 20 discoveries, or 24% of the global figure, putting Africa in first place. Looking at the estimated value of the discoveries, Africa is nearly equally placed with Latin America (CAD 22bn vs CAD 23bn), or 24% of the global figure. The important value is the value/spend ratio where Africa obtains a value of 1.38. This translates into every one unit spent on exploration, a return of 1.38 units can be expected. This indicates that Africa is still the region with the best potential return on investment.

Table 2-1: Comparison of exploration spend per region (extracted from Schodde, 2013a)

Region	Exploration spend (2012 CAD		No of discoveries		Tier 1 and 2 discoveries		Estimated value (2012 CAD bn)		Value/spend
Australia	12	10%	84	15%	14	17%	13	14%	1.08
Canada	21	18%	74	13%	15	18%	15	16%	0.71
USA	9	8%	19	3%	6	7%	5	6%	0.56
Latin	27	23%	133	24%	15	18%	23	24%	0.85
Pacific/SE	6	5%	23	4%	2	2%	4	4%	0.67
Africa	16	14%	124	22%	20	24%	22	24%	1.38
W Europe	3	3%	24	4%	1	1%	1	1%	0.33
Rest of	22	19%	78	14%	11	13%	10	11%	0.45
Total	116	100%	559	100%	84	100%	93	100%	0.80

2.5.3 Depth of deposits

One of the reasons for the high return on investment achieved in Africa is also highlighted by Schodde's (2013a:25) research into the average depth of discoveries made in certain geographic areas between 2003 and 2012. Reviewing the results (Figure 2-6), Schodde calculated an average depth of 74 metres. The average depth for African discoveries is 55 metres, which places Africa in second position, the first being Latin America. However, when South African discoveries are excluded from the calculation, the average depth drops to only 12 metres. This indicates that deposits discovered in Africa (when excluding South Africa) are the shallowest compared to other geographic regions. The implication is that it is potentially easier to find new deposits on the African continent than elsewhere in the world.

Industry experience with shallow deposits has shown that exploration costs are also potentially drastically reduced. For instance, the drilling depth of exploration holes, the number of samples and analyses per borehole, and other associated costs tend to be lower, the shallower the deposit. A downside to these shallow deposits is that most of these deposits will be mined by open cast methods, which could result in higher environmental impacts.

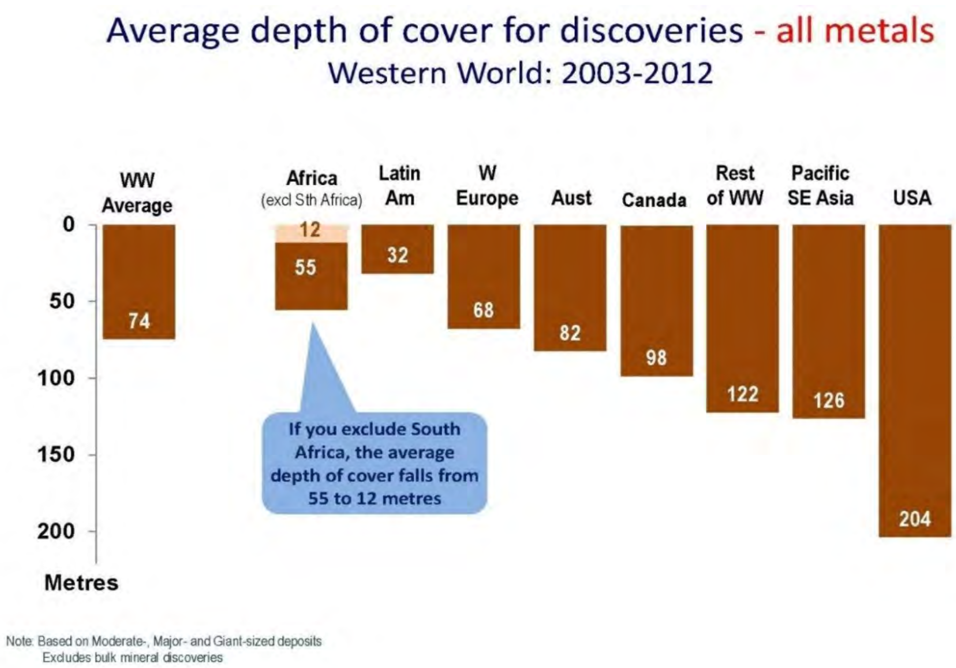

Figure 2-6: Average discovery depths (Schodde, 2013a)

2.5.4 Knowledge of African condition

Some companies are of the opinion that they possess the expertise to operate in Africa and they therefore have a competitive edge over their competitors (Bristow, 2012). Another perception exists that low entry and exit barriers exists in most African countries due to slack and/or careless policies and laws (Dougherty, 2013:339), which could be exploited by poor adherence of some companies. These relaxed legislative policies could act as a drawcard for some small cap exploration companies to target African projects.

Although small cap explorers conduct their business in Africa, they are often legally incorporated in other jurisdictions such as Canada, the reason being that equity financing is heavily subsidised and that corporate governance is lenient (Dougherty, 2013:349). Companies incorporated in Canada, but who operates in Africa have potential advantages over companies incorporated elsewhere, and who do not operate in Africa. These advantages are:

- Lenient corporate governance and subsidies in Canada,
- Potentially low entry and exits barriers to operating in Africa, and
- Potentially fruitful geological settings to find major deposits.

Since 1999 Behre Dolbear (2014) has compiled annual rankings, based on seven criteria, to assess mining investment potential. Of the twenty five countries reviewed in 2015, eight (or 32%) are African. The African countries, and their rank out of 25 (in parentheses), are as follows: Botswana (8), Namibia (9), Ghana (10), Zambia (12), Tanzania (13), South Africa (14), Mozambique (22) and DR Congo (25). This further illustrates the importance of the African continent in mineral exploration and extraction.

2.6 Impact of the global macro-economy on small cap exploration companies

A cornerstone of a free market society is the free supply and demand of goods and services (Moon *et al.*, 2006:6). An important aspect that needs to be considered when reviewing supply and demand specifically in the natural resources industry is the effect that time has on the long lead times that are required to progress from an exploration project to a producing mine operation that delivers a product. Supply and demand are often out of synchronisation, and this discrepancy between supply and demand leads to a cyclical nature that is reflected in exploration expenditures (Schodde, 2013a:4). PricewaterhouseCoopers (2014:3) confirms that the economic volatility and the oversupply of metals have led to a decline in commodity prices and a subsequent recalibration in terms of supply and demand.

Due to the cyclical nature of the mining industry, any unbalanced production causes commodity prices to significantly decline. In the past four decades, from 1975 to 2015, global exploration expenditure has gone through five cycles, with peaks at 1980, 1988, 1997, 2008 and 2012, and troughs at 1985, 1993, 2002, 2009 and 2015 as shown in Figure 2-7 below (Schodde, 2013b:4).

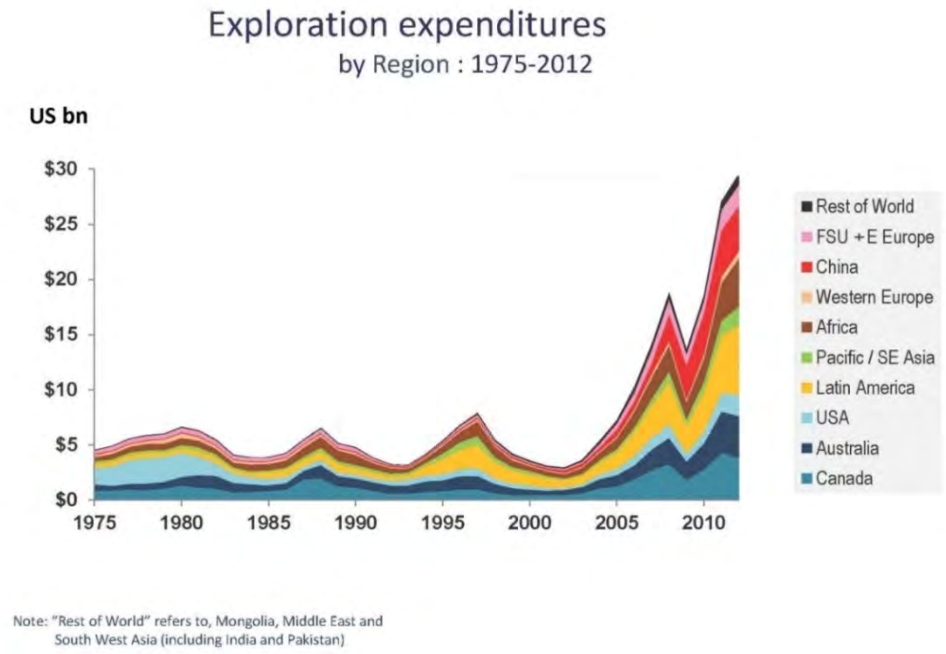

Figure 2-7: Exploration expenditures (Schodde, 2013b)

Declines in exploration expenditures for the period 1980 to 1985 was 41%, for 1988 to 1993 51%, for 1997 to 2002 62%, for 2008 to 2009 27% and, according to Schodde (2013b:56), the decline in expenditure in the current economic retreat for the period 2012 to 2015 is expected to be 28%. The question is how long the current economic retreat is going to last, and by how much the decline will ultimately be?

Reviewing Schodde's (2013a:6) data above as a percentage of total spend, Africa appears to account for 15% of the global spend in 2012. Africa's portion of exploration spending has remained relatively constant since circa 1998. In contrast, it is notable that the exploration spend in China has increased dramatically until approximately 2009, after which a decrease in exploration spend is evident (Figure 2-8).

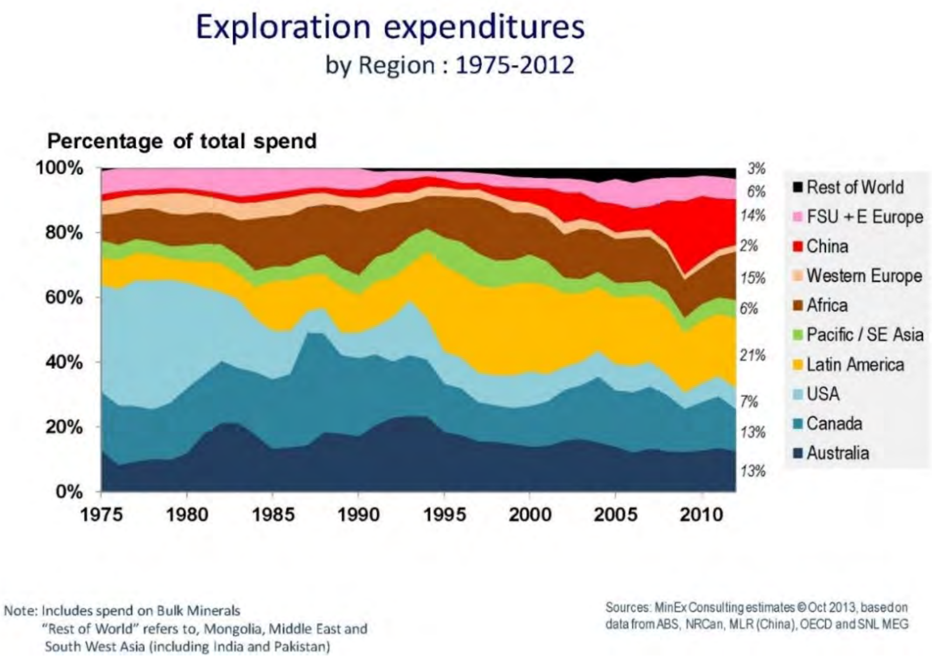

Figure 2-8: Exploration expenditures as percentages (Schodde, 2013a)

Despite the retreat in exploration expenditures during 2009 and 2015, the global exploration expenditure increased tenfold on a real basis for the period 2002 to 2012, and peaked at an all-time high in 2012 with an amount of USD 30bn (Schodde, 2013a:4). During the last ten years, there was a steep increase in the number of small cap exploration companies (Schodde, 2013a:50). This increase was largely driven by the boom in commodity prices (Schodde, 2013a:68). Simultaneously, the number of large companies increased in equal measure due to merger and acquisition (M&A) activities.

Schodde (2013b:28) further reviewed the spending on gold exploration and compared it to the gold price. He concluded that, since 1985, the funds spent on gold exploration was linked to the gold price. The conclusion can be made that the increasing numbers of small cap explorers want to access the resource rent that is available due to an increase in commodity prices (Figure 2-9).

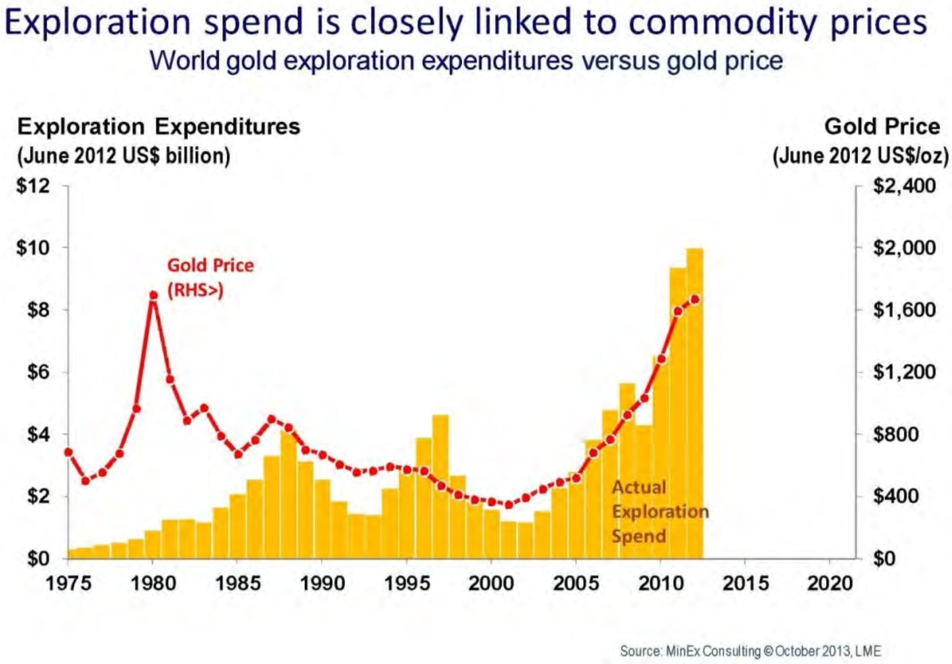

Figure 2-9: Exploration spend and commodity price (Schodde, 2013b)

The PricewaterhouseCoopers (2013:1) report paints a bleak picture of the mid-tier mining industry in Australia. Mid-tier companies are struggling to survive due to depressed commodity prices, reduced demand for raw materials and a lack of investors. Securing funding for mining development is a challenging business (PricewaterhouseCoopers, 2013:15), but even more so for small cap explorers, mostly due to the high risk associated with these companies, and the context of the business sector that they operate in.

According to Groves and Santosh (2015:397), the industry is currently facing a low base rate situation, with near zero returns. In an industry driven by business principles, explorers can do little or nothing to change the macro-economy. Although no comparative figures are available for the small cap exploration companies, the researcher is of the opinion that the situation is just as bleak, or even worse, for these companies in the current global economic situation. It is therefore evident that any further negative changes in global market sentiment, or in the future economic outlook, will have a significant negative impact on the survival of small cap explorers and on how they operate.

Negative markets will result in companies reappraising their projects, and realigning their operations, their corporate strategy and even their funding (PricewaterhouseCoopers, 2013:23). During global economic downturns, small cap explorers have reduced their spending on all but the most geologically prospective projects with the shortest lead time. They further reduced other non-technical expenditure to the absolute minimum or, in certain cases, could have completely stopped spending on it.

The global discovery rate of major deposits is declining, while the cost per discovery is rising steeply (Sillitoe, 2010:11). Together with a downturn in the global economy, it is creating a crisis for explorers (Groves & Trench, 2014:10). Schodde (2013b:14) confirms Sillitoe's statement with his own data being indicative of the exploration spend and reported discoveries of gold deposits in the Western world. It is observed that from 2006, the number of discoveries has decreased, while the exploration expenditure has increased dramatically since 2002, barring the 2008/2009 period when there was a slight decrease. See Schodde's (2013b) data below in Figure 2-10.

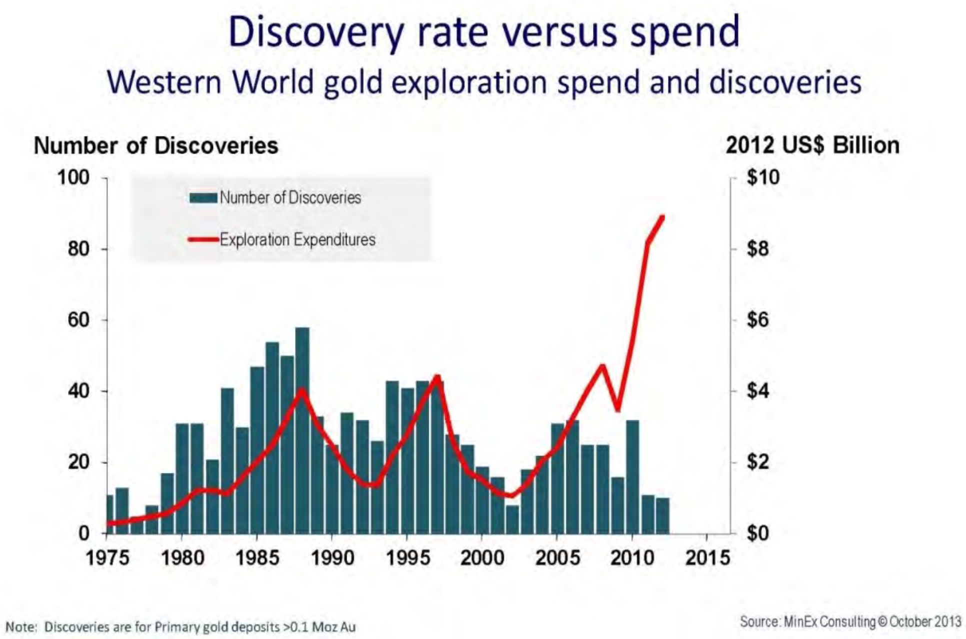

Figure 2-10: Discovery rate and expenditure (Schodde, 2013b)

When Schodde (2013b:15) includes the estimated number of unreported discoveries into his data, there is still a mismatch of discoveries related to the exploration spend (Figure 2-11). The increase in exploration spend can be attributed to increases in labour costs, drilling costs and other costs such as administration and rehabilitation costs.

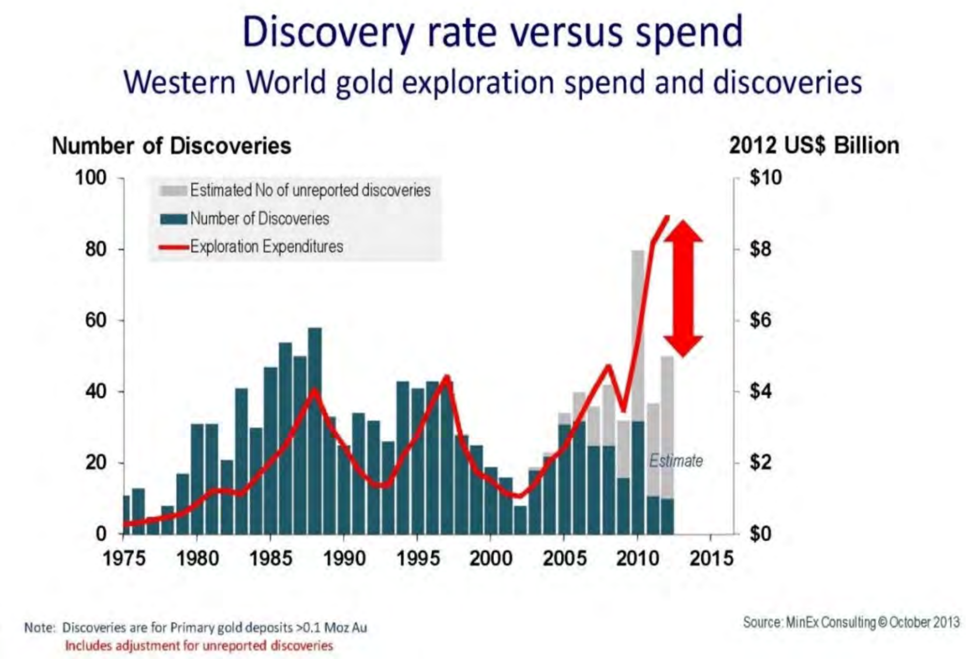

Figure 2-11: Discovery rate and expenditure including estimated unreported discoveries (Schodde, 2013b)

Schodde (2013b:17) compared certain input costs of Canadian and Australian exploration companies between 2000 and 2012, and observed that the average cost of core drilling (in USD/m) increased 88% for Canadian companies and 125% for Australian companies. Similarly, the average salary of an Exploration Manager increased by 83% for Canadian companies and 150% for Australian companies. The administration costs of a small cap exploration company in Australia increased by a staggering 170%. All these increases ultimately led to the surge in exploration expenditure, as illustrated by Schodde (2013b:16) and Sillitoe (2010:11).

Schodde (2013b:33) reviewed the administrative costs, exploration and development costs and the cash reserves of a number of Australia small cap companies between 1998 and 2013. He observed that the administrative costs remain relatively constant over time, with only small variations. Exploration and development costs vary as companies' cash reserves vary. During 2006 and 2007, large amounts of capital were raised, and this is reflected in both the cash reserves available and the capital spent on exploration and development. During 2008 and 2009, a period of global financial crisis, funding was difficult to obtain, and it is also reflected in the cash reserves available and the reduction in exploration and development costs (Figure 2-12).

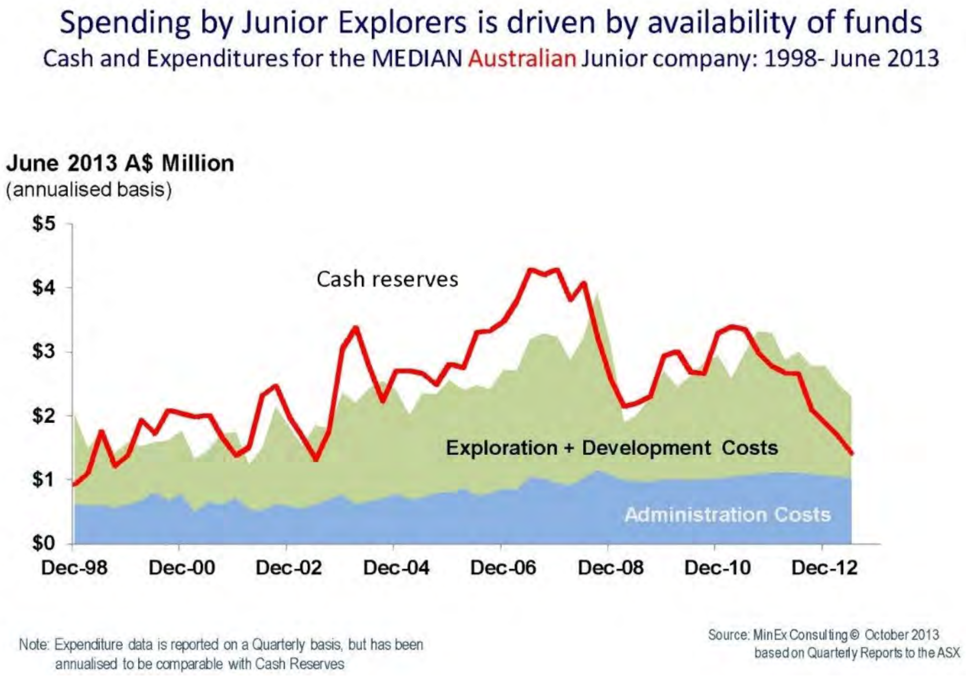

Figure 2-12: Exploration spending and cash reserves (Schodde, 2013b)

Although Schodde's (2013b:33) data does not cover the period between 2012 and 2015, the decline in funding continues.

The reduction in discovery rates and the associated increase in direct and indirect exploration costs, as well as the difficulty in obtaining capital to fund projects is leading to a situation where the number of active small cap explorers is decreasing. Schodde (2013b:34) states that the number of active Canadian small cap explorers decreased by 66% during the last major economic downturn. This equates to a decrease from 885 companies in 1988 to 307 companies in 2000 (Figure 2-13).

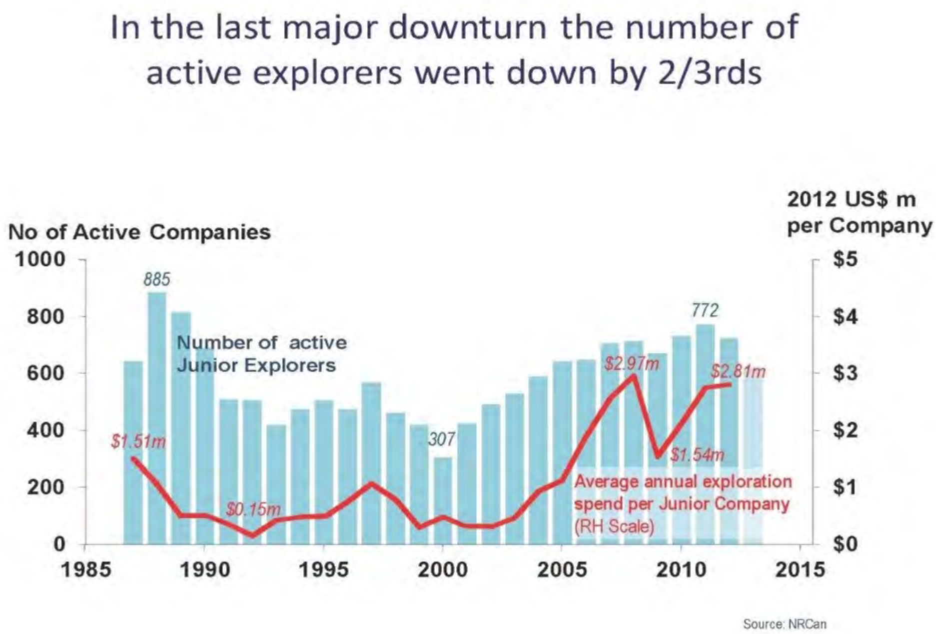

Figure 2-13: Cyclical nature of small cap exploration companies (Schodde, 2013b)

Groves and Trench (2014:10) further observes that due to the pressing need to obtain and allocate funds in a cost effective manner, small cap explorers could reduce their exploration expenditure by shifting focus from pure greenfields projects to brownfields projects. Sillitoe (2010:11) states that there is already a noticeable decrease in the funds being devoted to grassroots, or greenfields, exploration. This observation holds true irrespective of the global economic cycle. Groves and Santosh (2015:389) confirm this statement, but also add that an increased amount of time is now required to bring mines into operation.

Groves and Trench (2014:10) suggest that the resulting change in the scope of the exploration strategy could potentially affect the future discovery rates of world class deposits, as only pure greenfields exploration can result in finding tier 1 deposits. Sillitoe (2010:12) agrees with this observation and states that greenfields exploration remains a prerequisite if the long term demand for natural resources is to be met, seeing that mineral deposit sizes follow a log-normal distribution, meaning that for every tier 1 world class discovery, there are potentially three tier 2, twelve tier 3, and twenty smaller deposits being discovered (Marjoribanks 2010:7).

During economic downturns, small cap explorers tend to turn to larger companies to enter into deals that enable them to progress their projects further (Dzinkowski, 2009:20) and to also survive financially, as they often find themselves with a bloated staff compliment, high overhead costs and a lack of funds. As a result of downsizing, more experienced staff are dismissed (Dzinkowski, 2009:20) and, consequently, companies lose corporate expertise and knowledge that is needed when the economy eventually improves. Therefore, a large number of companies find themselves without the technical experience and know-how to restart or progress projects that were left idling.

2.7 Conclusions

Mineral exploration has historically been, and will continue to be, a cornerstone of humanity's existence on earth. As the global population increases each year, along with expanding industrialisation and urbanisation, the use of natural resources will become even more important for progress to continue.

The role that small cap exploration companies play in the exploration for world class deposits has been demonstrated by the large amount of capital that has been spent on exploration. This trend is expected to continue, as mid-tier and large companies have reduced their exploration spending due to the current global macro-economy. This reduction of exploration spend by larger companies occur every time that there is a recession in the extractive industry. Despite the risk they face and the difficulty they have in securing capital, small cap explorers will continue with their business, as larger companies are dependent on small cap explorers to discover new large world-class deposits.

The African continent has proven to be a geographic region where numerous world class deposits have been discovered. Research indicates that the ratio of capital spent on exploration in Africa, to the value of discovered deposits is the best globally. Geological settings are also favourable to discover not only large deposits, but ones which are easy to locate and to mine.

However, an obstacle facing the extractive industry in general is that the average cost per discovery is increasing. Schodde (2013b:16) reviewed the discovery rates of primary gold deposits in the Western world from 1975 through 2012, and he states that for the period 1978 to 1982, the average cost per discovery was USD 41 million, increasing to USD 84 million during the period 1998 to 2002. Schodde (2013b:16) estimates that this has increased to USD 150 million in 2012.

As a result of the factors mentioned above, particularly the increase in unit discovery costs, explorers have to ensure that every Dollar, Pound or Euro spent achieves the maximum return for both the shareholders and the company. The activities that will ultimately return an investment on capital are the exploration activities conducted on exploration sites. These activities vary in terms of geological information obtained, cost to conduct the activities, and the impact on the environment.

3 CHAPTER 3 - MINERAL EXPLORATION

3.1 Introduction

This chapter addresses mineral exploration practises and activities. An important aspect for this study is the definition of mineral exploration, and the reasons why mineral exploration is conducted, namely to gather geological information about a mineral occurrence. Various exploration techniques are available to obtain geological information, and their use is dependent on factors such as type of mineralisation, host rock, depth of mineralisation, cost effectiveness, time limitations and access, to name a few. Other ancillary activities are undertaken by exploration companies to enable them to conduct mineral exploration.

3.2 Mineral exploration definition

Mineral exploration cannot be defined in absolute terms, since various institutions appear to have differing opinions about what the term constitutes. To emphasise these differences, some of the definitions found in the literature are listed below:

- "The action of searching an area for natural resources" (Oxford Dictionaries, 2015)
- "… to determine some of the more important characteristics of the deposit. Among these are its size, shape, orientation in space, and location with respect to the surface, as well as the mineral quality and quality distribution and the quantities of these different qualities …" (Clark, 2015)
- "The intentional searching or prospecting for any mineral, excluding Oil and Gas Activities and mining …" according to Section 12 of the Johannesburg Stock Exchange Listings Requirements for Mineral Companies (JSE, 2013)
- The South African Mineral and Petroleum Resources Development Amendment Act (49 of 2008) distinguish between exploration and prospecting, where the first refers to petroleum and the latter to minerals. The Mineral and Petroleum Resources Development Amendment Act (MPRDAA) defines
    - exploration operation as: "… the re-processing of existing seismic data, acquisition and processing of new seismic data or any other related activity to define a trap to be tested by drilling, logging and testing, including extended well testing, of a well with the intention of locating a discovery;"

- prospecting as: "… intentionally searching for any mineral by means of any method (a) which disturbs the surface or sub-surface of the earth, including any portion of the earth that is under the sea or under other water; or (b) in or on any residue stockpile or residue deposit, in order to establish the existence of any mineral and to determine the extent and economic value thereof; or (c) in the sea or other water on land …"
- To further confuse the matter, the MPRDAA further defines another category named Reconnaissance, which it defines as: "… any operation carried out for or in connection with the search for a mineral or petroleum by geological, geophysical and photo geological surveys and includes any remote sensing techniques, but does not include any prospecting or exploration operation other than acquisition and processing of new seismic data;"

- Marjoribanks (2010:1) describes traditional prospecting as "… the search for simple visual indications of mineralisation;" exploration field activities as "… part of a strategy (often called a "play") to locate and define a particular economically mineable mineral commodity (ore) in a mineral province."

Despite the various definitions listed above, the acts of reconnaissance, prospecting and exploration involve the following:

> An act or action that searches systematically for mineral resources so as to determine the characteristics thereof.

For the purpose of this study:

- Reconnaissance, prospecting and exploration will be classified as the same activity, with the same purpose and will thus be grouped together.

- Exploration will be defined as the planned, structured and organised search for a mineral deposit by various means, the aim of which is to determine the characteristics of the mineral deposit, in order to determine its viability to be developed into a mineral resource or ore reserve, for potential economic extraction at a later date.

3.3 **Mineral exploration as the source of geological information**

The primary aim of a mineral exploration company is to search for and potentially develop an economic mineral deposit. When an exploration company conducts mineral exploration, the aim of the exploration programme is to gather information about a mineral deposit.

The information gathered by mineral exploration activities can shed light on the following aspects (Moon *et al.*, 2006:25-26, 33):

- The grade or tenure of the mineralisation
- Volume of the mineralisation
- Shape and orientation of the mineralisation
- Depth of the mineralisation
- Chemical composition of the mineralisation
- Deleterious constituents that occur along with the mineralisation, either having a potential impact on the metallurgical process or on the environment

The assessment of a mineral prospecting area involves progressing through distinct and definable exploration stages where each stage progressively adds to the geological knowledge of the prospecting area. Positive results obtained during an exploration stage will lead to further stages and an escalation of the exploration effort, whereas negative (or rather unsuccessful) results will lead to the exploration work being cancelled and stopped (Marjoribanks, 2010:5).

The Canadian Securities Administrators' National Instrument 43-101 (2012:7045) states that "exploration information" is geological, geophysical, geochemical, sampling, drilling, trenching, analytical testing, assaying, mineralogical, metallurgical and other similar information concerning a particular property that is derived from activities undertaken to locate, investigate, define, or delineate a mineral prospect or mineral deposit.

The importance of geological information is underscored by the numerous reporting codes that globally exist (CRIRSCO, 2015). These reporting codes define and set standards for the public reporting of information regarding mineral deposits. The most prominent codes are the following:

- JORC code (Australia)
- CIM Definition Standards NI 43-101 (Canada)
- SAMREC and SAMVAL codes (South Africa)

Other codes that exist are:

- PERC Reporting Standard (Europe)
- MRC Code (Mongolia)
- NAEN Code (Russia)
- SME Guide (United States of America)
- Certification Code (Chile)

The Australian, Canadian and South African codes are all similar in terms of the classification of exploration results, mineral resources and mineral (or ore) reserves. Figure 3-1 below illustrates the relationships between Exploration Results, Mineral Resources and Mineral (Ore) Reserves.

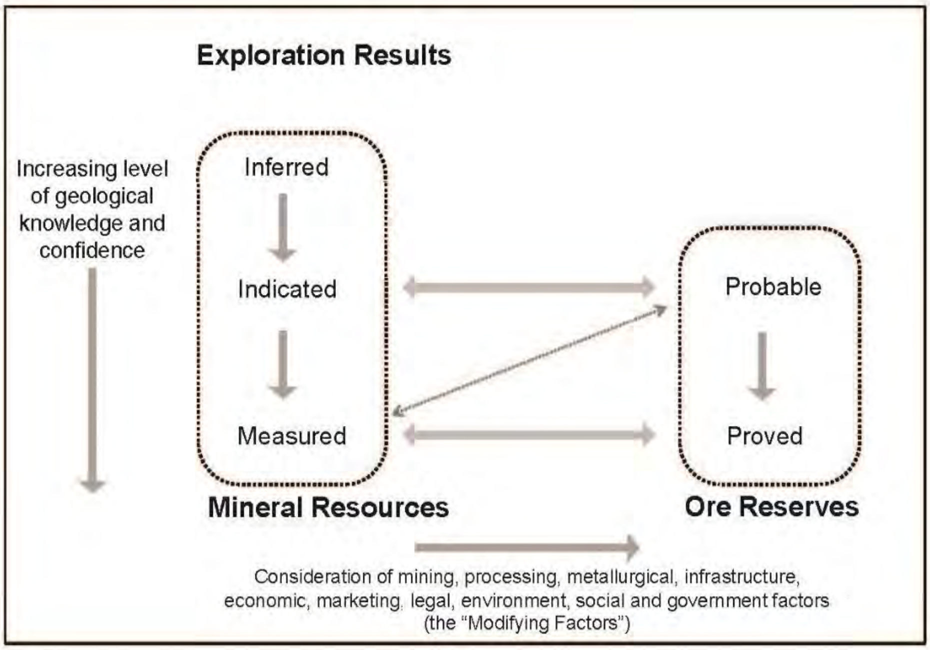

Figure 3-1: Relationship between Exploration Results, Mineral Resources and Mineral (Ore) Reserves (JORC code, 2012)

Exploration Results can only be converted to Inferred, Indicated or Measured Mineral Resources when the geological information and confidence increases. To highlight the importance of geological information and confidence, extracts from the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC, 2012) are listed below:

- Exploration Results "… is a statement or estimate of the exploration potential of a mineral deposit in a defined geological setting where the statement or estimate, quoted as a range of tonnes and a range of grade (or quality), relates to mineralisation for which there has been insufficient exploration to estimate a Mineral Resource."
- "An 'Inferred Mineral Resource' is that part of a Mineral Resource for which quantity and grade (or quality) are estimated on the basis of limited geological evidence and sampling. Geological evidence is sufficient to imply but not verify geological and grade (or quality) continuity. It is based on exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes."

- “An ‘Indicated Mineral Resource’ is that part of a Mineral Resource for which quantity, grade (or quality), densities, shape and physical characteristics are estimated with sufficient confidence to allow the application of Modifying Factors in sufficient detail to support mine planning and evaluation of the economic viability of the deposit. Geological evidence is derived from adequately detailed and reliable exploration, sampling and testing gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes, and is sufficient to assume geological and grade (or quality) continuity between points of observation where data and samples are gathered.”
- “A ‘Measured Mineral Resource’ is that part of a Mineral Resource for which quantity, grade (or quality), densities, shape, and physical characteristics are estimated with confidence sufficient to allow the application of Modifying Factors to support detailed mine planning and final evaluation of the economic viability of the deposit. Geological evidence is derived from detailed and reliable exploration, sampling and testing gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes, and is sufficient to confirm geological and grade (or quality) continuity between points of observation where data and samples are gathered.”

The four categories referred to above are summarised below in terms of the source of the information, the confirmation of continuity and the confidence of the estimate.

With the progression from Exploration Results to Inferred, Indicated and Measured Resources, the geological knowledge of a mineral deposit increases through the use of relevant and appropriate exploration techniques, (refer to column 2). As the geological knowledge increases, so the confidence in the geological and grade or quality continuity (refer to column 3) and in the estimations (refer to column 4) increase. Refer to Figure 3-1 below.

Table 3-1: Summary of differences between Exploration Results, Mineral Resources and Mineral (Ore) Reserves (extracted from JORC, 2012)

Category	Information derived from	Continuity	Estimate confidence
Exploration Results	Insufficient exploration	None	Statement
Inferred Resource	Appropriate techniques	Sufficient to imply but not verify	Limited confidence
Indicated Resource	Adequately detailed and reliable exploration	Sufficient to assume between points of observation	With sufficient confidence
Measured Resource	Detailed and reliable exploration	Sufficient to confirm between points of observation	With confidence

The higher a mineral deposit is categorised on the scale, the easier it will be for an exploration company to attract potential investors to invest in that company. A higher ranking equates to reduced risks in terms of a better understanding and knowledge of the geology, mineralised continuity and sufficient confidence in mineralisation estimates (reserves and resources).

A common misconception of mineral exploration is that it always leads to an operating mine (Marjoribanks, 2010:7). Baillie (2013:7, 8) presented the perceived and actual stages from exploration to operation graphically in Figure 3-2. The upper portion of the diagram indicates the perceived stages from exploration to operation, while the lower portion indicates the actual stages.

The misunderstood perception of the progress from exploration to operation follows a simplistic linear progression that is initiated with an exploration project, followed by a feasibility study period, a construction period and finally an operating mine. The reality, however, is not so straightforward. An exploration project is followed by feasibility study periods (pre-feasibility, feasibility and often bankable feasibility), during which the obtained geological information and knowledge can result in the exploration project being deemed to probably be unsuccessful, or alternatively worth pursuing further. The end result of this whole process are often an unsuccessful exploration project, but with geological information and knowledge that otherwise would not have been gathered.

If a feasibility study period indicates that an exploration project is viable, it could lead to further feasibility studies, which eventually could lead to a construction period and finally, an operating mine.

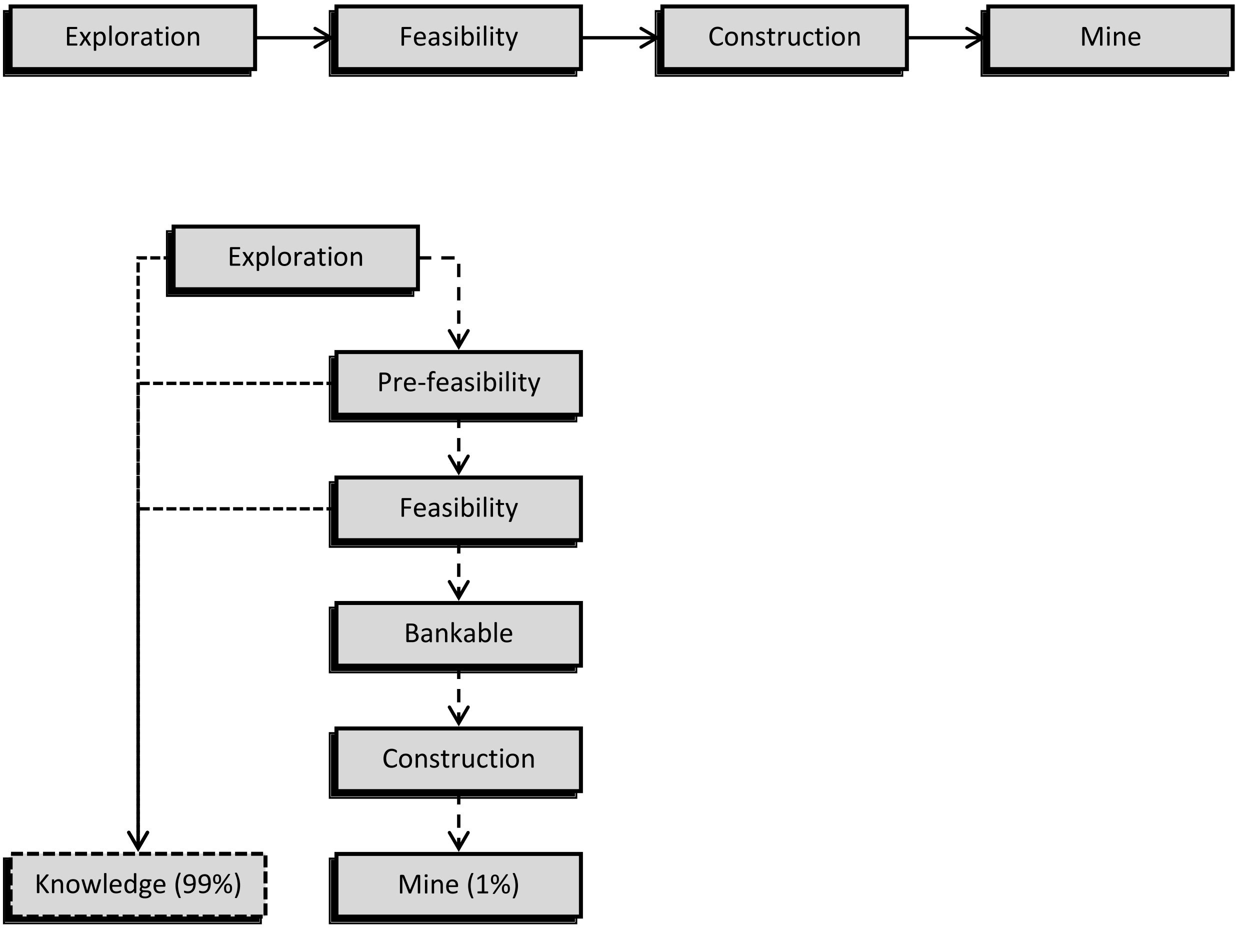

Figure 3-2: Idealised versus actual stages from exploration to operations (modified from Baillie, 2013)

In reality, as indicated by Baillie (2013:8) and Marjoribanks (2010:7), the number of exploration projects that ultimately result in an operating mine is at least a magnitude in size less than the exploration projects that are not successful. Marjoribanks (2010:7) indicated that the exploration projects that eventually become an operating mine diminishes on a logarithmic scale (Figure 3-3). The increase in geological knowledge obtained during each phase leads to a decision point being reached in terms of whether to advance an exploration project to the next phase of exploration or not to. The researcher agrees with Baillie's (2013:15) statement that exploration always leads to an increase in geological knowledge.

Mineral exploration consists of a number of interlinked, sequential and dependant stages, during which the capital expenditure increases and the geological risk reduces (Marjoribanks, 2010:5, 6; Moon *et al.*, 2006:52).

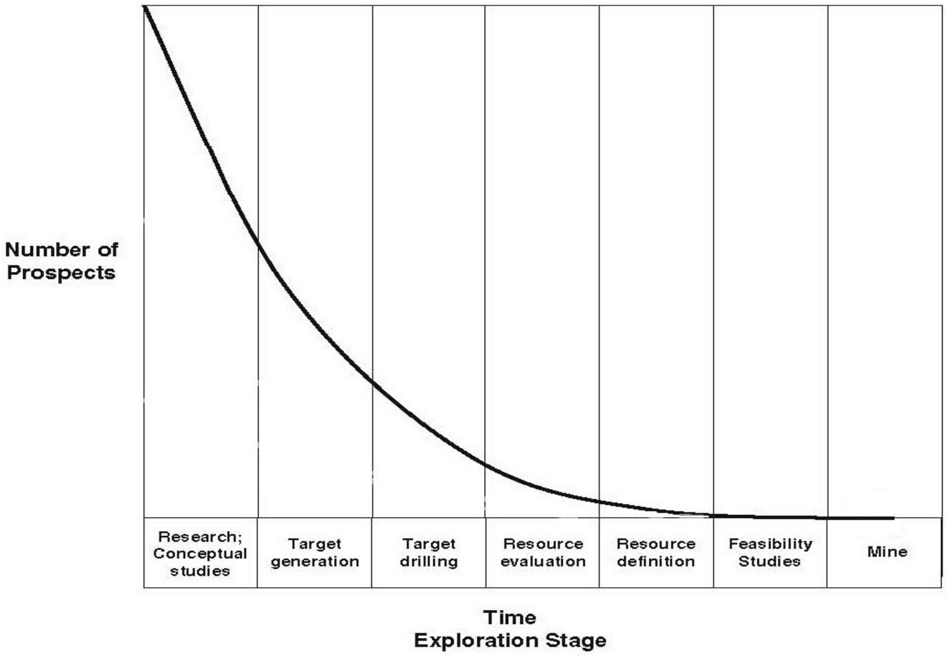

Figure 3-3: Number of projects from exploration to mine (Marjoribanks, 2010)

3.4 **Mineral exploration activities**

In most, if not all, instances the mineral deposits outcropping at, or very near the earth's surface have been found (Haldar, 2013:1). Exploration therefore needs to focus on deposits that are located deeper, or concealed by weathered or leached material, by float, or covered by thick soils (Haldar, 2013:1; Moon *et al.*, 2006:3). Fortunate discoveries of mineral deposits have given way to geological, geophysical, geochemical and remote sensing methods (Schodde, 2013a:20 - 23) that are capable of locating and identifying hidden mineral deposits that have not been previously detectable.

Various methods can be applied in locating hidden mineral deposits. These methods can be divided into direct and indirect mineral exploration methods, which will be discussed below (Haldar, 2013:51). The non-exploration, ancillary activities associated with an exploration project, will be discussed separately.

3.4.1 Direct mineral exploration methods

Direct mineral exploration methods can be defined as the physical collection of geological information by means of mapping, the excavation of any overburden, weathered or fresh rock, the drilling of any boreholes and the taking of any samples.

The objectives of direct mineral exploration methods are to obtain surface and sub-surface information, and representative samples to enable the description, interpretation and evaluation of a deposit (Haldar, 2013:117; Moon *et al.*, 2006:199).

Surface geological features and related information are captured on a map, either in hard copy format or in electronic format, along with sample, pit, trench and borehole locations. To visualise sub-surface geological information, three dimensional (3D) computer generated models are created of the sub-surface geological features. Information obtained from pits, trenches, boreholes and geophysical surveys are utilised to measure, plot and project these sub-surface features.

Sampling methods include: grab sampling, (rock) chip sampling and channel sampling (Moon *et al.*, 2006:207). Other sampling methods include soil sampling and stream sediment sampling (Haldar, 2013:127). Sub-surface sampling is achieved by excavations and the use of various drilling methods, such as auger drilling, rotary drilling, percussion drilling, reverse circulation drilling, sonic drilling and core drilling (Moon *et al.*, 2006:218-225). Drilling is considered one of the most important methods for obtaining samples, as it is through drilling that economic mineralisation is ultimately defined (Marjoribanks, 2010:75).

3.4.1.1 Geological mapping

Geological mapping and the preparation of geological maps and sections are key elements during the exploration process (Moon *et al.*, 2006:72). Geological mapping always forms part of the earliest stages in mineral exploration, since it forms an important control for later stages of exploration (Marjoribanks, 2010:13). The result of mapping can consist of hardcopy maps (Figure 3-4), or digital maps that are produced in any one of the various available geographic information system (GIS) software packages (Figure 3-5).

The stage of exploration will determine the scale, quality and amount of information required (Haldar, 2013:47). Initial mapping may consist of a sketch overlay on an aerial photograph, while detailed field mapping may consist of ground verification, such as outcrop mapping, structural measurements, petrographic descriptions, and relevant mineralisation descriptions and relationships. Various mapping techniques can be employed, depending on requirements such as scale, accuracy and speed (Marjoribanks, 2010:19). Mapping techniques employed by exploration geologists include:

- Plane table mapping
- Pegged grid mapping

- Tape (or pace) and compass mapping
- Topographic sheet mapping
- Photo (or remote sensing) mapping

The result of geological mapping should be considered as the capturing and graphical representation of relevant geological observations and interpretations (Haldar, 2013:47; Marjoribanks, 2010:13). The data is captured according to certain standards that allow review and reinterpretation of the information at a later stage.

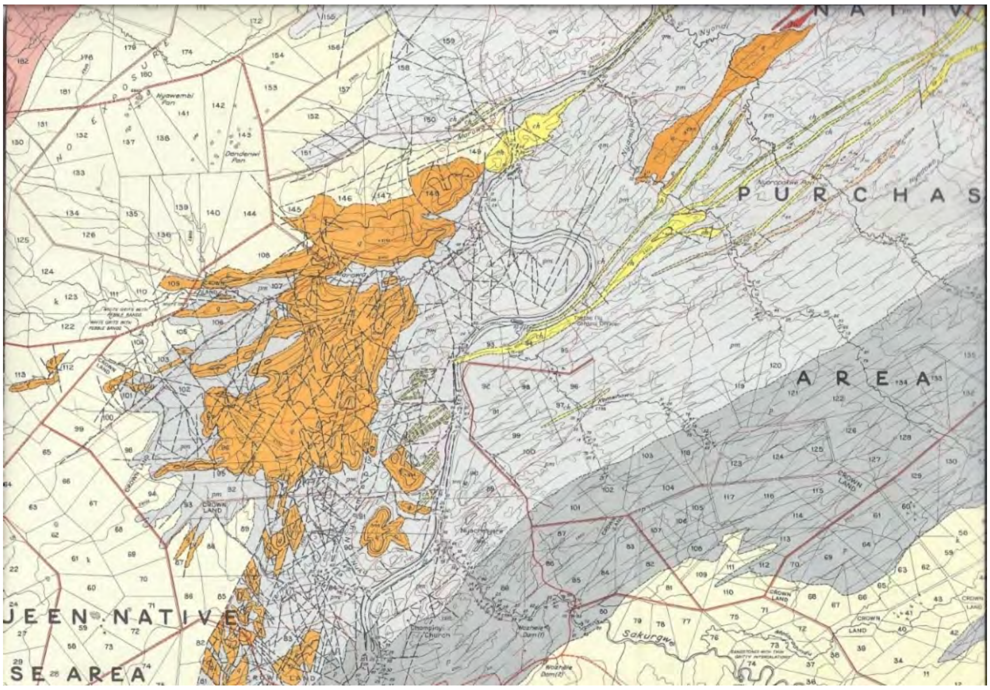

Figure 3-4: Extract from “Geological map of the country around the Copper Queen” (Leyshon, 1969)

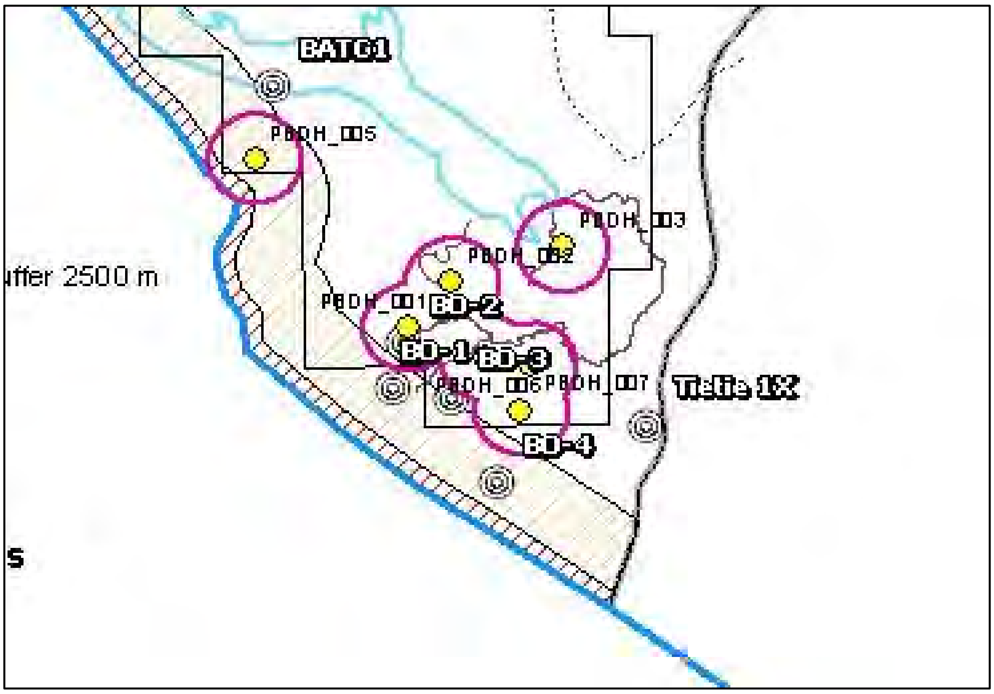

Figure 3-5: Example of a map generated from a Geographic Information System (Booyens, 2016a)

3.4.1.2 Surface sampling (soil, grab, rock chip and channel sampling)

Depending on the requirements of the mineral exploration programme, various types of samples can be collected on, or close to the surface. Surface sampling, as part of exploration geochemistry, relates to the enrichment or depletion of certain elements in the vicinity of a mineral deposit (Haldar, 2013:55).

Surface sampling methods incorporate the following sampling methods:

- Soil sampling

This method is used to sample surface, near surface or deeper soil horizons. The weathering from an orebody at depth can lead to the formation of a surface dispersion halo, around or adjacent to the deposit (Haldar, 2013:61; Marjoribanks, 2010:157). It is best to sample at the B-horizon soils, but sampling is usually conducted at depths of approximately 30 centimetres, with weights ranging from 0.1 - 0.2 kilogrammes for base metal exploration and up to 2.0 kilogrammes for larger samples. Soil sampling can be undertaken with a simple hand auger if deeper samples are required, or by excavating a small pit with a spade.

Soil sample spacing varies according to the survey requirement and, taking into account time and budget constraints, consists of one sample per square kilometre to as low as one sample per 300 square kilometres (Solovov, 1987:241, 245).

- Grab sampling

This method is used by collecting or taking a sample that is not in situ, i.e. a loose rock not in its original location (Moon *et al.*, 2006:207). Samples are collected at random, and can vary in size from 0.5 kilogrammes to larger sized samples, depending on the sample requirements.

- Rock chip and channel sampling

Rock chip samples are obtained by breaking off a piece of rock from the surface of a rock outcrop by using a hammer and chisel (Marjoribanks, 2010:160; Moon *et al.*, 2006:207). It is especially useful during mineral exploration to conduct petrographic and mineralogical analyses, as it is inexpensive and not time consuming (Figure 3-6). Petrography refers to the microscopic study, description and classification of rocks in thin sections (Blatt *et al*., 2006:510). According to the Merriam-Webster Learner's Dictionary (2016) mineralogy refers to the science of minerals, their properties, crystallography and classification.

Channel sampling is similar to rock chip sampling in that a sample is collected from the surface, but it differs in the sense that a continuous channel is sampled and collected, instead of a single sample as is the case of a chip sample (Haldar, 2013:63).

The size of a chip sample can vary from one kilogramme samples, for base metal exploration, to as much as five kilogrammes for gold mineralisation (Moon *et al.*, 2006:177). For channel samples, the weight can vary from 0.5 - 5 kilogrammes, with the channel rarely exceeding two metres in length (Moon *et al.*, 2006:207). Chip and channel sampling are conducted using a hammer and chisel, or using a circular saw to cut slots into the rock (Marjoribanks, 2010:160, 161).

3.4.1.3 Stream sediment sampling

Sediments in streams and rivers contain material derived from the process of rock weathering in the upstream or catchment areas and, as a consequence, may contain low levels of elements or indicator minerals that can be of interest to the exploration geologist (Marjoribanks, 2010:155). Due to mobility and dispersion, element or indicator mineral concentrations will vary significantly as the distance from the source increases (Haldar, 2013:65). The aim of stream sediment sampling is to obtain a representative sample of a catchment area. Stream sediment sampling can be used with great success in areas where residual overburden and active weathering occurs (Moon *et al.*, 2006:61, 165).

Stream sediment sampling can include both regional and local orientation surveys. Regional surveys can cover areas as large as 50 000 square kilometres with an average sample spacing of one sample per 15 to 20 kilometres (McClenaghan & Kjarsgaard, 2001:106), while local orientation surveys aim at identifying mineralogical and geochemical signatures of ore bodies (McClenaghan & Kjarsgaard, 2001:107).

Stream sediment sampling is conducted by obtaining sub-samples along 20 - 30 metres of an active stream, at depths of 10 - 15 centimetres. Depending on the target mineralisation, the sample size can vary from 0.5 kilogrammes for base metals, to 8 - 10 kilogrammes for gold. If a fine fraction is required for analyses, the original sample should be large enough to provide the required fine fraction (Moon *et al.*, 2006:165).

The results obtained by conducting orientation surveys will identify the most appropriate size fraction to be collected and analysed. Indicator minerals that are obtained from a stream sediment survey are often more abundant than the targeted mineralisation, visually and chemically distinct, sufficiently dense to be concentrated, of sufficient size and not easily weathered (McClenaghan & Kjarsgaard, 2001:89). The indicator element or mineral suit sampled for depends on the target mineralisation. For example, the indicator minerals for a diamond bearing kimberlite will include chrome-pyrope garnet, magnesium-ilmenite, chrome-diopsite, chromite, olivine and micro-diamonds (Lehtonen *et al*., 2015:25). Figure 3-7 shows the sampling of a stream for kimberlite indicator minerals.

Figure 3-6: Rock chip sampling (Asia Miner News, 2016)

Figure 3-7: Stream sediment sampling, Mount Olivet area, Lesotho (Booyens, 2014)

3.4.1.4 Pitting and trenching

The excavation of pits and trenches can be very valuable sources of information that can aid in obtaining or confirming lithological, structural and assay data in areas of shallow overburden (Marjoribanks, 2010:63), as well as to investigate geological, geochemical or geophysical anomalies. These excavations provide the opportunity to conduct systematic sub-surface mapping of the sidewalls and the floor and to conduct chip or channel sampling, where surface outcrops are not adequate and can therefore be used to obtain bulk samples for pilot processing (Moon *et al.*, 2006:83).

The typical minimum dimensions of a pit excavated for mineral exploration is 1.2 metres x 1.2 metres. The depth to which a pit is excavated depends on a number of factors, such as the depth of the bedrock, depth of the water table, the moisture content of the overburden, and the type of material that is excavated (Schoenleber, 2005:262; Moon *et al.*, 2006:218). For instance, the presence of a thick laterite capping will aid in the sidewalls not collapsing, whereas a cohesionless soil will need to be supported to prevent the sidewalls from collapsing. The excavated material is normally dumped on a single pile far enough from the pit so as to not hinder excavation work, or to prevent it from falling back into the pit. Pits of these dimensions are usually excavated manually, but for larger dimensions, mechanical equipment can be used. Figure 3-8 is an example of an overgrown pit excavated for the sampling of gold bearing material. In this instance the pit has not been rehabilitated, and poses a danger to both humans and animals, as it is not filled in, barricaded, or clearly demarcated.

Trenches are typically no less than 1.2 metres wide and spans any length necessary to expose the features that are of interest. The depth limitations are the same as for pits. Due to the large volume of material that is excavated, the material is piled directly next to the trench, either on one side or both sides of the trench. Trenches can be excavated manually or with mechanical continuous trenching equipment (Marjoribanks, 2010:64). Figure 3-9 is an example of a recently completed manually excavated trench.

Pits and trenches can also provide large samples for use in metallurgical analyses or to counter problems with variable grade distribution (Marjoribanks, 2010:63).

Figure 3-8: Non-rehabilitated and abandoned pit, overgrown by vegetation, Lake Sonfon area, Sierra Leone (Booyens, 2010a)

Figure 3-9: Recently completed, manually excavated trench, ready for sampling and mapping, Sadiola area, Mali (Booyens, 2001)

3.4.1.5 Drilling

A number of different drilling methods are available for mineral exploration (Haldar, 2013:118; Marjoribanks, 2010:75). The method used will depend on requirements such as time, cost, depth of target, stage of exploration and ease of access, amongst others (Marjoribanks, 2010:76; Moon *et al.*, 2006:84, 218). For a reconnaissance drilling programme, auger holes of two metres in depth might be sufficient, while for a delineation drilling programme, reverse circulation holes of up to 100 metres in depth would be required.

The drilling methods can be grouped into two main groups: 1) drilling that provides a broken and often incomplete sample, and 2) drilling that provides a whole and/or complete sample. The first group includes auger drilling, rotary drilling, mud rotary drilling, percussion rotary drilling, air-core drilling and reverse circulation drilling, while the second group includes sonic drilling and core drilling. These drilling methods are briefly described below.

- Auger drilling

Augers can be handheld or mounted on the back of a pick-up or a light truck. It is used to sample soft, unconsolidated material (Marjoribanks, 2010:77). Augers are not capable of penetrating hard ground, boulders or bedrock. Power augers mounted on the back of a vehicle is very useful for sampling deeper material where pitting cannot be conducted (Moon *et al.*, 2006:218).

Auger drilling is a rapid process and the material that needs to be sampled is continuously brought to the surface by the spiralling action of the auger. Samples are collected from the extracted material by collecting it in a sample pan or in a spade placed next to the auger stem. Auger holes can vary in diameter from a few centimetres to 15 centimetres for light drills, and up to one metre for large truck mounted drills. Holes can vary in depth from 50 centimetres to two metres for lights drills, and up to 30 metres for truck mounted drills (Moon *et al.*, 2006:218). Auger holes are generally drilled vertically. Spacing can range from a few metres apart to tens, or even hundreds of metres apart, depending on the requirements of the auger drilling programme. Figure 3-10 below indicates an auger drill preparing to start drilling operations.

- Rotary drilling, mud rotary drilling, percussion rotary drilling, air-core drilling and reverse circulation drilling

These drilling types are all of the non-coring type, in which a pneumatically operated hammer at the end of a drill string breaks, cuts or crushes rock chips from the bottom of the drill hole by means of rotation, percussion, a combination of rotation and percussion, or by cutting actions (Marjoribanks, 2010:85). The rock chips are flushed up to the surface by compressed air, foam or fluid (mud) that is pumped down the hole. The rock chip samples can either be flushed to the surface on the outside (rotary, percussion rotary drilling) or the inside (air-core and reverse circulation drilling) of the drill string (Marjoribanks, 2010:77, 85). Sample collection varies according to whether the sample is flushed on the outside or the inside of the drill string. When the samples are flushed on the outside of the drill string, it is collected by placing a sample pan or spade next to the drill string. When the sample is flushed on the inside of the drill string, it passes through a cyclone that is connected to the drill string by a rubber pipe. The cyclone separates fine and coarse material, and the coarse material is sampled at the bottom of the cyclone.

These drill rigs are generally mounted on the back of a truck (Figure 3-11) and, depending on the size, can be difficult to manoeuvre on site and between sites. Larger reverse circulation drill rigs are sometimes mounted on a chassis equipped with tracks in order to enable access to difficult-to-reach terrain. In addition, a support vehicle carrying fuel, drill rods, hammers and tools are required, while the compressor (that is needed to provide the compressed air) is sometimes a wheeled unit that needs to be towed between sites (Moon *et al.*, 2006:219, 220).

Figure 3-10: Typical auger drilling setup on the back of a light vehicle (Alecto Minerals, 2015)

Figure 3-11: Typical reverse circulation drilling setup with drill rig, compressor and support vehicle. Beaufort West, South Africa (Booyens, 2009a)

These methods are slower than auger drilling, but it also delivers a continuous flow of samples. Drill holes can vary in diameter from ten centimetres for Air-core holes, and up to specialised tri-cone bits of 66 centimetres. Hole depths vary from no less than five metres for Air-core holes, and up to approximately 350 metres for Mud Rotary holes, while the drilling angle can vary between the vertical and about 40° from vertical. Hole size, depth and angle are all dependant on the local conditions, such as lithology, weathering profile and water table. Drill spacing can extend as little as 12.5 metres to as much as 200 metres. Figure 3-12 shows a typical setup at a Mud Rotary drill hole, indicating the drilling mud circulation system. Figure 3-13 shows a cyclone being operated in wet drilling conditions.

Figure 3-12: Typical mud circulation setup at mud rotary drill rig, showing mixing tanks, pumps, return channels and reject pits. Koutou area, Republic of Congo (Booyens, 2015a)

Figure 3-13: Typical sample collection setup at reverse circulation drilling cyclone in wet conditions. Bakouma area, Central African Republic (Booyens, 2008)

- Sonic drilling

Sonic drilling, also known as rotary vibratory drilling, is a drilling method that operates on the principle of oscillation, rotation and vibration. These three forces combined allow the drilling to advance and penetrate the sub-stratum. When drilling through soft material such as sand and overburden, the drilling action causes the surrounding particles to fluidise, which allows the drill bit and drill string to advance. When drilling hard material such as competent rock, the drilling action causes the rock to fracture, creating dust and small rock fragments. The dust and fragments further assist in the drill bit advancing deeper into the rock. In most cases the drilling can be conducted without the use of drilling fluids. In certain cases, compressed air, water or drilling fluids can be utilised to speed up the drilling process. An important advantage of sonic drilling is that it is capable of continuous coring/sample delivery (Sonic Drill Corporation, 2011). Complete samples are collected in a tube that is brought to the surface, from which the sample is removed and placed into a plastic, sausage-shaped sampling bag, or into a core tray.

Sonic drill rigs can be mounted on a truck or a chassis with tracks. A support vehicle carrying fuel, drill rods, hammers and tools are required. Holes with a diameter of 40.5 millimetres up to 323.85 millimetres can be drilled, with drilling depths reaching up 180 metres, depending on lithology, drilling conditions and operator skill. Boreholes can be vertical or inclined.

- Core drilling

Core drilling (often incorrectly referred to as diamond drilling) is a drilling method whereby a rock sample is cut from the surrounding rock mass by means of a rotating drill bit (Marjoribanks, 2010:77). The drill bit is attached to the end of a rotating drill string, and the core sample, a cylindrical piece of rock, is captured and kept in a core barrel within the drill string. The core sample is recovered by raising the core barrel to surface using a small diameter cable and a winch, after which the sample is placed into a core tray (Marjoribanks, 2010:99; Moon *et al.*, 2006:220). Water, foam or drilling chemicals or drilling muds are used to lubricate and cool down the drill bit and drill string and also to flush away ground and cut rock fragments from the drill bit (Moon *et al.*, 2006:223).

Core drill rigs used in mineral exploration are usually mounted on the back of trucks, or sometimes on a chassis equipped with tracks. A support vehicle carrying fuel, drill rods, hammers and tools are required, as well as a water tanker to provide the water needed during the drilling operations. A water sump needs to be excavated close to the borehole collar to collect return water, and to act as a trap to capture any fine rock fragments in the water. Figure 3-14 indicates a small core drill rig used for the drilling of short holes. Figure 3-15 shows the water sump used to trap mud and fine rock fragments.

Figure 3-14: Typical small track mounted core drill rig, Hwange area, Zimbabwe (Booyens, 2012a)

Figure 3-15: Typical water sump to collect return water and to trap fine rock fragments, Hwange area, Zimbabwe (Booyens, 2012b)

Core drilling speed depends on the rock type, drilling depth, borehole diameter, type of drill bit and the type of drill rig. Core diameter sizes can vary from 18.4 millimetres up to 165.0

millimetres (Heinz, 1994:549). Boreholes can be drilled to a depth of approximately 2 000 metres, while the drilling angle can be anywhere between vertical and about 45° from vertical. Hole size, depth and angle are all dependant on the local conditions such as lithology, weathering profile and water table (Moon et al., 2006:224). Drill spacing can be as little as ten metres to as much as 200 metres. Figure 3-16 shows core samples being inspected at the drill site.

3.4.2 Indirect mineral exploration techniques

Indirect mineral exploration methods are defined as those mineral exploration methods which do not require taking a physical sample, but rather draw conclusions about the geology and mineralisation based on measurements taken at, above, or below the earth's surface. Indirect mineral exploration techniques include methods that are i) in contact with the earth's surface (on or below the surface), such as ground geophysical methods, or methods that are not in contact with the earth's surface (above the surface), such as ii) airborne geophysical methods or iii) remote sensing methods (Moon *et al.*, 2006:127).

Exploration geophysics uses instruments that measure certain physical characteristics of the underlying rocks, such as magnetic and gravity fields that results in large amounts of digital data which needs to be interpreted in order to identify potential exploration targets (Marjoribanks, 2010:143). Anomalies created by the differences or contrasts between different lithologies, or between mineralised and un-mineralised zones, are recorded and targeted as potential areas of interest for follow-up exploration (Moon *et al.*, 2006:127).

3.4.2.1 Ground geophysical methods

Geophysical survey methods provide information about certain physical properties of the earth and also, to a limited degree, the subsurface. Geophysical methods can be classified into two categories, i.e. active and passive. Active methods measure the response to electromagnetic, electric and seismic energy, while passive methods measure ambient electric, magnetic and gravity fields, as well as naturally occurring radiation.

- Electromagnetic, Resistivity and Induced polarisation methods

Electromagnetic surveys are probably the most important electrical method used. This method measures the electrical conductivity of subsurface rocks by using naturally occurring electromagnetic fields, or by applying an external electromagnetic field. When utilising an external electromagnetic or primary field, a secondary electromagnetic field is produced by conductive rocks. Data obtained from the primary and secondary fields, such as amplitude and phase differences are interpreted to obtain results based upon the conductivity of the rocks (Marjoribanks, 2010:151). Figure 3-17 show an operator with EM equipment conducting a survey.

As with all geophysical methods, EM surveys involve the detection of anomalies caused by certain deposits such as massive sulphides. Surveys can be conducted to explore for conductive rocks up to a depth of 100 meters (Whiteway and Loree, 1990:36).

Figure 3-16: Samples from core drilling being inspected, Hwange area, Zimbabwe (Booyens, 2012c)

Figure 3-17: Electromagnetic survey in progress at an overgrown site (Subsurface Geotechnical, 2016a)

Electrical (Resistivity) surveys are often used in conjunction with Induced Polarisation surveys. In this method, an electrical current is passed through the rock between transmitting and receiving electrodes, and the potential difference between two additional electrodes that do not carry any current are measured at specific locations. Figure 3-18 and Figure 3-19 shows Resistivity and IP surveys respectively.

The resistance of various rocks are calculated from the potential differences measured in the field, and anomalous values are subsequently identified, as the induced electric current follows the path of least resistance (Whiteway & Loree, 1990:36). Metallic sulphides, graphitic fault gouge or saline or brackish water will result in anomalous low resistivity measurements.

Induced Polarisation utilises an electrochemical effect caused by passing a primary alternating current through rocks. When the primary current is switched off, the decay of the secondary voltage is detected and measured over time, and a deduction of the size and position of the chargeable body can be made (Marjoribanks, 2010:151, 152). Induced polarisation is useful to identify sulphide deposits and weak conductive zones related to disseminated sulphides (Whiteway & Loree, 1990:36).

Figure 3-18: Resistivity survey as part of a follow up exploration programme (Subsurface Geotechnical, 2016b)

Figure 3-19: Induced polarisation array in process of being setup (Geosiam Geophysical Services, 2016)

Although Spontaneous Polarisation (also referred to as Self Potential) methods are not often utilised, it is mentioned here for the sake of clarity. Spontaneous polarisation occurs when weathering of, for instance, a sulphide body occurs in the presence of ground water. The subsequent chemical reactions result in natural potential differences that can be measured with the spontaneous polarisation technique (Haldar, 2013:88).

Surveys are conducted by a small team that moves a ground array of transmitters and receivers along traverse lines over the target area. Electrical surveys require the use of a generator or other electrical power source that can deliver the required voltage, and electrodes that are placed into the ground to transmit the current (Marjoribanks, 2010:152).

- Ground magnetic, gravity and radiometric survey methods

Magnetic surveys are conducted with a magnetometer, an instrument that measures and records minute irregularities in the earth’s magnetic field components, viz. the field direction, field inclination and field strength. The aim of a magnetic survey is to locate areas of anomalous magnetic susceptibility that are caused by rocks and minerals that are magnetic (Haldar, 2013:81). Figure 3-20 shows an operator conducting a field survey with a portable magnetic system.

Magnetite deposits, certain iron sulphides and mafic intrusives can be defined by their magnetic anomalies (Whiteway & Loree, 1990:34). All rock types possess, to a greater or lesser degree, some magnetic susceptibility and, consequently, a magnetic survey can be used to produce a surface map identifying various rock types (Marjoribanks, 2010:146).

In a ground magnetic survey, the magnetic sensor is mounted on a pole that is a constant and fixed distance above the ground surface and measurements are taken at fixed points along traverse lines over the survey area. Measurements and coordinates can be electronically recorded, or written down in a field book (Marjoribanks, 2010:146).

Gravity surveys are conducted with a gravimeter, an instrument that measures minute changes in the earth's gravity field (Haldar, 2013:78). Gravity anomalies indicate relative differences in the densities of various rock types, and are also utilised in the mapping of karsts. Figure 3-21 shows an operator in the process of setting up a gravity survey station.

Due to differences in the density characteristics of different lithologies, a gravity survey can produce an image of the sub-surface distribution of different lithologies (Marjoribanks, 2010:149). These images can be used in conjunction with geological and other geophysical maps to make deductions about the sub-surface geology and also as a rapid reconnaissance survey to delineate different lithologies.

Figure 3-20: An operator conducting a magnetic survey (Openground Resources, 2011)

Figure 3-21: Operator setting up a gravity survey station (New Area Geophysics, 2016a)

The three naturally occurring radioactive elements that are targeted are potassium (K), thorium (Th) and uranium (U) (Whiteway & Loree, 1990:38). The result of the decay of these radioactive elements consists of detectable alpha (α) or beta (β) particles, or gamma (γ) ray radiation. Radiometric surveys measure the natural radiation emanating from these radioactive elements, which is continuously emitted by rocks containing them.

Ground radiometric surveys are conducted with a multi-channel spectrometer that can individually measure radiation from these three elements (Marjoribanks, 2010:150), or with a single channel scintillometer that measures the total radiation (GF Instruments, 2015). Radiometric surveys can measure radiation emanating at, or very close (0.3 metre depth) to the earth's surface (Haldar, 2013:90). It is used in the exploration for uranium mineralisation, or to identify potassium or thorium bearing rocks such as granites and potassium enriched feldspars.

Small portable devices are either hand carried, or can be attached to motorised vehicles such as four wheeled motorcycles (quadbikes) or light utility vehicles. These surveys can be conducted by one or two persons that move the instruments along traverse lines over the target area. Figure 3-22 shows a small portable device being used to conduct a radiometric survey.

Similar to a magnetic survey, gravity and radiometric measurements can be taken at fixed points, along traverse lines over the area that needs to be surveyed, and captured electronically or in hardcopy.

Ground geophysical surveys are often supported by vehicles to transport crew, equipment and material (Figure 3-23).

Figure 3-22: Operator with ground radiometric instrument (Anon, 2016)

Figure 3-23: Typical ground geophysical survey support vehicle, M'patou area, Central African Republic (Booyens, 2010b)

- Seismic survey

The fundamental principle applied in a seismic survey is the propagation of seismic waves through the rock mass of the earth and the subsequent measurement of reflected and refracted waves. The source of the seismic waves used in a seismic survey can be from a vehicle mounted vibroseis system, the detonation of small explosive charges, or by dropping a weight on a metal plate, or by hitting it with a hammer. Figure 3-24 shows a vehicle mounted vibroseis system.

The shock wave created by the source is reflected and refracted from boundaries such as lithological contacts where there is a difference in the lithologies' elastic and density properties. The reflected and refracted waves are measured by an array of geophones spaced at known and regular intervals around the source (Haldar, 2013:77, 78). Measurements of the seismic wave's travel time to the geophones, as well as the wave energy are used to determine the density of different lithologies and also of the depth of reflectors, such as fault structures and prominent contacts (Whiteway & Loree, 1990:38).

A seismic survey requires a team that varies in numbers from a few to tens of members. Depending on the source used to generate the seismic waves, various machinery, tools and equipment is used. The survey requires the geophone array to be moved along traverse lines.

- Ground penetrating radar

Ground penetrating radar (GPR) is a relatively new method that is available to undertake geophysical surveys. Two antennae are utilised, one for transmitting the radar energy, and the other for receiving the reflected radar energy. Due to the small sizes of the latest versions available, antennas can be pulled manually, or for larger antennas, hooked up behind all-terrain vehicles or road going vehicles.

The GPR method can be utilised in a number of applications, including bedrock depth determination, river channel profiling and karst mapping, to name a few. Penetration depth varies according to the size of the antennas used and the spacing between the antennas. The depth can be anything from one metre to deeper than 30 metres (MALA, 2015). Continuous and immediate recording and displaying of the reflected radar energy is also possible during a survey.

Depending on the size of the ground penetrating radar, a small team is required that moves the antennae over the target area. Motorised vehicles can be used to move and transport heavier equipment. Figure 3-25 shows a small man-portable GPS system in an exploration application.

Figure 3-24: Truck mounted vibroseis systems conducting a seismic survey (IAGC, 2015)

Figure 3-25: Man-portable GPR system (New Era Geophysics, 2016b)

- Borehole geophysical survey

The use of boreholes in mineral exploration can be further utilised by conducting downhole borehole geophysical surveys. The aim of downhole borehole geophysical surveys is to obtain additional information about the subsurface that drill sampling cannot provide. These geophysical surveys provide detailed continuous logs of in-situ properties of the subsurface in the vicinity of the borehole.

In downhole borehole geophysics, a single probe (also known as a sonde) or a number of probes are lowered down the hole and measurements are taken as the probes are lowered down the borehole, or hoisted to the surface (Haldar, 2013:92). Measurements that can be obtained from a down hole survey includes radiometrics, temperature, hole diameter, hole deviation and acoustic televiewer images, to name a few. Measurements can be utilised to identify lithology, provide stratigraphic correlation and to determine rock characteristics such as porosity, permeability and density.

Hoisting operations are conducted using a winch that can be installed in the back of a light vehicle, together with a power source, the operator controls and data capturing and logging instruments (Haldar, 2013:92). Figure 3-26 shows an operator preparing instruments for a downhole survey.

Depending on the borehole depths and spacing, up to ten boreholes can be probed in a day. For quality control and assurance purposes, a validation (or calibration) borehole needs to be surveyed on a daily basis, before the actual survey starts, to ensure that all equipment and instruments are working properly. One operator with a fully equipped vehicle can conduct a borehole survey singlehandedly.

3.4.2.2 Airborne geophysical methods and remote sensing

Certain geophysical methods do not have to be in physical contact with the earth to be conducted. Characteristics of the rocks that need to be measured are noticeable and measurable above the earth's surface, despite some loss of sensitivity which occurs over distance. Imagery reflected or emitted from the earth can also be obtained over a large distance above the earth's surface (Knepper *et al.*, 1994:VI-3). Airborne geophysical surveys and remote sensing (which includes aerial photography) are conducted from two types of platforms, i.e. either fixed or rotary wing aircraft and from satellites (Moon *et al*., 2006:127). Limited use has been made by lighter-than-air Zeppelins and, recently, with the introduction of Unmanned Aerial Vehicles (UAV) or drones, to conduct airborne geophysical surveys (Thomson *et al*., 2007:22, 24).

For airborne geophysical surveys, sensors are housed in "stingers" attached to an aircraft, or in a cable towed "bird" (Moon *et al.*, 2006:120). Remote sensing and aerial photography uses cameras and sensors attached to aircraft or satellites facing the earth's surface. Figure 3-27 and Figure 3-28 respectively show a helicopter and an aircraft, both used for aerial geophysical surveys.

Figure 3-26: Downhole borehole geophysical survey in the Beaufort West area, South Africa (Booyens, 2009b)

Figure 3-27: Rotary wing aircraft used for aerial geophysical survey. Bakouma area, Central African Republic (Booyens, 2007a)

- Airborne geophysics

Airborne geophysical techniques, which include electromagnetic, magnetic, gravity and radiometric surveys, utilise the same principles as the corresponding ground based systems (Knepper *et al.*, 1994:VI-1), but are larger in size and more sensitive in order to allow it to be installed in aircraft.

Airborne geophysical methods have significant application in the mineral exploration industry, as it can assess areas of interest on scales that vary from local to regional (Knepper *et al.*, 1994:VI-1). It is a cost effective method to conduct large, regional-scale geophysical surveys that assist in initial geological reconnaissance, which aids in identifying areas of interest for detailed follow-up.

To increase the cost effectiveness of an airborne survey, multiple sensors can be fitted to an aircraft, which can be operated simultaneously. This enables simultaneous acquisition of different measurements.

Although airborne surveys are expensive, a key benefit is that large areas can be quickly surveyed. Surveys can be flown at either a constant altitude, or at a constant height above the earth's surface (Moon *et al.*, 2006:128) and, depending on the terrain, can be as low as 80 metres above the surface (Hutchins & Wackerle, 2007:879). Survey flight lines are parallel to each other, and can be as close as 100 metres apart (Moon *et al.*, 2006:130), orientated as perpendicular to the strike of the geology as possible.

Airborne geophysical data can be provided in digital image formats to assist with incorporating it into existing datasets such as geological maps and drilling data, consequently assisting with interpretation.

- Remote sensing

Remote sensing is the process of acquiring information about an object in which the sensor is not in direct or intimate contact with the object. In mineral exploration, remote sensing encompasses those techniques that collect and record electromagnetic radiation reflected from the earth's surface (Haldar, 2013:99; Marjoribanks, 2010:137). The relevant electromagnetic radiation covers a wide spectrum and is collected in three spectral bands: i) visible and near-infrared band, ii) thermal infrared band and iii) microwave band (Knepper *et al.*, 1994:VI-3). Remote sensing is conducted by using sensors and cameras directed at the earth's surface that are mounted on aircraft or satellites (Moon *et al.*, 2006:125). The sensors capture the data by scanning the relevant areas of interest. The data can either be i) information about the physical properties of the surface, or ii) spatial information about the surface landform (Knepper *et al.*, 1994:VI-3). By comparing the known spectral responses of minerals or mineral groups, areas with hydroxide minerals, silica and clay alteration can be identified over large areas of interest. Remote sensing can also be utilised in geo-environmental studies and research to identify surface alteration and anomalous vegetation patterns (Hoover *et al*., 1995:23). Remote sensing data can rapidly identify areas of interest spanning vast geographic areas, as well as evaluating landforms and relationships. The use of satellite imagery and aerial photographs have proven to be more cost effective and faster than ground-based initial exploration (Knepper *et al.*, 1994:VI-5). Knepper *et al.*(1994: VI-5) further state that, if compared to conventional exploration methods, combining satellite data with other data, such as geological, geophysical and photographic data, areas of high interest can quickly and inexpensively be located. Remote sensing methods provide results in digital image format that can efficiently be processed (Hoover *et al*., 1995:23). Processed data is interpreted visually and/or digitally to extract information (Moon *et al.*, 2006:121).

Multi- and hyperspectral data imagery can be obtained from various satellites such as Landsat, SPOT (Sabins, 1999:158, 159) and Terra (Van der Meer *et al*., 2012:116), or more recently from high resolution aircraft borne cameras such as AVIRIS (Sabins, 1999:161). Although spectral imagery also operates in the visible and near-infra red band, the spectral system divides the bandwidth into 128 or 224 bands, with a horizontal resolution of 1 - 10 metres, as opposed to the limited number of up to ten bands of Landsat TM (Thomson *et al.*, 2007:30) and SPOT XS (Sabins, 1999:161). The increased spectral bands allows for more descriptive characterisation to be made of the reflective and transmitted spectrum originating from minerals (Thomson *et al*., 2007:30). Sensors mounted on satellites and aircraft gather data from reflected or transmitted electromagnetic spectrum (Moon *et a*l., 2006:104) emanating from the earth. As different materials have different reflective characteristics, different intensities are reflected off of each surface and, based upon these reflections, interpretations can be made about the surface characteristics (Marjoribanks, 2010:142), such as alteration or hydrothermal zoning. Hydrothermal alteration zones of porphyry copper deposits, which contain a mixture of primary mineral assemblages and newly formed minerals, as well as the identification of iron and clay minerals (Sabins, 1999:157) formed due to alteration, can easily be identified by means of spectral data (Ramakrishnan & Bharti, 2015:885). Satellite imagery interpretation has become a standard method in mineral exploration, and has proven to be successful in a number of applications, such as structural, lithological and hydrothermal interpretations (Ramakrishnan & Bharti, 2015:884 - 887).

Aerial photographs are widely utilised in the mineral exploration industry as a method of conducting reconnaissance geological mapping (Knepper *et al.*, 1994:VI-3). Photogeological methods utilise aerial photos (in panchromatic black and white, black and white on infrared film, colour or colour infrared) to acquire information about the surface of the earth (Haldar, 2013:96). Depending on the requirements, oblique or vertical photos can be captured (Marjoribanks, 2010:27). The subsequent interpretation of aerial photographs assists in identifying geological features such as the surface expression of faults and dykes, surface outcrops of rocks, intrusions, tectonic lineaments and surface texture, as well as other features such as vegetation type, topography, drainage patterns, erosion and land use (Haldar, 2013:99; Moon *et al.*, 2006:123). Figure 3-29 shows the inside of an aeroplane used for photographic surveys.

Figure 3-28: A fixed wing aircraft used for airborne geophysical surveys showing stingers housing the survey instruments (Geoscience Australia, 2016)

Figure 3-29: Inside the cabin of an aerial survey aircraft showing dual camera holes for LIDAR and photogrammetric surveys (Aerial Survey, 2016)

3.4.3 Other mineral exploration techniques

Other, less well-known and lesser used sampling methods exists and these can also be used in mineral exploration. These include:

3.4.3.1 Hydrogeochemical sampling

Hydrogeochemical sampling of water sources is limited due to the fact that not all elements are soluble, and concentrations are often low and difficult to measure. However, hydrogeochemistry has been successfully used in dry areas with poor outcrops (Moon *et al.*, 2006:176). Hydrogeochemical sampling can be undertaken on two water sources, viz. surface water (rivers and streams) and ground water (wells, springs and boreholes). Groundwater sampling has better potential in geochemistry than surface water sampling (Haldar, 2013:65).

Groundwater geochemistry has been utilised in uranium exploration where deep aquifers have been sampled (Moon *et al.*, 2006:175). Samples of one litre are required, and analyses must be completed within 48 hours of collection (Haldar, 2013:66).

3.4.3.2 Biogeochemical and geobotanical sampling

The use of vegetation in mineral exploration can be divided into two areas: biogeochemistry and geobotany. Biogeochemistry is the study of the relationship between the geochemistry of a given area and its flora and fauna. This includes the recycling of elements between the environment and the cells of living organisms. The elemental content of a specific organism is measured and used as an indication of the underlying geology. Geobotany is the study of the geochemical relationships between flora and the underlying geology. The presence, or absence, or condition of specific plant species can be related to the bedrock or mineralisation in a given area (Haldar, 2013:66).

The sampling of vegetation, as part of a biogeochemical survey has proven to be an effective technique in mineral exploration for identifying masked mineral deposits (Reid & Hill, 2010:105, 106), or in areas where surface sampling is difficult (Moon *et al.,* 2006:175). Vegetation absorbs water and nutrients through their roots (Haldar, 2013:67), and transpires any excess residues through their leaves (Reid & Hill, 2010:105). During this process, concentrations of trace amounts of elements can be detected in recent plant growths. Biogeochemical sampling is conducted on one plant species only, and on one part of the plant and, generally, during first and second year growth. Moreover, due to seasonal variations, biogeochemical sampling is time restricted (Reid & Hill, 2010:108). A sample size of approximately 500 grams is required per sample (Moon *et al.*, 2006:177).

Effects of the underlying geology may often be attributed to the health and type of vegetation (Awadh *et al.*, 2013:224), as well as vegetation patterns (Baker & Brooks, 1988:221). An example of such is the use of the mauve copper flower (*Becium homblei*) which can be used as an indicator plant for copper mineralisation in the Zambian Copper Belt (Baker & Brooks, 1988:222). Baker and Brooks (1988:224) found in a study of geobotany over a nickel deposit that clear indicators existed which showed a marked difference in the low shrubs that covered the deposit to that of the surrounding rainforest. However, the application of indicator plants was shown to be less reliable than the biogeochemistry method. Furthermore, satellite remote sensing can be utilised to identify areas where vegetation indicates stress due to high or low levels of metals in the soil (Moon *et al.*, 2006:176).

3.4.3.3 In-situ soil gas sampling

This sampling method utilises quantified gases to differentiate potential mineralisation from surrounding unmineralised areas (Haldar, 2013:67). In greenfields mineral exploration, anomalies in the soil gasses are interpreted in order to identify potential geochemical anomalies at depth. These gases can permeate through fissures, fault planes, permeable rock and unconsolidated material to the surface. Various techniques are available to sample and measure soil gasses, such as emanometers, Alpha meters and the Track Etch method (Whiteway & Loree, 1990:39).

A gas collector/sampler is buried for periods of up to 60 days to enable detection of gases that originates from mineralisation. This sampling method primarily identifies the aerial extent of mineralisation, but cannot provide information on mineralisation depth. A passive survey over periods of up to 60 days can overcome the detrimental effect of high soil moisture and low permeability, whereas a survey lasting minutes or hours could be severely impacted by moisture and permeability (AGI, 2015a).

Depending on the type of collector or sampler that is used, a small one centimetre diameter hole is made to 60 centimetres depth by a hand tool and the gas sampler is then inserted into the hole and left for the duration of the survey. Other types of samplers/collectors require a larger diameter (10 centimetres diameter) and deeper (one metre) hole that can be drilled with a hand auger.

Sample spacing varies depending on the mineralisation type, from a number of sampling points per square kilometre up to one sample per square kilometre. Claims that successful surveys were conducted over mineralisation of 550 metres deep have been made (AGI, 2015b; AGI 2015c). This technique, targeting radon gas, can be utilised in the exploration for uranium mineralisation.

3.4.3.4 Termite mound sampling

In tropical areas, termite mounds have successfully been sampled, as certain types of termites are known to burrow very deeply into the earth. This enables geologists to obtain material from deep under the surface which, under normal conditions, would not be accessible to sampling (Moon *et al.*, 2006:82).

3.4.3.5 Portable X-ray fluorescence

X-ray fluorescence (XRF) is an analysis method that can determine the concentration of elements and it has been in use for a significant period of time. With the recent development of smaller and lighter instruments, XRF analysers can easily be taken out of a typical laboratory setup into the field (Sarala *et al.*, 2015:64).

Portable or handheld XRF (p or hXRF) equipment has become widely used in field applications, such as the in situ analyses of soils and rocks during exploration. With the development of modern x-ray detectors, savings in time, labour and money can be achieved by utilising this technology. The obvious advantages of using portable XRF instruments are its speed of operation and its simplicity, the relaxed sample preparation requirements, immediate availability of results and the non-destructive nature of the method (Liangquan *et al*., 2005:61) (Figure 3-30).

Sarala *et al*. (2015:82) state that results obtained from their study indicate that pXRF results are comparable to results obtained from laboratory based XRF and aqua regia-based analyses.

3.5 **Other activities associated with mineral exploration**

A number of other ancillary activities that are not directly related to exploration also transpire before and during mineral exploration. These activities include establishment and running of a field camp, creation and construction of access roads, transport of staff, material and equipment, and also the preparation, analyses and storage of samples. To enable the exploration activities to be undertaken, a properly staffed, site-based, exploration team will have to be accommodated on site to conduct all the required activities (Moon *et al.*, 2006:70). Along with the exploration team, a support team will be required for other ancillary activities.

3.5.1 Field camp establishment

The scale of the staffing, and the speed at which exploration is conducted will be determined by the duration of the prospecting licence (Moon *et al.*, 2006:70). The shorter the duration of the prospecting licence, the more urgently the exploration work has to be concluded and, consequently, the larger the staff compliment will be. An exploration camp needs to be established in or close to the target area to ensure that the mineral exploration programme is conducted as expeditiously as possible. Where a town or village is close to the exploration area, suitable facilities can be obtained that can be used for accommodation, offices, stores, and sample preparation areas. In remote areas, tented field camps (Figure 3-31) are established to meet the requirements of the exploration programme (Moon *et al.*, 2006:71).

Figure 3-30: A portable XRF in a field use application (U.S. Precious Metals, 2016)

Figure 3-31: Tented camp in Bakouma area, Central African Republic (Booyens, 2007b)

Where exploration continues for longer periods, for instance upon renewal of exploration licences, semi-permanent camp facilities can be constructed utilising bricks or timber (Figure 3-32).

A crucial aspect of exploration camps is their ability to provide potable water and food for staff, and the disposal of waste (Figure 3-33), sewage and waste water. Along with the provision of food and water to the camp, the necessity of electricity for, among other reasons, communication is also needed. Electricity is most often provided via petrol or diesel generators, but for small-scale exploration camps, solar or wind generated electricity can be considered. The presence of generators requires the necessity of storing large quantities of fuel on site (Figure 3-34).

Figure 3-32: Exploration field camp in Lake Sonfon area, Sierra Leone (Booyens, 2010c)

Figure 3-33: Waste disposal site of an exploration camp. Koutou area, Republic of Congo (Booyens, 2015b)

The storage of chemicals, used during the drilling process, also requires a safe and secure place and this can be provided at the exploration camp where security measures can be put in place to ensure safekeeping under restricted access (Figure 3-35).

Figure 3-34: Fuel storage facility. Koutou area, Republic of Congo (Booyens, 2015c)

Figure 3-35: Drill chemicals storage area. Koutou area, Republic of Congo (Booyens, 2015d)

In certain cases, radioactive sources are used in borehole geophysical surveys. These radioactive sources have to be stored in a suitable, secure and restricted setup (Figure 3-36), as may be required by local regulations.

3.5.2 Site access and transport

Exploration camps are usually sited to ensure easy and quick access via roads. However, to access exploration areas and exploration targets within the exploration area, access roads have to be created. Access roads for vehicles and heavy machinery, such as drill rigs, are required during the drilling process. Access roads along drill lines are required to move vehicles and machinery between one drill site to another (Figure 3-37).

Figure 3-36: Bunker for storage of radioactive source, Koutou area, Republic of Congo (Booyens, 2015e)

Figure 3-37: Site access laterite road, Lake Sonfon area, Sierra Leone (Booyens, 2010d)

Depending on the location of the exploration areas and upon road conditions, air charters can be useful in transporting material and equipment to and from remote sites (Adams & Morrall, 2008:39). The advantage of air charters is that it is much quicker than road transport and, depending on the type of aircraft, a complete camp setup can be mobilised using a single flight (Adams & Morrall, 2008:39) (Figure 3-38).

3.5.3 Sample preparation and analysis

An important aspect of mineral exploration is sample preparation and analyses. The first step in this process oftentimes already starts at the exploration camp (Figure 3-39). Depending on the sample type and the aim of sample analysis, various tasks can be performed on different samples. Sample preparation can include the washing of chip samples to remove any dirt or dust, and the removal of weathered areas by using a hammer and chisel to remove them. Samples from auger drilling can be reduced in size by applying various sample reduction techniques, such as coning and quartering, or by using a riffle splitter. Core samples are normally split either in half core or quarter core, before bagging the individual samples. Stream sediment samples are air dried and often sieved to a specific size fraction before being submitted for laboratory analysis.

Figure 3-38: Offloading equipment from cargo plane. Bakouma area, Central African Republic (Booyens, 2007c)

Figure 3-39: Core drilling samples being prepared for analyses, Koutou area, Republic of Congo (Booyens, 2015f)

Due to the size and weight of samples, storage of different samples often occurs at the exploration camp (Figure 3-40 and Figure 3-41). Different samples can be stored for various reasons, ranging from the storage of excess samples from stream sediment sampling, to the storage of quartered or halved core samples, and the storage of pulps and rejects that is returned from the laboratory. It is standard practise to keep samples in storage for as long as possible, in the event of samples being required to conduct check assays or to re-log and resample core samples.

Figure 3-40: Storage facility for RC drill chips. Beaufort West area, South Africa (Booyens, 2009c)

Figure 3-41: Drill core storage shed. Koutou area, Republic of Congo (Booyens, 2015g)

With recent technological improvements, X-ray Fluorescence (XRF) analysis can be conducted on site using handheld or portable instruments.

3.6 Conclusions

Mineral exploration, despite its having alternate definitions and interpretations, entails the action of systematic searching for mineral occurrences so as to determine qualitative and quantitative characteristics of a mineral occurrence.

During the process of mineral exploration, the information obtained about a mineral occurrence provides information about the grade and volume of a mineralised body, the shape and depth of the mineralisation, the chemical composition of the mineralisation as well as the presence of any deleterious constituents.

By increasing the amount of relevant geological information about a mineral occurrence, the confidence level in the mineral occurrence increases. This increase is reflected in the different categories of the various global reporting codes for the public reporting of information pertaining to mineral resources and ore reserves.

To increase the amount of relevant geological information about a mineral occurrence, mineral exploration activities have to be conducted. Mineral exploration activities are grouped into two categories for this study: direct mineral exploration techniques and indirect mineral exploration techniques.

Direct mineral exploration activities entail physical sampling, excavation, drilling or the taking of any samples to obtain a representative sample of the mineral occurrence, in order to enable evaluation thereof. Indirect mineral exploration activities entail methods that are either in contact or not in contact with the earth's surface, and are used to make deductions about the underlying geology based on measurements or images.

Ancillary and associated mineral exploration activities are those activities that need to be conducted in order for mineral exploration to be successfully undertaken.

All the activities undertaken by a mineral exploration company during mineral exploration have an impact on the environment. Impacts can vary from little or no impact to a very large impact, from a short term impact to a long term impact and from impacts that can be remedied to impacts that cannot. The following chapter will review and discuss the environmental impacts of exploration activities.

4 CHAPTER 4 - ENVIRONMENTAL IMPACTS

"But besides this, the strongest argument of the detractors is that the fields are devastated by mining operations, for which reason formerly Italians were warned by law that no one should dig the earth for metals and so injure their very fertile fields, their vineyards, and their olive groves. Also they argue that the woods and groves are cut down, for there is need of an endless amount of wood for timbers, machines, and the smelting of metals. And when the woods and groves are felled, then are exterminated the beasts and birds, very many of which furnish a pleasant and agreeable food for man. Further, when the ores are washed, the water which has been used poisons the brooks and streams, and either destroys the fish or drives them away. Therefore the inhabitants of these regions, on account of the devastation of their fields, woods, groves, brooks and rivers, find great difficulty in procuring the necessaries of life, and by reason of the destruction of the timber they are forced to greater expense in erecting buildings. Thus it is said, it is clear to all that there is greater detriment from mining than the value of the metals which the mining produces" (Argicola, 1556).

4.1 **Introduction**

INTOSAI WGEA (2010:8, 28) states that the environmental impact of mining starts at the exploration stage, continues with the extraction and processing of minerals and ceases only when mining operations are decommissioned. Appiah and Osman (2014:3) further state that environmental impact of mining processes has the potential to create a number of different impacts of various magnitudes.

Published literature and research on the environmental impact of mineral exploration activities is limited or simply unavailable for the purposes of this study. Consequently, the available data and information of mining's environmental impact will be utilised and reviewed, in order to project abovementioned data and information into the sphere of mineral exploration activities. To understand the potential environmental impact of any activity on the environment certain actions can be performed, such as audits and assessments.

4.2 **Audits and assessments**

Even though environmental audits and assessments do not form part of this study, a concise overview will be provided, since it is essential to understand how the environmental impact of an activity is determined. Environmental assessments should be conducted during three stages of a project: firstly, pre-activity baseline audits; secondly, as ongoing audits during the activity and, lastly, as post-activity audits (Appiah-Opoku & Bryan, 2013:38). Appiah-Opoku and Bryan (2013:38) indicate that three groups of stakeholders are involved in the auditing process, viz.

the project proposer during baseline audits, regulators during ongoing audits and the general community during post-auditing.

Appiah-Opoku and Bryan (2013:38, 39) further state that despite the importance of environmental assessments, little attention is paid to follow-up programmes in most African countries. Follow-up programmes are vital for monitoring and evaluating the impact of activities on the environment, in order to mitigate any environmental damage, to determine the efficiency of mitigating measures and to identify shortcomings in mitigating methods (Appiah-Opoku & Bryan, 2013:38).

Gwimbi and Nhamo's (2016:19) reviewed platinum mining activities along the Great Dyke in Zimbabwe and reaffirmed the above sentiment, by stating that the implementation of documented mitigating measures in Environmental Impact Statements/Assessments into actual activities in Environmental Management Plans is largely based on procedure and that it is dictated by legislation. Subsequently, they conclude that only 52% of mitigating measures that were proposed in Environmental Impact Statements were converted into planning conditions by the project proposer (Gwimbi & Nhamo, 2016:20).

4.3 **Existing environmental research**

4.3.1 The impact of selected mineral exploration activities

According to INTOSAI WGEA (2010:16) the mineral exploration stage, and the activities it involves, "… generally produces the least-pronounced adverse environmental effects …" and are "… frequently dismissed as localised." However, the potential impact of mineral exploration can include land degradation, soil erosion, deforestation, air pollution, water pollution, loss of terrestrial and aquatic habitat systems and the loss of biodiversity.

In addition, INTOSAI WGEA (2010:21 - 23) tabulated the main physical impacts on the environment caused by the different mining phases (General, Exploration, Mining and Ore Processing/Plant Operation). An extract of the table, reflecting selected activities of the exploration phase, is reproduced below (Table 4-1).

Table 4-1: Summarised list of exploration activities, physical impacts, time frame and mitigation (extracted from INTOSAI WGEA, 2010).

Activity	Physical impact	Time frame	Mitigation [5]
Access road and construction	Potential influx of population may lead to increased natural resources use [1]	Potentially long term	Minimise where possible
Line cutting	Removal of vegetation. Soil erosion. Possible habitat destruction [2]	Short term if mitigated	Minimise line width, re-vegetation where necessary
Trenching and pitting	Land scars. Danger to fauna, livestock	Short term	Infill after sampling, mapping Re-vegetation
Drilling	Noise and vibration (impact depends on proximity to settlements) [3]	During drilling only	Discussions with public to minimise nuisance
	Land clearing for drill sites.	Short term	Re-vegetation
	Soil and water contamination by oil spills and drilling wastes	Short term [4]	Sound maintenance of machinery, management of waste

The listed mineral exploration activities in Table 4-1 are not exhaustive when compared against the activities discussed in Chapter 3 of this study. Nevertheless, this extract indicates the varied physical impacts caused by different activities, as well as the varied time frames over which the impacts can occur. Some shortcomings identified from the INTOSAI WGEA (2010) study are mentioned below:

(1) The creation and use of access roads impact soil erosion and/or compaction. It can be long term if not mitigated properly after closure.
(2) Possible encroachment of plant species during regrowth that were not originally part of the natural state before activities commenced.
(3) Also soil degradation and compaction during activities. Can be long term if not mitigated properly after closure.
(4) Impact can be long term if not mitigated properly.
(5) Mitigating measures should include auditing, monitoring and maintenance of each activity.

4.3.2 The impact of a specific mineral exploration activity

As part of a study funded by the Finnish Funding Agency for Innovation, Sarala (2015:11 - 22) compared different drilling techniques to sample basal till during mineral exploration. One of the aims of this study was to identify the technique that would have the lowest environmental impact during exploration (Sarala, 2015:12). The sampling techniques reviewed consisted of the following: i) mechanically excavated test pits, ii) crawler mounted GM100 type core drill rig, iii) six-wheeled forest tractor mounted pneumatic drill rig, iv) crawler mounted GM200 type core rig, v) lightweight crawler mounted Bandvagn percussion drill rig and vi) crawler mounted CRS-V sonic drill rig (Sarala, 2015:15). Selected information and the environmental impact of each method are tabulated below in Table 4-2.

Table 4-2: Selected information of different basal till exploration techniques (extracted from Sarala, 2015)

Method	Sites	Working days	Environmental impact (*)
Mechanical test pit	71	19	3
Crawler GM100 coring	33	28	4
Tractor pneumatic	21	14	4
Crawler GM200 coring	25	30	4
Crawler Bandvagn percussion	8	18	5
Crawler CRS-V sonic	6	6	4

(*) 1 = High impact, 5 = Low impact

The environmental impact of each method was related to i) vehicle tracks on the surface, ii) ground disturbance caused by each method, iii) excavated material or drill cuttings and drilling fluid on surface, iv) requirement of support vehicles such as water tankers and air compressors and v) the possible sources of contamination. Sarala's (2015:21) recommendations, based on the results of the study, include the following: drill rig should be a i) crawler mounted, easily manoeuvrable, light weight, vehicle, being of ii) multi-purpose design (i.e. pneumatic/percussion with coring capabilities in one rig), supported by a iii) crawler mounted, light support vehicle to transport water and air compressor and with iv) the ability to collect excess drill cuttings and drilling fluid.

What Sarala's study (2012) did not consider was the surface and subsurface compaction caused by the various types of equipment tested. If compaction is not rehabilitated properly, negative consequences such as surface erosion (from surface compaction), poor root development and poor water infiltration (from subsurface compaction) could develop.

What both INTOSAI WGEA's (2010) and Sarala's (2015) studies indicates is that different exploration activities and sampling methods impact differently on the environment. Although Sarala's (2015) study was conducted in snow covered, forested terrain, the results obtained can be considered applicable to other geographically diverse exploration areas, particularly in terms of identifying the most appropriate exploration method that has the lowest environmental impact.

4.4 Environmental impact of exploration activities

For the purposes of this study, reproduction and formulation of INTOSAI WGEA's (2010) and Sarala's (2015) findings were attempted. All the exploration activities listed in Chapter 3 of this study were tabulated, incorporating responses and observations from the study questionnaires and site visits, as well as from field work the researcher conducted.

The approach that was used aimed to determine the specific environmental impact of an exploration activity. The potential environmental impact of an activity does not take into account the diverse activities that pre-empt it. For example, when reviewing the impact of core drilling, the activity of creating access roads is not considered. Additionally, the exploration activity of satellite based remote sensing merely reviews the impact of the activity on the exploration site, but does not consider the environmental impact of launching the satellite.

Table 4-3 below is a qualitative indication of what exploration activities impact which specific environmental area(s), viz. air, surface water, ground water, soil/land, fauna and flora. Only two possible options could be selected, namely "Yes", which implies that a specific activity potentially could impact an environmental area, or "No" which implies that an activity does not impact an environmental area. The entries indicate that the potential impact of mineral exploration as a whole impacts on all the environmental areas, although not all as a result of the same activity. The exception to this is the two activities of camp establishment and site access and transport, which potentially impacts all the environmental areas.

Table 4-3: Qualitative indication of the potential impacts of different exploration activities of various environmental areas.

Group	Activity	Air	Surface water	Ground water	Soil/Land	Fauna	Flora
Direct mineral exploration activities	Geological mapping	No	No	No	No	Yes	Yes
	Surface sampling (soil, grab, rock chip, channel)	No	No	No	Yes	Yes	Yes
	Stream sediment sampling	No	Yes	No	No	Yes	Yes
	Pitting and trenching	No	Yes	Yes	Yes	Yes	Yes
	Auger, rotary, mud rotary, percussion rotary, air-core, reverse circulation drilling	Yes	Yes	Yes	Yes	Yes	Yes
	Sonic drilling	Yes	Yes	Yes	Yes	Yes	Yes
	Core drilling	Yes	Yes	Yes	Yes	Yes	Yes
Indirect mineral exploration activities	Ground electromagnetic, resistivity and induced polarisation survey	No	Yes	No	Yes	Yes	Yes
	Ground magnetic, gravity and radiometric survey	No	Yes	No	Yes	Yes	Yes
	Seismic survey	Yes	Yes	No	Yes	Yes	Yes
	Ground penetrating radar	No	Yes	No	Yes	Yes	Yes
	Borehole geophysics	No	No	Yes	No	No	No
	Airborne geophysics survey	Yes	No	No	No	Yes	No
	Aircraft based remote sensing survey	Yes	No	No	No	Yes	No
	Satellite based remote sensing	No	No	No	No	No	No
Other exploration activities	Hydrogeochemical sampling	No	Yes	Yes	No	No	No
	Biogeochemical and geobotanical sampling	No	No	No	No	Yes	Yes
	In-situ soil gas sampling	No	Yes	No	Yes	Yes	Yes
	Termite mound sampling	No	No	No	Yes	Yes	No
	Portable X-ray fluorescence	No	No	No	No	Yes	Yes
Ancillary and associated activities	Field camp establishment	Yes	Yes	Yes	Yes	Yes	Yes
	Site access and transport	Yes	Yes	Yes	Yes	Yes	Yes
	Sampling preparation, analyses and storage	Yes	Yes	Yes	Yes	No	No

Following on the qualitative indications of Table 4-3 above, the subsequent step is to semi-quantify the impact of the exploration activities on the different environmental areas. The objective of Table 4-4 below is thus to semi-quantify the impact of exploration activities on the different environments, viz. air, surface water, ground water, soil/land, fauna and flora. The entries in Table 4-4 indicate the potential impact of each exploration activity on individual environments, and for the purposes of this study was categorised as one of four: “Negligible”, “Small”, “Medium” and “Large”. These classifications quantify the impact only in terms of whether it impacts more or less than other activities. No attempt was made to quantify an absolute magnitude for each activity.

To further advance the process, a numeric value was allocated to each of the four indications used in Table 4-4 (Negligible = 1, Small = 2, Medium = 3 and Large = 4). This allowed for the determination of a simple average value of each exploration activity’s impact on each of the six environmental areas (Table 4-5).

As an example, geological mapping is indicated as only potentially affecting fauna and flora, while air, surface water, ground water and soil/land are unaffected. The indicated effect on fauna and flora is both regarded as “Negligible”, i.e. a value of 1. To calculate the indicative average value that geological mapping has on the environment as a whole, the values allocated to the impact on fauna and on flora are added (1 + 1 = 2), and were then divided by the number of areas that are affected, namely fauna and flora (2 / 2 = 1). The value of 1 is thus the indicative average value ascribed to the potential impact of geological mapping on the environment.

The indicative average value, along with an overall potential impact of each activity, ranging from Negligible, Almost Negligible, Negligible-Small, Small, Small-Medium, Medium, Medium-Large and Large are tabulated in Table 4-5.

In order to gauge the time frame for when each activity could potentially impact on the environment, an additional column was added to indicate whether a particular exploration activity will have an impact only during the activity, or whether over the short, medium or long-term period following completion of the specific activity.

Table 4-4: Semi-quantitative indication of the potential impacts of different exploration activities of various environmental areas.

Group	Activity	Air	Surface water	Ground water	Soil/Land	Fauna	Flora
Direct mineral exploration activities	Geological mapping					Negligible	Negligible
	Surface sampling (soil, grab, rock chip, channel)				Small	Negligible	Negligible
	Stream sediment sampling		Small			Small	Negligible
	Pitting and trenching		Medium	Small	Medium	Large	Medium
	Auger, rotary, mud rotary, percussion rotary, air-core, reverse circulation drilling	Large	Medium	Medium	Large	Medium	Medium
	Sonic drilling	Medium	Medium	Medium	Large	Medium	Medium
	Core drilling	Medium	Large	Large	Large	Medium	Medium
Indirect mineral exploration activities	Ground electromagnetic, resistivity and induced polarisation survey		Negligible		Small	Negligible	Negligible
	Ground magnetic, gravity and radiometric survey		Negligible		Small	Negligible	Negligible
	Seismic survey	Medium	Medium		Medium	Medium	Medium
	Ground penetrating radar		Negligible		Small	Negligible	Small
	Borehole geophysics			Negligible			
	Airborne geophysics survey	Medium				Small	
	Aircraft based remote sensing survey	Medium				Small	
	Satellite based remote sensing						
Other exploration activities	Hydrogeochemical sampling		Small	Small			
	Biogeochemical and geobotanical sampling					Small	Small
	In-situ soil gas sampling		Negligible		Medium	Negligible	Small
	Termite mound sampling				Small	Medium	
	Portable X-ray fluorescence					Negligible	Negligible
Ancillary and associated activities	Field camp establishment	Large	Large	Large	Large	Large	Large
	Site access and transport	Medium	Large	Medium	Medium	Large	Medium
	Sampling preparation, analyses and storage	Small	Small	Small	Medium		

Table 4-5: Comparative numeric value, overall potential impact and time frame for mineral exploration activities.

Group	Activity	Value	Overall potential impact	Time frame
Direct mineral exploration activities	Geological mapping	1.0	Negligible	During activity only
	Surface sampling (soil, grab, rock chip, channel)	1.3	Negligible – small	Short term, unless rehabilitated
	Stream sediment sampling	2.0	Small	Short term, unless rehabilitated
	Pitting and trenching	3.0	Medium	Long term, unless rehabilitated
	Auger, rotary, mud rotary, percussion rotary, air-core, reverse circulation drilling	3.3	Medium – large	Long term, unless rehabilitated
	Sonic drilling	3.2	Medium – large	Long term, unless rehabilitated
	Core drilling	3.5	Medium – large	Long term, unless rehabilitated
Indirect mineral exploration activities	Ground electromagnetic, resistivity and induced polarisation survey	1.3	Negligible – small	Short term, unless rehabilitated
	Ground magnetic, gravity and radiometric survey	1.3	Negligible – small	Short term, unless rehabilitated
	Seismic survey	3.0	Medium	Medium term, unless rehabilitated
	Ground penetrating radar	1.5	Negligible – small	Short term, unless rehabilitated
	Borehole geophysics	2.0	Small	Short term, unless rehabilitated
	Airborne geophysics survey	2.5	Small – medium	During activity only
	Aircraft based remote sensing survey	2.5	Small – medium	During activity only
	Satellite based remote sensing	0.0	Negligible	Not applicable
Other exploration activities	Hydrogeochemical sampling	2.0	Small	During activity only
	Biogeochemical and geobotanical sampling	2.0	Small	During activity only
	In-situ soil gas sampling	1.8	Negligible – small	Short term, unless rehabilitated
	Termite mound sampling	2.5	Small – medium	Short term, unless rehabilitated
	Portable X-ray fluorescence	1.0	Negligible	During activity only
Ancillary and associated activities	Field camp establishment	4.0	Large	Long term, unless ongoing rehabilitation
	Site access and transport	3.3	Medium – large	Long term, unless ongoing rehabilitation
	Sampling preparation, analyses and storage	2.3	Small – medium	Long term, unless ongoing rehabilitation

It is important to take cognisance of the frequency and duration of an activity whenever the potential impact of exploration activities on the environment is reviewed. In other words, the more an exploration activity is undertaken, the larger the environmental impact of that activity will likely be. The same holds true when considering the duration of an exploration activity - the longer an activity is conducted, the larger its potential impact on the environment will likely be. These two factors are project dependent and will vary between different mineral exploration projects, since all projects are not the same in terms of geological and mineralogical settings, location, and availability of services and, lastly, the environmental setting of the project.

4.5 Mineral occurrences and common associations

An additional step in identifying the impact of mineral exploration on the environment was undertaken by compiling a list of commonly explored minerals. Commonly associated deleterious constituents found along with each of these minerals were identified from various literature sources as well as health and other risks, and are included in Table 4-6 below.

Table 4-6: Table of commonly extracted minerals and their associated deleterious constituents (extracted from Cairncross & Dixon, 1995; Wilson & Anhaeusser, 1998; Kyser, 2008; ATSDR, 2016).

Group	Subgroup	Mineral	Common deleterious constituents and health risks
Metallic	Precious metals	Gold	Sulphides, Arsenic, Uranium
		Silver	Sulphides, Lead, Copper & Cobalt
		Platinum Group	Sulphides & Arsenic
	Ferrous metals	Iron	Sulphides & Arsenic
		Manganese	None. Neurotoxic in high levels.
		Nickel	Sulphides & Arsenic. Toxic and other health hazards even at low levels.
		Chromium	None. Chromium hexavalent (Cr_6) extremely toxic
		Molybdenum	Sulphides & Lead

Group	Subgroup	Mineral	Common deleterious constituents and health risks
		Tungsten	None
		Vanadium	None. Pollutant and health risks
		Cobalt	Sulphides & Arsenic. Health risks even at low levels
	Nonferrous metals	Copper	Sulphides & Arsenic
		Lead (& Zinc)	Sulphides, Cadmium, Bismuth & Antimony. Toxic
		Tin	Sulphides & Molybdenum
	Minor metals	Antimony	Sulphides & Lead
		Beryllium	None. Extremely toxic
		Bismuth	Sulphides, Lead, Cadmium & Antimony
		Cadmium	Sulphides. Toxic at low levels
		Lithium	None. Soil pollutant
		REE	None
		Zirconium	Uranium & Thorium
Non-metallic	Energy and coal	Coal	Sulphides
		Uranium	Radioactive. Health risk
		Phosphates	Uranium
	Gemstones	Diamonds	None

It should be noted that Table 4-6 is not exhaustive in terms of minerals that are explored for, nor is the associated deleterious constituents absolute regarding its presence or absence. Table 4-6 should only be considered as an indication of deleterious associations that can be found for the most commonly explored for minerals. Important to note is that in some case the mineral that is explored for can also be harmful to the environment, either causing pollution or being toxic to living organisms.

4.6 **Impact of deleterious constituents on the environment**

Deleterious constituents can comprise various elements or compounds, and can affect and impact the environment as well as living organisms. Examples of the impact of deleterious constituents associated with minerals are acid generation and metal leaching, which are also naturally occurring processes. Acid generation and metal leaching may, however, have a negative impact on the environment if not properly addressed.

4.6.1 Sulphides

As is evident from Table 4-6, sulphides are associated with a large number of mineral occurrences. Sulphides are a compound of sulphur (S) and another element, or group of elements, which comprise an economically important class of minerals.

When sulphides are exposed to water (H_2O) and oxygen (O_2), it can lead to the formation of a weak acid that results in an increase in acidity, precipitation and release of metals, and the depletion of oxygen levels. As an example, when pyrite (FeS_2) is oxidised, it results in the formation of sulfuric acid according to the formula:

$$2FeS_2 + 7O_2 + 2H_2O \Rightarrow 2FeSO_4 + 2H_2SO_4$$ (Manahan, 2009:406)

The term acid mine drainage (AMD) or acid rock drainage (ARD) (or alternatively similar terms) describe the low pH or acidic waters caused by oxidation of sulphide minerals (Manahan, 2009:406), and the subsequent higher solubility of many metal trace elements which could be harmful to the environment in the soluble state. The consequences of AMD are much worse than AMD itself. AMD is a severe consequence of nearly all sulphide bearing mineral deposits.

4.6.2 Metal trace elements

A major point of concern of the leaching of metals is the associated toxicity (MABC, 2009:53). Heavy metals such as lead (Pb) and cadmium (Cd) are known to have a wide range of adverse biological effects (Manahan, 2009:940). Arsenic (As) occurs in a number of toxic compounds that can be absorbed through the lungs and intestines of humans and animals. Mercury (Hg), that enters the body, disrupts metabolic processes in the brain or it can damage the kidneys (Manahan, 2009:859).

4.6.3 Radioactives

Radioactive elements such as uranium (U) and thorium (Th) have unstable nuclei that emit charged alpha (α) or beta (β) particles, in the form of radioactivity, or gamma (γ) ray radiation (Manahan, 2009:7, 452).

Radiation is harmful since it initiates chemical reactions in living tissue, such as the destruction of bone marrow, which is responsible for the creation of red blood cells. Genetic damage due to radiation is not immediately noticeable, but may take a number of years and in some case a number of generations, to become apparent (Manahan, 2009:453).

4.7 **Conclusions**

The introductory quote to this chapter from Agricola, nearly five centuries ago, could well have been voiced today - what he described is still pertinent and occurring today.

There are a variety of methods that can be utilised to monitor the impact of exploration activities on the environment. These include the use of audits and assessments before, during and after exploration, periodic site visits and investigations by regulatory authorities, reviews of companies' environmental monitoring reports and documents, and following up of complaints by local communities (Appiah & Osman, 2014:14). Environmental pollution is well addressed in South Africa in other legislation besides the MPRDAA, such as in the National Environmental Management: Waste Act, National Environmental Management: Biodiversity Act and the Conservation of Agricultural Resources Act. However, as indicated, if follow-up programmes are not seen as being important aspects of environmental assessments, no or little benefit will be gained from their implementation.

Previous studies have addressed the impact of exploration activities on the environment, but these have been either generalised or only focussing on specific exploration activities. This study, however, aimed to indicate qualitatively and semi-quantitatively the impact of mineral exploration activities on specific environmental areas. The result is a tabulation of an overall potential environmental impact of mineral exploration activities.

A review of the most commonly explored minerals highlights potential deleterious constituents, as well as their impact on the environment and living organisms.

To regulate the mineral exploration industry and its activities mineral -, environmental and other legislation is required to ensure that sound and proper decisions are made. Legislation sets standards and principles to be used and adhered to during and after decision making processes. This ensures the sustainable use and development of mineral resources, as well as the conservation and management of the environment which is affected by mineral exploration, while also promoting socio-economic development. The following chapter will review the legislation applicable to mineral exploration activities.

5 CHAPTER 5 - MINING AND ENVIRONMENTAL LEGISLATION

5.1 Introduction to legal systems

Many countries compete for investment in their respective economies and this is especially true regarding the mining industry. Numerous governments have adopted modern legislation to attract investments into the mineral exploration sector (Hutchins & Wackerle, 2007:879). Any study regarding the environmental impact of small cap exploration companies' various activities requires a discussion regarding legislation pertaining to these activities.

However, before discussing specific legislation relating to mineral exploration and the environment, it is important to have a basic understanding of the foundation upon which the laws of each jurisdiction, which will be discussed in this chapter, is based. Different jurisdictions have different laws, and these laws are often derived from different traditions, i.e. Civil law, Common law, Customary law and Religious law (uOttowa, 2015). A brief summary of the four different legal traditions are given below. The aim is not to discuss comparative law, but to provide some historical background on the development of each tradition and where it is mostly used.

Civil law is the oldest and most widely distributed legal tradition in the world. It dates to approximately 450 BCE when the first publication of the XII Tables appeared in Rome. It is the dominant legal tradition in Western European countries and their former colonies (Merryman, 1969:2, 3). To simplify Civil law, it can be described as being drafted by Legislators and subsequently codified. Judges are appointed as civil servants with a limited role in applying laws and act as investigators during legal disputes.

The date ascribed to the emergence of the Common law tradition is 1066 CE. This was the year when the Normans, led by William the Conqueror, conquered England at the Battle of Hastings. Anglo-Saxon law was the foundation of English law before this conquest and it was not documented. The King issued legislation which amended or supplemented the law as and when required (Humby *et al.*, 2012:94, 95). British imperialism led to the subsequent expansion of the British Empire and, consequently, the Common law tradition was widely distributed across the world. To simplify Common law, it can be described as drawing primarily upon precedent and case law from higher courts (Humby *et al.*, 2012:96). Laws are continuously developed by judges who play an active part in its development and who also act as arbiters during legal disputes.

Customary law can be defined as "... a body of customs and traditions which regulates various kinds of relationships between members of a community …" (Kenya Law Resource Center, 2016). The use and acceptance of a custom or tradition is key in determining whether such a custom or tradition acquires the force of law. Customary law reflects the values of a community with respect to their norms during a specific period. Furthermore, for customary law to be accepted, it must have antiquity (Kenya Law Resource Center, 2016).

Contemporary religious law incorporates Christian Canon law, Jewish Halakha and Islamic law. In this study, however, religious law refers specifically to Islamic (or *Sharia*) law, as it is the only religious law currently evident in Africa. Sharia law is based on Allah's command for Muslim society and is primarily derived from the *Qur'an* and from Muhammad's (PBUH) traditions (s*unnah*) and sayings (*hadith*) (Johnson Raisch, 2006).

5.2 **Laws in Africa**

To illustrate the complexities of the laws that are in place across African countries, a simple comparison was made, using information obtained from the University of Ottawa, of fifty six African countries (Figure 5-1). Of the listed fifty six countries, only six countries' laws are based on a single legal tradition, five on Civil law (Angola, Benin, Cape Verde, Central African Republic and La Reunion) and one country's law on Religious law (Maldives). The remaining fifty countries' laws are all a combination of two or more of Civil, Common, Customary and Religious traditions. The extreme case is Somalia, whose laws are based on all four. Civil law is part of the legal system in thirty eight countries, while Customary law forms part of thirty seven countries' legal systems. Common law is found in twenty one countries' legal systems, while Islamic law forms part of fourteen countries' legal systems (uOttowa, 2015).

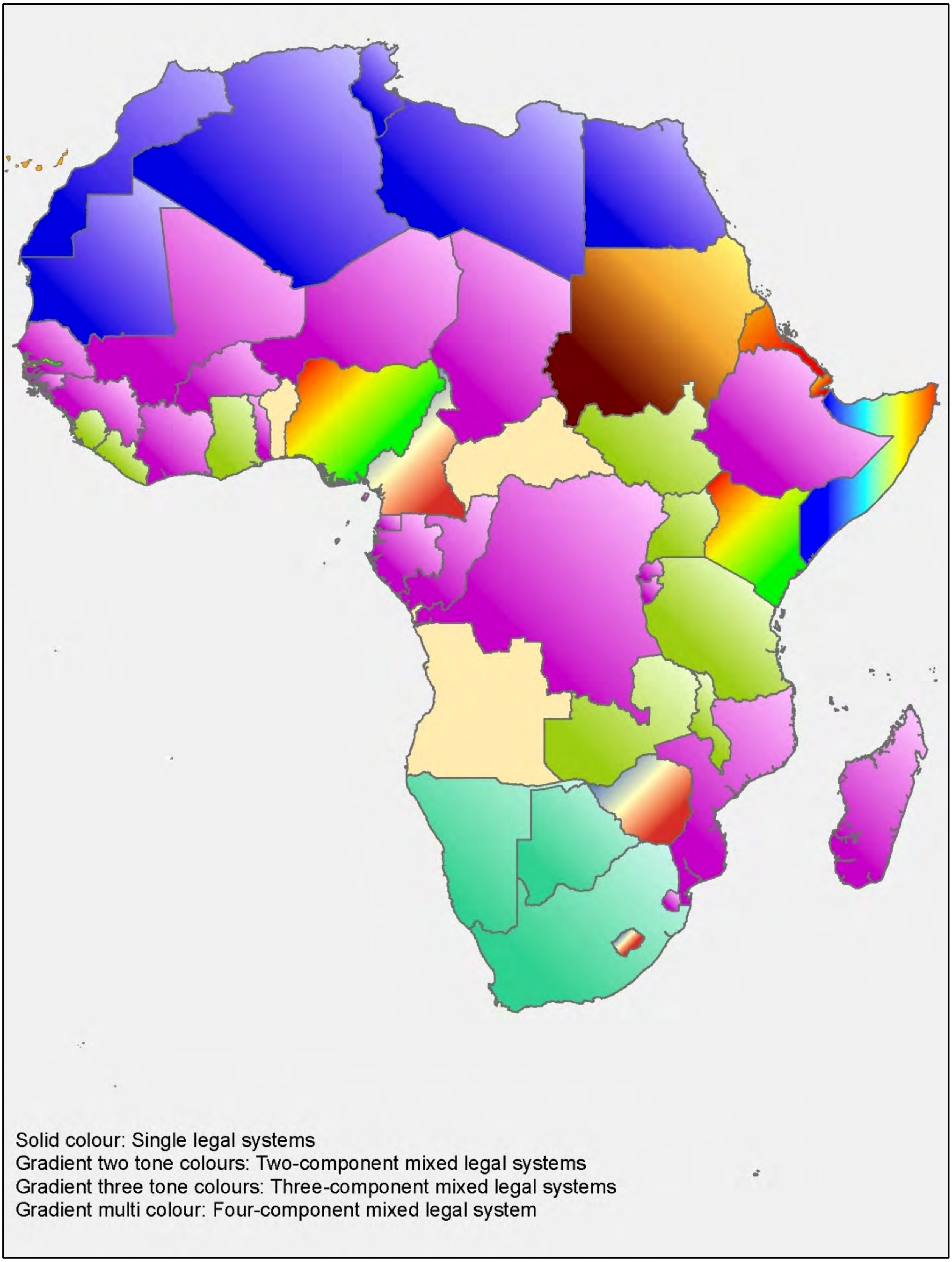

Figure 5-1: Comparison of African countries' use of various legal components (after uOttowa, 2015)

This simple comparison clearly indicates how complex the legalities could be for mineral exploration companies operating across borders in Africa. It is essential that these companies understand the relevant legal frameworks, or alternatively, make use of a legal expert to assist with legal matters.

5.3 Selected legislation from across Africa

Data obtained from the recently launched African Mining Legislation Atlas website (AMLA, 2015a) was utilised to select a number of countries' mineral exploration legislation for comparison. Initial selection criteria were based on the following:

- Official publication of the legislation available in English;
- Availability of the legislation on official government websites or portals;
- The relative importance of the extractive solid minerals industry for a country, reflected as a country's economic dependency on minerals and its status at the Extractive Industries Transparency Initiative (EITI) (Table 5-1).

Countries selected based on the above criteria are Botswana, South Africa and Tanzania. To expand the list of countries, one additional country has been selected, Sierra Leone.

Table 5-1: Mineral and environmental legislation of selected countries

	English laws	Online	Dependency	EITI	Economic Community
South Africa	Yes	Yes	High	No status	SADC
Botswana	Yes	Yes	High	No status	SADC
Sierra Leone	Yes	No	High	Compliant	ECOWAS/CEN-SAD
Tanzania	Yes	Yes	High	Compliant	SADC/EAC

The rationale behind selecting Sierra Leone is to review the legislation of a country that was ravaged by a war funded primarily through conflict minerals. The purpose of this section of the study is not to explain or interpret the law, but only to highlight the relevant sections applicable to mineral exploration.

5.3.1 South African legislation

Mineral exploration in South Africa is regulated by the framework Mineral and Petroleum Resources Development Act (28 of 2002) (MPRDA) and the proposed Mineral and

Petroleum Resources Development Amendment Act (49 of 2008) (MPRDAA) which, at the time of this study, still needed to be approved and gazetted. Subsequent to the framework legislation is a number of Notices and Regulations (AMLA, 2015b).

The MPRDA and proposed MPRDAA amend and repeal various other Acts and Sections of Acts. These include, but are not limited to, the Mine Health and Safety Act (29 of 1996), the Survey Act (8 of 1997), the National Environmental Management Act (107 of 1998), the Expropriation of Mineral Rights Act (96 of 1969), the Minerals Act (50 of 1991) and the Mineral and Energy Laws Rationalisation Act (47 of 1994).

Environmental matters are regulated by the framework National Environmental Management Act (107 of 1998) (NEMA) and other acts, such as the National Water Act (36 of 1998) (NWA), National Environmental Management: Waste Act (59 of 2008) (NEMWA) and the National Environmental Management: Air Quality Act (39 of 2004) (NEMAQA).

5.3.1.1 The Minerals and Petroleum Resources Development Amendment Act 49 of 2008

A historical overview of South African mineral law is not necessary, but it must be kept in mind that South African mineral law has always been based upon Roman and Roman-Dutch law. For a historical overview of South African mineral law, refer to Van der Schyff (2012).

Although the MPRDAA has not been promulgated as of yet, this study will refer to it nonetheless.

Firstly, it is important to note that the South African MPRDAA caters for both solid minerals and hydrocarbons (oil and gas); as opposed to other countries such as Botswana, Tanzania and Sierra Leone that has promulgated separate acts for each of these sectors.

Secondly, the MPRDAA does not have any sections specifically dedicated to mineral exploration. Rather, the whole MPRDAA has to be reviewed to identify any paragraphs, sections, subsections and points that are relevant to the activity of mineral exploration.

Thirdly it can be argued that the MPRDAA has consolidated various aspects covered by amended and appealed Acts.

In relation to possible environmental matters, the MPRDAA refers to environmental authorisation that is required before any activity can be conducted. In Section 13, which is an amendment of Section 17 of the MPRDA, the new proposed MPRDAA further states that "… the prospecting will not result in unacceptable pollution, ecological degradation or damage to the environment." The MPRDAA further states that the principles set out in Section 2 of the NEMA has to be adhered to for all exploration activities.

5.3.1.2 National Environmental Management Act 107 of 1998 and other Acts

The South African Constitution (1996) addresses the environment directly in Section 24 and makes it a basic right of citizens to have an environment that is protected and not harmful to their health or wellbeing.

A number of sectorial pieces of legislation is also applicable to environmental matters, such as the previously mentioned National Water Act (36 of 1998) (NWA), National Environmental Management: Waste Act (59 of 2008) (NEMWA), the National Environmental Management: Air Quality Act (39 of 2004) (NEMAQA), the National Environmental Management: Biodiversity Act, the National Environmental Management: Protected Areas Act and the National Heritage Resources Act.

The NEMA Section 2 refers to guiding environmental management principles that apply to actions that may significantly affect the environment.

According to the NEMA, an Environmental Authorisation is required for any listed or specified activities. Listed activities can be found in the Environmental Impact Assessment (EIA) Regulations Listing Notices, where mineral exploration is listed in Notice 1 (South Africa, 2014). Activities listed in Listing 1 require a Basic Assessment to be undertaken and completed, rather than a detailed Environmental Impact Assessment (EWT, 2016).

5.3.1.3 Summary

After reviewing the MPRDAA, the view is that this Act does not place enough emphasis on exploration and exploration activities, but rather focusses on mining (of solid minerals) and production (of oil and gas). When compared to other jurisdictions' legislation, the question arises whether the MPRDAA should have solely made provision for solid minerals, rather than combining the solid minerals industry and the oil and gas industry in one act. Section 13 however does address some issues related to exploration activities.

The fact that the MPRDAA places so much emphasis on mining and production could be attributed to the effort of the government to distribute the benefits of natural resources to the whole of the population. However, by neglecting exploration and exploration activities, it could potentially lead to a situation in the future where not enough new discoveries are made to replace mined-out deposits. The long term impact of this decision is an unknown.

On the other hand, South Africa’s legislation regarding environmental affairs can arguably be viewed as one of the best on the continent. The environment is addressed in the Constitution and, moreover, the framework NEMA and sectorial legislation covers a broad range of areas.

5.3.2 Botswana legislation

Mineral exploration in Botswana is regulated by the framework Mines and Minerals Act (17 of 1999). This Act has been in effect for the past 16 years and, according to the African Mining Legislation Atlas website (AMLA, 2015c) a proposed amendment is planned for the near future.

5.3.2.1 The Mines and Minerals Act 17 of 1999

As opposed to the South African MPRDAA, the Botswana Mines and Minerals Act (17 of 1999) (MMA) has clearly identified sections dedicated to the Administration of the MMA (Part III: 7 to 12), to Prospecting licences (Part IV: 13 to 24), Environmental Obligations (Part IX: 65), as well as to Regulations (Part XII: 80), Offences and penalties (Part XIII: 81 to 84), as well as to Records and information (Part XIV: 85 to 88).

Nowhere in the MMA does it prescribe any statutory prerequisites that need to be adhered to, nor is any other environmental legislation specifically referred to in the MMA, the only reference that occurs is:

“… in accordance with the law in force from time to time in Botswana and in accordance with good mining industry practice, conduct his operations in such a manner as to preserve …” (Mines and Minerals Act, 17 of 1999).

5.3.2.2 Environmental law

According to Faure and Du Plessis (2011:52-53) Botswana’s legislation is hierarchical, beginning with the Constitution, which is supplemented by Legislation and finally Common Law. These three sources form the basis of environmental law in Botswana.

The Constitution, however, does not specifically make provision for the protection of the environment (Faure & Du Plessis, 2011:54). Neither is there a single environmental legal framework in place, but rather a set of sectorial legislation that targets particular sectors of the environment (Faure & Du Plessis, 2011:58). The Ministry of Environment, Wildlife and Tourism fulfils the role of coordinator of environmental issues (Faure & Du Plessis, 2011:62). The Environmental Impact Assessment Act (6 of 2005) (EIAA) was enacted to determine and provide for mitigating measures for the effect of specified projects and activities that may have an adverse impact on the environment. Under the EIAA, the Department of Environmental Affairs is the authority that determines the need, or otherwise, for an EIA for any proposed activities (Faure & Du Plessis, 2011:67).

For all projects a Preliminary Environmental Impact Assessment needs to be submitted and, upon screening, a preliminary assessment is made that determines under which category a project resides and whether it requires an EIA. Under the EIAA, projects are classified into three categories: Category A which requires a full EIA, Category B which requires a partial EIA and Category C which do not require an EIA. For Category A and B projects an Environmental Statement is required when conducting exploration for certain minerals and when certain activities are conducted as part of exploration (ALB, 2015).

The MMA further requires that continuous rehabilitation is conducted from time to time and at the end of operations, which requires the site to ultimately be reclaimed as far as practically possible and to an acceptable degree (ALB, 2015).

5.3.2.3 Summary

The MMA is clear in its aims, being simple, concise and easy to understand with regard to exploration activities. This potentially assists exploration companies in understanding what is required before, during, and after exploration activities.

The same can however not be said of environmental legislation. There is no common objective in the sectorial environmental laws and, also, an absence in coordinated action related to environmental matters (Faure & Du Plessis, 2011:58). Faure and Du Plessis (2011:69) state three potential areas of ineffectiveness in the environmental legislation, viz. the absence of uniformity in standards of environmental management across the various existing legislation, the sporadic nature of existing monitoring instruments, and certain enforcement measures that do not exist in all laws.

Despite the shortcoming of the environmental legislation, the EIAA is unique in that it specifically addresses trans-boundary issues between neighbouring countries.

According to Jefferis (2009:88) Botswana's policy towards the extractive industry is considered to be amongst the best in the world, and has been facilitated through open and transparent mineral licencing.

5.3.3 Tanzania legislation

Mineral exploration in Tanzania is regulated by the Mining Act (14 of 2010) (MA) and has been in place for six years. Regulations made under the MA were published in 2012. Amendments to the MA have been brought about by the Extractive Industries (Transparency and Accountability) Act (16 of 2015) (EITAA). Tanzania's Constitution does not contain any environmental protection provisions (AMLA, 2015c).

5.3.3.1 The Mining Act 14 of 2010

The Tanzania MA is divided into sections relating to specific areas, such as General Principles (Part II: 5 to 18), Administration (Part III: 19 to 22), Mineral Rights relating to Exploration Licence (Part IV, Division A: 28 to 36), Mineral Rights relating to Supplementary provisions (Part IV, Division E: 62 to 72) and others.

No mention is made of environmental obligations relating to exploration activities under the sections applicable to mineral exploration, or to any other legislation applicable to the environment. However, upon surrendering a portion of, or the whole exploration area, it is stated in the MA that upon surrender the licensing authority needs to be satisfied that the land is left "… in a condition which is safe, which accords with good mining practise, and as applicable, conforms to the requirements of the environmental management plan… and environmental management …" (Mining Act, 14 of 2010).

However, a requirement states that the holder of a mineral right under Division A (i.e. a Reconnaissance Licence) of the MA, shall have insurance cover in respect of "… pollution and environmental damage … of which the holder … may be responsible …" (Mining Act, 14 of 2010).

A second requirement is that the Minister may publish regulations relating to "the avoidance of pollution …and the regulation of all matters relating to protection of the environment…" (Mining Act, 14 of 2010).

The EITAA was promulgated in 2015 and although it addresses a number of points, exploration activities, environmental compliance and legal requirements relating to exploration was not amended.

5.3.3.2 The Environmental Management Act 20 of 2004

The principal law applicable to the environment is the Environmental Management Act (20 of 2004) (EMA). Subsidiary legislation is administered by the National Environmental Management Council, which includes various regulations such as the Environmental (Registration of Environmental Experts) Regulation of 2005, the Environmental Impact Assessment and Audit Regulation of 2005, the Environmental Management (Air Quality Standards) Regulations of 2007, the Environmental Management (Soil Quality Standards) Regulations of 2007, the Environmental Management (Water Quality Standards) Regulations of 2007, the Environmental (Solid Waste Management) Regulations of 2009, the Environmental (Hazardous Waste Control and Management) Regulations of 2009, the Environmental regulations - Strategic Assessment and Environmental Management (Fees and Charges).

Faure and Du Plessis (2011:489) however state that environmental legislation is "… broad, segmented and occasionally focuses on a particular sector". The mining industry has its own sectorial policy which deals with prevention and reduction, control and elimination of environmental damage (Faure & Du Plessis, 2011:500).

The Third Schedule of the EMA lists the type of projects that require an EIA, and Point 6 refers to Mining, including quarrying and open-cast extraction, but do not refer to exploration.

According to Steyn and Stevens (2016:60) an Environmental Impact Statement (EIS) and an Environmental Management Plan (EMP) must accompany all mineral rights applications, except those for a Prospecting Licence required for exploration.

5.3.3.3 Summary

The structure of the MA is not dissimilar to that of the Botswana MMA. As with other jurisdictions' legislation, the MA excludes the exploration and production of petroleum. The MA makes it easy for exploration companies to determine what is legally required to conduct exploration activities.

In conclusion, Faure and Du Plessis (2011:517) state that although the framework environmental legislation is enacted, it does not create a balance between economic development and environmental protection, due to a lack of clear and proper mandates. Nor does it prevent the abuse of power and corruption.

5.3.4 Sierra Leone legislation

Mineral legislation in Sierra Leone falls under the Mines and Minerals Act (2009) (MMA). The MMA has been in effect for more than seven years, and no known amendments are planned. The Environmental Protection Act (2000) (EPA) regulates environmental matters. The EPA has been in effect for more than sixteen years, and although it allows for Regulations to be made, none could be found relating to mineral exploration (AMLA, 2015e).

5.3.4.1 The Mines and Minerals Act 12 of 2009

The Mines and Minerals Act (12 of 2009) (MMA) of the Republic of Sierra Leone governs the exploration and mining of minerals. The MMA is subdivided into different parts, covering amongst others Reconnaissance Licences (Part VIII sections 56 - 68), Exploration Licences (Part IX sections 69 - 83) and Protection of the Environment (Part XV sections 131 - 137).

Under Part VIII section 57 (j), the holder of a reconnaissance licence has to provide details of any effects on the environment that are of an adverse nature, as well as an estimate of the financial cost of combating these effects (Sierra Leone, 2009). Part VII section 65 (1) (g) requires the holder of a reconnaissance licence to "… maintain and restore, from any damage resulting from reconnaissance operations, the land subject to the licence to a safe state and in compliance with environmental laws and standards". In Part IX section 70 (j) a holder of an exploration licence "… shall provide details of any significant adverse effects which the carrying out of the programme of exploration operations would be likely to have on the environment … and an estimate of the cost of combating such adverse effects …" (Sierra Leone, 2009).

Part XV of the MMA addresses the protection of the environment. According to the MMA, only small-scale and large-scale mining applications require an EIA and, in the case of a large scale mining application, an EMP is to be submitted along with the licence applications.

The MMA however states that "… every holder of a mineral right shall carry on its operations in a manner that is reasonably practicable in order to minimize, manage and mitigate any environmental impact including but not limited to pollution resulting from such operations." The MMA further states that " … there may be included in a mineral right granted under this Act such conditions relating to- (a) the rehabilitation reinstatement, levelling, regressing, reforesting and contouring of any part of the exploration … area …that may have been damaged or deleteriously affected by exploration or mining operations…" (Sierra Leone, 2009).

5.3.4.2 The Environment Protection Act 2 of 2000

In Sierra Leone environmental matters are regulated by the Environmental Protection Act (2 of 2000) (EPA). In the First Schedule of the EPA, the listed activities that require an EIA are set out. Although the extractive industry is mentioned under this Schedule (mining, quarrying, extraction of sand, gravel, peat, oil and gas), no mention is made of exploration activities (Sierra Leone, 2000).

5.3.4.3 Summary

As observed in other jurisdictions, the Sierra Leone legislation pertaining to the exploration for minerals follows a similar format, in the sense that separate sections are dedicated to different areas and actions. However, the legislation relating to environmental actions and protection is lacking in terms of addressing the specific area of mineral exploration. No efficient tool exists in current legislation to manage environmental impacts of exploration activities.

5.4 **Conclusions**

In reviewing the different countries' mineral and environmental legislation, it is important to note the balancing of interest viz. economic development and environmental protection. These aspects are often opposing each other, instead of complimenting and working together to achieve the same goal.

Countries approach this balancing of interests in different ways, depending on their own unique situation, such as economic dependence on mineral resources, internal policies and citizen demands.

By comparing, for instance, South African mineral legislation to that of Sierra Leone, it can be observed that South African legislation is more focussed on mining and production (of oil and gas) as opposed to exploration. Sierra Leonean legislation places nearly equal emphasis on exploration and mining. This difference could be attributed to the fact that South Africa has a mature minerals segment consisting of various types of mines, where various commodities are being extracted, and beneficiation of raw mineral products occur. Sierra Leone, on the other hand, was ravaged by a decade long civil war that only ended in 2002. Subsequently, the economy had to be rebuilt, and years of disinvestment had to be reversed. Mineral legislation in Sierra Leone is therefore probably geared toward attracting new entrants into the country to establish new business ventures, such as exploration companies.

Reviewing the environmental legislation of the different countries, it appears that environmental matters and protection are addressed at various levels of legislation. South Africa for instance, addresses the environment in its Constitution, in framework environmental and mineral legislation and in sectorial legislation. Botswana, a country that is a major diamond producing country, does not address environmental issues in its Constitution, but has various acts that are segmented to cover different environmental aspects. The same can also be stated with regard to the Tanzanian environmental legislation.

As a result, the environmental requirements to conduct mineral exploration vary dramatically in the legislations of the four countries reviewed. To conduct exploration in South Africa, an Environmental Authorisation, specifically a Basic Assessment is required. In Botswana, a Preliminary Environmental Impact Assessment needs to be submitted, which is then screened to determine if a full EIA, partial EIA or no EIA is required. Tanzania does not require an EIS or EMP to conduct exploration, and in Sierra Leone no EIA is required either. It can thus be argued that, in order to conduct mineral exploration, environmental requirements in certain jurisdictions are not sufficiently detailed to regulate the potential environmental impact of exploration.

The adoption by African governments of new mining and environmental legislation, over the last few decades, are fairly extensive. The aim, however, should be to develop more detailed and comprehensive legal frameworks for the minerals industry in order for foreign direct investments to be promoted and increased, along with the development of a clear legal framework for mining activities and environmental protection.

The positive aspect of these recommended actions would be to provide companies with clarity and certainty relating to the legal framework, but it will also require a more detailed due diligence process from them, before exploration and related activities can be conducted in a particular jurisdiction.

6 CHAPTER 6 - QUESTIONNAIRE AND SITE VISTS

6.1 Introduction

This chapter aims to address the research aims and objectives of the study, as set out in Chapter 1 Section 1.3 and in Table 1-1.

Non-experimental empirical research was utilised to confirm literature-based observations and results, but also to broaden currently available data. The non-experimental empirical research utilised in this study consisted of two components: i) observations of a population by means of a questionnaire and ii) by conducting selected field site visits.

The reasons for utilising non-experimental empirical research are as follows:

- Traditional (or superstition-based) and historical knowledge has been trusted and/or used for too long,
- To assist in integration of research and practise, and
- It is the most appropriate method for this type of research.

Furthermore, the objectives of utilising non-experimental empirical research are as follows:

- To identify and learn from the collective experience of industry role players,
- To confirm and advance theoretical ideas from the literature, and
- To prove relevancy of the theory by conducting real world observations

6.2 Questionnaire

In order to obtain feedback from the mineral exploration industry on the subjects of environmental impact and legal requirements, it was decided to distribute a questionnaire for collecting information and data directly from the industry and related role players.

The aim was to obtain descriptions and assessments of the trends, attitudes and practices of aspects covered by this study, namely whether small cap mineral exploration companies are aware of the impact of their activities on the environment, adhere to environmental requirements and are aware of and adhere to relevant legislation. The questionnaire was to act as baseline for the site visits.

6.2.1 Structure, design and content

The questionnaires were distributed digitally via the internet and electronic mail, and returning data was also collected digitally. The questionnaire consisted of checklists and open-ended questions, thus allowing for quantification of the respondents' behaviour.

Content and design features were limited to the extent necessary for respondents to understand the questions, to stimulate response and to lower measurement error. The questionnaire was designed with input from the North-West University Potchefstroom Campus' Statistical Consultation Services.

The study population comprised small cap mineral exploration companies operating in Africa. The sample comprised willing participants. Small cap mineral exploration companies with multiple projects and/or multiple commodities in different African geographical regions was not excluded. No distinction was made between private, listed or state operated entities. Hydro-carbon (oil and gas) exploration companies would, however, be excluded from the population.

The statistical results were scrutinised by the Statistical Consultation Services of the North West University (Potchefstroom Campus).

The questionnaire was designed to obtain various types of relevant information. The questionnaire consisted of forty eight questions, categorised into four sections: demographic/company related (fourteen questions), exploration related (ten questions), environmental related (fourteen questions) and legal related (nine questions).

Section A of the questionnaire (demographic/company related) investigated company backgrounds, such as activities, size, locations and listings. Section B (exploration related) reviewed exploration activities in terms of staff, budgets, impact of global macro-economy and the influence of environmental and legal issues on exploration. Section C (environmental related) investigated environmental aspects, i.e. staff, plans and policies, impact of exploration activities on the environment and the mitigation thereof. Lastly, Section D (legal related) investigated legal aspects with regard to staff, feedback and review. See Appendix A for the questionnaire sent out to participants.

6.2.2 Results

A total of 29 questionnaires were returned, as well as two responses not related to submitted questionnaires. All returned questionnaires were included in the data. The questionnaire was designed in a manner that did not require respondents to complete all the questions, but rather allowed them to complete only those that were applicable to their respective companies and activities. See Appendix B for the tabulated data obtained from the questionnaires.

The data from the returned questionnaires was captured with the use of Adobe Acrobat 7.0 Professional's "Form Data" function. Data was exported in "Comma Separated Value" format and subsequently tabulated, analysed, prepared and presented with Microsoft Excel 2010 software.

The responses obtained from the questions within the four sections of the questionnaire were interpreted according to six groupings in order to address similar aims and objectives:

- *Group 1*: Was the target population reached with the questionnaire?
- *Group 2*: What is the corporate background of the respondents?
- *Group 3: Aspects relating to the African business of the respondents.*
- *Group 4: What are the spending allocations of the companies in terms of* exploration, environmental and legal activities?
- *Group 5*: What is the staffing situation of the companies in terms of exploration, environmental and legal staff?
- *Group 6*: Aspects relating to the environment.

The results are discussed according to the groups mentioned above, and for each question the responses are tabulated and summarised with an interpretation.

6.2.2.1 Group 1: Was the target population reached with the questionnaire?

Question 1: What is your principle business activity?

Responses	Number	Percentage
Received	29	
Not answered	0	
A (Mineral Exploration)	17	59%
B (Mining)	12	41%
C (Other)	0	0%

Interpretation*:*

The number of respondents that indicated mining (41%) as their primary business activity is comparable to, but less than, the number that indicated mineral exploration (59%) as their primary business activity. However, the possibility exists that the mining respondents also undertake exploration activities on or around their mining leases as part of ongoing resource development. All the responses were thus considered.

Question 2: Which of the following does your company mainly target?

Responses	Number	Percentage
Received	29	
Not answered	0	
A (Solid minerals)	29	100%
B (Oil and gas)	0	0%

Interpretation:

All respondents indicated solid minerals as their target commodity. No respondents indicated that their target commodity is oil and/or gas. All the responses were considered.

Question 5: Describe the size of you company?

Responses	Number	Percentage
Received	29	
Not answered	0	
A (Small/Junior)	18	55%
B (Mid-Tier)	8	28%
C (Major)	5	17%

Interpretation:

The majority of responses were from small/junior sized companies (55%). Responses from mid-tier (28%) and major sized (17%) companies were noticeably less. The ratio of small/junior to mid-tier to major sized companies is approximately 3:2:1. Mid-tier and major sized companies potentially experience and face similar issues. All the responses were considered.

Question 10: Where does your company mainly operate?

Responses	Number	Percentage
Received	29	
Not answered	0	
A (Africa)	26	90%
B (Asia)	2	7%
C (Australia)	0	0%
D (Europe)	0	0%
E (North America)	0	0%
F (South America)	1	3%

Interpretation:

An overwhelming majority of the responses (90%) were from companies operating in Africa. Responses from other regions were negligible - two respondents (7%) from Asia and one respondent (3%) from South America. All responses were considered.

Group 1 interpretation

Although a number of respondents indicated that their principle business activity is mining related, it should be kept in mind that the possibility exists that exploration activities do occur on or around these mining leases. Exploration in these areas could face similar issues as what exploration companies do. Furthermore, the responses from mid-tier and major companies were not disregarded. Finally, the responses indicated that the vast majority operate in Africa, but the respondents from Asia and South America were not disregarded. The conclusion from Group 1 questions is that the target population was reached.

6.2.2.2 Group 2: What is the corporate background of the respondents?

Question 3: Do you target single or multiple commodities?

Responses	**Number**	**Percentage**
Received	29	
Not answered	0	
A (Single)	12	41%
B (Multiple)	17	59%

Interpretation:

Responses received indicate a slight preference by companies to target multiple commodities (59%) as opposed to single commodity (41%). This could indicate a risk reduction strategy by respondents and an opportunistic view on the future economic potential of different commodities. All the responses were considered.

Question 4: Ownership of respondent's companies?

Responses	Number	Percentage
Received	29	
Not answered	0	
A (Owner/Operator)	24	83%
B (Consultancy)	2	7%
C (Contractor)	1	3%
D (Governmental)	1	3%
E (Non-Governmental Organisation)	1	3%
F (Other	0	0%

Interpretation:

The vast majority of the responses (83%) indicated that respondents' companies are Owner/Operator. Respondents from other categories are negligible, with only two respondents (7%) indicating that their companies are consultancies. All the responses were considered.

Question 6: Is your company listed, private or government or state owned enterprise?

Responses	Number	Percentage
Received	29	
Not answered	0	
A (Listed)	16	55%
B (Private)	12	41%
C (Government or State Owned Enterprise)	1	3%

Interpretation:

Respondents are from both listed and private companies, with a preference (55%) for companies to be listed. The number of private companies (41%) could reflect difficulty in obtaining financial support from investors on stock exchanges. All responses were considered.

Question 7: Where is your primary listing?

Responses	Number	Percentage
Received	28	
Not answered	1	
A (Australia ASX/NSX)	6	21%
B (Canada TSX/TSX-V)	5	18%
C (South Africa JSE/AltX)	3	11%
D (UK LSE/AIM)	2	7%
E (USA NYSE/Other)	0	0%
F (Other)	1	4%
G (Not applicable)	11	39%

Interpretation:

Responses indicate that companies are listed mostly in Australia (21%) and Canada (18%), with South Africa (11%) also featuring. This reflects the expectation of companies to list in areas with access to exploration and mining financing, and to investors with an investment strategy aimed at exploration and mining. All the responses were considered.

Question 8: How long has your company been in existence?

Responses	Number	Percentage
Received	29	
Not answered	0	
A (< 2 years)	0	0%
B (2 – 4 years)	7	24%
C (> 4 years)	22	76%

Interpretation:

Respondents overwhelmingly indicated (76%) that their companies were in existence for more than four years. The current economic situation relating to mineral resource companies could possibly deter new entrants from entering the sector, as well as being a reflection of investors not being prepared to back new entrants. All the responses were considered.

Question 9: Is your Head/Operational Office situated in the same country as your primary listing?

Responses	**Number**	**Percentage**
Received	28	
Not answered	1	
A (Yes)	9	32%
B (No)	8	29%
C (Not applicable)	11	39%

Interpretation:

Respondents indicated nearly an equal number of companies (32% vs 29%) whose head office/operational office is situated in the same country as their primary listing. Cost reduction measures by companies could result in downsizing of locations to minimise expenses. All responses were included. Number of respondents who indicated “Not applicable” relate to Question 7 responses.

Group 2 interpretation

The corporate background of the respondents did not highlight any unexpected or anomalous points. Responses were in line with expectations, literature findings and the trend in the mineral exploration industry that is due to the current global macro-economic conditions impacting the mineral resources industry.

6.2.2.3 Group 3: Aspects relating to the African business of the respondents.

Question 11: If you conduct business in Africa, what is the main reason?

Responses	Number	Percentage
Received	29	
Not answered	0	
A (Due to local knowledge)	7	24%
B (Due to mineral potential)	22	76%
C (Due to ease of doing business)	0	0%
D (Due to ease of legal aspects)	0	0%
E (Due to potential value spend per project)	0	0%
F (Other)	0	0%
G (Not applicable)	0	0%

Interpretation:

The majority of the respondents (76%) indicated a preference to operate in Africa due to the mineral potential of the region. This could be related to the number of major deposits that have been discovered on the continent and the possibility that further similar deposits could still be undiscovered. All the responses were considered.

Question 12: Do you operate in more than one country?

Responses	Number	Percentage
Received	29	
Not answered	0	
A (Yes)	21	72%
B (No)	8	28%

Interpretation:

Most of the respondents (72%) indicated that their companies operate in more than one country. This could be attributed to spreading and reducing political risk, or to companies targeting the same commodity in different regions. All responses were included.

Question 13: How long has your company conducted business in Africa?

Responses	Number	Percentage
Received	29	
Not answered	0	
A (< 2 years)	1	3%
B (2 – 4 years)	6	21%
C (> 4 years)	21	72%
D (Not applicable)	1	3%

Interpretation:

A large and significant number of respondents (72%) indicated that their companies have been in operation in Africa for more than four years. This supports the responses from Question 8, and the impact of the global economy on new entrants into the mineral resources sector. All the responses were considered.

Group 3 interpretation

Respondents' input regarding their business activities in Africa did not highlight any unexpected points. Responses were in line with expectations for the study, as respondents indicated that the mineral potential of Africa is still a major reason for doing business in the region. Furthermore, many companies operate in more than one country in Africa, as opposed to those who operate only in a single country. The vast majority of respondents indicated that they have been operating in Africa for more than four years.

6.2.2.4 Group 4: What are the spending allocations of the companies in terms of exploration, environmental and legal activities?

Question 18: When committing funds to exploration projects, how much is spent on exploration activities?

Responses	**Number**	**Percentage**
Received	28	
Not answered	1	
A (< 25%)	6	21%
B (25% - 50%)	7	25%
C (50% - 75%)	8	29%
D (> 75%)	7	25%

Interpretation:

Responses are spread nearly equal between the different categories. However, respondents indicated that most companies (29%) spend between 50% and 75% of funds on exploration activities, followed equally (25%) by companies that spend between 25% and 50% and more than 75%. The lowest number of respondents (21%) indicated that their companies spend less than 25%. The results are a reflection of the fact that companies in the mineral resources industry are spending less money on exploration activities due to the current global macro-economic situation. The impact of increases in operating expenses could also impact the funds available for exploration activities. Furthermore, funds are possibly diverted to activities necessary for the survival of companies in the current economic climate. All the responses were considered.

Question 19: When committing funds to exploration projects, how much is spent on environmental activities?

Responses	**Number**	**Percentage**
Received	28	
Not answered	1	
A (< 5%)	14	50%
B (5% - 10%)	12	43%
C (10% - 20%)	1	4%
D (> 20%)	1	4%

Interpretation:

Respondents indicated that companies spend nearly equally (50% vs 43%) between two categories, i.e. less than 5% and between 5% and 10% of funds on environmental activities. A low number (4%) of respondents indicated spending more than 10% on environmental activities. A number of reasons can lead to low spending, ranging from decreased funds available to conduct environmental activities, potential low importance placed on environmental activities, to non-adherence to environmental requirements. All the responses were considered.

Question 20: When committing funds to exploration projects, how much is spent to ensure legal compliance to environmental requirements?

Responses	**Number**	**Percentage**
Received	28	
Not answered	1	
A (< 5%)	16	57%
B (5% - 10%)	10	36%
C (10% - 20%)	1	4%
D (> 20%)	1	4%

Interpretation:

Most respondents (57%) indicated spending of less than 5% on legal compliance. A number of reasons can lead to low spending, ranging from decreased funds available to conduct environmental activities, potential low importance placed on environmental activities, to non-adherence to environmental requirements. All the responses were considered.

Question 21: To what extend does the macro-global economy impact your exploration activities?

Responses	**Number**	**Percentage**
Received	29	
Not answered	0	
A (Almost no impact)	1	3%
B (Small impact)	3	10%
C (Medium impact)	10	34%
D (Large impact)	15	52%

Interpretation:

The most respondents (52%) indicated that the global macro-economy has a large impact on their exploration activities. This could be due to reduced financing available to companies in the mineral resources industry, and the subsequent low demand from raw material importing countries such as China and India. All the responses were considered.

Question 22: Has your spend on exploration activities in the past four years?

Responses	**Number**	**Percentage**
Received	28	
Not answered	1	
A (Significantly decreased)	17	61%
B (Slightly decreased)	7	25%
C (Remained constant)	0	0%
D (Increased)	4	14%

Interpretation:

The majority of respondents (61%) indicated that spending on exploration activities in the past four years decreased significantly. These responses are reflective of those of Question 21 above, concerning the impact of the global macro-economy on companies that operate in the mineral resources industry. It is noteworthy to observe the number of respondents (14%) that indicated an increase in exploration spending. All the responses were considered.

Question 30: To what extend does the macro-global economy impact your environmental activities?

Responses	**Number**	**Percentage**
Received	29	
Not answered	0	
A (Almost no impact)	14	48%
B (Small impact)	8	28%
C (Medium impact)	2	7%
D (Large impact)	5	17%

Interpretation:

Most respondents (48%) indicated that the global macro-economy has almost no impact on their environmental activities. An explanation can be that environmental activities in general could be of low importance to companies and, consequently, that low importance activities are not affected much. All the responses were considered.

Question 31: Has your spend on environmental activities in the past four years?

Responses	**Number**	**Percentage**
Received	28	
Not answered	1	
A (Significantly decreased)	7	25%
B (Slightly decreased)	5	18%
C (Remained constant)	10	36%
D (Increased)	6	21%

Interpretation:

The most respondents (36%) indicated that spending on environmental activities has remained constant. A large number however indicated that spending has either significantly (25%) or slightly (18%) decreased, as opposed to the number that indicated an increase (21%) in spending. The decrease in spending on environmental activities can be related to companies diverting funds to activities that will ensure the survival of the company. All the responses were considered.

Group 4 interpretation

Responses regarding spending allocations on exploration, environmental and legal activities (relating to environmental compliance) were in line with expected results, as well as with literature findings and the current trend in the mineral resources industry. The spending allocations are a reflection of the current global macro-economic climate in terms of reduced commodity demand from countries such as China and India (but also globally) and the low prices for raw materials. Funds are most probably diverted to activities that will ensure the survival of the company, and away from non-essential activities such as environmental matters.

6.2.2.5 Group 5: What is the staffing situation of the companies in terms of exploration, environmental and legal staff?

Question 15: Do you employ permanent Geological staff?

Responses	**Number**	**Percentage**
Received	29	
Not answered	0	
A (Yes)	20	69%
B (No)	9	31%

Interpretation:

Respondents indicated that the majority of companies (69%) employ geologist(s) on a permanent basis. The number of companies (31%) who do not permanently employ geologists could be due to companies preserving funds in the current difficult economic climate by reducing permanently employed geologists, and employing them only on an ad-hoc basis. All the responses were considered.

Question 16: If not, do you mainly make use of the following?

Responses	**Number**	**Percentage**
Received	16	
Not answered	13	
A (Consultants)	3	19%
B (Contractors)	3	19%
C (Both)	10	63%

Interpretation:

Respondents indicated that a combination of consultants and contractors (63%) are utilised where companies do not employ full-time geologists. These responses are reflective of the responses from Question 15 above. All the responses were considered.

Question 17: Has your Geological staff during the past four years?

Responses	**Number**	**Percentage**
Received	28	
Not answered	1	
A (Increased)	8	29%
B (Decreased)	10	36%
C (Remained constant)	10	36%

Interpretation:

Respondents indicated nearly an equal distribution (29% vs 36% vs 36%) between increase, decrease and constant staffing levels for geologists over the past four years. Results are however biased slightly towards a decrease and constant levels (36%). Companies that managed to stay in business up to this point, have probably already reduced staffing levels to the absolute minimum necessary. The four year time span might be too short to clearly reflect the impact of the current state of the mineral resources industry. All the responses were considered.

Question 25: Do you employ full-time Environmental staff? (Not SHQ)

Responses	**Number**	**Percentage**
Received	29	
Not answered	0	
A (Yes)	8	28%
B (No)	21	72%

Interpretation:

The majority of respondents (72%) indicated that their companies do not employ permanent Environmentalists. A number of reasons for this are possible, such as reduced staff levels due to economic climate, small/junior companies not seeing the requirement or need to employ Environmentalists, or limited funds being available to employ Environmentalists on a permanent basis. All the responses were considered.

Question 26: If not, do you mainly make use of the following?

Responses	**Number**	**Percentage**
Received	23	
Not answered	6	
A (Consultants)	15	65%
B (Contractors)	3	13%
C (Both)	5	22%

Interpretation:

Respondents indicated a preference to utilise environmental consultants (65%) over contractors (13%). This could be attributed to the fact that companies utilise environmentalists on a “come in, do the work, deliver feedback, and go out” short-term basis. This way of operating could possibly be aimed at reducing costs and staffing levels. All the responses were considered.

Question 27: Has your Environmental staff during the past four years?

Responses	Number	Percentage
Received	26	
Not answered	3	
A (Increased)	4	15%
B (Decreased)	7	27%
C (Remained constant)	15	58%

Interpretation:

The majority of respondents (58%) indicated that Environmental staffing levels remained constant over the past four years. The reason can be due to the fact that companies utilise environmental consultants instead of employing their own Environmentalists, as reflected by the responses from Questions 25 and 26 above. All the responses were considered.

Question 40: Do you employ permanent Legal staff?

Responses	Number	Percentage
Received	29	
Not answered	0	
A (Yes)	12	41%
B (No)	17	59%

Interpretation:

Respondents indicated a slight preference (59%) for their companies to not employ permanent Legal staff. Reasons similar to those given for Question 25 could also be the cause. The similar results for “a” and “b” responses are however unexpected. All the responses were considered.

Question 41: If not, do you mainly make use of the following?

Responses	**Number**	**Percentage**
Received	29	
Not answered	11	
A (Consultants)	15	83%
B (Contractors)	2	11%
C (Both)	1	6%

Interpretation:

Respondents indicated a clear preference (83%) for their companies to utilise Legal consultants. These results are not too dissimilar from those of Question 26 and the same reasons could be substantive in this regard. All the responses were considered.

Group 5 interpretation

The feedback received from respondents is within expectations. Reviewing geological, environmental and legal staffing levels, and the use of consultants and contractors within these three disciplines, an insight of the current state of the mineral resources industry is gained. Staffing levels have reduced after 2009 due to the global macro-economic situation facing the mineral resources industry and companies utilise consultants and contractors on an ad hoc basis, to reduce staffing levels and other overhead costs.

6.2.2.6 Group 6: Aspects relating to the environment

Question 23: When planning your exploration programmes, do you involve Environmental staff to highlight potential environmental issues?

Responses	Number	Percentage
Received	27	
Not answered	2	
A (Hardly ever)	8	30%
B (Sometimes)	7	26%
C (Regularly)	6	22%
D (Most of the time)	6	22%

Interpretation:

A near equal response to the different options was observed, with a trend towards less involvement (30%) by Environmental staff. An explanation for this could be that companies do not think it is necessary to involve Environmental staff in planning exploration activities, or due to the fact that respondents indicated that the majority of their companies do not employ permanent Environmentalists, as reflected in the responses to Question 25. All the responses were considered.

Question 28: Does your company have an Environmental Management Plan in place?

Responses	Number	Percentage
Received	29	
Not answered	0	
A (Yes)	23	79%
B (Unsure)	4	14%
C (No)	2	7%

Interpretation:

An overwhelming majority of respondents (79%) indicated that their companies have an Environmental Management Plan in place. This response was expected, as it is often a prerequisite requirement that companies have to adhere to before exploration activities can occur, or before exploration permits are granted. All the responses were considered.

Question 29: How well is your Environmental Management Plan implemented?

Responses	**Number**	**Percentage**
Received	25	
Not answered	4	
A (Poorly)	3	12%
B (Below average)	5	20%
C (Better than average)	10	40%
D (Very well)	7	28%

Interpretation:

The majority of respondents (40%) indicated that their Environmental Management Plan (EMP) is implemented better than average. A number of respondents, however, indicated a poor (12%) or below average (20%) implementation of their EMP. The failure to sufficiently implement EMPs could possibly indicate that not enough emphasis is being placed by companies on the importance of EMPs, or to a lack of understanding or commitment by the responsible staff. All the responses were considered.

Question 33: Do you mitigate the impacts of your exploration activities on the environment?

Responses	**Number**	**Percentage**
Received	28	
Not answered	1	
A (Hardly ever)	3	11%
B (Sometimes)	7	25%
C (Most of the time)	10	36%
D (Nearly always)	8	29%

Interpretation:

Most respondents (36%) indicated that their companies mitigate the impact of environmental activities most of the time. A near equal response from respondents indicated that their companies mitigate the impact sometimes (25%) or nearly always (29%). A few respondents (11%) indicated that they hardly ever mitigate the impacts of exploration activities. Some companies might make deliberate decisions to not mitigate the impacts, as they might be planning to return to sites to conduct follow up or ancillary work. Another explanation could be that site remediation is the responsibility of contractors, such as the cleaning of drill sites by drilling contractors. All the responses were considered.

Question 34: Do you make use of independent consultants that verify your adherence to environmental plans and legal requirements?

Responses	**Number**	**Percentage**
Received	28	
Not answered	1	
A (Hardly ever)	4	14%
B (Sometimes)	13	46%
C (Most of the time)	8	29%
D (Nearly always)	3	11%

Interpretation:

The majority of respondents (46%) indicated that their companies sometimes use independent consultants to verify adherence to environmental and legal requirements. Referring to Questions 25 and 26, the responses are understandable. All the responses were considered.

Question 35: Does your environmental staff conduct regular site visits?

Responses	Number	Percentage
Received	26	
Not answered	3	
A (Annually)	8	31%
B (Quarterly)	6	23%
C (Monthly)	6	23%
D (Weekly)	6	23%

Interpretation:

An anomalous result was received. Respondents' equal responses (23%) in indicating the frequency of environmental staff's site visits (quarterly, monthly and weekly) are unexpected in light of the responses to Questions 25 and 26. The expected result was that the number of responses for weekly and monthly would have been the least, followed by quarterly and annually. This should be seen in relation to the fact that companies indicated a preference to utilise environmental consultants. It is expected that consultants do not spend weeks on end on a site, but rather conduct visits on a regular basis, i.e. a six-monthly or annual basis. No explanation is forthcoming to justify this result. All the responses were considered.

Question 36: Does your environmental staff report to head/operational/site office their findings, observations and recommendations relating to environmental matters?

Responses	Number	Percentage
Received	27	
Not answered	2	
A (Hardly ever)	5	19%
B (Annually)	6	22%
C (Quarterly)	7	26%
D (Monthly)	9	33%

Interpretation:

A slight preference (33%) for monthly reporting is forthcoming from the respondents. The number of respondents that indicated hardly ever (19%) cannot be fully explained when considering Questions 25 and 26. All the responses were considered.

Question 37: Are any alterations implemented to your exploration activities based on environmental findings, observations and recommendations?

Responses	**Number**	**Percentage**
Received	28	
Not answered	1	
A (Hardly ever)	7	15%
B (Sometimes)	13	48%
C (Most of the time)	4	14%
D (Nearly always)	4	14%

Interpretation:

Responses indicate that companies only sometimes (48%) implement adjustments to exploration programmes based on environmental considerations. This could be attributed to the fact that companies regard exploration activities as being more important to their success than the environment. All the responses were considered.

Question 38: Are the environmental requirements applicable to your activities and/or sites sufficient to ensure protection of the environment?

Responses	**Number**	**Percentage**
Received	28	
Not answered	1	
A (Not really)	3	11%
B (Somewhat)	3	11%
C (Mostly)	17	61%
D (Absolutely)	5	18%

Interpretation:

The vast majority of respondents (61%) indicated that they view environmental requirements as being mostly sufficient to protect the environment. The reasoning for this could be that environmental protection has become an important topic in general, but specifically in the mineral resources industry. All the responses were considered.

Question 42: Does your legal staff conduct regular site visits?

Responses	Number	Percentage
Received	23	
Not answered	6	
A (Annually)	15	65%
B (Quarterly)	6	26%
C (Monthly)	2	9%
D (Weekly)	0	0%

Interpretation:

The majority of respondents (65%) indicated that site visits are conducted on an annual basis by legal staff. This result was expected. All the responses were considered.

Question 43: Does your legal staff report to head/operations/site office their findings, observations and recommendations relating to environmental matters?

Responses	Number	Percentage
Received	27	
Not answered	2	
A (Hardly ever)	13	48%
B (Annually)	7	26%
C (Quarterly)	4	15%
D (Monthly)	3	11%

Interpretation:

Respondents indicated that legal staff hardly ever (48%) reported their considerations regarding environmental matters to head/operations/site offices. This could be attributed to the possibility that legal staff does not consider environmental matters as part of their responsibility, and also that site visits by legal staff are only conducted on an annual basis. All the responses were considered.

Question 44: Are any alterations implemented to your exploration activities based on legal findings, observations and recommendations?

Responses	**Number**	**Percentage**
Received	27	
Not answered	2	
A (Hardly ever)	13	48%
B (Sometimes)	6	22%
C (Most of the time)	6	22%
D (Nearly always)	2	7%

Interpretation:

Similar to the responses to Question 37, responses indicate a lesser likelihood of companies adjusting exploration activities based on legal considerations. In this instance however, adjustments due to legal considerations hardly ever (48%) occur. This could be attributed to companies regarding exploration activities as being more important to their success than the environment. All the responses were considered.

Question 45: Is your operational/site staff aware of what environmental legal compliance is required by your exploration activities?

Responses	**Number**	**Percentage**
Received	27	
Not answered	2	
A (Not really)	0	0%
B (To some extent)	6	22%
C (Moderately)	7	26%
D (Nearly always)	14	52%

Interpretation:

Responses indicate that operational/site staff is nearly always (52%) aware of what environmental legal compliance is required. This can be viewed in light of the responses of Question 28 and 29, where respondents indicated that their companies have EMPs and that it is well implemented. All the responses were considered.

Question 46: Are the environmental laws of the country where you operate in, and which are applicable to your activities, clear and unambiguous?

Responses	**Number**	**Percentage**
Received	29	
Not answered	0	
A (Not really)	6	21%
B (To some extent)	5	17%
C (Moderately)	11	38%
D (Largely)	7	24%

Interpretation:

Respondents stated that they view environmental laws as moderately clear (38%) and unambiguous. It can be argued that legal jargon and technical terms make it difficult for people with no legal background to understand the meanings. All the responses were considered.

Question 32: What impact does your exploration activities have on the following environments? (Surface & Ground water, Fauna & Flora and Air & Soil/Land).

	Surface water		**Ground water**	
Responses	Number	Percentage	Number	Percentage
Received	28		28	
Not answered	1		1	
A (Almost no)	14	50%	14	50%
B (Small)	7	25%	9	32%
C (Medium)	6	21%	4	14%
D (Large)	1	4%	1	4%

Interpretation:

Most respondents (50%) indicated that for both surface and ground water, their activities have almost no impact.

	Fauna		**Flora**	
Responses	Number	Percentage	Number	Percentage
Received	28		28	
Not answered	1		1	
A (Almost no)	12	43%	7	25%
B (Small)	12	43%	15	54%
C (Medium)	2	7%	5	18%
D (Large)	2	7%	1	4%

Interpretation:

Respondents indicated that their exploration activities have small (43%) to almost no (43%) impact on fauna and a small (54) impact on flora.

	Air		Soil/land	
Responses	Number	Percentage	Number	Percentage
Received	28		28	
Not answered	1		1	
A (Almost no)	17	61%	3	11%
B (Small)	11	39%	19	68%
C (Medium)	0	0%	4	14%
D (Large)	0	0%	2	7%

Interpretation:

Respondents indicated that their exploration activities have almost no (61%) impact on air and a small impact (68%) on soil/land.

Group 6 interpretation

The responses for Group 6 questions warrant broader interpretations, as it indicates the impact on the environment which is the main focus of this study.

Respondents indicated in Questions 28, 29, 23 and 34 that their companies do have EMPs in place and that these plans are, according to respondents, implemented better than average, but that Environmental staff are less likely to be involved during the planning of exploration programmes, which would allow them the opportunity to highlight potential environmental issues. This is despite respondents indicating that independent consultants sometimes verify companies' adherence to EMPs and legal requirements.

Respondents further indicated in Questions 35, 36 and 37 that, in most cases, Environmental staff conducted site visits on an annual basis and reported their findings on a monthly basis. The environmental reporting on a monthly basis can be related to the fact that most companies produce monthly reports of their activities. This however could mean that so-called environmental reporting does actually not mean in-depth reporting, but only reporting on a broad superficial scale. Alterations to exploration activities, based on environmental concerns, were only sometimes implemented. These responses have to be viewed in light of the responses to Questions 25 and 26 relating to the employment of Environmental staff and the use of consultants.

More concerning responses were received for Questions 42, 43 and 44. In most cases, Legal staff conducted site visits on an annual basis and they hardly ever report environmental matters. Consequently, alterations to exploration activities, based on legal concerns hardly, ever occur.

Responses to questions 33, 38, 45 & 46 indicated that companies mitigate the impact of exploration activities most of the time; environmental requirements are mostly sufficient to protect the environment; operational/site staff is nearly always aware of what environmental compliance is required and, lastly, environmental legislation is moderately clear and unambiguous.

Responses to question 32 a, b and c relate to the perceived impact of exploration activities on various environments, namely surface and ground water, fauna and flora and air and soil/land. The specific responses from respondents can be attributed to impacts that are visually observable only. Those impacts that are not easily visible could have been overlooked, such as sub-surface compaction of soils.

6.2.3 Additional comments from respondents

Two responses unrelated to the questionnaires were received. The respondents' opinions differ significantly, and are quoted below:

- Respondent 1: "Strict environmental legislation has to be adhere (sic) to in all the countries I have worked over the last couple of years such as RSA, Namibia, Tanzania, Burkina Faso, Rwanda and Burundi before exploration licences could be obtained and at least annual environmental reports have to be submitted."
- Respondent 2: "Based on my experience with a range of mining companies, I believe that your research will show that junior exploration and mining companies do in fact disregard a great deal of both common law and statutory law requirements - funding is obviously an issue and funds are channelled into producing samples."

Interpretation: Respondent 1 commented on the environmental legislation that needs to be adhered to before obtaining exploration approvals, as well as the requirement to submit (annual) environmental reports. However, the respondent does not make any comments regarding the impacts of exploration activities on the environment, nor of the rehabilitation of said exploration activities. The adherence of mineral exploration companies to environmental legislation and requirements are paramount to ensure exploration activities are carried out in an environmentally friendly and sustainable manner. Respondent 2 clearly states the opinion that exploration (and mining) companies disregard laws and requirements in their actions, and that funding is applied to aspects that improve a company's chance of proving a successful project through, for example, producing geological samples.

6.2.4 Summary

All the completed questionnaires that were received was included in the final dataset, and used for drawing the conclusions.

Although only 29 completed questionnaires were returned, the current situation in the mineral exploration industry should be considered. This is particularly the case when considering the number of small cap exploration companies, which are currently conducting active exploration in Africa and, in addition, limitations posed due to these companies' willingness to share information. Consequently, the number of respondents can be taken as being sufficient to at least confirm the information obtained from literature reviews and to confirm the current state of the mineral exploration industry.

Although the participants of the questionnaire are, and will remain anonymous, it was completely voluntary and participation depended wholly on potential respondents' willingness to participate. Furthermore, potential respondents might have been reluctant to participate, due to their lack of adherence to legislation. Corporate policy and non-disclosure agreements might also have inhibited participation and subsequent feedback.

6.3 **Site visits**

Site visits were conducted to exploration sites located in three countries in Africa.

6.3.1 Structure and format

Site visits were included in this study to provide an alternate source of information and to also confirm and verify baseline data obtained from the questionnaires. Sites that were visited were located in different countries, not only in order to ensure coverage of different legal requirements, but also that different mineral commodities and different companies were investigated. Three sites were visited. These sites were in:

- Republic of Congo
- South Africa
- Botswana

Site visits consisted of structured interviews with responsible staff and followed by visual inspection and verification of exploration activities, camp activities and other related activities.

6.3.2 Site visit findings and interpretation

To protect the identity of the companies and the location of the sites visited, identifying information is not disclosed. Observations from the site visits are summarised below:

6.3.2.1 Visit to a Congolese potash exploration site

An extended visit was conducted to a potash exploration site in Republic of Congo. The visit spanned a continuous period of three months. Various activities were observed during this period, ranging from drill site clearing, drilling, downhole geophysics; site de-establishment and rehabilitation; camp activities that included delivery of bulk hydrocarbons, transport of dry chemicals, transport and use of a radioactive source and, lastly, removal of refuse and sewage. Various consultants and contractors were on site during this period to conduct different activities.

A wide range of activities were observed during the site visit which ranged from the lining of sumps (Figure 6-1), drill site clearing and drilling (Figure 6-2), access road use and establishment (Figure 6-3) to refuge collection, storage and removal (Figure 6-4).

Figure 6-1: Lining of sumps with plastic sheeting (Booyens, 2015h)

Figure 6-2: Drill site in forest (Booyens, 2015i)

Figure 6-3: Access road to drill site (Booyens, 2015j)

Figure 6-4: Refuge collection site at camp (Booyens, 2015k)

The largest environmental impact of this company's exploration activities is caused by ancillary activities associated with the field camp. Due to the ongoing exploration activities and work requirements, a large number of employees are accommodated in the camp. The camp requires continuous electrification, and consequently the diesel generators are in operation 24 hours every day. Furthermore water is extracted from a water well to provide in the daily requirements. Refuge and sewage that are generated in the camp are collected and removed off site when the storage capacity has been filled. The overall environmental impact of the camp activities is medium to large, while the exploration activities' impacts are small to medium.

Impressions gained and observations made during the extended period on site were that exploration activities were conducted in an environmentally friendly manner. This is despite the fact that the company does not have an environmental department, or a dedicated staff member responsible for environmental matters. Corporate culture, as well as staff members that take on various roles, ensure compliance to the country's legislation and company requirements.

The exploration sites are located within a buffer zone surrounding a prominent national park. A disturbing trend that was noticed is that loggers are using the cleared drill lines in the forest to access difficult terrain to fell trees. These trees are used for creating charcoal and rough timber planks, which are then sold in the larger towns

6.3.2.2 Visit to a South African coal exploration site

A three day site visit of five sites was conducted to a coal exploration site in South Africa. A general introductory meeting was held with all the exploration staff, after which specific interviews were conducted with two of the exploration geologists and the Exploration Superintendent.

The five sites visited were spread over a large geographic area. At two sites active exploration work was in progress, which consisted of core drilling and sampling (Figure 6-5). The remaining three sites were historic drill sites that were in various stages of rehabilitation.

The drill sites were barricaded off, and sumps were excavated to collect return drilling fluids and solids. Proper ablutions were provided for drilling crews at the drill site (Figure 6-6), and chemicals were kept within a spill tray (Figure 6-7). Core samples were placed on core racks next to the drill rig. Access to the drill sites was maintained along established roads and tracks, except where none existed. New access roads were kept to a minimum. The transportation of staff, equipment and material to, and from the drill sites are kept to a minimum.

This company is investigating the use of biodegradable drilling chemicals and portable sumps that can be picked up and placed on the back of a truck. This will enable the sump residue to be dumped in a designated dumping site that has been approved in terms of environmental requirements.

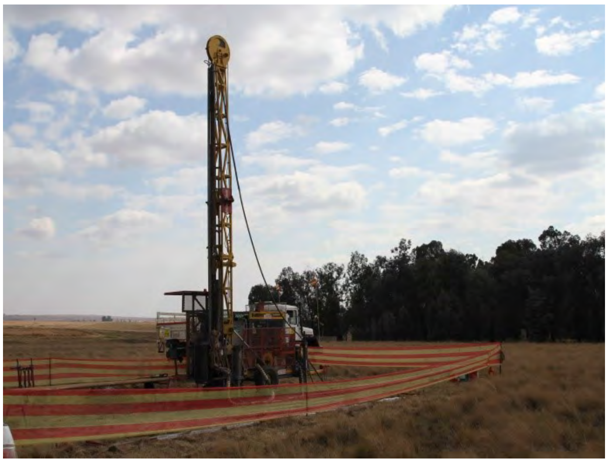

Figure 6-5: Core drill rig at coal exploration site (Booyens, 2016c)

Figure 6-6: Mobile ablution facilities at drill site (Booyens, 2016d)

The visits to the three historic drill sites indicated the three stages of rehabilitation that is followed. The first stage of rehabilitation involves the removal of all drilling equipment and samples and the general cleaning of the site, the second stage involves the levelling of the drill site and removal of all spills and wastes (Figure 6-8). The final stage of rehabilitation involves the ripping of the access road and working area (Figure 6-9) and aerating and seeding or revegetation of the sites. Additionally, brush or bush packing is done over disturbed working areas. Trees, branches and shrubs that were removed prior to exploration activities are placed over disturbed areas to allow pioneer species to establish easily. Before and after photographs were taken of the working area, i.e. before activities commence and again after rehabilitation have been completed and the landowner is required to sign close-out documentation upon completion of all activities.

Figure 6-7: Drilling chemicals in spill tray at drill site (Booyens, 2016e)

Figure 6-8: Drill site after completion of phase two rehabilitation (Booyens, 2016f)

Figure 6-9: Access road to drill site ready for rehabilitation (Booyens, 2016g)

This company's impact on the environment is basically restricted to two aspects, namely site access and drilling activities. In most instances new access roads or tracks have to be created, although existing roads and tracks are used when available. It was observed that employees follow the company's requirements to not leave the designated tracks. Vehicle movement to and from the drill sites are further restricted to the absolute minimum. The impact of drilling activities is reduced by barricading off the drilling area. No activities are allowed outside the drilling areas, and measurements such as the use of spill trays for chemicals, core trays for core samples and chemical ablutions for the drilling crews are utilised. The environmental impact of the exploration activities is considered to be small.

A number of wetlands are located within the areas where exploration drilling occurs. Before any drilling can commence, an Environmental Impact Assessment (EIA) has to be completed, and if any drill sites are within, or closer than 100 metres of a wetland, the drill site has to be moved outside the 100 metre buffer zone.

This company is well funded and staffed, despite ongoing reductions in exploration expenditure and a reduction in staff numbers. Observations made at the drill sites and rehabilitated sites indicate that operations are conducted in an environmentally responsible manner and that proper rehabilitation of disturbed sites occurs.

6.3.2.3 Visit to a Botswana uranium exploration site

A four day site visit was undertaken to an exploration site in Botswana where uranium and coal deposits are present. Site visits and a visit to the field camp were conducted.

Although both coal and uranium deposits occur on this concession, exploration activities target uranium mineralisation. Three areas were visited, these included one of the four bulk sampling pits, an area where closely spaced drilling occurred and a trench that is utilised to dispense excess, reject drill samples and returned laboratory samples.

The bulk sampling pit (Figure 6-10) consists of an access ramp approximately four metres wide and 20 metres long. The bulk sampling pit's surface dimensions are approximately five metres by five metres and it is approximately three metres deep. Uranium mineralisation is visible on the sidewalls on the access trench and pit (Figure 6-11). A low perimeter fence is erected around the pit for access control measures.

Figure 6-10: Bulk sampling pit in background with access ramp in the foreground (Booyens, 2016h)

Figure 6-11: Uranium mineralisation (yellow staining) on sidewalls of sampling pit (Booyens, 2016i)

To enable access to the drill sites, a baseline was opened up with cross cutting drill lines accessing the drill hole locations. The baseline and some of the drill lines are still used for access (Figure 6-12), while other drill lines were left un-rehabilitated and are overgrown (Figure 6-13).

Figure 6-12: Drill line used for access (Booyens, 2016j)

Figure 6-13: Overgrown and un-rehabilitated drill line (Booyens, 2016k)

At the drill sites that were visited, a number of collapsed borehole collars were observed, as well as fine drill chips contaminating the areas around the drill collars (Figure 6-14).

The discard trench is used to dump excess sample material generated from the drilling activities and reject and returned sample material from the analytical laboratories (Figure 6-15 and Figure 6-16). A low perimeter fence consisting of single strands, with an unlocked gate is used for access control to this trench (Figure 6-17).

Figure 6-14: Collapsed drill hole collar in foreground, and contaminated areas clearly visible around borehole collars (Booyens, 2016l)

Figure 6-15: Trench used for discarded samples (Booyens, 2016m)

At the field camp, it was further observed that a large proportion of the drill core is kept and stored unsecured. Core is left exposed to the elements, which resulted in the core weathering and loss of integrity (Figure 6-18). Furthermore, a large number of steel drums are on site, containing returned sample material from the analytical laboratory (Figure 6-19). These drums are supposedly to be discarded in the discard trench.

Figure 6-16: Close up photograph of discarded samples in discard trench (Booyens, 2016n)

Figure 6-17: Fence used as access control at discard trench (Booyens, 2016o)

This company's activities in general impacted the environment more than what was observed at the other two site visits. All the environmental areas (air, surface and ground water, soil/land, fauna and flora) were in some way or the other affected by their activities. Ground compaction, soil erosion, bush clearing, disturbance of surface water and possible contamination of ground water are some of the impacts observed. Furthermore, health dangers to living organisms are created by the careless dumping of plastic bags in the discard trench, as well as by the exposed uranium mineralisation in the sampling pit. Due to confidentiality agreements, the researcher was not allowed to take any measurements to determine the level of radioactivity on the various sites. This company's environmental impact is medium to large, mostly due to the fact that no remediation occurred.

Local inhabitants of the area use the access roads and drill lines to obtain firewood and to reach grazing areas for herds of cattle. This result in degradation of roads and tracks, and deforestation in areas that was previously inaccessible.

Figure 6-18: Exposed core in field camp (Booyens, 2016p)

Figure 6-19: Drums containing returned samples from the analytical laboratory (Booyens, 2016q)

Observations made of this company's activities at the various sites indicate that, in this instance, operations are not conducted in an environmentally responsible manner. Limited rehabilitation of disturbed sites was attempted, as well as attempts to implement access control to potentially harmful sites. Overall, the rehabilitation of this company's sites are not adequate, despite having a Safety, Health, Radiation, Environmental and Community Manager on site and having standard operating procedures in place relating to environmental management and requirements for contractors.

6.3.3 Summary

To enable objective reviews of the activities conducted by small cap exploration companies, site locations were:

- Spread across three different jurisdictions,
- Spread across different commodities and,
- Spread across different companies.

This allowed for observations on how different countries' laws are implemented and adhered to; how exploration activities and their impacts vary depending on the commodity, and how various companies treat and respond to environmental requirements.

Observations made during the visits to the different sites indicated a varying range of activities and the impact of each on the environment. Companies' responses to the impact of the various activities differed and were dependant on a number of issues. Factors observed during the site visits that affect how companies respond to, and ultimately abide by, environmental adherence range from the type of biome (for instance savannah or forest), the type of exploration work conducted (for instance drilling or excavating a trench), the staffing levels of the company, funding available for environmental rehabilitation, demands and requests from land owners and/or occupiers, the visual impact of the activities and how the general public is affected and impacted.

It was evident from the site visits that the three companies had differing views on environmental rehabilitation. In the case of the South African site, the manner in which exploration activities are conducted and how the environment is treated can be attributed to strict environmental legislation, land owner and/or occupier inputs and the corporate social responsibility employed by the company. In the case of the Congo site, the company's actions are driven by corporate culture. Employees have taken ownership of the company's policies and procedures and, despite the fact that no single person is responsible for environmental matters, exploration activities are conducted in a responsible manner within the framework set by the applicable environmental and other legislation. In contrast with the two other companies, the Botswana company clearly falters in environmental rehabilitation of sites affected by exploration. This is despite the fact that the company seems well funded and staffed. Reasons for this could be that the land on which the exploration activities were undertaken is communal land and no single landowner feels obliged to take ownership or responsibility. Also, as mentioned in a previous section of this research, there is no common objective or overriding vision in the environmental legislation of Botswana. This could result in exploration companies not being audited and or assessed for environmental matters.

6.4 **Conclusion**

The current state of the extractive minerals industry should be borne in mind when considering that only 29 completed questionnaires were returned. The impact that the global macro-economy has on the number of active small cap exploration companies in Africa, as well as the fact that some participants or companies might not have been willing to share information – due to corporate policy, non-disclosure requirement, or lack of adherence to legislation and poor environmental track records – could have impacted on the number of returned questionnaires.

Two responses unrelated to the questionnaires were returned that provided divergent views on the subjects of legislation and compliance.

Concerning the site visits, it may be argued that due to similar constraints experienced with the questionnaires, only three companies were willing to allow site visits. Fortunately, the three sites were in different jurisdictions, conducting exploration for different commodities and were run by different companies.

Conclusions drawn from the returned questionnaires confirm that the target population was reached. Furthermore, no unexpected or anomalous issues were highlighted regarding the corporate background of the respondents, nor relating to aspects of the respondents' business in Africa. The spending allocations of respondents' companies were in line with expectations and available literature. Similarly, the staffing situation was as expected and confirms the literature findings.

Conclusions drawn from the responses relating to environmental matters are noteworthy. Although it was indicated that companies have EMPs in place and that these plans are implemented on a scale of better than average, environmental staff are unlikely to be involved during the planning of exploration activities. A further conclusion can be made that the use of independent consultants do not necessarily imply adherence to EMPs. The fact that environmental staff conduct site visits and report their findings and observations, are not reflected in adjustments made to exploration programmes. A concern arises that although legal staff conducts site visits, they hardly ever report on environmental matters. Consequently, as can be expected, hardly any adjustments occur to exploration activities due to legal recommendations. Finally, it can be concluded that due to operational staff that are aware of the necessity to ensure environmental compliance, the impact of exploration activities are often mitigated. This is due to the consequence of sufficient environmental requirements that are moderately clear and unambiguous.

Being aware of the limitations imposed by a very limited number of completed questionnaires and responses, it may still be argued that those received were sufficient to at least confirm the information obtained from the literature reviews. Furthermore, the current state of the mineral exploration industry (as outlined by the literature reviews) are confirmed by the results obtained from the questionnaire and the three site visits.

Although only two responses unrelated to the questionnaires were received and the respondents' opinions differ notably, it can for this very reason be argued that they were made from different perspectives. The first response relates to environmental legislation that needs to be adhered to before receiving exploration approvals, as well as the requirements to submit environmental reports. The second response states that companies disregard legislation and allocate funds to actions that will impact the core business.

Observations made during the visits to the three different sites indicated the use and application of various exploration activities. The impact of each of the activities on the environment was observed, as well as the different mitigating efforts applied to the impact of these activities. Although compaction of the surface was observed at all the sites, no attempt was made to quantify the degree of compaction. Responses to the environmental impacts varied and were dependant on a number of issues, such as the type of biome, the type of exploration activity, staffing levels, funding, land owner and/or occupier demands, visual and social impact.

7 CHAPTER 7 - CONCLUSIONS, FINDINGS AND RECOMMENDATIONS

This concluding chapter will briefly summarise the reviewed literature, followed by a discussion of the findings of the questionnaire and site visits. A reversed fishbone diagram (Figure 7-1) is provided that considers the reviewed literature, the questionnaire and the site visits within the context of the study's problem statement, aims and objectives. The diagram provides a summative illustration of the drivers and inputs that can affect small cap exploration companies' impact on the environment. Some practical implications of the findings and a summative assessment and is provided.

7.1 Summary of literature review

Relevant literature indicated that mineral exploration will continue to be essential for future generations. The steady increase of the global population, along with expanding industrialisation and urbanisation, will continue to drive the need for natural resources and therefore, the rent seeking behaviour of exploration companies.

Small cap mineral exploration companies spend large amounts of capital on exploration, whereas mid-tier and major companies reduced their exploration expenses due to the current global macro-economic conditions. Despite the various risks small cap mineral explorers face, along with the difficulty in raising capital and obtaining the required resources, a review of existing research and literature indicates that small cap explorers will continue to conduct their business across the world and thus in Africa.

Favourable geological settings, ratio of capital spend to the value of discoveries and ease of discovering not only world class deposits, but also deposits that are more easily located and mined, will continue to draw exploration companies to Africa.

Mineral exploration is the action of systematic searching for mineral occurrences, with the aim of determining the qualitative and quantitative characteristics of a mineral occurrence.

During mineral exploration, information is obtained regarding the grade and volume, geometry and depth, chemical composition, as well as the presence of any deleterious constituents of a mineralised occurrence. An increase in the relevant geological information of a mineral occurrence ultimately leads to an increase in confidence. This increase in confidence is reflected in the mineral resource (and ore reserve) categories used in reporting codes, for public reporting of information pertaining to mineral resources and ore reserves.

Research shows that the only method for increasing relevant geological information is to conduct mineral exploration. Within the parameters of this study, mineral exploration is grouped into two categories: direct and indirect mineral exploration techniques. Direct mineral exploration refers to those activities that entail physical measurements, sampling, excavation and drilling. Indirect mineral exploration activities refer to and consist of methods that are in contact with, or close to, the earth's surface and deductions are based on measurements or images. There are also other ancillary activities associated with mineral exploration which are required for successful completion of exploration, such as transport and camp establishment.

It is evident from the research that the various activities undertaken during mineral exploration impact the surrounding environments. Environmental impacts vary in intensity, duration and the degree of mitigation.

Mining and exploration activities are subject to legislation to ensure that decisions are made per sound and proper principles. A review of appropriate literature emphasises the role that legislation plays in determining standards that ensure sustainable use and development, as well as conservation and management of any environment affected by mineral exploration.

Research further indicated that mineral and environmental legislation tends to follow a balancing act between economic development and environmental protection. It is also evident that the selected countries that were reviewed, follows different legislative approaches, which are often dictated by unique situations such as economic dependence, internal policies and citizen demands.

By comparing different jurisdictions to one another, it was observed that certain legislation is more focussed on mining and production, as opposed to exploration, while alternative legislation regard exploration and mining as nearly the same concept. Difference in legislation could be attributed to whether a country has a mature minerals industry, or whether a country has an economy that requires investment in the minerals sector. Mineral legislation in different countries thus fulfil different roles, e.g. for attracting new entrants or regulating a mature sector.

Broader research indicated that environmental matters are addressed at various legislative levels. Some countries address the environment on constitutional level, in framework legislation and in sectorial legislation. Others do not address environmental issues on constitutional level, but rather in various acts. Of the four countries reviewed by this study, it is evident that legislative environmental requirements vary dramatically. It is further apparent that environmental requirements in certain jurisdictions are not sufficient to regulate the potential environmental impact caused by exploration.

Although the adoption of recent mining and environmental legislation by African governments is notably extensive, a more detailed and comprehensive legislation should be applied to the minerals industry to enable the development of clear legal frameworks for mining activities and environmental protection. These frameworks will provide companies with clarity regarding their environmental obligations, even though this will compel them to utilise a more comprehensive and expensive process before exploration activities can be conducted.

Different methods are available to monitor the environmental impacts of mining and exploration activities, including the use of audits and assessments, investigations via site visits by relevant experts, reviews of environmental monitoring reports and documents, and following up on complaints and concerns. However, when monitor programmes are not treated with the importance it deserves, no or little benefit will be gained through their use.

Previous studies that addressed the impact of exploration activities on the environment have either been generalised, or focussed on a specific activity. This study, on the other hand, attempted to indicate the impact of mineral exploration activities on specific environmental areas by means of a qualitative and semi-quantitative approach which made tabulation of potential environmental impacts of mineral exploration activities possible.

A review of the most commonly explored minerals further highlighted potential deleterious constituents and its potential impact on the environment and on the health of living organisms.

7.2 **Summary of findings from the questionnaire and site visits**

The aim of the questionnaires was to confirm the preceding literature-based research and where possible, to further expand on presently available data and derived information. The use of questionnaires and the site visits further provided direct input from industry role players for use in this study.

7.2.1 Questionnaire

The researcher is satisfied that the target population of the survey questionnaire was reached. No unexpected or anomalous issues were forthcoming with regard to the corporate background, aspects of the respondents' business in Africa, and respondents staffing situation. Responses were in line with expectations and research findings from the available literature. The responses from the completed questionnaires are sufficient to confirm the information obtained from the literature review and research.

Conclusions drawn from responses relating to the environment are noteworthy. The responses indicate that exploration companies have EMPs in place and that these plans are implemented on a scale of better than average. However, environmental staff is unlikely to be involved during the planning of exploration activities and the use of independent consultants do not imply adherence to EMPs. Environmental staff conducting site visits and report on findings are not reflected in adjustments made to exploration programmes. A similar trend is noted regarding legal staff conducting site visits. Reporting on environmental issues seldom occurs and hardly any adjustments are made to exploration activities due to legal recommendations. It is also forthcoming from the results that site based exploration staff is aware of environmental necessities, and that the impact of exploration activities is often mitigated, although environmental requirements are only moderately clear and unambiguous.

Two responses, unrelated to the survey questionnaire, were submitted to the researcher. These responses have totally divergent views regarding legislation and compliance.

The first response notes that environmental legislation needs to be adhered to before receiving exploration approvals and it indicates the requirements to submit environmental reports. The second response states that companies disregard legislation, and rather allocate funds to actions that will impact the core business. These differing responses, arguably from differing perspectives, substantiate the initial decision to conduct this study.

7.2.2 Site visits

Site visits to exploration sites in different jurisdictions, exploring for different commodities and operated by different companies were undertaken as part of the research.

The site visits allowed the researcher to observe the use and application of exploration activities in different settings. Observations further indicated the environmental impact of activities, as well as the efforts applied by the various companies to mitigate the impact of these activities. Applied mitigating measures were varied and dependant on several factors.

The current state of the mineral exploration industry was confirmed by the results obtained from the survey questionnaire and the site visits.

7.3 **Reversed Fishbone Diagram**

Referring to this study's problem statement, aims and objectives, a reversed fishbone diagram (Figure 7-1) illustrates the various drivers and inputs that can affect small cap mineral exploration companies' impact on the environment. The complexity of these inputs were highlighted in the literature reviews and from the results obtained from the questionnaires and the findings and observations from the site visits. From the diagram, it is evident that numerous factors can influence a company's behaviour towards environmental impacts and mitigation, either directly (internal factors such as training of staff and implementation of EMPs) or indirectly (external factors such as legislative environment and geological settings). A company can only address those factors that are of an internal origin; factors originating externally are beyond a company's control.

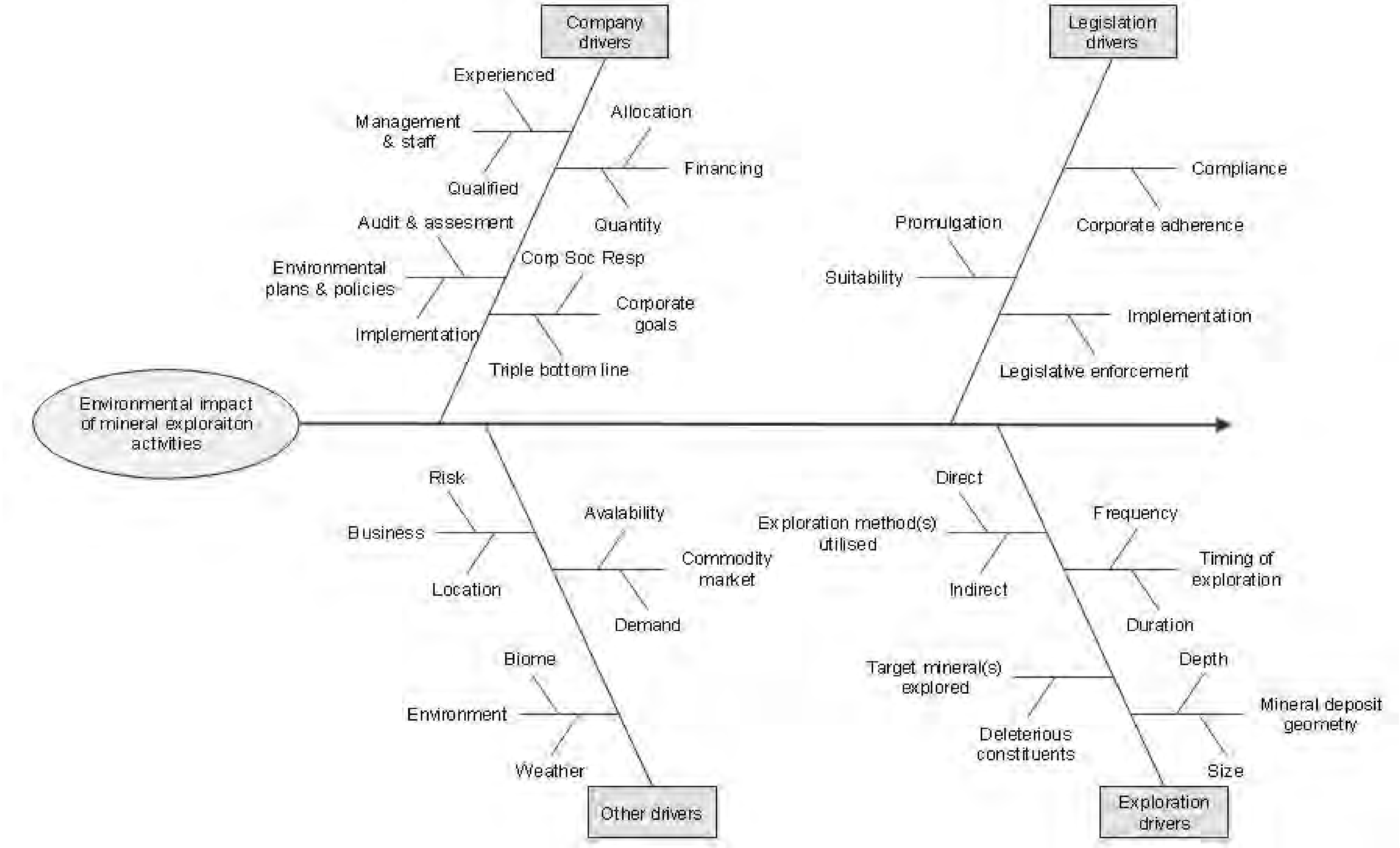

Figure 7-1: Reversed fishbone diagram indicating drivers and inputs affecting small cap mineral exploration companies' impact on the environment.

7.4 **Practical implications of findings**

Based on the literature reviews, the outcomes of the questionnaires and the findings from the site visits, it is evident that different views exist regarding the potential impact caused by solid mineral exploration activities on the environment. Responses from the questionnaires and observations made during the site visits further indicate that companies' perception of, and response to, environmental impacts vary. No clear opinion exists as to the impact, if any; that exploration activities have on the environment.

The differing opinions forthcoming from the research further justify the initial decision to conduct this study.

7.4.1 Value of the research

The research findings of this study can assist and add value to the following three spheres concerning the mineral exploration industry:

Governments (including national, provincial and local government departments such as Mineral Resources, Environmental Affairs, Water and Justice)

- For Government departments and institutions, this study provides an overview of the exploration activities and techniques employed by exploration companies in the search for minerals. Furthermore the potential environmental impact caused by each of these activities can be gauged upfront, identified and appropriate environmental management actions implemented.

Small cap mineral exploration companies (including exploration, environmental and legal staff, company directors and management and shareholders).

- Small cap mineral exploration companies can benefit by becoming aware of the varied legislation in place across Africa, as well as the importance placed on exploration by different countries and the various environmental legislation requirements. Possible short comings in corporate structures, such as staffing, finance and policies and procedures can be addressed before exploration activities commence.

Interested and affected parties (IAPs) (including land owners/occupiers and local communities)

- IAPs can obtain an objective view of how exploration activities could potentially impact their lives and land use. The explanations of the various exploration activities could assist IAPs to understand the actions of exploration companies, and also the rationale behind their actions. Furthermore IAPs can become aware of the potential harmful impact caused by exploring for specific minerals.

The research has extended the limited available literature on this subject by combining a multi-disciplinary approach to solid mineral exploration, legal requirements and environmental impact into a single study. Furthermore, these findings can aid research into any combination of the three disciplines mentioned above, by highlighting and identifying overlaps and impacts of one or more disciplines on any of the other disciplines. The impact of one discipline on the others needs to be understood and quantified to aid future progression of each discipline and their interaction.

7.5 **Final conclusions**

The Africa Mining Vision, established in 2009 by African Union Heads of State, aims to better integrate mining into developmental policies at the local, national and regional levels (AMV, 2009a). A key challenge is to "… create and sustain mineral wealth without compromising environmental, social and cultural consideration, and ensuring a regulatory framework that encourages mineral creation …" (AMV, 2009b:24).

The preceding paragraph raises important issues regarding i) creating mineral wealth ii) without compromising the environment and iii) ensuring a regulatory framework that encourages mineral wealth creation. Merely conducting activities in an environmentally sustainable manner is no longer adequate. Overall performance needs to incorporate a broader range of measurables, such as those applied to the triple bottom line concept, i.e. environmental quality, economic prosperity, and social capital and equity (Slaper & Hall, 2011:7-8).

This study found that:

- Opinions regarding environmental impacts vary and differ amongst questionnaire respondents;
- Observations made during the site visits indicate that practices vary from site to site, based on various factors such as regional legislation and company situation;
- Companies view and acknowledge environmental matters as important, but do not necessarily take appropriate action to mitigate the effects and impacts of their actions.
- Exploration activities do affect the environment, but can be conducted in such a manner as to minimize its impact and the duration of the impact.

It is therefore crucial to emphasise the importance of potential impacts of exploration activities to all role players and to further enhance their understanding of the shortcomings in their respective domains of legislation and company management.

7.6 **Recommendations for future studies**

The following recommendations for future studies should be considered and conducted:

- In-depth literature study of mineral and environmental legislation, specifically aimed at exploration activities.
- In-depth case studies to review the impact of mineral exploration activities on the environment.
- A survey of governments and interested and affected parties on the potential impacts of exploration activities.
- Determine and review the impact of exploration activities on social-economic and social-ecological systems.
- In-depth study of small cap exploration companies in other geographical areas, i.e. Canada, Australia and South America, and compare with companies operating in Africa.

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ANNEXURES

APPENDIX A: QUESTIONNAIRE

QUESTIONNAIRE

This questionnaire forms part of an MSc in Environmental Sciences, entitled "The environmental impact of small cap mineral exploration companies: A review of African activities and legislation." The title is registered under the Research Unit for Environmental Sciences and Management, School of Geo- and Spatial Sciences of the North-West University, Potchefstroom Campus, in South Africa.

The Supervisor and Co-supervisor for this study is Ms. D.M. van Tonder and Mr. P.W. van Deventer from the North-West University and the Assistant Supervisor is Dr. J.C. Loock (University of the Free State, retired).

The questionnaire has four sections and a total of 48 questions. Section A addresses Demographic information, Section B Exploration Information, Section C Environmental Information and Section D Legal information. It should not take more than 10 minutes to complete the questionnaire.

Information such as names of respondents, company names, locations etc. will under no circumstances be published in the Dissertation or any other place, nor will such information be provided to any other party, in any format, whatsoever.

If you have any additional comments or queries, please feel free to contact me directly at michael.booyens@gmail.com

Thank you for taking the time to complete the questionnaire, it will add valuable insight into the current state of the industry.

Michael Booyens

Pr Sci Nat (40047/05)

MGSSA

- **Please read each question carefully, and select the answer that is most applicable to, or the closest to the actual current situation of your company.**
- **Some questions only allow for a single answer, while others allow multiple answers.**
- **Where applicable, space is available to enter additional comments.**
- **When completed, please click on the "Submit" button at the end of the questionnaire.**

Section A: Demographic information

1. What is your principle business activity?
   a. Mineral Exploration
   b. Mining
   c. Other
2. Which of the following does your company mainly target?
   a. Solid minerals
   b. Oil and gas
3. Do you target single or multiple commodities?
   a. Single
   b. Multiple
4. Is your company?
   a. Owner/Operator
   b. Consultancy
   c. Contractor
   d. Governmental
   e. Non-Governmental Organisation
   f. Other
5. Describe the size of you company? (Small/junior = no operating sites)
   a. Small/Junior
   b. Mid-Tier
   c. Major
6. Is your company?
   a. Listed
   b. Private
   c. Government or State Owned Enterprise
7. Where is your primary listing?
   a. Australia (ASX/NSX)
   b. Canada (TSX/TSX-V)
   c. South Africa (JSE/AltX)
   d. UK (LSE/AIM)
   e. USA (NYSE/Other)
   f. Other
   g. Not applicable
8. How long have your company been in existance?
   a. < 2 year
   b. 2 - 4 years
   c. > 4 years

9. Is your Head/Operational Office situated in the same country as your primary listing?

   a. Yes

   b. No

   c. Not applicable

10. Where does your company mainly operate?

    a. Africa

    b. Asia

    c. Australia

    d. Europe

    e. North America

    f. South America

11. If you conduct business in Africa, what is the main reason?

    a. Due to local knowledge

    b. Due to mineral potential

    c. Due to ease of doing business

    d. Due to ease of legal aspects

    e. Due to potential value spend per project

    f. Other

    g. Not applicable

12. Do you operate in more than one country?

    a. Yes

    b. No

13. How long have your company conducted business in Africa?

    a. < 2 year

    b. 2 - 4 years

    c. > 4 years

    d. Not applicable

14. Any additional comments pertaining to demographics?

Section B: Exploration information

15. Do you employ full time Geological staff?

    a. Yes

    b. No

16. If not, do you mainly make use of the following?

    a. Consultants

    b. Contractors

    c. Both

17. Have your Geological staff during the past 4 years?

    a. Increased

    b. Decreased

    c. Remained constant

18. When committing funds to exploration projects, how much is spent on exploration activities?

    a. < 25%

    b. 25% - 50%

    c. 50% - 75%

    d. > 75%

19. When committing funds to exploration projects, how much is spent on environmental activities?

    a. < 5%

    b. 5% - 10%

    c. 10% - 20%

    d. > 20%

20. When committing funds to exploration projects, how much is spent to ensure legal compliance to environmental requirements?

    a. < 5%

    b. 5% - 10%

    c. 10% - 20%

    d. > 20%

21. To what extend does the macro-global economy impact your exploration activities?

    a. Almost no impact

    b. Small impact

    c. Medium impact

    d. Large impact

22. Has your spend on exploration activities in the past 4 years?

    a. Significantly decreased

    b. Slightly decreased

    c. Remained constant

    d. Increased

23. When planning your exploration programmes, do you involve Environmental staff to highlight potential environmental issues?

    a. Hardy ever

    b. Sometimes

    c. Regularly

    d. Most of the time

24. Any additional comments pertaining to exploration?

Section C: Environmental information

25. Do you employ full time Environmental staff? (not SHEQ)

    a. Yes

    b. No

26. If not, do you mainly make use of the following?

    a. Consultants

    b. Contractors

    c. Both

27. Have your Environmental staff during the past 4 years?
    a. Increased
    b. Decreased
    c. Remained constant
28. Does your company have an Environmental Management Plan in place?
    a. Yes
    b. Unsure
    c. No
29. How well is your Environmental Management Plan implemented?
    a. Poorly
    b. Below average
    c. Better than average
    d. Very well
30. To what extend does the macro-global economy impact your environmental activities?
    a. Almost no impact
    b. Small impact
    c. Medium impact
    d. Large impact
31. Has your spend on environmental activities in the past 4 years?
    a. Significantly decreased
    b. Slightly decreased
    c. Remained constant
    d. Increased
32. What impact does your exploration activities have on the following environments? (please make selection for each line a to f).

	Almost no	Small	Medium	Large
a. Air				
b. Surface water				
c. Ground water				
d. Soil/Land				
e. Fauna				
f. Flora				

33. Do you mitigate the impacts of your exploration activities on the environment?
    a. Hardly ever
    b. Sometimes
    c. Most of the time
    d. Nearly always
34. Do make use of independent consultants that verify your adherence to environmental plans and legal requirements?
    a. Hardly ever
    b. Sometimes
    c. Most of the time
    d. Nearly always

35. Does your environmental staff conduct regular site visits?

    a. Annually

    b. Quarterly

    c. Monthly

    d. Weekly

36. Does your environmental staff report to head/operational/site office their findings, observations and recommendations relating to environmental matters?

    a. Hardly ever

    b. Annually

    c. Quarterly

    d. Monthly

37. Are any alterations implemented to your exploration activities based on environmental findings, observations and recommendations?

    a. Hardly ever

    b. Sometimes

    c. Most of the time

    d. Nearly always

38. Are the environmental requirements applicable to your activities and/or sites sufficient to ensure protection of the environment?

    a. Not really

    b. Somewhat

    c. Mostly

    d. Absolutely

39. Any additional comments pertaining to environment?

Section D: Legal information

40. Do you employ full time Legal staff?

    a. Yes

    b. No

41. If not, do you mainly make use of the following?

    a. Consultants

    b. Contractors

    c. Both

42. Does your legal staff conduct regular site visits?

    a. Annually

    b. Quarterly

    c. Monthly

    d. Weekly

43. Does your legal staff report to head/operations/site office their findings, observations and recommendations relating to environmental matters? Annually, quarterly, monthly

    a. Hardly ever

    b. Annually

    c. Quarterly

    d. Monthly

44. Are any alterations implemented to your exploration activities based on legal findings, observations and recommendations?

   a. Hardly ever
   b. Sometimes
   c. Most of the time
   d. Nearly always

45. Is your operational/site staff aware of what environmental legal compliance is required by your exploration activities?

   a. Not really
   b. To some extent
   c. Moderately
   d. Nearly always

46. Are the environmental laws of the country where you operate in, and which are applicable to your activities, clear and unambiguous?

   a. Not really
   b. To some extent
   c. Moderately
   d. Largely

47. Any additional comments pertaining to legal?

48. Any general or specific closing comments, observations or questions?

Submit **Reset Form**

APPENDIX B: QUESTIONNAIRE DATA

	Question	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16
	Questionnaire Section	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B
	Answer Group	1	1	2	2	1	2	2	2	2	1	3	3	3	5	5
1	Completed questionnaire Dzingi.pdf	1a	2a	3b	4a	5a	6b	7g	8c	9c	10a	11a	12a	13b	a	a
2	Questionnaire final Ian Hunt.pdf	1b	2a	3b	4b	5a	6b	7g	8b	9c	10a	11a	12a	13b	b	b
3	Questionnaire final acap.pdf	1a	2a	3a	4a	5a	6a	7a	8c	9b	10a	11b	12b	13c	a	Off
4	Questionnaire final de decker.pdf	1a	2a	3a	4a	5b	6b	7g	8c	9c	10a	11a	12a	13c	a	c
5	Questionnaire final geo.pdf	1a	2a	3b	4a	5a	6b	7g	8c	9a	10a	11b	12b	13c	a	a
6	Questionnaire final hanekom.pdf	1b	2a	3b	4a	5b	6a	7b	8c	9b	10a	11b	12a	13c	a	c
7	Questionnaire final jjvr.pdf	1a	2a	3b	4e	5a	6a	7a	8c	9b	10a	11b	12a	13c	a	c
8	Questionnaire final js.pdf	1a	2a	3b	4a	5a	6a	7a	8c	9a	10a	11b	12a	13a	b	b
9	Questionnaire final kb.pdf	1a	2a	3b	4c	5a	6b	7g	8c	9a	10a	11a	12a	13c	b	c
10	Questionnaire final krogh.pdf	1b	2a	3a	4a	5c	6a	7d	8b	9b	10b	11b	12a	13c	a	Off
11	Questionnaire final loretti.pdf	1b	2a	3a	4a	5b	6a	7c	8c	9a	10a	11b	12a	13c	a	c
12	Questionnaire final malf.pdf	1a	2a	3a	4a	5a	6b	7g	8b	9b	10a	11b	12b	13b	b	c
13	Questionnaire final mb.pdf	1a	2a	3b	4a	5a	6a	7a	8b	9c	10a	11b	12a	13b	b	b
14	Questionnaire final morule.pdf	1b	2a	3a	4a	5b	6a	7c	8c	9a	10a	11b	12b	13c	a	c
15	Questionnaire final moses.pdf	1a	2a	3b	4a	5b	6b	7g	8c	9c	10a	11b	12a	13c	a	Off
16	Questionnaire final obiora.pdf	1b	2a	3b	4a	5a	6b	7g	8b	9c	10a	11a	12a	13b	b	a
17	Questionnaire final pratas.pdf	1a	2a	3a	4a	5c	6a	7b	8c	9a	10a	11b	12a	13c	a	Off
18	Questionnaire final schmidt.pdf	1b	2a	3b	4a	5b	6b	7g	8c	9c	10a	11b	12a	13c	a	Off
19	Questionnaire final submitted vellies.pdf	1a	2a	3b	4b	5a	6b	7g	8c	9c	10a	11a	12a	13c	b	c
20	Questionnaire final swanepoel.pdf	1a	2a	3a	4a	5a	6a	7a	8c	9b	10a	11b	12b	13c	a	Off
21	Questionnaire final tpucheu.pdf	1a	2a	3b	4a	5a	6b	7g	8b	9c	10a	11b	12a	13c	a	Off
22	Questionnaire final wheeler.pdf	1a	2a	3a	4a	5a	6a	7a	8c	9b	10a	11b	12b	13c	b	c
23	Questionnaire final-ales2.pdf	1a	2a	3b	4a	5a	6b	Off	8c	Off	10a	11a	12b	13d	a	Off
24	Questionnaire final_Graham.pdf	1b	2a	3b	4a	5b	6a	7b	8c	9a	10f	11b	12a	13c	a	Off
25	Questionnaire final_sb.pdf	1b	2a	3a	4a	5b	6a	7b	8c	9b	10a	11b	12a	13c	a	Off
26	Questionnaire final_svd.pdf	1a	2a	3a	4a	5a	6a	7b	8c	9c	10a	11b	12a	13c	a	Off
27	Questionnaire frikkie.pdf	1b	2a	3a	4a	5c	6a	7d	8c	9a	10a	11b	12a	13c	a	Off
28	Questionnaire%20final antwi.pdf	1b	2a	3b	4d	5c	6c	7f	8c	9c	10b	11b	12a	13c	b	c
29	Questionnaire%20final lindeque.pdf	1b	2a	3b	4a	5c	6a	7c	8b	9a	10a	11b	12b	13b	a	Off

Check	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29
Total	29	29	29	29	29	29	28	29	28	29	29	29	29	29	16
Off	0	0	0	0	0	0	1	0	1	0	0	0	0	0	13
a	17	29	12	24	16	16	6	0	9	26	7	21	1	20	3
b	12	0	17	2	8	12	5	7	8	2	22	8	6	9	3
c	0			1	5	1	3	22	11	0	0		21		10
d				1			2			0	0		1		
e				1			0			0	0				
f				0			1			1	0				
g							11				0				

Off	0%	0%	0%	0%	0%	0%	4%	0%	4%	0%	0%	0%	0%	0%	81%
a	59%	100%	41%	83%	55%	55%	21%	0%	32%	90%	24%	72%	3%	69%	19%
b	41%	0%	59%	7%	28%	41%	18%	24%	29%	7%	76%	28%	21%	31%	19%
c	0%			3%	17%	3%	11%	76%	39%	0%	0%		72%		63%
d				3%			7%			0%	0%		3%		
e				3%			0%			0%	0%				
f				0%			4%			3%	0%				
g							39%				0%				

		17	18	19	20	21	22	23	25	26	27	28	29	30	31	32a	32b
	Question	17	18	19	20	21	22	23	25	26	27	28	29	30	31	32a	32b
	Questionnaire Section	B	B	B	B	B	B	B	C	C	C	C	C	C	C	C	C
	Answer Group	5	4	4	4	4	4	6	5	5	5	6	6	4	4	6	6
1	Completed questionnaire Dzingi.pdf	c	d	a	a	c	a	c	b	a	c	a	c	b	d	a2	b1
2	Questionnaire final Ian Hunt.pdf	a	a	a	a	d	a	d	b	b	a	a	c	b	c	a1	b2
3	Questionnaire final acap.pdf	b	c	a	a	d	a	c	b	a	Off	a	c	a	c	a1	b1
4	Questionnaire final de decker.pdf	a	c	b	a	c	a	a	b	c	c	a	c	a	d	a2	b3
5	Questionnaire final geo.pdf	b	c	a	a	b	a	a	b	c	b	a	a	b	b	a2	b3
6	Questionnaire final hanekom.pdf	a	a	b	b	d	b	d	a	Off	c	a	c	b	c	a2	b2
7	Questionnaire final jjvr.pdf	a	d	b	b	d	a	b	b	a	b	b	b	d	a	a1	b1
8	Questionnaire final js.pdf	c	c	a	a	c	b	b	b	a	c	a	c	a	c	a1	b1
9	Questionnaire final kb.pdf	b	b	c	b	d	a	c	b	c	c	a	c	a	a	a1	b3
10	Questionnaire final krogh.pdf	c	a	a	a	d	a	a	a	Off	b	b	a	a	a	a1	b1
11	Questionnaire final loretti.pdf	b	a	a	d	d	a	a	a	a	b	c	b	d	a	a1	b1
12	Questionnaire final malf.pdf	Off	Off	Off	Off	c	Off	Off	b	a	Off	a	Off	c	Off	Off	Off
13	Questionnaire final mb.pdf	a	b	a	a	c	d	a	b	a	c	c	Off	a	c	a2	b2
14	Questionnaire final morule.pdf	a	a	b	b	b	a	d	b	a	c	a	d	a	d	a2	b2
15	Questionnaire final moses.pdf	c	b	b	a	d	a	b	b	a	c	b	a	b	a	a2	b2
16	Questionnaire final obiora.pdf	c	b	b	b	b	d	a	b	a	c	a	b	a	c	a1	b3
17	Questionnaire final pratas.pdf	c	c	b	a	d	a	b	b	b	c	a	c	a	b	a2	b1
18	Questionnaire final schmidt.pdf	c	b	b	b	d	a	c	b	a	a	a	d	a	c	a1	b3
19	Questionnaire final submitted vellies.pdf	c	d	a	a	d	b	b	b	a	c	a	d	d	c	a1	b1
20	Questionnaire final swanepoel.pdf	b	c	a	a	c	a	d	b	b	c	a	c	a	c	a1	b2
21	Questionnaire final tpucheu.pdf	b	d	a	a	d	d	b	b	a	c	b	Off	b	c	a1	b1
22	Questionnaire final wheeler.pdf	b	d	b	b	d	a	d	b	c	b	a	d	d	a	a1	b1
23	Questionnaire final-ales2.pdf	b	d	a	a	d	a	Off	a	Off	b	a	d	d	a	a1	b1
24	Questionnaire final_Graham.pdf	b	b	b	b	c	b	c	a	Off	a	a	c	a	d	a1	b1
25	Questionnaire final_sb.pdf	a	c	b	b	c	b	c	a	Off	a	a	Off	b	b	a1	b2
26	Questionnaire final_svd.pdf	c	b	b	b	c	b	a	b	a	c	a	b	a	b	a2	b3
27	Questionnaire frikkie.pdf	b	d	a	a	d	a	a	a	a	b	a	b	b	b	a1	b1
28	Questionnaire%20final antwi.pdf	a	c	d	c	a	d	d	b	c	Off	a	d	a	d	a2	b1
29	Questionnaire%20final lindeque.pdf	c	a	a	a	c	b	b	a	Off	c	a	d	c	d	a2	b4

	17	18	19	20	21	22	23	25	26	27	28	29	30	31	32a	32b
Check	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29
Total	28	28	28	28	29	28	27	29	23	26	29	25	29	28	28	28
Off	1	1	1	1	0	1	2	0	6	3	0	4	0	1	1	1
a	8	6	14	16	1	17	8	8	15	4	23	3	14	7	17	14
b	10	7	12	10	3	7	7	21	3	7	4	5	8	5	11	7
c	10	8	1	1	10	0	6		5	15	2	10	2	10	0	6
d		7	1	1	15	4	6					7	5	6	0	1
e																
f																
g																

	17	18	19	20	21	22	23	25	26	27	28	29	30	31	32a	32b
Off	4%	4%	4%	4%	0%	4%	7%	0%	26%	12%	0%	16%	0%	4%	4%	4%
a	29%	21%	50%	57%	3%	61%	30%	28%	65%	15%	79%	12%	48%	25%	61%	50%
b	36%	25%	43%	36%	10%	25%	26%	72%	13%	27%	14%	20%	28%	18%	39%	25%
c	36%	29%	4%	4%	34%	0%	22%		22%	58%	7%	40%	7%	36%	0%	21%
d		25%	4%	4%	52%	14%	22%					28%	17%	21%	0%	4%
e																
f																
g																

	Question	32c	32d	32e	32f	33	34	35	36	37	38	40	41	42	43	44	45	46
	Questionnaire Section	C	C	C	C	C	C	C	C	C	C	D	D	D	D	D	D	D
	Answer Group	6	6	6	6	6	6	6	6	6	6	5	5	6	6	6	6	6
1	Completed questionnaire Dzingi.pdf	c1	d2	e1	f1	d	b	b	c	b	c	b	a	a	a	a	45d	d
2	Questionnaire final Ian Hunt.pdf	c3	d1	e1	f1	c	b	a	b	b	c	b	b	a	b	b	45c	d
3	Questionnaire final acap.pdf	c1	d2	e1	f2	c	a	c	d	a	c	b	a	Off	Off	Off	45c	c
4	Questionnaire final de decker.pdf	c1	d4	e2	f1	a	c	a	b	b	c	a	Off	a	b	b	45d	d
5	Questionnaire final geo.pdf	c3	d3	e2	f3	b	b	a	b	a	b	b	a	a	a	a	45b	c
6	Questionnaire final hanekom.pdf	c2	d2	e3	f3	c	c	a	c	b	c	b	a	a	b	a	45b	a
7	Questionnaire final jjvr.pdf	c2	d2	e1	f2	b	b	a	b	b	c	b	a	a	a	b	45b	c
8	Questionnaire final js.pdf	c1	d2	e1	f2	c	c	b	c	c	d	b	a	a	b	c	45d	c
9	Questionnaire final kb.pdf	c2	d3	e4	f3	d	b	Off	a	b	c	b	a	Off	a	a	45d	b
10	Questionnaire final krogh.pdf	c1	d2	e2	f2	a	a	c	a	a	a	a	Off	b	a	b	45c	b
11	Questionnaire final loretti.pdf	c1	d2	e2	f2	b	b	b	c	a	c	a	Off	a	b	a	45d	c
12	Questionnaire final malf.pdf	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	b	a	Off	Off	Off	Off	d
13	Questionnaire final mb.pdf	c2	d3	e2	f3	b	a	a	a	b	b	b	a	a	a	a	45b	a
14	Questionnaire final morule.pdf	c2	d2	e2	f2	d	d	c	d	b	a	a	Off	c	c	c	45d	d
15	Questionnaire final moses.pdf	c2	d3	e2	f2	b	b	Off	Off	a	b	b	a	Off	a	a	45b	a
16	Questionnaire final obiora.pdf	c1	d2	e1	f2	c	b	b	b	a	c	b	b	b	a	a	45c	b
17	Questionnaire final pratas.pdf	c2	d2	e1	f1	c	a	b	d	d	c	a	Off	b	d	c	45d	c
18	Questionnaire final schmidt.pdf	c3	d2	e2	f2	c	c	d	d	c	c	a	Off	b	c	b	45b	c
19	Questionnaire final submitted vellies.pdf	c1	d2	e1	f2	a	b	a	b	b	d	b	a	a	b	b	45d	a
20	Questionnaire final swanepoel.pdf	c2	d2	e3	f3	b	c	b	c	c	c	a	a	a	a	a	45c	a
21	Questionnaire final tpucheu.pdf	c1	d1	e1	f1	c	b	d	d	a	a	b	a	a	a	a	45c	b
22	Questionnaire final wheeler.pdf	c1	d2	e2	f2	d	d	d	d	d	d	b	c	a	b	d	45d	d
23	Questionnaire final-ales2.pdf	c2	d1	e1	f1	d	b	c	a	b	d	b	a	Off	a	a	Off	d
24	Questionnaire final_Graham.pdf	c1	d2	e1	f1	d	b	d	d	d	d	a	Off	a	c	d	45d	c
25	Questionnaire final_sb.pdf	c1	d2	e2	f2	c	c	c	c	b	c	a	Off	b	c	c	45d	a
26	Questionnaire final_svd.pdf	c3	d2	e2	f2	b	c	c	c	b	c	b	a	a	a	a	45c	c
27	Questionnaire frikkie.pdf	c1	d2	e1	f2	d	b	a	a	b	c	a	Off	Off	a	a	45d	b
28	Questionnaire%20final antwi.pdf	c1	d2	e2	f2	d	d	d	d	d	c	a	Off	c	d	c	45d	c
29	Questionnaire%20final lindeque.pdf	c4	d4	e4	f4	c	c	d	d	c	c	a	Off	b	d	c	45d	c

Check	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29
Total	28	28	28	28	28	28	26	27	28	28	29	18	23	27	27	27	29
Off	1	1	1	1	1	1	3	2	1	1	0	11	6	2	2	2	0
a	14	3	12	7	3	4	8	5	7	3	12	15	15	13	13	0	6
b	9	19	12	15	7	13	6	6	13	3	17	2	6	7	6	6	5
c	4	4	2	5	10	8	6	7	4	17		1	2	4	6	7	11
d	1	2	2	1	8	3	6	9	4	5			0	3	2	14	7
e																	
f																	
g																	

Off	4%	4%	4%	4%	4%	4%	12%	7%	4%	4%	0%	61%	26%	7%	7%	7%	0%
a	50%	11%	43%	25%	11%	14%	31%	19%	25%	11%	41%	83%	65%	48%	48%	0%	21%
b	32%	68%	43%	54%	25%	46%	23%	22%	46%	11%	59%	11%	26%	26%	22%	22%	17%
c	14%	14%	7%	18%	36%	29%	23%	26%	14%	61%		6%	9%	15%	22%	26%	38%
d	4%	7%	7%	4%	29%	11%	23%	33%	14%	18%			0%	11%	7%	52%	24%
e																	
f																	
g																	