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MINING CONCEPTS IN ARTISANAL MINING AND SMALL SCALE PROCESSING OF SANDSTONE IN QWAQWA (FREE STATE – SOUTH AFRICA)
DECLARATION

I, Ewembe Yuka Fontama, declare that this dissertation is my personal effort with the guidance of my supervisor and co-supervisor. Any other sources cited are fully quoted and referenced. I am proud to submit this dissertation entitled, “Mining Concepts in Artisanal Mining and Small Processing of Sandstones in QwaQwa (Free State – South Africa)” for the Degree of Master of Technology in Extraction Metallurgy (MTECH) to the University of Johannesburg, Republic of South Africa.

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ABSTRACT

Sandstone is a medium-hard sedimentary rock consisting largely of quartz grains. The cementing property between the grains varies, and can be siliceous (composed of silica), calcareous (compose of carbonates), or ferruginous (compose of iron oxides). Sandstone exists in many colours, from reddish, greyish to yellowish. Time and the elements of nature have given sandstones unique characteristics and qualities such as, colour, strength and beauty, which makes sandstone a commodity in high demand around the world, particularly in the construction industry, where it is used for cladding of building, artefact, tombstone, diverse decorations, grindstone for grains, and the sharpening of tools.

A preliminary assessment indicates there is an urgent need to promote and protect the artisanal mining and small-scale processing of sandstones in QwaQwa (Free State, South Africa). In recent years, this small industry has gone through instability, due to technical and socio-economic difficulties. Research on the mining concepts in artisanal mining and small-scale processing of sandstone could also be partially or fully applicable to some artisanal mining activities of other commodities such as marble, granite, limestone and other related minerals.

Due to the economic opportunity sandstone presents, it is important to understand the mining concepts and related challenges when mining sandstone. The research work was done through the investigation of different sandstone mining sites within QwaQwa, and multiple mining sites in other rural communities of Cameroon and Lesotho. Studies carried out on the sites will help support technical and other human factors being researched in QwaQwa, which is the main research location. The research on mining concepts involved interaction with miners, data collection, observations of mining and processing techniques, and a discussion on technical and social problems faced by miners and stakeholders. As a mining consultant, the focus was on two major core principles involved, namely technical and human aspects, respectively. The technical aspects examined are the mining techniques applicable to the artisanal mining and small-scale processing of sandstone, the handling and transportation of the mineral. A cash flow model was established to confirm a profitable mining operation. As the technical and human aspects were addressed, the researcher generated guidelines and best practices applicable to the artisanal mining and small scale processing of sandstone in QwaQwa. The comparison of different mining activities in multiple mining sites helped reinforce guidelines and best mining practices of mining activities.
The research identifies nine splitting and seven processing techniques applicable and should assist miners. The human aspects such as mining legislation, health and safety considerations, and environmental concerns discussed under the mining concepts also generated guidelines and best practices applicable to the artisanal mining and small-scale processing of sandstone in QwaQwa. These formed the background used in benchmarking of the mining activity. Also the researcher derived a six years cash-flow model for a 100m$^2$ sandstone reserve in QwaQwa which indicates a positive net present value (NPV) of R560 532, 61.

Mining sandstone can create employment in a rural community such as QwaQwa where poverty is on the rise. Therefore miners should be advised accordingly on progressive mechanisation for both artisanal mining and small-scale processing techniques applicable to sandstone. Progressive mechanisation can be achieved through funds raising, to purchase new equipment and also to increase the size of the mining activity. Key players, such as government, willing investors, and other research interest groups, should be brought in for proper collaboration and efficiency.
DEDICATION

I would like to dedicate this dissertation to all those men, women and children who lost their lives or suffered illness during the course of mining valuable minerals around the world, in order to put food on the table for themselves and their families, or to enhance the lives of others through mining and processing.
ACKNOWLEDGEMENT

My sincere gratitude to all miners and stakeholders that I worked with for this project. I want to acknowledge the contribution of my supervisor Prof. Antoine F. Mulaba Bafubiandi, Head of the School of Mining, Metallurgy & Chemical Engineering of the University of Johannesburg, for encouraging and guiding me throughout the research process. I will also like to acknowledge the academic contributions of my co-supervisor Dr. Steven Rupprecht, Senior Lecturer at the Department of Mining Engineering, University of Johannesburg. My sincere gratitude to Dr. Andre W. Dougall, the former Head of Department of Mining Engineering at the University of Johannesburg. I will also like to acknowledge the immense contribution of the entrepreneur Mr. Kharafu J. Motsamai owner of Kharafu Sandstones, and to all my colleagues from the Minerals Processing and Technology Research Group (MPTRG) from the University of Johannesburg. I also thank my dear wife, Ms. Delphine N. Ndifor, for all her care during the period of hard work.
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<tr>
<td>ABET</td>
<td>Adult Basic Education &amp; Training</td>
</tr>
<tr>
<td>AMV</td>
<td>Africa Mining Vision</td>
</tr>
<tr>
<td>ASM</td>
<td>Artisanal And Small-scale Mining</td>
</tr>
<tr>
<td>AMSPS</td>
<td>Artisanal Mining And Small-scale Processing of Sandstones</td>
</tr>
<tr>
<td>BATNEEC</td>
<td>Best Available Technology Not Entailing To Excessive Cost</td>
</tr>
<tr>
<td>BGP</td>
<td>Blasting Gun Powder</td>
</tr>
<tr>
<td>CSMI</td>
<td>Centre for Sustainability in Mining and Industry (WITS)</td>
</tr>
<tr>
<td>DMR</td>
<td>Department of Minerals Resources</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>HDI</td>
<td>Human Development Index</td>
</tr>
<tr>
<td>ILO</td>
<td>International Labour Organisation</td>
</tr>
<tr>
<td>MPRDA</td>
<td>Minerals and Petroleum Resources Development Act</td>
</tr>
<tr>
<td>MHSA</td>
<td>Mines Health &amp; Safety Act</td>
</tr>
<tr>
<td>MQA</td>
<td>Mining Qualification Authority</td>
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<tr>
<td>MINTEK</td>
<td>Mining Technology</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-Governmental Organisation</td>
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<tr>
<td>N/A</td>
<td>Not Applicable</td>
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<tr>
<td>OHS</td>
<td>Occupational Health and Safety</td>
</tr>
<tr>
<td>RQD</td>
<td>Rock Quality Designation</td>
</tr>
<tr>
<td>SSETA</td>
<td>Services Sector Education and Training Authority</td>
</tr>
<tr>
<td>SADEC</td>
<td>Southern African Development Community</td>
</tr>
<tr>
<td>VOD</td>
<td>Velocity of Detonation</td>
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# LIST OF UNITS

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<tr>
<td>cm</td>
<td>Centimetres</td>
</tr>
<tr>
<td>&quot;</td>
<td>Inch</td>
</tr>
<tr>
<td>₹</td>
<td>Indian Rupee (1 ₹ = R0.2)</td>
</tr>
<tr>
<td>kg</td>
<td>Kilogram</td>
</tr>
<tr>
<td>km</td>
<td>Kilometre</td>
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<tr>
<td>m</td>
<td>Metre</td>
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<td>µm</td>
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<td>%</td>
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<td>lb.</td>
<td>Pound</td>
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<tr>
<td>ZAR</td>
<td>South African Rand (1USD = R13)</td>
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<td>USD</td>
<td>United states of America Dollars</td>
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CHAPTER 1

INTRODUCTION

1.1 Introduction of Chapter 1
This Chapter introduces the motivation for the research, and presents the problem statement, objectives and research questions. Chapter 1 also justifies the research, applicability of the research, the locality of research, an introduction to the mining concepts, and outlines of the entire dissertation.

1.2 Motivation for the research
The motivation to complete this research project arises from the fact that there is the possibility to create employment and alleviate poverty within a rural community through the artisanal mining of minerals like sandstone, granite, limestone and marble. When a team of researchers from the Minerals Processing and Technological Research Centre (MPTRC) from the University of Johannesburg visited the small town of QwaQwa on the 3rd of March 2015, the team observed that the mineral sandstone, which is in high demand in many countries like America, Netherlands and the Middle East, were visible as outcrops in and around the town of QwaQwa.

According to the South African Council for Geoscience, the Free State Province and neighbouring Lesotho has a significant amount of sandstone resources (Johnson & Wolmarans, 2008), which present economic opportunities through artisanal mining and the small-scale processing of sandstone. Such economic opportunity can assist the community in alleviating poverty and creating jobs. As a mining researcher, it worth to generate mining concepts to assist the rural people of QwaQwa as well as around the country with skills and techniques applicable to artisanal mining and the small-scale processing of sandstone. According to Nel (2006), the role of an engineer in a society is someone who innovates and creates wealth by getting the right people, aiming at right target, as well as consistently monitoring, and checking quality throughout the product realisation process. An engineer develops social awareness; manages functions like research, design and production, as well as broader functions such as marketing and project management (Nel, 2006). By applying managerial skills and techniques, it is possible to determine opportunities provided by the sedimentary multi-coloured rock, which is in such a high demand throughout the world, mostly in the construction industry. For example, if more South Africans can be sensitised to using sandstone as a building material, this will boost the industry and promote
environmental sustainability. According to the department of minerals resource, a recent report indicates that, despite the abundance of sandstone in South Africa, the mineral still remains under-exploited when compare to granite and slate (DME, 2005). Sandstone is a naturally existing sedimentary rock, which is environmentally friendly when compared to cement blocks made from toxic chemicals. It is difficult for miners to get jobs in the minerals industry where, according statistics South Africa, 8000 jobs are currently at risk in the mining sector (Stat SA, 2015). Therefore, artisanal mining may be an employment opportunity for many seeking jobs after training or graduation. There is also a high level of motivation to be found in training and partnership in artisanal and small-scale mining within the mineral processing and technological research centre in the Department of Mining and Metallurgy at the University of Johannesburg.

1.3 Problem statement
In recent years, most African countries, including South Africa, have struggled to encourage artisanal and small-scale mining of minerals such as gold, diamond, marble, granite and sandstone. The sandstone in QwaQwa as shown in Figure1.1, presents an economic opportunity, but mining the mineral comes with technical and socio-economic challenges. The challenges have hindered mining activity, and left production levels low till this moment, whereas the demand for sandstone is on the rise, both locally and internationally (Dolley, 2009). The research indicates a need for sustainability in the artisanal mining and small-scale processing of sandstones in QwaQwa. The artisanal miners are in need of funding, training, and equipment. They expect assistance from stakeholders around the country, such as government, NGOs, MINTEK, DMR, MQA and universities (Kharafu, 2016). Besides funds, training and equipment, there are other needs, such as listed below:

- proper training and extra skills for sandstone mining and processing;
- basic equipment in mining and processing of sandstone;
- external support from government and other stakeholder;
- improving low morale;
- improved mineral transportation which is a problem during the mining process and distribution of sandstone;
- regulation of marketing, publicity and pricing of sandstone;
- mitigation of low wages and remuneration;
- improved social security; and
- legalisation of mines themselves, which is onerous and protracted.
The above are the major needs artisans face, but other needs shall be discussed in Chapter 3 which elaborates on mining concepts. It is only by applying proper mining concepts, guidelines and best practices that miners can achieve the objectives listed in the paragraph below.

**Figure 1.1**: The status-quo of artisanal mining and small-scale processing of sandstones in QwaQwa: (A) QwaQwa sandstone formation; (B) An artisanal miner; (C) Small-scale processed sandstone blocks.

### 1.4 Objectives of the research

The objective of the study was to develop mining concepts to assist sandstone miners in QwaQwa through progressive mechanisation, guidelines, mining techniques, and best practice; to be able to advise artisans and stakeholders accordingly as to how to mine sandstone economically and sustainably; and to ensure productivity is increased without compromising the safety of miners. Other objectives are listed below:

- To attract more young people into the industry of artisanal sandstone mining, by convincing them that they can make a better living through mining sandstone;
- To encourage artisans to become entrepreneurs in the field, and not to wait too long for government or other stakeholders. To show them how to team up and overcome the challenges they face;
- To bring forth new splitting, processing, and transportation techniques into what is a failing industry;
- To beneficiate sandstone resources into commercial products, and ensure long term sustainability of sandstone mining.
1.5 Research questions

1. Why is the sandstone industry in QwaQwa less productive?

To consider this question, it is necessary to locate key mining sites where artisanal mining activities have been going on in recent years, by interacting with the miners in order to get their opinion on the subject, what they think, how they feel, and what the way forward might be for them. So far, three major mining sites have been located within QwaQwa, as well as other mining sites beyond South Africa, particularly in Puma, Cameroon.

2. Can the artisanal mining and small scale processing of sandstones in QwaQwa be revived in order to address the current economic challenges faced by miners?

To improve artisanal mining and small-scale processing of sandstone activities in QwaQwa South Africa, there is a need to convince miners themselves that they can produce a variety of marketable sandstone products, through the introduction of new tools, machinery, and techniques. In addition, unemployed youth and other community members ought to join the business by organising seminars around QwaQwa, or having regular meetings with locals to explain the economic benefit of sandstone, involving buyers and consumers of sandstone products to share their viewpoints on the subject.

3. How could the attention of Government and other stakeholders be drawn upon in order to assist miners?

A significant way of doing this, is to organise local and provincial seminars with government and other stakeholders meeting with miners at least once every year. The miners ought to be given the opportunity to present the various challenges they face, and ought to have the opportunity to develop an association of sandstone miners in QwaQwa, meeting at least once every two months, where the can address needs timeously and effectively.

4. How can artisanal and small-scale miners be assisted to acquire the much needed sandstone machinery?

A cutting machine is very important for small-scale processing, however, financing for such equipment constitutes a major problem. Therefore, other stakeholders such as MINTEK, MQA, DMR, universities, or individuals willing to assist the local miners must be invited to raise funds or to provide cutting machines to the miners in QwaQwa. Miners should be advised on progressive mechanisation, as well as how to engage in savings and joint ventures to secure the procurement of modern machinery, basic tools, and personal protective equipment.
5. **How can sandstone deposit in QwaQwa be mined sustainably?**

Even though most of the miners can not read or write, local interpreters or translators can be deployed to translate any verbal or written communication that has been documented into the local dialect for better communication. It is likewise necessary to ensure the miners are well-instructed with regard to the methods of the artisanal mining techniques and best practices discuss in **Chapter 3** of the dissertation.

6. **Will artisanal miners in QwaQwa be willing to accept new techniques in mining and the small-scale processing of sandstones?**

It may be difficult to convince artisanal miners to accept and integrate new techniques and principles in the mining and processing of sandstones. For this reason, it will take time, patience and substantial evidence to demonstrate to them that progressive mechanisation of the artisanal sandstone mining in QwaQwa is viable. The work will be done by showing to them images and explaining to them how such techniques have been successfully applied elsewhere, that is, in India, Lesotho (Lekokoaneng), and Cameroon (Puma).

1.6 **Justification of the study**

Sandstone as a mineral presents economic opportunities within the rural community, where the mineral sits, sandstone has economic potential in changing the lives of many and creating new jobs in QwaQwa. Therefore enhancing mining concepts and the processing techniques of sandstone will provide an opportunity for the people of QwaQwa and a community as a whole towards social upliftment. The research also justify the status quo of stakeholders who has social responsibility to ensure that artisanal mining and small-scale processing of sandstone becomes a success across QwaQwa and countrywide, but has rather seen limitations so far. In addition, there is high demand for sandstone in QwaQwa, with Cashbuild alone demanding about 1000 tons of sandstone every month (Kharafu, 2016).

1.7 **Location and proximity of the research**

QwaQwa is a small town of 33,700km² (13011.643 square miles), which falls under the District of Thabo Mofutsanyane, located in the South East of the Free State as shown in **Figure1.2 (B)**. It is also called Phuthaditjhaba. The name QwaQwa means (whiter than white) in the native Sesotho language, because of the snow that covers the Drakensberg mountain peaks to the South of the area. QwaQwa is situated 28° South and 27° East (PSDF, 2013), it has a population of 736,200 and a population density of 254.2 /km² (658.4 / square mile). QwaQwa was first an independent
part of the former Orange Free State, bordering Lesotho until 1994. After apartheid, the region was renamed the Free State. The Free State was a major educational centre, as the home of the University of QwaQwa, now known as the University of Free State. The population of QwaQwa is comprised of 46% Black African, with whites, coloured and Indians also represented (PSDF, 2013). **Figure 1.2 (A) and (B)** shows South Africa’s map and the map of the Free State province respectively (OECD, 2010).

![Figure 1.2](image)

**Figure1.2**: (A) South Africa’s map showing the Free State province along-side neighbouring Lesotho; (B) The map of Free State depicting QwaQwa with a black arrow.

### 1.8 Description of mining concepts applicable

The researcher used a mixed methods approach of both qualitative and quantitative techniques, but was predominantly qualitative. The qualitative research will be undertaken according to three steps, through a process of artisanal mining and small-scale processing of sandstone:

1. Gathering useful and valuable information through interaction with miners, members of the community, stakeholders, and observation of mining tasks.

2. Application of mining concepts, guidelines and best practices pertaining to artisanal mining and the small-scale processing of sandstone.

3. A qualitative report will compare mining activities in different mining sites beyond QwaQwa through the comparison of technical findings. Three main criteria will be applicable for the qualitative method: (A) significance of the data with its social and cultural impact; (B) sufficiency of data and coverage of its analysis; and (C) transparency of analysis.

The quantitative approach of the research will establish a cash-flow model, search of the correlation between different age groups, genders and categories, and their ability to deadlift and
transport stones within and out of the mine. The quantitative research also explains how an artisan can perform hasty laboratory and a non-laboratory tests on sandstone to determine the type and quality of sandstone or its suitability, where artisans may lack proper testing facilities in rural areas. There will also be benchmarking of the mining activity as described in Chapter 5.

1.9 Applicability of the research

Research on the mining concepts in the Artisanal Mining and Small Scale Processing of Sandstones in QwaQwa (Free State) and studies carried out in different mining sites in Puma (Cameroon) and Lesotho (Lekokoaneng) can be useful to both artisanal and small-scale (ASM) and to some extent large-scale sandstone mining operations. According to the mining techniques and principles of sandstones mining detailed in Chapter 3, these mining techniques can be applicable around the world, except for legislation that might change from one country to another. Therefore, for any individual or group of individuals willing to start their own artisanal mine, this research is instructive. Whether locally or abroad, this research can assist miners in identifying the shortcomings of artisans, and in closing the gap between artisans and governments or other stakeholders. There is a need to encourage young people into the artisanal and small-scale mining (ASM) sectors in order to absorb the nearly 500 or more students who graduate from mining schools in South African universities each year. The University of Johannesburg alone certifies 100–150 students each year with either a national diploma or a degree. Therefore, it is impossible for the big mines or multinationals to absorb all the students. The artisanal and small scale mining sector ought to be considered an alternative for job creation. It is important to note that although the research was conducted in QwaQwa and on sandstone, this does not imply limited applicability to either of these aspects.

The research can be used to instruct the artisanal miners already in the industry to improve the safety and quality of their work as they mine sandstone, limestone, slate, marble, soap stone, travertine and similar commodities within QwaQwa as a regional centre, as well as countrywide. This document can help stimulate entrepreneurship between new comers in artisanal mining, particularly those willing to mine sandstone, thereby facilitating their activities and encouraging the miners already discouraged. The research work can also be a boost to those already in the field mining sandstones. There are still other under-exploited areas related to the mining concepts in the artisanal mining and small-scale processing of sandstone, such as proper resource management. Other researchers may have researched related topics and many others are yet to consider sandstone as a mineral of interest.
1.10 **Outline of the dissertation**

This subheading gives an outline of the dissertation. **Chapter 2** deals with the literature review. It investigates the importance of sandstone, existing theories and practices in the artisanal mining and small-scale processing of sandstone, and expresses the viewpoint of the researcher on the topic. **Chapter 3** of the dissertation deals with the mining concepts examined through a mixed method of both qualitative and quantitative techniques. **Chapter 4** looks at the interrelationship between sandstone mining activities in different mining sites which includes QwaQwa (South Africa), Puma (Cameroon) and Lekokoaneng (Lesotho), with analysis discussions. **Chapter 5** presents the interpretation of findings and results. It also looks at benchmarking and analysis of the findings and results obtained from previous chapters. **Chapter 6** presents recommendations and concluding remarks, and shows the way forward in the artisanal mining and small-scale processing of sandstone. This chapter review the overall research and suggests vital recommendations to artisans and stakeholders. The dissertation ends with a bibliography, an appendix and a glossary, depicting additional pictures, graphs and tables, which are considered supplementary materials.
**Research flow sheet**

- **Registration at UJ for MTECH Topic:**
  - Mining Concepts in Artisanal Mining and Small scale Processing of Sandstone
  - 03/03/2015

- **Starts Writing Dissertation:**
  - June 2015

- **Submission of Proposal:**
  - Proposal Accepted

- **Gathering of Information through Interactions and Mine Site Visitation:**
  - Between March & May 2015

- **Dissertation Outline**
  - Chapter 1: Introduction
  - Chapter 2: Literature Review
  - Chapter 3: Methodology
  - Chapter 4: Relating Studies Conducted on Different Mining Sites
  - Chapter 5: Presentation of Findings
  - Chapter 6: Conclusions and Recommendations

- **Starts with Chapter 2:**
  - The Literature Review

- **Submission of the Literature Review:**

- **Planning of Second Trip to QwaQwa and Presentation Preparations:**
  - November 2015 to January 2016

- **Starts With the Mining Concepts:**
  - January 2016

- **Submission of the Mining Concepts:**
  - July 2016

- **Analysis of Methods and Techniques Applicable:**

- **Submission of a Review Article on Mining Techniques in Artisanal Mining and Small Scale Processing of Sandstones:**

- **Submission of a Progress Report on Dissertation:**
  - 30/09/2015

- **Review of the dissertation with supervisors:**
  - August 2017

- **Submission of the Dissertation:**
  - December : 2017

- **Conclusions and Recommendations:**
  - December 2016

- **Compiling of Dissertation:**
  - January 2017
1.12 Conclusion of Chapter 1

Chapter 1 has provided a brief overview of the study. It is important to read through Chapter 2, which is a review on the artisanal mining of sandstone, in order to obtain a broad view on the topic. In addition, further reading of Chapter 3 sheds more light on the mining concepts with the intention of assisting QwaQwa sandstone miners.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to the literature review

Artisanal mining is so important that it contributes between up to 20% to the GDP of many countries in Sub-Saharan Africa (Rupprecht, 2014). According to Rupprecht, artisanal mining currently constitutes five percent of South Africa’s GDP. Artisanal mining, also known as subsistence mining, plays an important role in the livelihood of the people of QwaQwa (Free State). Egypt and its past is strongly associated with stone mining particularly sandstone. Over 200 quarries dating 3500 years old have been discovered in Egypt. Humans started mining sandstone in the late predynastic period using stone tools, later iron tools aided with fire (Harrell & Storemyr, 2009). Evidence of huge stone mining activities in Egypt can be found in archaeological sites of temple buildings and pyramids, where it is possible to find ornamental stones, sarcophagi, shrines, stelae, statues, and sculptures. Sandstone as a mineral creates an important economic opportunity for the people living in QwaQwa, and provides them with income for their different basic needs, alleviating poverty and unemployment. In recent years, there has been a gender shift in the artisanal and small-scale mining sector, with more women becoming involved, as valuable resources become scarce (Yakovleva, 2007). According to locals, the artisanal mining of sandstone in QwaQwa has been losing momentum, where in some places, one can observe that the mining activity has completely halted. The loss of momentum justifies the need to discuss the mining concepts in artisanal mining and small-scale processing of sandstones in QwaQwa. Through this initiative, issues ranging from mining and processing techniques, sustainability, safety, as well as socio-economic and political issues shall receive attention. The Africa Mining Vision (AMV) created by the United Nations Economic Commission for Africa, has done extensive research on artisanal and small-scale mining (ASM) and has published several documents on artisanal and small-scale mining. In November 2002, a seminar on artisanal and small-scale mining was held, and a vision statement was outlined as follows: “[to] contribute to sustainably, reduce poverty and improve livelihood in African artisanal and small scale mining communities by the year 2015 in line with the Millennium Development Goals” (AMV, 2002). Several years on now, these goals have not been entirely achieved. Figure 2.1 (A) and (B) shows a geographical and a geological map of South Africa respectively (Johnson & Wolmarans, 2008).
2.2 Defining artisanal mining in context of the research

Mining activity describes the process of extracting valuable minerals for economic benefit. According to a broad definition, mining activities can be categorised to avoid ambiguity. It is also important to differentiate the scale of the mining activities between, respectively: (1) large-scale mining; (2) small-scale mining; and (3) artisanal mining. To date it has been difficult for scholars and researchers to agree on a definition of artisanal and small-scale Mining (ASM) in order to contextualise and differentiate them. This extended ambiguity has caused certain tension between individuals, companies, institutions, and governments. Greed has contributed to worsening the problem, as some people turn to accepting a definition of the subject only to their favour. This study aims to contextualise and differentiate mining activities from one another, to the extent that this serves the mining and processing industry. In the Minerals Processing and Technology Research Centre (MPTRC) at the University of Johannesburg, the MPTRC is committed to this aspect, in order to support or re-shape the views of our partners in the industry.

In the South African context, artisanal mining falls under the same definition of small-scale mining, often termed (ASM). The MPRDA (Minerals and Petroleum Resources Development Act of 2002), defines artisanal and small-scale mining as any mining activity where: (a) the mineral in question can be mined optimally within a period of two years; and (b) the mining area in question does not exceed 1.5 hectares in an overall total of five hectares, and allows for a mining permit (Ledwaba, 2017). However, one might ask whether the definition satisfies to describe most artisanal and small-scale mining activities in South Africa. In fact, QwaQwa is one such instance where the definition does not serve. In QwaQwa, people have been mining for many years and many of them mine over smaller areas less than 1.5 hectares. Most
often, the definition of artisanal and small-scale mining will vary from one country to another, where some characteristics and principles are now widely applied when defining artisanal and small-scale mining as an activity.

The research will compare relevant legislation on artisanal and small-scale mining in different countries around the world, and will investigate the way in which parameters such as capital costs, operating costs, tonnages, operating surface area, human resources, commodities, and loyalty have influenced the definition of artisanal and small-scale mining activities. Artisanal and small-scale mining in other counties, for example the Republic of Cameroon, is seen as the major mining activity, and the sector employs many people and demands more attention from government. What could be the reason? Hoadley states that artisanal and small-scale mining activities are mostly poverty-driven, where there is a correlation between the Human Development Index (HDI), i.e. the position of countries, and the proportion of the total workforce involved in artisanal and small-scale mining. The tendency is for countries with low HDI positions to have a high proportion of workers employed in artisanal and small-scale mining (Hoadley & Limpitlaw, 2004).

2.2.1 Terminology

Sandstone is defined or identified in different contexts depending on how the definition best suits its application. Here, sandstone is sometimes identified as a mineral, and in other cases as an ore. In most circumstances, its definition is merely that of an otherwise unspecified type of rock.

The geological definition of sandstone: According to Jos Lurie, sandstone is a sedimentary rock composed of sand size grains of minerals, rocks or organic materials bound by a matrix of silt or clay-size particles that occupy the spaces between sand grain particles. Sandstone is one of the most abundant sedimentary rocks found in most basins around the world. According to Jos Lurie, the word ‘sand’ in sandstone simply refers to the particle size of the grains within the rock, rather than the material of which it is made, where particle size can vary between 0.0625-2 mm. The sand in sandstone is composed of up to 90% quartz, while other sands can contain a significant amount of feldspar (Lurie, 2008).

Definition of sandstone as a mineral: A mineral is an element or chemical compound that is normally crystalline, and that has been formed as a result of geological processes (Nickel, 1995). This constitutes the most common definition of sandstone. However, when there is an element we need to extract from the sandstone, say silica, the second definition becomes valid.
**Definition of sandstone as an ore:** An ore is a type of rock that contains sufficient minerals with important elements, including non-metals, that can be used in their natural state, such as a sandstone block used as a building material (Segalstad, 1997).

**Definition of sandstone as a rock:** According to Ehlers, rock is that substance of which the earth is made (Mibe, 2014). Other popular authors define a rock as a hard substance, formed of mineral matter. A piece of rock could be quarried and worked into a specific size or shape for a particular purpose, like paving or building stone. Most uneducated artisans define a rock simply as a stone, and differentiate them as sandstone, shale, granite or slate.

### 2.3 A brief geology of QwaQwa sandstone

Sandstone is a medium-hard sedimentary rock, consisting largely of quartz grains. These grains are resistant, and tend to resist. The cementing property between the grains varies; if siliceous (composed of silica), the rock as a whole is particularly resistant; if ferruginous (iron oxides), or calcareous (carbonates), the rock is susceptible to chemical attack (Lurie, 2008). A coarse sandstone composed of grains is called grit, and if there is too great a proportion of feldspar grains present, the formation is called Arkose. When there is abundant and partially unaltered rock chips present, the rock is called Greywacke. A variation of sandstone grain sizes is defined in Table 2.1 (Lurie, 2008).

In South Africa, sandstone is found among the younger rock formations, such as in the cave sandstone known as the Clarens Formation found among other places such as Golden Gate in the eastern Orange Free State. In this region, most mountain ranges are capped by metamorphic rocks e.g., the Magaliesburg range (Lurie, 2008). Sandstone formation takes place in two main stages. Firstly we have a layer or layers of sands which accumulates with time to form sediments either from sources like water from a river, sea or from the wind in deserted areas. Secondly the sand then accumulates and becomes sandstone as it gets compacted by pressure from overlying deposits, while the sand particles become cemented by the precipitation of minerals within the sand grains and the pore space (Mcbride, 1963). In most areas where sandstone is mined in QwaQwa, miners do so merely by sight and experience in terms of differentiating the various qualities and types of stones. They don't often conduct tests to determine the exact qualities of their stones. Whereas if the industry is required to grow and gain trust, the testing of sandstone is necessary in order to meet customer's demand and credibility. The stones may look alike, but their chemical properties are different. Where sandstone is mined, there is the possibility of finding quartzite, slate, limestone, travertine, marble and granite deposits alongside. These minerals can be mined separately according to demand, or simultaneously. It is important to know the location and quality of sandstone you want to mine so that the supply meets the original selection or testing criteria of the stone properties, and have predictable behaviour when subjected to load,
moisture, abrasion and heat (Quick, 2000). Table 2.2, describes the classification of siliceous sedimentary rock (Lurie, 2008).

Table 2.1: Grain size definition

<table>
<thead>
<tr>
<th>Fragment</th>
<th>Size (mm)</th>
<th>Fragment</th>
<th>Size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder</td>
<td>&gt; 256</td>
<td>Coarse sand</td>
<td>0.5 – 2.0</td>
</tr>
<tr>
<td>Cobble</td>
<td>64 – 256</td>
<td>Medium sand</td>
<td>0.25 – 0.5</td>
</tr>
<tr>
<td>Pebble</td>
<td>8 – 64</td>
<td>Fine sand</td>
<td>0.05 – 0.25</td>
</tr>
<tr>
<td>Granule</td>
<td>2 – 8</td>
<td>Silt</td>
<td>0.005 – 0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clay</td>
<td>&lt; 0.005</td>
</tr>
</tbody>
</table>

Table 2.2: Classification of siliceous sedimentary rock

<table>
<thead>
<tr>
<th>Essential Composition</th>
<th>Mechanically Formed</th>
<th>Organically Formed</th>
<th>Chemically Formed</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siliceous Sandstone</td>
<td>Quartzite</td>
<td>Radiolarian Chert</td>
<td>Siliceous Sinter</td>
<td>Sandy Soil</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Silcrete Chert</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Flint</td>
<td></td>
</tr>
</tbody>
</table>

2.4 Economic benefits of sandstone applications

Due to its strength and beauty, sandstone is widely used in the construction industry, while other applications include gardening, flooring, landscaping and walling. Due to a lack of modern tools in QwaQwa for the shaping of sandstone for different uses, most of the sandstone produced in QwaQwa are used as bricks and for cladding.

The Centre for Sustainability in Mining and Industry (CSMI) has conducted research on artisanal and small-scale mining for the purposes of the the Mining Qualification Authority (MQA), and the State-owned science council (MINTEK), which serves the national interest through research in minerals. In August 2010, a report was published on artisanal and small-scale mining, with the aim of assisting the MQA and other stakeholders in the artisanal and small-scale mining sector, to assess the broad status of the artisanal and small-scale mining in South Africa, to identify important development issues associated with the sector, and come up with new and effective initiatives that might provide knowledge and skills (Mutemeri, et al., 2010). Other means to stimulate sandstone mining is addressed by Hoedoafia, who has suggested that artisanal miners ought to be regrouped, and form associations or smaller groups so that their problems can easily be addressed, as they will feel free to express their
difficulties within themselves (Hoedoafia, 2014). Mining, including small scale and artisanal mining, is a critical sector for national and local development in South Africa (Rogerson, 2011). Many people might underestimate the variety of applications of sandstone, but sandstone is indeed commodity in high demand in the construction industry worldwide. In context, Dougall, (2004) believes that if miners apply the Employee Share Ownership Participation Scheme (ESOPS) as a tool in this sector, artisanal mining and small-scale processing of sandstone could be a catalyst for Black Economy Empowerment (BEE), since the product is located in an area predominantly populated by black communities (Dougall, 2004). After visiting three different countries, one would realise that there is a need for sandstone products, and sandstone could be a potential substitute for ceramic tiles, baked bricks, and cement blocks. Whenever sandstone is proposed as a replacement for these products, it is most likely to have that advantage, due to its decorative properties and it is environmentally friendly. QwaQwa sandstone is currently used to build a complexes in affluent Johannesburg suburbs like Sandton, Fourways and Bryanston. Most property owners insist the buildings should be decorated with at least 80% sandstone, with helicopters sometimes used to transport sandstone from QwaQwa to Johannesburg (Kharafu, 2015). In Cameroon, the entire enclosure of the headquarters of the Central African Bank (BEAC) was built with sandstone. In the Republic of Congo (Brazzaville), the BCH Bank, (Banque Congolaise D’Habitat) is entirely walled with sandstone. On enquiring after the origin of these stones, it is reported that the stones where imported and the building was decorated with sandstone by a foreign company. According to Madhavan, (2005) India is one of the world’s leading exporters of sandstone products, particularly marble, which is the igneous version of sandstone, and employs the highest number of artisans in the sector more than Italy and China. India is a leading exporter of natural stone and ranks third in terms of tonnage, after Italy and China. India export sandstone to the Netherlands, United States, and the Middle East. India accounts for about 27% of the world’s total natural stone production. Natural stone is hugely popular in India. The domestic consumption of dimensional stone in India exceeds ₹50,000 million per annum or $1.163 million (Madhavan & Raj, 2005). According to MINTEK, most sandstones for addressing the South African tile market is being imported from India and Indonesia, priced at around R100 less than local sandstone for a square metre. The demand for sandstone products is on the rise in South Africa, where most private and commercial properties are being built with sandstone. This rise in consumption reveals the market potentials of sandstone, and indicates the industry has potentials to grow. The question is as to how to boost the artisanal mining sector in South Africa to produce enough sandstones capable to compete with those produced in Lesotho and India, which are the major competitors.
2.4.1 **Different sandstone products**

**Tiles**
Sandstone tiles are one of the most used products in terms of applications. They are mostly four-sided, but vary in size and thickness, and can have: rough surfaces; one surface polished; or both surfaces polished. Sandstone tiles are mostly used for flooring and the cladding of walls.

**Cobbles**
These are stone sizes ranging from a pebble to a boulder. Cobbles are waste products from the shaping and sizing of larger sandstone ore body. They are mostly used for decorative purposes. Cobbles are fireproof, require little maintenance, and don’t require paint, due to their natural beauty.

**Slabs**
Slabs are broad pieces of sandstone that come in several shapes: square, rectangular, round, and oval. The size of sandstone piece varies and can reach 1×2m, with a thickness ranging from 1-10cm or more. The slab of sandstone can be rough on both sides or smoothed on one side only, or one surface polished, or both surfaces polished in the desired thickness. A large variety of household artifacts are made of slabs, as they find many other applications including making tables, benches or tombstones.

**Strips**
Strips are mostly used in construction industry worldwide, and sandstone strips are long, slender pieces with nearly the same width. Sandstone strips have become an important product of most construction activities using the stone. Sandstone is cut into strips of different lengths and widths, as required. These strips can be customised or made in different dimensions for different applications. They are used for cladding walls, roofing, and flooring purposes. Multi-colored strips are used to make different designs on walls.

**Bricks**
Sandstone bricks are used for walls and paving hard surfaced floors. Walls made of sandstone bricks need not be painted. Sandstone is quite hard, compact, fine, and possess good compressive strength and low absorption property.

**Pebbles**
Sandstone pebbles are generally small, mostly round, sometimes square stones, which are naturally available or mechanically created in different sizes. The pebbles are decorative stones mostly used in houses, artificial ponds, gardens, lounges, open-air theatres, aquaria, parks, out-doors and fountains.

**Raw Blocks**
Sandstone raw blocks are large pieces of sandstone with no fixed shape. They are chiselled and cut into different forms. Raw blocks are often used for carving out statues and monuments, or sawn into slabs or tiles with the use of a cutter or a gang saw (Madhavan & Raj, 2005).
2.4.2 **Used as a building material**

Sandstones in different sizes and shapes could be used as tiles, building blocks, in flooring, walling, paving, loadbearing masonry, walkways, and cladding of building as shown in **Figure 2.2**. When crushed in concrete and asphalt, it can be used as a fill in dike and as jetty construction.

![Figure 2.2: Sandstone used as building material for; (A) Cladding of building; (B) Building blocks; (C) Walling](image)

2.4.3 **Used for artistic & aesthetic purposes**

Sandstone is ideal for caving and architectural uses as pillars, arches, garden furniture, fountains, grinding stones, landscaping, tombstone, curbstones, fireplaces, craft and stone art. Generally it is used as a decorative stone as shown in **Figure 2.3**.

![Figure 2.3: Sandstones used for artistic and aesthetic purposes. (A) Statue made of sandstone. (B) Sandstone used for decorations. (C) Sandstone used as tombstone.](image)

2.4.4 **Chemical and industrial applications**

Since sandstone is resistant to acid and alkali, it is used in the chemical industry in flooring, wall fixing and lining. Use in cladding when crushed as an inert material and also for fire proofing.
2.4.5 Domestic and agricultural uses of sandstone (Tailings)

Due to the fact that sandstone is abrasive and resistant to weathering, it can be used for sharpening household metal tools like knives and scissors. Sandstone tailings from processing units estimated at 1% is used to retain moisture in agricultural lands and also to prevent pests or use as a pesticide.

2.5 A general review of artisanal mining of sandstone

South Africa has put in place structures by the DMR (Department of Mineral Resources) in the mining charter to safeguard the interests of artisanal and small-scale miners under the MPRDA Act 28 of 2002, whose main objectives are to develop skills, the community, beneficiation, procurement, ownership and employment equity (DMR, 2015). Developing a mineral strategy or policy is a small step forward and implementing these strategies is a bigger step forward, however, making viable policies doesn’t guarantee successful policy implementation, only that there will be recourse to a formal follow-up strategy. Policy development is an intellectual process whereas policy implementation is an operational process (Mtegha, et al., 2010). Artisanal and small-scale mining are major contributors to the national income, and a recognised pillar for poverty reduction as an economic activity, it has the potential to contribute to sustainable development, while successfully aiding the development of rural communities like QwaQwa (Debrah, et al., 2014).

The definition of artisanal and small-scale mining has always been debated to have a universally acceptable definition, a unique definition is avoided as it is believed to be curb unnecessary conflict (Hollaway, 1991). Even though artisanal and small-scale mining has different definitions, one would agree this type of activity refers to individuals, families, groups or cooperatives. It is mostly informal with little or no mechanisation. The definition may vary from one country to another. For example, in Brazil, when defining the artisanal and small-scale mining, the following criteria must be applicable: size of reserve; sales volume; duration of the mining cycle; number of employees; size of mine; capital costs; operational costs; and labour productivity (Hentschel, et al., 2003). Artisanal mining of sandstones started since the very existence of humans, because artefacts or sculptures dating up to 17000 years old have been discovered. Some people might not see sandstones as a valuable mineral, having the same considerations as gold, platinum, coal or diamonds, however it fits the definition of a mineral in terms of mineral exploration. Mineral exploration is the process of finding ore i.e., commercially viable concentrations of minerals to mine. The way a sandstone is mine is totally different from other minerals or industrial minerals, conventional mining is the process of blasting, loading, hauling, crushing, milling, and beneficiation. It is very difficult to identify these processes in the mining of sandstones, mostly when mining as artisans. This is due to the nature of the mineral and its applications. In South Africa, MINTEK has been working with the
MQA (Mining Qualification Authority) and SETA (Services Sector Education and Training Authority) to train candidates in artisanal and small-scale mining. It has been reported that around 2500 people have been trained in artisanal and small-scale mining and mining-related courses under this programme. The main aim of these schools are to assist artisanal and small-scale miners to operate effectively and efficiently in a self-sustaining manner. In QwaQwa, MINTEK has helped in obtaining the mining permit and has registered seven small-scale miners already. They have also assisted in the beneficiation process, where mostly women have been employed to beneficiate sandstone into saleable products like cobblestones and curb stones. MINTEK is a vital partner in artisanal and small-scale mining of sandstones in QwaQwa and the rest of South Africa (MINTEK, 2012). At present, the main concern about the artisanal mining of sandstone in QwaQwa is how these artisans can improve their mining and processing methods, so that they can improve from using smaller tools such as chisel and hammer, to acquiring huge diamond wire cutters or armed chained cutting machines for high volume production. Mechanisation is important, because not only will it increase production, but there will also be more quality in the final marketable product, and less waste generated (Sariisik & Sariisik, 2010). The dream of most of the artisans is to acquire a Diamond disc cutter machine used to process sandstone blocks. A cutting machine is very expensive for an artisan, that’s why they are strongly relying on external aid. Using the Diamond disc to cut sandstones will help keep the dream of the artisans alive, because they will rapidly move from artisanal to small-scale production, which is the wish for government and all stakeholders.

Through the investment of a small capital in the artisanal mining and small-scale processing of sandstones, it is possible for small-scale mining activity to increase its scope, and create more jobs within the rural community. The artisanal mining and small-scale processing of sandstone, if properly managed, may in few years become a small-scale mining activity employing a larger number of people, with real potential to uplift communities by alleviating poverty.

2.6 How to mine sandstone economically

Mining sandstones economically means making profit without compromising safety. An increase in productivity ought to imply an increase in profit. It is repeatedly claimed that developing the artisanal and small-scale mining sector can provide jobs and promote regional and community development, particularly in rural South Africa (McGill & Theart, 2006). By world standards, South Africa’s subsistence and artisanal mining sector is small, and needs to grow. Current estimates are around 30,000 people or more actively engaged in the artisanal and small-scale mining in South Africa, with more women employed in the sector (Mintek, 2013). This contrast sharply with our neighbour, Zimbabwe, where it is estimated that ±200
000 people are engaged in some form of artisanal mining activity. It is anticipated that the numbers in South Africa will increase rapidly (Peake, 1998). In artisanal mining, Peake identified firstly technical issues include: environmental; economic (funding); legislative compliance; negotiating permits; ore body evaluation; low order technologies (hoisting and support); and degree of competence; and secondly, structural issues include mostly informal; and not all of these miners are in a co-operative or syndicated (Peake, 1998).

Government should commission research on sandstone, as it is often done with gold. Government should also convene a forum of artisanal mining of the mineral with various stakeholders involve, and they should be consulted periodically, with meaningful outcomes made available to the public (Paget, 2015). Though the mining sites in QwaQwa are located in a remote rural area, one can not ignore health and safety issues in such operations, because the mining activity deals with humans, therefore health and safety ought to become an important consideration. According to the international labour organisation (ILO), Occupational Health and Safety (OHS) is an important issues for the world’s 13 million or so small-scale miners who work in surface mines. Community progress in dealing with diseases and accidents affecting artisanal and small-scale mining will require a better understanding of the risks, hazards, practices and behaviour involved in order to prevent them (Walle, et al., 2001). Occupational health and safety identifications of materials and methods varies in different mining activities. In the artisanal mining of sandstone, very little equipment is used, and therefore equipment hazards may not be as serious as in artisanal gold mining. Great care must be taken when dealing with safety in the work place, as well as hazards specific to each of them, with the observation and analysis of tasks, tools and the processes related to their use in the mining sites (Elenge & De Brouwer, 2011).

Most mining activity require energy used to break the rock into a more economical size ready for beneficiation or application. For sandstone, sizes is consequential, such that the primary tools of the sandstone miners are a chisel and hammer. Most mining activity employs explosives. However, for sandstone, a huge amount of energy from explosives might produce undesirable sizes. Using gun power to create a streak or huge lumps is preferable. In Puma (Cameroon), artisans use heat from firewood or charcoal as an energy source to create fissures on the sandstone bedrock. This is understandable because they mine inside the equatorial forest, where fire wood is abundant. For this reason, artisans find it significantly easier to use the free energy from the firewood rather than applying their physical energy in breaking rock portions from bedrock, as the miners in QwaQwa do. The main point of interest in the mind of any artisanal miner of sandstone is how to mine sandstone with the least possible energy and within the shortest period of time. In artisanal mining and small-scale processing of sandstone, rock splitting is like doing half of the job and transportation requires another 50% of the effort. It is not easy to transport lumps of rocks from 5-100kg either to
storage or to a delivery truck. Acquiring a means of cheaper transportation will increase profit and production in the mining activity. The mining of sandstone is normally done in two phases. Firstly, the splitting of sandstone, and secondly, the cutting or processing.

The research has identify several mining techniques applicable to sandstone which involves splitting and cutting techniques. The splitting techniques are: using chisel and hammer; using plugs and feathers; hydraulic or mechanical splitting; using expansive mortar; explosive splitting; water jets and using fire for splitting. Cutting or processing techniques include: cutting with stone cutting machines e.g., diamond wire sawing; using chain saw cutters; diamond disc cutters; sculturing or carving; hydraulic press and computerised tools. Cutting or processing can also be done using water jets, jet flame cutting, and slot drilling. Several splitting, cutting and processing techniques shall be discussed in Chapter 3 under mining concepts. Nine splitting and seven processing techniques discussed in Chapter 3 are the practical and most adaptable to the artisanal and small-scale mining of sandstone. According to Ashmole, (2008) there are two major methods of the artisanal rock splitting of sandstone. Firstly, is applying high energy with the use of explosives or mechanical splitting using hydraulic props; and secondly, splitting with lesser energy by applying only the physical strength of a person using basic tolls like chisel and hammer, plugs and feathers or expansive mortars (Ashmole & Motloung, 2008). Research on stone mining, particularly sandstone is not popular like other minerals like gold. Sandstone mining, be it artisanal or small-scale, involves two major processes, namely splitting and cutting. There is no doubt that selection of the right technique, tools, and correct location for mining will significantly contribute to the sustainability of the venture.

2.7 The theory of microwave in sandstone mining

Previous research on sandstone splitting by the MPTRC was done on microwaves. Microwaves are those waves with frequency band range between 1 to 100GHz, in this band components and circuits are on the same wavelength. Microwave circuits and system are used in communication systems, radar, commercial and consumer heating and drying ovens (Karamel, et al., 1998). Puschner, (969) presented a model of a microwave heating machine, in form of a crane fitted with a microwave system on the end of an adjustable boom for applying microwave energy to rock material to break it apart. The problem is, this is a colossal machine, and very expensive to run. Could this be applicable to the artisanal and small-scale mining of sandstone, as previous research suggests? Another problem is that in the artisanal mining, miners are avoiding communition, whereas in the case of the use of microwaves, rocks are highly fragmented. Microwaves involve a transfer of electromagnetic energy. The electromagnetic energy has to be transferred to the material by means of hollow lines, the aperture of which has to be provided directly at the rock in order that the desired thermal
wedge forms the requisite thermal stresses to split the rock (Puschner, 1969). Mubiayi, (2010) worked on microwave technology in the artisanal mining of sandstone, but the technology has never been implemented. He suggested that microwaves with single mode cavity at 3300W from a magnetron, irradiated in 20 seconds, could breakup sandstones as it raises the temperature at 450°C (Mubiayi, 2010). Eventually, microwaves at high intensity will heat up and break the sandstone, but challenges thus arise as to whether this can be done economically and safely. While working on the economical aspect, there are three considerations to be made when designing a microwave equipment or any other equipment that could cut through sandstone economically. Firstly, the capital cost and operating costs, the cost to construct a magnetron capable of assisting artisans in the mining industry, and the operating cost, which is the cost to run such machine, because it requires too much power or electricity to generate the heat needed in form of a microwave. A second consideration is product quality, where too much heat from the microwave may damage the quality of the sandstone we are intending to mine, and may also affect its quality to resist corrosion from other elements like water, wind, sun, acids, or alkaline solutions. This is because, as temperatures from microwaves rise to 450°C, most of the water from the sandstone evaporates, leaving it friable and vulnerable to those elements cited above, noting that sandstone ought to be mined in a condition were the stone is strong and resistant enough for construction purposes. Thirdly, the manoeuvrability of the machine, when mining sandstone one needs highly flexible equipment, where artisans succeed in such operations because they mine to acquire specific portions of both rock size and quality. It is a sort of segregated or scattered mining.

2.8 A brief analysis of other sandstone mining sites different from QwaQwa

Sandstone mining in Africa is widely considered to be an artisanal and small-scale mining activity, with India leading in terms of production globally. The research examined sandstone mining sites in two different countries within Africa practicing artisanal mining of sandstone, viz, Lesotho and Cameroon, with aim to compare observations and outcomes. In these rural communities, even though they mine the same product, they do so in different ways and have different goals and aims, despite all the difficulties they encounter. In Lesotho, just a short drive outside Maseru in the small town of Ty, the sandstone mining is booming, from men with chisel and hammer to industrial machines, the entire sandstone belt geologically shared by Lesotho and South Africa is much busy with mining activity than that neighbouring QwaQwa, South Africa (Seboholi, 2014). A local sandstone miner and business man in Lesotho shared his thoughts about the commodity by stating “sandstone mining is not complicated as one might thought”, where he sees the artisanal mining and small scale processing of sandstones as a primary production sector capable of addressing the challenges of high unemployment
levels and poverty in rural communities. The other mining site considered here is in Puma in the Republic of Cameroon. On these sites, production is also much higher as compare to QwaQwa due to a high motivation between miners.

2.9 The link between sandstone artisanal miners and stakeholders

One would expect a harmonious relationship between artisans, and other interested parties in the business of sandstone, but this is not the case in the field. Working with artisans can be very difficult, because this is an informal sector, with little or no rules, miners do not often observe the rules presented to them by experts in the field. They often take the opportunity of any situation that arises and mine the way it pleases them to do, despite regulations. Rupprecht, (2014) has worked with artisanal miners in Rwanda for a long time, and admits it is very difficult for artisans to keep their promises and commitments, every time they are assigned to apply a certain procedure, say on safety, they will do so for the few days under his presence. As he returns to South Africa, the miners will return to their old mining methods (Rupprecht, 2014). They may ignore the dangers that surround them, whereas the working environment presents a high risk if not addressed. During the time spent with artisans from QwaQwa and Puma, the author realised they mine for a daily living, without a long-term plan. The artisanal miners don’t care about projects that will yield benefits tomorrow, as they want immediate solutions to daily problems (Besala, 2015). This is understandable since the miners must provide for their families every day, they may not have any grant from government, salary or pension. They rely on their craftsmanship to survive, and they are surviving. Much has to be done to make the whole mining process sustainable for them, i.e. safe, profitable and productive (Mackay & Bangerter, 2006). One of reasons the artisanal mining and small-scale processing of sandstones has not been mechanised or be a point of interest for investors could be the lack of capital and knowledge. The lack of basic requirements has caused artisanal mining and the small-scale processing of sandstones to lag behind other commodities, such as gold or granite, which have moved quiet rapidly from artisanal to small-scale mining, where modern machinery is employed more frequently. Investors often neglect projects on sandstone because it demands craftsmanship and machinery that is not yet readily available. Most work on sandstone is done manually. Therefore, machines sensitive enough to work in such a manner could be very tricky, and ought to be well understood because customers sometimes give specifications that demand highly skilled labour. It is important that there be a good relationship between artisanal miners and large scale miners, because there is often infighting between them. The artisans often see the large-scale mining companies as taking away their jobs, and the large-scale mining companies often accuse the small-scale miners of disrupting the market with cheaper products. In addition, government often accuse
artisanal and small scale miners of evading tax. All the issues need to be addressed for there to be a good relationship between artisanal and small-scale mining and the large mining companies (Hentschel, et al., 2003).

The infighting between the artisanal miners of sandstone in QwaQwa is counterproductive, because it does not encourage market competition or productivity, but it is an infighting emanating from jealousy and hatred. The infighting is harming the industry of sandstone mining in the area, because a group or a person believes he or she should be the only one mining sandstones in a particular area, and greedily believes any resource from a stakeholder must be allocated to him alone. Cooperation is required over competition.

2.10 Conclusion
Sandstone has a very long, rich history and has interacted with the daily activities of humans for many years. Sandstone is both beautiful and strong, used in a diversity of applications. Mining sandstones comes with certain challenges, particularly when it comes to artisanal mining. It is obvious that artisanal mining in South Africa is not as popular as in many underdevelop or developing countries like India and China. From the review, there is a great opportunity for the artisanal mining and small-scale processing of sandstone in QwaQwa to grow as seen in some mining sites in other countries. This can also be achieve through substantial market, while considering other technicalities like transportation and the product quality. There is enough sandstone to mine in QwaQwa with young people seeking employment. The solution is to bring forth policies which can help grow the industry. The research will actually change viewpoints of stakeholders and their thoughts and perception about sandstone, and its potential benefit the local community.
CHAPTER 3

MINING CONCEPTS

3.1 Introduction to the mining concepts in artisanal mining and the small-scale processing of sandstones

The mining concepts outlined here are designed to achieve best practices and contribute to the guidelines for the artisanal mining and small-scale processing of sandstones. An outline of the mining concepts used shall be discussed separately in the next paragraph. From the mining techniques, processing techniques, chemical and physical properties of sandstones, human elements, environmental considerations, and a cash-flow model, the research methodology uses both qualitative and quantitative analysis, but largely qualitative. A qualitative research aims to explore the human elements of a given topic, where specific methods are used to examine how individuals see and experience things. Qualitative methods are best for addressing the why questions that researchers have in mind when they develop their projects, whereas quantitative approaches are appropriate for examining who has engaged in behaviour or what has happened and experiments can test particular interventions (Denzin & Lincoln, 2011). In this research, a range of conversant methods shall be applied, such as interactions, observations, reading diaries, books, journals and publications. It is very important to have a research design that provides the discipline of how to plan and conduct the empirical research, which includes the applications of both qualitative and quantitative methods (SALKIND, 2004).

A research design will identify people with the requisite credentials and talents to perform certain tasks. These individuals are mentioned in the research acknowledgements and also in the bibliography, or as a reference. The research methodology will be guided by ethical considerations and professionalism, because mining is a high-risk profession, with extensive workplace challenges. Ethics is a code of practice that shows how a professional group, such as engineers, ought to work, and what type of relationship they ought to have with their clients, associates or stakeholders. Investigating complex social realities can be very problematic, as cultural and social values, as well as ethics which differs as one moves from one environment to another. By gathering the elements necessary for the research methodology, it will be easy to reach the research objectives. Data collection is critical in understanding how small-scale mining activity works. Statistics can be seen as the art of learning from data and are concerned with the collection of data, its subsequent description, and its analysis, which often leads to the drawing of conclusions (Shanmugam, 2015). The following paragraph describes an outline of the mining concepts to be examined here.
3.2 Outline of the mining concepts in artisanal mining and the small-scale processing of sandstones

Below is a list of nine outlines which constitute the core of Chapter 3.

- Introduction to mining concepts
- Flow sheet of mining concepts
- Main research tools
- Mining techniques in the artisanal mining of sandstones
- Processing or cutting techniques in small-scale processing of sandstone
- Transportation and handling techniques
- Chemical and physical properties of sandstone
- Human elements and related ethics
- Environmental concerns
- Cash flow model of a 100m² sandstone project in QwaQwa
3.3 Mining concepts flow sheet

- Introduction to mining concepts
- Mining techniques in the artisanal mining of sandstone
- Processing techniques in the artisanal mining of sandstone
- Chemical and physical properties of sandstone
- Human elements and related ethics
- Environmental concerns
- Transportation and handling techniques
- Research tools:
  1. Interactions
  2. Observations
  3. Mining sites
- Five steps in extracting a sandstone block
- Cash flow model on a sandstone project
- Conclusion and recommendation

Completion of Chapter 3
3.4 Main research tools

The three main research tools used for the research are: interactions, observations, and the mining sites. It is important to know how miners feel about a particular technique, process or legislation through interaction with respondents. The tool will assist to gather data through observation on various mining sites within QwaQwa, Neighbouring Lesotho and Cameroon. The research methodology is largely qualitative, but some data gathered for quantitative analysis will be discussed under this chapter so as to help support other claims and demands for the research.

3.4.1 Interactions with miners and stakeholders

The researcher had one-on-one sessions with landowners, employers, splitting miners, processing miners, general workers, machine operators, and drivers. No questionnaire was handed to respondents and most of the data was collected and documented by the researcher due to a high level of illiteracy. Below are questions discussed with respondents during the survey.

Questions asked during sessions were the following:

- Artisans opinions on the artisanal mining and small-scale processing of sandstones in QwaQwa
- Do artisans have hope that things can change for the better?
- What are the difficulties miners are currently faced with in QwaQwa?
- Who are currently the main stakeholders?
- What level has been reached by the artisanal mining and small-scale processing of sandstones in QwaQwa?
- What are the contributions of artisanal mining and small-scale processing of sandstones to the livelihood of the people of QwaQwa and the rural community?

3.4.2 Observations on mining sites

Observations consist of carefully watching the mining process from testing, planning, splitting, processing, transportation, packaging, and distribution. The observations have been a vital tool for the research, because it is through observations that most splitting, processing and transportation techniques were established. Workers where observed for many hours on how their daily tasks are carried out and documented. Most of the observations where enhanced, and a better practice brought forward and advised accordingly in Chapter 5.

3.4.3 Main mining sites in QwaQwa

The main focus of the research is on artisanal miners of sandstone in QwaQwa. The research also compare three sandstone mining sites in two different countries which are. Lesotho (Lekokoanaeng), and Cameroon (Puma), in order to assist with technical and socio-political
aspects to complement the mining concepts. When visiting various mining sites, technical information on the sites shall be collected, such as how many workers are involve in each of the sites, the age groups involved, qualifications and skills, daily activities, preferences, sales, income and production rates.

A brief description of mining site (1) PERENG
The site is located around three kilometres north of the town of QwaQwa. It employs six permanent artisanal miners and covers an area of about 100m², where the main types of sandstones mine in Pereng are Greywacke & Arkose used as bricks and tiles. The Pereng mine has been in existence for about 10 years and is owned by Kharafu Sandstones, the largest sandstone producer in QwaQwa. Kharafu Sandstones is our major and credible source of information and data collection, though there are other mining sites around from which other research was conducted.

A brief description of mining site (2) MAKWANE
The site is located about four kilometres north of the town of QwaQwa. It employs four permanent artisanal miners and covers an area of approximately 80m², the main type of sandstone mine here is the yellowish grit sandstone used mainly in making artefacts. This mining area has been in existence for approximately twenty years owned by Kharafu Sandstones.

A brief description of mining site (3) MESIMATSO
The site is located in the north about six kilometres away from the town of QwaQwa. It employs five permanent artisanal miners and occupies an area of approximately 250m², where the main type of sandstone mined here is Greywacke, mostly used as tiles or bricks for cladding. Mesimatso is a new mining site very remote from the community. It has been exiting for approximately five years, and is also owned by Kharafu Sandstones.

3.5 Mining techniques in the artisanal mining of sandstone
There are many techniques use in sandstone mining, the researcher will be investigating techniques relevant to artisanal mining, particularly in rural communities like QwaQwa. There are other splitting and processing techniques recommended by the researcher to assist artisanal miners in a way forward towards progressive mechanisation. Nine splitting techniques will be scrutinised, including levering and channelling. The splitting techniques includes, the use of chisel and hammer, fire, gunpowder, micro-blaster, plug & feather, crowbar, pickaxe, expansive mortar, pneumatic rock hammers (PRH), water jets, diamond wire and diamond disc.
3.5.1 **Sandstone extraction**

Extracting a rock such as sandstone without the use of any explosive, is done by stressing the rock beyond its tensile strength, where different rocks have different tensile strengths, and some break easier than others. It is important to break a rock by stressing it at points of natural weakness e.g., cracks, lamina, and intrusion points. For example a seamy sandstone rock will easily break, due to the line of weakness. There are several techniques used to extract sandstone. Nine sandstone splitting techniques which may be applicable to QwaQwa artisanal mining of sandstones shall be examined. The splitting techniques exclusively depend on the location, type of sandstone, resource availability, and skills of the miner. For example there is not enough wood in QwaQwa to split sandstone using fire, which will make it a difficult option, because there is no forest located in this region. Applying or choosing the most appropriate splitting technique is important as it can help to optimise both profit and improve safety. An appropriate splitting technique requires consideration of technical, socio-economic, political and historical factors. Generally, it should match the ore body geometry and be of lower cost (Ataei, et al., 2008).

![Process flow diagram for sandstone extraction](image)

3.5.2 **Five steps in extracting a sandstone block**

Before extracting a sandstone block, there is a sequence of activities to follow to ensure proper management and safety in the work platform. This section examines five major steps to ensuring the rock mass is properly removed and prepared either for processing or for sale. The major steps include identification of the potential sandstone deposit or the sandstone rock mass to be mined. After identification, the site should be cleaned, marked and set ready for splitting. Steps for extraction are as follows:
Step 1: Identification of potential sandstone deposit

The artisan starts by identifying the potential deposit or a particular type of sandstone and the specific location to commence the mining activity. The identification is usually done by observation, due to past experience, or chipping a sample of the target stone to test for quality, strength or coloration. A miner may be attracted to a particular site depending on the customer’s order, or he may chose an area to mine simply because it is easy and accessible. A dangerous, rough and inaccessible mining site ought to be the last resort or be avoided if possible. Where the outcrop is not visible enough, a small portion of the overburden or vegetation may be remove to access the potential deposit for sampling or to have a clear sight of the sandstone deposit. If necessary, drilling may be performed, depending on the depth of the deposit.

Mining structure and planning

Most artisanal sandstone miners in QwaQwa will prefer to mine outcrops at higher elevations and not at the foot or bottom of deposits. The reason for this is because they want to access easy outcrops, make use of gravity for easy transportation, avoid waterbeds or wet sandstone, and keep away from lowlands accessible to farmers and their crops.

Mine planning architecture showing different open-cast models

Different terrains possess different challenges when mining in an opencast. Before opening a new sandstone mine, the miner should consider the sequence of the mining activity, the sandstone geometry, whether it is flat, hilly or on an incline. In order to achieve safe and easy access, the mining activity should be carried out in a specific sequence, depending on the geometry of the sandstone deposit. Typical QwaQwa sandstone geometry is shown in the Figure 3.1 below.

![Figure 3.1: QwaQwa sandstone deposits](image)

Figure 3.1: QwaQwa sandstone deposits: (A) an unmined sandstone covered with vegetation; (B) artisanal mining close to the mountain’s foot; (C) an artisanal miner besides his processed sandstone.
The architecture of a sandstone deposit can determine what extraction method the miner can apply. Below are different geometry or architecture of sandstone deposits.

**Symmetric deposits**: Easy to mine with a variety of splitting techniques

**Hilly deposits**: Easy to mine with limited splitting techniques

**Inclined deposits**: Easy to mine with limited splitting techniques

**Trench deposits**: Difficult to mine, demands skilled labour and selective splitting technique

**Inclined deposits with overburden**: Difficult and very costly deposit to mine

QwaQwa deposits are mostly outcrops which are often symmetrical, hilly, or inclined, making it an easy target for miners.

**Step 2: Clearing of mining site and removal of the overburden**

After identification of the mining site, the immediate mining perimeter must be cleaned either manually or with machines. The site can be cleaned manually with the use of machetes, wheel barrows and shovels. Machines like bucket wheels, tractor loader backhoe (TLB), engine saw, front-end loaders could be hired for a bigger area to be cleaned. After clearing and cleaning of site, extra water should be removed, or the mining perimeter should be provided with a proper water exit by digging a drainage to drain out excess water. In case of a basin, the water can be removed using a bucket or a water pump if necessary. **Figure 3:2**, shows mining sites with an overburden to be cleaned.

![Figure 3.2](image)

**Figure 3.2**: (A) A tropical sandstone mining site with its overburden partially removed; (B) QwaQwa greywacke mining site with its thick black soil and vegetation partially exposed.

**Step 3: Area marking**

When the mining area is dry or free of mud, the miner should mark out the area on the rock mass deemed necessary to be extracted as indicated in **Figure 3:2 (A)**. The size of the rock mass mark off should be at the discretion of the miner, and will depend on what splitting technique to carry out, the customer’s order, or what size of the sandstone mass he can manage after the split. Marking of a very large size may pose a problem during splitting or lifting, if the size of the target rock mass is too small, the work output may be delayed. The
sandstone surface can be marked with a chalk, charcoal, marking pencil or even a metal strip. Mining should commence preferably at the edge of the outcrop, or if possible, a first cut can be created at a particular point, provided the mining activity is proceeded in benches preferable from a higher elevation to a lower elevation as shown in Figure 3.3 (B). Mining sandstone in benches must be the ultimate way to approach a sandstone deposit, because of its many advantages, such as safety and good yield.

![Figure 3.3: Area marking. (A) Marking of face using a colour chalk or charcoal; (B) Recommended bench mining.](image)

**Step 4: Extraction and selection of extracting technique**

After marking the rock face, the miner should consider which splitting technique to apply as discussed in the previous section. When choosing the splitting techniques, the technique will depend on the discretion of the miner, where he is obliged to consider certain elements like the rock strength, and the availability of resources. An artisan with little money may choose a chisel and hammer, whereas an artisan with enough money can purchase a jackhammer or other electric tools for splitting.

No matter what extraction technique the miner chooses, there are three major principles involved in order to extract the sandstone. The principles are levering, channeling, and splitting as shown in Figure 3.4 (A), (B) and (C).

**Three main principles of stone extraction**

**Levering**

Levering is a simple and practical way of extracting sandstone. It is done by inserting either a crowbar or a lever into a plane of weakness of the rock like bedding plane or cracks. Once inserted, force is applied on the tool tilting towards the horizontal to force the rock to expand and break loose.
Channelling

Channelling is like carving into the rock. It is done by chipping into the rock mass, so that it can be separated from the bedrock. It can be done using tools such as chisel and hammer, pickaxe, fire, sawing or drilling into the rock. Figure 3:4 (D), (E), and (F) shows basic extraction tools.

Splitting

Splitting is a widely applied principle used in extracting sandstone. It is done by creating fractures into or stressing the rock either by hammering, wedging, blasting, or heating.

Figure 3.4: Three major sandstone extracting principles and basic extraction tools. (A) Levering; (B) Splitting; (C) Channelling; (D) Chisel and hammer; (E) Wedge and feather; (F) Use of expansive mortar.

Step 5: Removal and storage

After splitting the rock mass as describe in Section 3.5.3 to 3.5.11, the rock is then safely remove to a safe storage or nearby location, either for processing, sale or further transportation as indicate in Figure 3:5. Hanging rocks should be removed using a crowbar or pickaxe if too strong to be removed by the bare hands. Stone blocks ought to be placed in an interlocking manner to prevent falling or rolling, as it may cause injury or bloc a pathway. Lifting and transporting techniques described in Section 3.7 could be applicable.
Figure 3.5: Removal and storage of sandstones. (A) Huge sandstone blocks are temporarily stacked closed to the bedrock and are transported directly for processing to avowing double handling; (B) Piling pattern of sandstone bricks; (C) Heaping of sandstone slabs.

3.5.3 Splitting of sandstones using only chisel and hammer

This is the traditional, popular, and most applicable method of artisanal mining of sandstone used not only in QwaQwa, but all over the world. One would believe the method is very popular, because it is the cheapest and most adaptable. Even though there are different splitting techniques, a chisel and hammer may still be used when applying the other splitting techniques. The artisan may need only the basic tool of chisel and hammer of different shape and sizes as described in Table 3:1, and the miner being medically fit to carry out a mining operation. A hammer could vary in weight from 0.90kg, 1.36-1.81kg depending on the miner’s discretion and his ability to handle the tool, and also with chisels of different sizes to best fit the crack or create that impact needed to initiate splitting.

Table 3.1: Shows various sizes, length and weight of hammer and chisel from Builders Hardware SA

<table>
<thead>
<tr>
<th></th>
<th>Weight (kg)</th>
<th>Total length (mm)</th>
<th>Point width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hammers</strong></td>
<td>0.90, 1.36, 1.81</td>
<td>273.05, 279.40,</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>285.75, 400.05</td>
<td></td>
</tr>
<tr>
<td><strong>Chisels</strong></td>
<td>0.23, 0.45, 0.91,</td>
<td>203.20, 215.90,</td>
<td>15.88, 31.75,</td>
</tr>
<tr>
<td></td>
<td>1.36max</td>
<td>304.80, 317.50</td>
<td>79.38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>317.50</td>
<td></td>
</tr>
<tr>
<td><strong>Other tools</strong></td>
<td>Scutch hammer,</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>cold chisel, scutch chisel, bolster chisel, picks, crowbar, club hammer and jackhammer.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Splitting process

How to make a starter hole or a notch

A starter hole is a small hole chipped into a stone to facilitate the penetration of a chisel or a bigger bit prior to splitting. It is made preferably using a star-bit chisel or another chisel, provided it can create a starter hole needed for splitting. Cracks or openings of natural weakness in the rock could also be used as starting points in initiating a split.

Effective use of a chisel and hammer in the artisanal mining and small scale processing of sandstones

The chisel and hammer are the two major tools involved in the splitting of sandstone in artisanal mining. If they are not properly applied, they can be less productive or create injuries. Below are critical steps to ensuring the effective use in splitting of sandstone, keeping in mind that obtaining a specific split is achieved through extensive experience.

This subsection looks at some fundamental forces or the physics applicable to the use of a chisel and hammer with two major forces applicable: first, the potential energy (PE), viz. energy due to position of the body PE = m × g × h; second, the kinetic energy (KE) is the energy due to motion of a body KE = ½ × m × v². If a gravitational acceleration (g) is acting on a mass of an object (m) at a height (h) that object is said to have PE in joules (J), while if a force (F) acts on a stone of mass (m) originally at rest (i.e. initial velocity u = 0) and accelerates it to a velocity (v) over a distance (s):

Work done = KE = Force × Distance = m × a × s

The acceleration of the hammer could be calculated as (a = v²/2×s)

Example of impulse force (assume a linear motion)

Note: momentum before impact = momentum after impact

and kinetic energy before impact = potential energy

Energy lost in the blow = KE before impact – KE after impact

Average resistance against the stone block (R) as it moves a distance of (δ) after impact.
Technical procedures to be observe during splitting as shown in (Figure 3:6).

1. Put on the appropriate protective gear i.e. hand gloves, safety googles, safety boots and a work uniform.
2. Place the tip of the chisel at the point where you anticipate a split.

3. Lean the chisel towards the larger mass of the stone, i.e. the chisel should not be placed perpendicular to the stone, as it might chip the stone, rather than a split.
4. With the chisel place at an angle between 45-60°, tap the end of the chisel with your hammer with enough force necessary to create a split. You may need several hits on the chisel before you observe the desired split.
5. Repeat the process on the notches of the marked line until you get a complete split along the score line.
6. Several chisels may be used if necessary. In case one gets stuck the other might serve to release the other one by expanding the rock with a hit on the recently placed chisel.
7. A stuck chisel on the rock can be remove by beating the chisel in a front and backward movement until it becomes loose.

**Splitting of a grit (laminated sandstone)**

The process involve in splitting a sandstone rock like grit is very different from that of a sandstone like greywacke, because a sedimentary sandstone rock like grit is made of lamina as shown in Figure 3:7 (A), therefore splitting takes place horizontally on the bedrock in-between two lamina by inserting a chisel between the laminae in order to create a split. During splitting, around 5 to 30cm or more of a lamina can be removed, depending on what size the miner requires or what force his equipment can exert on the sandstone. A final blow to remove the piece comes with the aid of a long crow bar, inserted where the chisel has created a gap you apply the lever. Multiple chisels could be inserted, and depending on the width and strength of the stone, the split will follow the path of least resistance. Generally, the idea is to remove as much lamination as possible to achieve a comfortable bench height.

**Splitting of a greywacke (non-laminated sandstone)**

A greywacke is a consolidated to be type of sandstone with no lamination as shown in Figure 3:7 (B). Splitting generally is done vertically or starts from the top to the bottom of the bedrock. Greywacke should also be mine in benches in the form of lumps of varying sizes, depending on customer’s order or at the miner’s discretion. Splitting can be done in different ways, but in a typical artisanal mine, which employs chisel and hammer, splitting commences by creating several lines of weakness, using a star bit chisel to notch guide holes on top of the stone. The guide holes help to prevent bouncing and scarring of stone, as well as to facilitate the penetration of chisels and bits. Many other splitting tools can be further used to split greywacke, depending on the availability of the tools. Other splitting techniques used to split greywacke sandstones are plug and feathers, jackhammer, crowbar, expansive mortar, or gunpowder, which will be discussed in the same chapter.

![Figure 3.7: Two major types of sandstone in QwaQwa. (A) Grit sandstones; (B) Greywacke sandstones.](image)
Applicability and specifications are described in Table 3:2.

**Table 3.2: Applicability and specifications while using a chisel and hammer**

<table>
<thead>
<tr>
<th>Process</th>
<th>Tools</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Applicability</th>
</tr>
</thead>
</table>
| Percussion | Hammers, pounders, chisels, and picks | -Cost effective  
-Flexible  
-A single miner can use the tools for splitting | -Requires skills  
-Low recovery  
-Used mostly on smaller sandstone block  
-Can cause severe injury to the body | -Very common in QwaQwa. Recommended for artisanal mining of sandstones |

### 3.5.4 Splitting of sandstone with wedge and feather, crowbar and pick.

Wedge and feather or plug and feather are also two basic tools in artisanal mining of sandstones shown in Figure 3:8, similar to chisel and hammer a wedge and feather come in different sizes and shapes. The tools are designed to split rocks by applying a force when driven into a natural crack or a drilled hole into the rock. According to Mateus (2008), the procedure of splitting sandstone using wedge and feather is described below.

**Procedure**

1. Drill holes along the split line at desired spacing depending on the strength, thickness and length of the rock. For hard splits, drill holes deeper and closer together. Your split line could be a straight or curve pattern. Holes spacing could be estimated at 15cm apart.

2. Insert the wedge and feather into the drilled hole as shown, make sure the feathers or ears face the direction you want the stone to split. Position the feathers into the hole such that flat sides of the wedge becomes parallel to the line where breaking will likely occur.

3. Hit the wedge repeatedly with a hammer into the slot in-between the feathers. Wait for a moment until cracks occur, or if you see the feather stick into the rock, tap the wedge lightly front and back until it is freed. Finally, you can remove the wedge and if necessary continue same procedure with the next wedge and feather. It is a slow procedure and one has to be cautious so as to allow the tools to yield strength accordingly. After splitting, make sure no wedge or feather is left stuck within the stone, always count the number of wedges and feathers before leaving the working area (Mateus & Araújo, 2008).
Figure 3.8: Splitting with wedge and feather. (A) A wedge and a feather; (B) Drilled holes preparation (C) Penetration of wedge using a Hammer.

A **Pick** is like a hammer, but has a pointed tip, used to expose and enlarge points of natural weakness on a rocks. It is possible to break soft rocks with a pick without hitting with a hammer.

A **Crowbar** is an accompanying tool used to give a final blow when deem necessary, preferably only when the crack is wide enough to accommodate the crowbar. Crowbars are of different sizes, length and weight, and must be used appropriately. See method applicability and specifications in Table 3.3.

### Table 3.3: Applicability and specifications while using a wedge and feather

<table>
<thead>
<tr>
<th>Process</th>
<th>Tools</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wedging</td>
<td>-Iron wedge, and feather</td>
<td>-Cost effective</td>
<td>-Requires skills</td>
<td>-Not common in QwaQwa.</td>
</tr>
<tr>
<td></td>
<td>-Wooden wedge, and feather</td>
<td>-Flexible</td>
<td>-Can cause severe injury to the body</td>
<td>Recommended for artisanal mining of sandstones.</td>
</tr>
<tr>
<td></td>
<td>-Chisels and hammer</td>
<td>-A single miner can use the tools for Splitting</td>
<td>-Low recovery rate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Can handle bigger sandstone blocks</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.5.5 Splitting of sandstone by fire

Using fire is an artisanal splitting technique mostly adopted in areas where there is abundant wood or coal, which is particularly notable in one of the artisanal mining sites in Puma, Cameroon. There is no mining of sandstones using fire in QwaQwa. The main reason for this is that QwaQwa is arid, and lacks forests, which imply mining with fire produced by firewood.
could be very costly or even impossible for the artisans. Even though firewood is used, chisel, hammer and crowbar are also used. One doesn’t know exactly when this mining method started. But it is believed that the mining method existed since the dawn of mankind when humans discovered fire and started using tools made from forge iron. All rock splitting activities needs energy similar to the energy we get from the heat from fire. The heat is monitored so that a desired temperature is maintained: if the heat is too high, the rock might become fragmented to which is undesirable; if the heat is insufficient, the rock might not fracture. Therefore, using firewood for splitting requires specific skill. When the heat produces a crack on the rock, one can now apply the chisel, hammer or crowbar for the final split before the rock gets cold. Other sources of heat energy within QwaQwa may come from waste or low grade coal. Figure 3:9, shows the splitting process using fire.

![Figure 3.9: Splitting technique using fire. (A) Firewood set on top of the target rock; (B) A flat chisel is inserted at point of weakness.](image)

**Heat energy, specific heat capacity and thermal conductivity of sandstone**

The first law of thermodynamics, also known as law of conservation of energy, states that energy cannot be created or destroyed in an isolated system. In the case of heating sandstone with fire to split the stone, the energy is transferred from the fire to the sandstone, even though most of the energy is lost as heat in the surrounding environment (Bird & Ross, 2012).

**Techniques and procedure applicable to create high stress and cracking**

The techniques of heat transfer from fire to a stone is a method that begins by trial and error, until the miner gets use to, because many factors might influence the heat transfer process, such as:

1. The type of fire set on top of the rock;
2. The procedure observed during fire setting; and
3. The environment and other elements of nature, such as humidity and sunlight.

**Procedure to follow when using wood to produce fire**

1. Choose the right wood i.e., a wood with high calorific value and low moisture content.
2. Mark out the area which you intend to split.
3. Clean the rock surface and make sure it is free from water, soil or any chemical.
4. Place the wood closer enough to the rock and set the fire.
5. Monitor the temperature or time it takes to reach a temperature of between 400-
   500°C. At this temperature range, the rock will have expanded considerably. The
   expansion of the rock will be notice through sounds like popcorn being made.
6. Remove the fire off the rock completely, and start splitting by inserting and lifting the
   rock at a point with a chisel and a hammer or a crowbar.

Placing the wood horizontally on the rock will yield quicker heat transfer onto the rock rather
than inclined wood. Timing how much time the fire has lasted may also give an indication to
the artisan as to whether he can initiate a split, where generally, a fire burning for thirty minutes
to an hour may be enough. It is preferable to use a thermocouple or infrared thermometers to
measure the heat when mining using fire, because they are safe to use and can be easily
moved. Avoid high temperatures, as this might destroy some chemical and physical properties
of the rock. It is essential to know the coefficient of linear expansion of the sandstone rock
before heating, the coefficient of linear expansion will enable the miner to know exactly at what
temperature the rock can produce a reasonable crack for a split to be initiated.

**Coefficient of linear expansion**
The coefficient of linear expansion is the amount by which unit length of a material expands
when the temperature is raised by one degree (1°C-1) or as per kelvin (K-1).

If a material of initially length $L_1$ and at initial temperature of $t_1$ and having a coefficient of
linear expansion $\alpha$, has its temperature increased to $t_2$, then the new length $L_2$ of the material
can be calculated as shown in Table 3.4.

**Example**
The coefficient of linear expansion of rock masses measuring 1–4 metres, which expands
after heating for 30 minutes from 30°C to 460°C can be determined using the formula below.

New length = original length + expansion:

$$L_2 - L_1 = L_1 \alpha \times (t_2 - t_1)$$

$$\alpha = \frac{L_2 - L_1}{L_1 \times (t_2 - t_1)}$$

**Table 3.4:** Calculations on the coefficient of linear expansion.

<table>
<thead>
<tr>
<th>$L_1$ (mm)</th>
<th>$L_2$ (mm)</th>
<th>$L_2 - L_1$ (mm)</th>
<th>$t_1$ (°C)</th>
<th>$t_2$ (°C)</th>
<th>$t_2 - t_1$ (°C)</th>
<th>$\alpha$ (°C⁻¹ or K⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>1002</td>
<td>2</td>
<td>30</td>
<td>400</td>
<td>370</td>
<td>$5.4 \times 10^{-6}$</td>
</tr>
<tr>
<td>2000</td>
<td>2003.5</td>
<td>3.5</td>
<td>30</td>
<td>430</td>
<td>400</td>
<td>$4.3 \times 10^{-6}$</td>
</tr>
<tr>
<td>3000</td>
<td>3005</td>
<td>5</td>
<td>30</td>
<td>460</td>
<td>430</td>
<td>$3.8 \times 10^{-6}$</td>
</tr>
<tr>
<td>4000</td>
<td>4007.5</td>
<td>7.5</td>
<td>30</td>
<td>490</td>
<td>460</td>
<td>$4.0 \times 10^{-6}$</td>
</tr>
</tbody>
</table>
From the table above, one could see that the rock mass expands as the temperature increases and the larger the rock mass the greater the expansion at constant temperature. This method of splitting possesses several disadvantages as described in **Table 3.5**.

### Table 3.5: Applicability and specifications while using fire

<table>
<thead>
<tr>
<th>Process</th>
<th>Tools</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>Firewood, coal, charcoal, hammers, chisels and picks.</td>
<td>-Cost-effective</td>
<td>-Polluting</td>
<td>-Not used in QwaQwa. Recommended for QwaQwa if a cheap energy source is available.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-A single miner can use heat for splitting</td>
<td>-Requires longer period to yield</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Restricted to areas with plenty of wood</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Requires much skills</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Can cause burns</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Over heating may damage the sandstone</td>
<td></td>
</tr>
</tbody>
</table>

#### 3.5.6 Splitting of sandstone with low energy explosives

The use of low energy explosive is not popular within artisanal miners of sandstones due to the cost, technique and availability of resources. Blasting is becoming increasingly unpopular within stone miners, due to the availability of increasingly sophisticated cutting machines in the market. The explosives used here are those with low VOD (Velocity of Detonation), mostly gun powder and Micro-Blaster cartridges. Using explosives to break a stone demands a great deal of skill, and is used mostly in medium or large-scale operations. For sandstone mining, drilling and charging, only a single hole on the line of weakness of a rock can inflict the desirable split you may need.

1. **Using gun powder:** Gunpowder is a deflagrating explosive, which has no shock energy, and works by means of pressure gases generated by deflagration. In practice, it is done by igniting the blasting gun powder in suitably tamped drilled holes. According to a stone quarry in Cameroon, using gun powder in the splitting process observed can be described beneath with additional images in **Figure 3.10**.

#### Splitting process

1. Drill a 12mm diameter hole in the rock about 45cm deep using a masonry drill bit. Make sure the hole is 30cm to 50cm from the face of the target rock.
2. Clean out the hole from dust by using a bicycle pump attached to an aluminium pipe 70cm long and 6mm in diameter.

3. Pour about 20 grams of gunpowder into the hole using a small funnel. The gun powder can be measured using a graduated cooking shot glass.

4. Place the right length of cannon fuse in the hole and make sure you know the burn rate of the fuse in order to keep a safe distance. Ensure there is a good fuse/powder connection by corkscrewing the fuse into the powder by a millimetre or so.

5. Backfill the hole with clay mull into 3mm balls, drop them into the hole and tamp them down with a 6mm wooden rod. Tamp the clay in the hole after placing every 5-10 clay balls. Place sandbags tightly around the tamped hole.

6. Detonate the fuse at a safe distance, ensuring that nobody is in the blast area.

**Precautions:** It is advisable to conduct a small-scale test and be familiar with the technique of knowing how much explosive or what holes length is enough to create the desirable crack or split needed. Make sure people and property are far away from the blast area, because flying rocks can cause injuries or even death (Hustrulid, 1999)

![Figure 3.10: Splitting of sandstones with gunpowder. (1) Drill a hole into the rock using a hand drill; (2) Clean and charge holes with gunpowder; (3) Insert the ignition fuse and cord; (4) Stand at a safe distance and blast.](image)

2. **Using micro-blaster:** A micro-blaster is an actuator used to fire small powder-filled cartridge, which comes with a connecting cord. As observed in a road construction site in Zambia that used to break rocks, and according to the United States Department of Transportation, a micro-blaster is a light-weight, fast and economic portable tool used to break smaller rocks weighing 45-450kg, and to break stone vertically or horizontally.
The system breaks rocks by means of expansive gases and can split rock along a fairly straight line. The system comes with a special 8mm diameter cartridge design, to be inserted into a 10-30cm hole drilled into the stone. The micro-blaster is then placed in the hole on top of the cartridge as shown in Figure 3.11.

**Splitting process**

1. Use a portable 110V rotary hammer drill to drill the 10-30cm holes. Drills could be battery or fuel powered.
2. Use a pump to blow out dust and debris out from the drilled hole. This could be bicycle pump with an extension pipe.
3. Insert the 8mm cartridge into the prepared holes with the brass cap pointing up. Transparent tapes can also be used to insert the charge into the hole to prevent misfire or in case the hole is not well cleaned.
4. Places the micro-blaster actuator on top of the cartridge with the safety mechanism locked and cock, make sure it aligns with the hole and fits properly. Then unlock the safety mechanism.
5. Cover the charge holes using old carpets or light rubber mats to prevent flying rocks and minimise noise.
6. Fire the micro-blaster at a safe distance from flying rocks by pulling the 7m connecting cord from its end (Beckley, 2005). Using a micro-blaster has limitations as described in Table 3:6.
**Figure 3.11:** Sandstone splitting using a micro-blaster. (1) Micro-blaster kit; (2) Cartridge inserted into a drilled hole; (3) Cartridge covered with rubber mat or carpet to prevent flying debris; (4) Broken rock.

**Table 3.6:** Applicability and specifications while using low energy explosives

<table>
<thead>
<tr>
<th>Process</th>
<th>Tools</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blasting</td>
<td>-Cartridges, micro-blaster, drills, connecting cord, and mats or gun powder, fuse, bicycle pump, clay.</td>
<td>-High yield -Flexible -Quick to install</td>
<td>-Expensive -Dangerous -Low recovery due to high fragmentation -Requires skilled Miner -Generates noise and dust</td>
<td>-Not common in QwaQwa. Recommended for artisanal mining of sandstone.</td>
</tr>
</tbody>
</table>

3.5.7 **Splitting using expansive mortar or cement**

The technique has become popular in recent years and largely used by artisanal and small scale mining in splitting of stones around the world, but is not common amongst sandstone miners. Expansive mortar is a noise-free, safe, cost-effective, environmentally friendly and non-explosive stone splitting agent. The stone cracking powder is seen today as an efficient technique in quarrying. It can be used to crack blocks of marble, granite, onyx or sandstone. Expansive mortar is a non-poisonous and tasteless product mainly made of silicates, cement, slow coagulant, and aluminium calcium acid. There are different types of expansive mortars as shown Table 3.7, the application will depend on the rock temperature on which it should to be applied. According to splitting procedures observed in a mining site in Cameroon using Geekay industrial expansive mortar, the process can be detailed as follows:

**Splitting process**

1. Select the correct expansive mortar, the expansive mortar is chosen depending on the rocks temperature as indicated below. Note the reaction time of the expansive mortar to create a crack, which may vary from 24-72 hours. The higher the rock temperature and the closer together the holes, the quicker the rock will crack, otherwise the rock may not crack properly.
Table 3.7: Types of expansive mortars and rock temperatures according to Geekay Industrial

<table>
<thead>
<tr>
<th>Type</th>
<th>Rock temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCA I</td>
<td>20°C - 35°C</td>
</tr>
<tr>
<td>SCA II</td>
<td>10°C - 25°C</td>
</tr>
<tr>
<td>SCA III</td>
<td>0°C - 15°C</td>
</tr>
</tbody>
</table>

2. Prepare the following items described below with the procedure illustrated in (Figure 3.12).
   - Demolition agent or expansive mortar
   - Clean and cold water
   - Plastic or metal bucket
   - Beater or wooden rod for mixing
   - Safety goggles, rubber gloves, dust proof mask and hard hat
   - Thermometer

![Figure 3.12: Splitting using expansive mortar or cement. (1) Rock face preparation with a hand drill; (2) Mixing of expansive mortar in a plastic bucket; (3) Pouring of expansive into drilled holes; (4) Parallel split rock.](image)

3. Drill and clean holes
   Holes are drilled on the rock that needs to be cracked along 80-90% of its length; the holes are marked prior to drilling to obtain the desired pattern. Holes are normally drilled using an electric drill, the size of which will depend on the rock strength. Hole spacings should vary from 300-500mm. The distance between the holes will depend on the type of the rock, where the closer the holes, the quicker it will crack. Holes should not exceed a 40mm drill. The holes’ diameter will determine the cracking result, and it is advisable to apply parallel hole spacing.
for a better split (Bakhtavar, 2011). Holes that are too small will result in subpar performance, where holes that are too large will result in blowout shots. After drilling, holes must be kept clean from dust and water by using compress air or vacuum. Damp holes are preferable as they facilitate cracking. Before drilling, you should consider the maximum broken rock size you can safely manoeuvre.

4. Mix

Mix expansive mortar with clean, cold water in a plastic bucket, do so by gradually pouring a bag of expansive mortar to 1.5-1.7 litres of water. Stir until you obtain a smooth, lump free slurry. The proportion of water to expansive mortar mixture could be estimated as being 1:3. Use only open containers for mixing, and avoid adding extra water as this might reduce concentration or effectiveness. Not more than 10kg of expansive mortar should be mixed at any one time.

5. Pour

Within ten minutes of mixing, pour the mixed slurry into the predrilled holes. Do not look directly into the charged holes for the next 2-6 hours. Tamp the mortar to remove air pockets by using a piece of rod or stick, to poke holes. Plug holes immediately after filling using a tarp or wet hay, and cover holes with straw mat to avoid direct sunlight on the mortar. For horizontal or slant holes, use a grouting pump to fill if possible. If you can not afford a grouting pump, horizontal holes could be filled by inserting a small plastic pipe into the hole or by filling a sausage-shaped plastic bag with mortar, then insert it into the predrilled horizontal or slant hole. The essence of this is to retain the slurry effectively.

6. Expand

The reaction time of expansive mortar varies from 24-72 hours, depending on other factors like the rock strength and temperature. The chemical reaction of expansive mortar with water generates heat, and can continue to exert pressure for up to five days, reaching 96.52 Mpa. Crack direction is likely to follow the holes pattern, propagation begins then the cracks widens. It is important to note that holes pattern design must allow the material to move to the free space as mortar expands.

7. Precautionary measures are listed below

- Wear the appropriate PPE, e.g. safety goggles, gloves, dust mask and overalls.
- Always consider the rock temperature and the type of mortar to use.
- Holes diameter should be a minimum of 28mm and must not exceed 40mm.
- Holes that are too shallow might results in blowouts. Hole depth must be four times longer than its diameter or more.
- Never use metal or glass containers to fill mortar.
- Don’t use hot water to mix mortar.
- Do not mix mortar that is more than 10kg at any given time.
Always carry out a small-scale tests before a major operation.

**How much mortar is required per drill size**

32mm Drill x 1 meter deep hole = 1.3kg mortar
z34mm Drill x 1 meter deep hole = 1.5kg mortar
38mm Drill x 1 meter deep hole = 1.8 kg mortar

**Some estimated weights per m² of each material according to the density**

Sandstone 1m² = 2.2 to 2.7 tonne
Granite 1m² = 3 tonne
Limestone 1m² = 2.4 tonne
Concrete 1m² = 2.4 tonne

**Table 3.8: Applicability and specifications while using expansive mortar**

<table>
<thead>
<tr>
<th>Process</th>
<th>Tools</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expansion</td>
<td>Mortar, drill, water, thermometer, plastic bucket,</td>
<td>-Safe to use -Environmentally Friendly -High recovery -A single miner can use the method for splitting</td>
<td>-Takes long period to yield -High costs of mortar</td>
<td>-Not used in QwaQwa. Recommended for artisanal mining of sandstone.</td>
</tr>
</tbody>
</table>

### 3.5.8 Splitting of sandstone with a pneumatic rock hammer (PRH) or hydraulic rock hammer

Also known as jackhammers, a Pneumatic Rock Hammer (PRH) or a Hydraulic Rock Hammer demands a certain level of skill to operate, and is good for laminated sandstones for the hammer to easily penetrate the lamina or line of weakness. It is not suitable for very hard sandstones or large chunk to split. A jackhammer requires electricity, therefore plans should be made to generate electricity if it is not available on site by using either a small generator or batteries. Generally a jackhammer can be used for technical purposes, and small-sized sandstone. Unlike electric hammers, a pneumatic rock hammer uses compress air and breaks through rock by inflicting continuous blow on contact with the rock. They come in different sizes as shown in Figure 3.13 (Raghavan, 2014), and are also expensive to purchase. Using a pneumatic rock hammer to break sandstone can be a very complicated task, because if not well-handle on the stone, it can break the stone into irregular shapes or sizes. A hydraulic rock
hammer uses a hydraulic pressurised system and comes fitted in articulated excavator like a caterpillar fitted with a single chisel.

**How to use a pneumatic rock hammer (PRH)**

1. Choose the correct PRH e.g., a heavy or medium capacity.
2. Place the compressor in an open place to minimise noise.
3. Put on the appropriate personal protective equipment e.g., hand gloves, earplugs, safety boots and safety glasses.
4. Move the PRH by using the legs to avoid back strain or injuries.
5. Use the right chisel depending on the rock formation; a crowbar should be kept standby to lever up and loosen rocks.
6. The PRH should be used at a slight angle, tilted towards your body, to prevent the chisel getting stuck in the stone. Tilting will also allow you to have a better grip on the hammer, preventing a loss of control.

**Precautions:** Close the air supply and disconnect the air host when leaving the PRH unattended. If the PRH gets stuck, release it by moving it back and forward or from side to side. When using a PRH, the miner must locate the electric cord on their shoulder to prevent accidental damage or electrocution. Use a water spray to minimize airborne dust and avoid working for a long period to reduce body fatigue (Chao & Henshaw, 2002). **Table 3.9,** outlines the advantages and disadvantages of a PRH.

![A](image1.png) ![B](image2.png)

**Figure 3.13:** Splitting with electric hammer chisel or a pneumatic rock hammer. (A) Pneumatic rock hammer; (B) Different chisels used on a pneumatic rock hammer.

**Table 3.9:** Applicability and specifications while using a pneumatic rock hammer

<table>
<thead>
<tr>
<th>Process</th>
<th>Tools</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percussion</td>
<td>Pneumatic rock hammer, hydraulic rock hammer,</td>
<td>-Safe to use</td>
<td>-High cost</td>
<td>-Not used in QwaQwa.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Flexible and easy to use</td>
<td>-Used in splitting technical sandstone blocks</td>
<td>Recommended for</td>
</tr>
</tbody>
</table>
3.5.9 Splitting of sandstone using water jets

According to Ciccu, a water jet pumps water using a motor, coupled to a pump. Water is pumped at high velocity ranging from 1-10m/min and a pressure of 100-300Mpa at a standing distance of within 50-150mm depending on the proximity of the rock. The rock is split through a repeated passage of the jet at an angle across the split line. The jet creates a groove on the rock through backward and forward movement of the jet nozzle and cuts at a rate of 6.5m²/h approximately, depending on the rock strength. The nozzle diameter can vary from 0.1-0.5mm depending on the type of rock you wish to split (Ciccu, 2012). The splitting parameters above will depend mostly on the rock strength and its chemical composition. Among other advantages listed in Table 3.10, it is a very flexible tool.

Table 3.10: Applicability and specifications while using water jets

<table>
<thead>
<tr>
<th>Process</th>
<th>Tools</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percussion</td>
<td>Motor pump, water, host pipes</td>
<td>-Safe to use</td>
<td>-High cost</td>
<td>-Not used in QwaQwa, Recommended for artisanal mining of sandstone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-High recovery</td>
<td>-Requires water to work</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Environmental friendly</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Smooth surface during splitting</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Flexible and easy to use</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-A single miner can use the tools for splitting</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.5.10 Splitting of sandstone using diamond wire

A report from the institute of geology and mineral exploration by Arvantides, (2011) elaborates on the sawing of sandstone, which can also be considered as a splitting technique. Diamond wire sawing is a widely used technique in cutting stones. A diamond wire sawing uses a highly abrasive steel wire coated with diamond beads. The wire is lubricated with a constant supply of water as it rotates and cuts through the rock. The cutting process is as follows: the wire
forms a loop around the rock mass; and backward movement of the wire on guided rails from the rock face gradually cuts through the rock, as the highly abrasive wire moves around the rock mass. Table 3.11, outlines the advantages while using a diamond wire for splitting.

Table 3.11: Applicability and specifications while using a diamond wire

<table>
<thead>
<tr>
<th>Process</th>
<th>Tools</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friction</td>
<td>Motor, metal frame with rails, abrasive steel wire</td>
<td>-Good for massive rocks &lt;br&gt;-High yield</td>
<td>-High cost &lt;br&gt;-Dangerous when operating &lt;br&gt;-Needs water &lt;br&gt;-Requires high skills &lt;br&gt;-Not flexible</td>
<td>-Not used in QwaQwa. Recommended for artisanal mining of sandstones and mechanisation.</td>
</tr>
</tbody>
</table>

3.5.11 Splitting of sandstone using a chainsaw or a diamond disc

A chain saw is used to cut soft sandstones with fractures like the grit sandstones. It looks like the saw used to cut trees. It has a portable and movable arm with abrasive chains made of tungsten carbide or diamond beads, which cuts through rock as it rotates. It can cut a stone at a depth of up to 6m deep.

A diamond disc is a disc blade powered by an electric or engine motor. The diamond disc is mounted on rails or on an excavator, it comes in different sizes and capacity. Disc cutting is good in cutting soft rocks vertically. Though smaller disc can cut horizontally (Arvantides, 2011). Among other disadvantage listed in Table 3.12 it is expensive to purchase.

Table 3.12: Applicability and specifications while using a chainsaw or disc saw

<table>
<thead>
<tr>
<th>Process</th>
<th>Tools</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friction</td>
<td>Chain saw, diamond disc electric or engine motor, steel blades, chains, excavator</td>
<td>-Safe to use &lt;br&gt;-Flexible</td>
<td>-High costs &lt;br&gt;-Not good for primary splitting &lt;br&gt;-Generates noise and dust &lt;br&gt;-May need water</td>
<td>-Not used in QwaQwa. Recommended for artisanal mining of sandstones and mechanisation.</td>
</tr>
</tbody>
</table>
3.6 Processing or cutting techniques in the artisanal mining of sandstone

Processing is what adds value to any sandstone product, even though its hard work to achieve as the final product gets ready for the markets. Processing or cutting techniques of sandstone has rapidly improved in recent years, due to the high demand for quality sandstone. Most often, sandstone processing is done in two stages, viz. primary and secondary processing. Seven processing or cutting techniques have been identified in this research, which are: processing with a chisel and hammer; cutting with diamond cutting disc blades; numeric processing; using a pneumatic chisel or processing with impact; and abrasive and measuring tools. All these techniques shall be discussed in the next paragraph with their relative advantages and disadvantages as related to the small-scale processing of sandstones in QwaQwa.

Primary processing of sandstones
Primary processing could be the use of a diamond disc cutting blade, chisel and hammer or a pickaxe. At this stage, the product size is often rough, and bigger than in the secondary processing stage. A customer may require a sandstone at this stage depending on its application or unavailability of an advance processing techniques.

Secondary Processing of sandstones
Secondary processing is a more refined processing stage, which includes a more précised shaping or polishing techniques. Secondary shaping requires artistic and aesthetic skills in order to achieve a well finished product. Secondary shaping of sandstones is done using abrasive tools, water jets, honed finishing or thermal treatment with flame torch.
There are different machines available in the market to cut even the most difficult rock formation. After splitting, comes the cutting or processing. Processing is what gives the sandstone its smooth surface and makes it easy to use for construction applications. Therefore, a block coming for cutting or processing should be of an acceptable size and shape. A single cutting machine can be enough to treat sandstones split by up to 10-20 artisanal miners working every day. Cutting or processing is a more expensive process than splitting in producing saleable sandstone products of different shapes e.g., square, rectangular, hexagonal, and irregular sandstone. A single block can be carved and chipped with precision tools for tombstones, monuments, ornamental stones and sarcophagi. Seven major cutting or processing techniques are to be discussed in the next section.

3.6.1 Cutting with diamond saw blade or steel blade
Processing of sandstones involves cutting or sawing. It is done with a high speed motor using a diamond-impregnated blade, generally called diamond saw blade. A diamond saw blade or steel blade is expensive for artisans, but indispensable as shown below in Figure 3.15. Sandstone contains quartz, which is very hard to cut through, measuring seven on the Mohs scale of hardness and with a density of 2.7 g/cm³. During processing, the wear of cutting blades becomes a big problem which can affect the productivity and economics of the stone cutting operations, where one has to determine the relationship between various types of sandstone and the wear resistance of the diamond tool (Neves, et al., 2012). It is proven that a sandstone that contains too much iron, is more difficult to cut through, and this type of sandstone causes more wear on the diamond blade than those stones with clay as binding matrix, or those without a binding compound like grit. Cutting with a diamond cutting disc or steel blade, has revitalise the artisanal mining and small-scale processing of sandstone, and it is a mere dream for most artisans in QwaQwa to acquire such equipment. The equipment is expensive for artisans and requires electricity or diesel to run, as well as water for cooling and lubrication. Artisans rarely have enough capital to buy or run the machine. There are two types of cutting techniques, one that can cuts dry, i.e. without water, and another which requires water for cutting. The machine uses a high speed circular steel blade or a diamond disc to cut through the stones as they rotate. A cutting machine is an indispensable tool in sandstone mining, be it artisanal or large scale, as the product has to be delivered already processed. The cutting machine requires electricity, or a generator, and a constant supply of water in order to operate. Arrangements should be made around the mining site for the machine so that transportation cost is kept at a minimum. The machine is easy to use because once calibrated to cut at a specific size, it cuts sandstone at high speed with incredible ease. Processing and size reduction in the artisanal mining of sandstone is done typically in two ways: using a chisel and hammer, or a diamond disc cutting blade. A diamond cutting blade has three major capabilities listed in Table 3.13.
Mechanical properties of a diamond cutting blade

The cutting machine varies in size and capacity, and its circular steel blade is powered by an electric motor, it cuts dry or wet i.e., using water depending on the strength of the sandstone. Using a non-geared electric motor, it can run at speeds from 1500-5000 rpm (revolution per minute) and can consume a 1000w (1kw) or more of power. Water is pumped to cool the blade through water pump depending on the head (H) capacity of its motor. See Figure 3.14 (Bayram & Erhan, 2012).

\[ \begin{align*}
F_t &= \text{Tangential force} \\
V_p &= \text{The peripheral speed} \\
d &= \text{Cutting depth} \\
W &= \text{Width of saw blade segment} \\
V_c &= \text{The work piece traverse speed} \\
SE &= \text{Calculating the energy consumed per unit volume of material removal (SE).}
\end{align*} \]

\[ SE = F_t \times V_p \times d \times W \times V_c \]

Figure 3.14: Depicts forces, angles, and speed of a saw blade as it cuts through a rock. A water tank on the left is used to lubricate the cutting blade.

Figure 3.15: A diamond cutting blade for small-scale processing of sandstone. (A) QwaQwa; (B) Puma (Cameroon).

Table 3.13: Applicability and specifications while using a disc blade

<table>
<thead>
<tr>
<th>Process</th>
<th>Tools</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percussion</td>
<td>Saw blade or diamond disc,</td>
<td>-Safe to use</td>
<td>-High cost</td>
<td>-Not used in QwaQwa.</td>
</tr>
<tr>
<td></td>
<td>electric motor,</td>
<td>-Flexible and easy to use</td>
<td></td>
<td>Recommended</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.6.2 Processing with chisel and hammer

Processing with hammer and chisel is mostly done using a point head chisel. Sandstones processed with a hammer and chisel could be used for decoration, bricks, artefacts, tombstones and monuments as shown in Figure 3.16. Processing with chisel and hammer is very different from splitting with the same tool, here it demands craftsmanship to use the tools. The stone is shaped by the artisan according the customer’s requirement, or at the discretion of the artisan as he display his skills and technological know-how to attract potential buyers of sandstone products. This is a very slow process, and it can take days to finish a single product. This method of processing is advantageous for a beginner with little capital, see Table 3.14.

![Figure 3.16: Artisanal processing of sandstones with hammer and chisel in QwaQwa.](image)

Table 3.14: Applicability and specifications while using a chisel and hammer

<table>
<thead>
<tr>
<th>Process</th>
<th>Tools</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Applicability</th>
</tr>
</thead>
</table>
| Percussion| Chisel and hammer | -Cheap tools ideal for a beginner miner  
-A single miner can use the tools for splitting | -Low yield  
-Used to process smaller sandstone block  
-Can cause injury to the body | -Main processing tools used in QwaQwa.  
Recommended for small processing of sandstone. |
3.6.3 Processing with a hydraulic press
As shown in Figure 3.17 (A), this is a mechanical device, easy to fabricate. The main component is a hydraulic jack, mounted on a metallic frame. When compressed it creates pressure on an angle line metal strip, which cuts straight through sandstone. For the rock to split, the pressure exerted by the hydraulic jack on the stone should exceed the uniaxial compressive strength of the sandstone, which ranges between 8-60Mpa (Mubiayi, 2009). It is easy to use, but very slow in terms of productivity. A hydraulic press requires skill and precision to operate. It works perfectly with laminated sandstones. It can cost approximately R2000 to R3000 to build such form of a processing equipment. See Table 3.15 for the disadvantages.

![Figure 3.17: Small-scale and artisanal processing of sandstones using a hydraulic press. (A) Full image of a hydraulic press with operator behind; (B) Processing of grit sandstone by splitting with the aid of a flat end hammer on the line of weakness or lamination.](image)

Table 3.15: Applicability and specifications while using a hydraulic press

<table>
<thead>
<tr>
<th>Process</th>
<th>Tools</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percussion</td>
<td>Three ton hydraulic jack, metal frame, angle iron, lever</td>
<td>-Safe to use -Flexible and easy to use -Generates little noise or dust -A single miner can use the tools for splitting</td>
<td>-Low yield -Used in splitting smaller sandstone block</td>
<td>-Used in QwaQwa. Recommended for small scale processing of sandstones.</td>
</tr>
</tbody>
</table>
3.6.4 Processing of sandstone through carving or sculpturing
Stone carving or sculpturing is done either using hand tools, machine tools, or numeric tools. Carving is a creative art, and requires a lot of craftsmanship. Working with a particular tool can create a particular bond towards that tool, where some artisans say they can ‘communicate’ with these tools. The processing of stones demands focus and concentration of energy over a small area either by carving, splitting, chipping or sanding. All these are forms of control breakage, and require diligence. During processing, artisans apply their tools and skill to remove the right amount of material just from the right place. It is sometimes difficult to get that chip you really desire, because each stone will chip depending on its internal structure, force, and angle of the chisel.

3.6.4.1 Using hand tools
According to Coates, there are three main categories of hand carving tools, which includes: (1) impact shaping tools; (2) abrasive or erosion shaping tools; and (3) measuring tools. Images are shown belon in Figure 3.18 (Coates, 2015).

1. Impact shaping tools
Impact tools include a hammer or a combination of both a hammer and a chisel and an axe. An axe comes in different cutting edges e.g., the point, claw or tooth, and buchard. The cutting edges can easily be incorporated into a single axe head. When carving with a chisel and hammer, one hand holds the chisel or adjusts the stone or position it stone at an angle, while the other hand drives the force with the hammer capable of creating the desirable impact on the target. The hand also adjust the chisel in multiple tiny adjustments after successive hits from the hammer by the other arm (See Figure 3.18 (A), (B), and (C)).

2. Abrasive or erosion shaping tools
Abrasive tools are mostly used in the finishing phase, nevertheless they can be used as shaping tools. During medieval times, a stone could be used against a stone as an abrasive tool, whereas today, there are lots of high tech electric powered abrasive tools available. Most abrasive tools today are sand papers, or metal tools embedded with nuggets of harder material, where the sharp metallic edges can scrap over stone with less resistance, as shown in Figure 3.18 (E).

3. Measuring tools
Measuring tools are used to achieve greater precision and quality in stone processing. There are many kinds of measuring tools, including a straight edge, sliding bevel, L-square, as well as the spirit level and plumb line, and templates, as shown in Figure 3.18 (F). Also measuring tools include callipers and pointing machine, a pointing machine is a three-dimensional pantograph capable of reproduce points proportional between smaller and larger models. To
be explicit, the carving is based on a full-size model, and a mirror image of measurements, transferred one-by-one to replicate the original on another scale (Coates, 2015). Today, a more computerised version as described below has replaced callipers and pointing devices for a more precise and finish sculpture.
Figure 3.18: Sandstone processing tools: (A) Different hammers and axes; (B) Flat end chisels; (C) Abrasive chisels; (D) Grinder for polishing; (E) Abrasive hammer; (F) Templates; (G) Pneumatic, or air hammer; (H) Scaling and edging with pneumatic or air hammer; (I) Three-dimensional pantograph.
3.6.4.2 Using semi-mechanised tools

A typical example of a semi-mechanised processing tool is a pneumatic or air hammer. Other mechanised tools may include electric grinders and drills. This is a power tool with a piston cylinder which carves through a stone by creating many small blows on a particular point of the stone. It is capable of making very long smooth lines on stone Figure 3.18 (G) and (H). The hammer uses air pressure and processes sandstone by impacting constant blow using its hammer with a chisel head on the part of sandstone that needs to be removed. It can be used in edging, chipping, and scaling. It is of high initial capital cost to some artisanal miners, but will be a very important tool for small-scale operations. The air hammers come in various sizes and require electricity from the grid, or from a small generator of at least 1kw. This processing technique is not used in QwaQwa, but is highly recommended for artisans in QwaQwa as described in Table 3.16.

Table 3.16: Applicability and specifications while using a semi mechanised tools

<table>
<thead>
<tr>
<th>Process</th>
<th>Tools</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Applicability</th>
</tr>
</thead>
</table>
| Percussion  | Pneumatic rock drills, electric grinders and electric drills, generator | - Safe to use  
- Flexible and easy to use  
- A single miner can use the tool to process sandstones | - High cost  
- Used in processing smaller sandstone block  
- Generates noise and dust | - Not used in QwaQwa.  
Recommended for the small scale processing of sandstones |

3.6.4.3 Using numeric or computerised tools

Stone processing using numeric tools is a computer-based 3D modelling programme used to carve through a stone or replicate an image as programmed by the computer as shown in Figure 3.19 (A). The computer numeric control (CNC) is fitted with a robotic arm, which mills or chips through the stone fitted lathes. Numeric tools works with high precision and can enlarge an image to up to 2m long.

Procedure

According to Hayes, (2015) the process of digital fabrication is called photogrammetry, it works as follows: a 3D laser scan used to scan the object and capture a unique constellation of positioning points. The software will then generate the scanned information of the 3D polygon mesh onto the computer screen. A maquette is created and repaired to prepare the polygon mesh for fabrication. The next process is called data fabrication, the computer is connected to the 3D robotic printer, using a six Axis Kuka robot equipped with a spindle powering electroplated diamond stone milling tool (Hayes, et al., 2015). After the fabrication, handheld
abrasive or impact tools are used to smooth edges and give the sculpture a final finished touch. The specifications of numeric tools are describe in Table 3.17.

**Table 3.17: Applicability and specifications while using numeric or computerised tools**

<table>
<thead>
<tr>
<th>Process</th>
<th>Tools</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percussion</td>
<td>Computer, 3D software, lathes,</td>
<td>- Safe to use</td>
<td>- High cost</td>
<td>- Not used in QwaQwa. Recommended for small-scale,</td>
</tr>
<tr>
<td></td>
<td>robotic arm</td>
<td>- Flexible and easy to use</td>
<td>- Requires highly-skilled worker</td>
<td>industrial and high precision processing of sandstone.</td>
</tr>
</tbody>
</table>

**Figure 3.19:** Multiple images of carving sculpturing and tailings: (A) Numeric sculpturing; (B) Bridge saw; (C) Sandblaster; (D) Tailings from sandstone processing (Czekaj, 2016).

3.6.5 **Honed and thermal processing of sandstone**

These are secondary processing techniques used to process sandstones for aesthetic and artistic uses. Honed processing is done using a polishing pad; whereas thermal processing is done using flame or blow torch device, and the application of resins or acrylic paint of different colours may be added to give the stone a final lustre, or to make it resistant to moisture and corrosive chemicals (Dolley, 2009). Honed and thermal processing techniques are expensive
and demand skill, and are recommended for QwaQwa miners as a secondary processing technique, which can attract new customers and increase sales in terms of variety.

3.6.6 **Processing of sandstones with highly mechanised abrasive tools**

Diamond polishing is done using polishing wheels, the polishing wheels comes in different geometric designs to process different shapes and sizes of the stones. Water is often used during the grinding process. The use of abrasive tools involves a polishing technique used to give the stone a smooth lustre. The water acts as a lubricant and as a coolant same time, as it is poured between the abrasive disc and the stone. The use of abrasive tools has several advantages listed in Table 3:18.

**Processing methods and tools from ABRA product catalogue includes:**

**Sandblasting:** Sandblasting is a double-separation of abrasive and dust filtration with a filter cleaning dust tank with the aid of compressed air as shown in Figure 3.19 (C). The machine or technique is used to engrave on tomb slabs. It shapes the stone through a continuous blast of air on a target portion of the stone.

**Edge profiling:** Edge profiling is a method of milling and polishing of stones, where the machine produce shapes of a quarter-round, half-round or simple side stones. The machine uses flat diamond cutters and polishing pads.

**Polishing pad:** Polishing pads are circular discs made of a high resistant canvas material used in polishing of stones. It is used wet, and comes in a 100mm disc of different granulation of 100 mm, 50’, 100’, 200’, 400’, 800’, 1500’ and 3000’.

**Bridge saw:** This is a laser-guided cutting machine mounted on a rotatable and tillable. It its programmable and can cut through granite sandstones or marble. An example of a bridge saw is the PLC600 as shown in Figure 3.19 (B).

**Engraving:** Engraving is designed to create or engrave extremely precise images and designs on stones, glass, or metals. It is done using a computerised Photomaster mini, equipped with an adjustable impact stylus.
Table 3:18: Applicability and specifications while using highly-mechanised abrasive tools

<table>
<thead>
<tr>
<th>Process</th>
<th>Tools</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrasion, percussion and suction</td>
<td>Sandblaster, edge profiler, bridge saw, diamond saw, photo master, column grinder and rock splitter</td>
<td>-High productivity</td>
<td>-High capital and operating costs</td>
<td>-Not used in QwaQwa. Recommended for the mechanisation of small scale processing of sandstone.</td>
</tr>
</tbody>
</table>

3.6.7 **Raw blocks, pebbles, cobbles and tailings**

During processing, approximately five percent (5%) of the processed sandstone is left over, with 4% as raw blocks, pebbles, or cobbles, and 1% as tailings from sawing blades (see Figure 3.19 (D)). The tailings are drained and stored in bags ready for sales. The tailings are used as pesticide for agricultural purposes, whereas the raw blocks, pebbles and cobbles are sold as waste, or classified according to their sizes to be sold as decorative stones or used as landfills.

3.7 **Transportation and handling techniques in artisanal mining of stones**

Transportation and handling is one the greatest challenges faced by artisanal miners in QwaQwa. In the mining sites, miners are handling and transporting blocks of sandstone in different sizes and shapes. Working in such an environment can be very dangerous and challenging. It is difficult to move blocks of sandstones around a bedrock, loading them into storage areas, or transporting them to vehicles without considering adequate techniques and safety measures. Miners should always bear in mind the responsibilities they undertake as they get involved in dangerous mining activities like lifting and transporting of sandstones, where avoiding injuries is very important, because if a person gets hurt or sick, it may jeopardise livelihoods.

3.7.1 **Transportation techniques applicable**

Stones have high densities, like metals, which makes them very heavy, and therefore, moving a stone from one place to another requires energy and skill. Transporting sandstone should be done in a safe and appropriate manner to avoid injury, increase production, and reduce damages caused by mobility. The research will focus on five (5) transportation techniques...
available and applicable to the artisanal mining and small-scale processing of sandstones in QwaQwa. Easy transportation can be achieved by applying the following methods:

**Wheelbarrows or dolly:** As shown in Figure 3.20 (H), (I) and (K) a wheel barrow could be used to transport small sizes of stone blocks packed together. This is a cheap and affordable means by which stone blocks are transported within the workplace. It is mostly used on flat or near-horizontal terrain. A dolly can easily transport small blocks of stones as heavy as 115kg, where because of its low centre of gravity, you can push or walk backward while pulling the loaded dolly. For a quick break, rest the handle on your thigh to support the weight. A wheelbarrow or a dolly, both have high manoeuvrability, capable of moving through narrow paths downhill, or pulling backward and pushing loads uphill. The method is highly recommended for QwaQwa miners, because they still struggle transporting huge blocks with their bare hands.

**Three pieces of PVC pipes or wood:** This an ancient method of transportation still in use today, particularly in rural areas. Not very familiar to miners in QwaQwa, the method can be used when transporting huge blocks over a short distance, preferably on flat terrain, often used to transport regularly shaped stone blocks weighing from 100kg to a tonne (see Figure 3:20 (J)). This is done by lifting the front edge of the stone with a pick or crowbar, then placing the flat surface of the stone block on at least three pieces of PVC pipes or wood, the stone is pushed to roll towards the target direction in a continuous motion, by repeatedly removing the freed PVC or wood piece behind and placing it in the front. One should always make sure there are two PVC pipes, or wood pieces, beneath the stone when in motion or at rest. When descending an incline, great caution should be taken to avoid accident.

**Manual transportation using clamps:** Clamps exist in different sizes and can haul a block of stone weighing up to 200kg in a single load. It will require two people to use a clamp as shown in Figure 3.20 (E). It is good for short distances, ranging from 5m to 50m, and can be used on rocky or steep terrain. The clamp is a rugged, tubular steel constructed for the transportation of smaller, irregularly shaped stones, boulders or ashlar by hand, lifting using additional suspension lugs. It has adjustable opening width, regulated by cotter pins. Lifting tightens the grips, and the stone is released only when the clamp is place on the ground. The clamps are also recommended for miners in QwaQwa in transporting small blocks after splitting.

**Transportation system mounted on vehicle:** This is an expensive system to build or purchase, the system is ideal to transport big blocks of stones over long distances. It is built with clamps and hoisting mechanisms to hoist and manoeuvre heavy block of stone. It can be mounted behind your pickup trucks, box trucks, flat-bed trailers, or other commercial vehicles as shown in Figure 3.20 (F). During lifting, the strain on the cable can be intense, therefore
one must ensure the right amount of load is hoisted with the right cable. The risk of injury due to cable snap-back can be minimised by placing a blanket, tarp or a coat over the strain line to absorb any suddenly released tension force. This is the main transportation method used in QwaQwa to transport sandstone from the mining sites to the processing plant.

**Motorcycle or a bicycle:** Not very common in South Africa or QwaQwa, using a bicycle or a motorcycle is very common in other African countries like Cameroon, for the transportation of goods including stones. It is highly flexible, and can access the most difficult topographies. A motorcycle or a bicycle can transport just a small volume of rock up to 100kg, and can move relatively fast depending on the terrain. Figure 3.20 (G) shows few grinding stones to be attached behind a motorcycle for transportation. The stone is attached using a rubber cord, to attach the stone on the motorcycle’s carriage.

**Cushioning and transportation:** To ensure that a stone product is transported and delivered in good condition, cushioning the stone is a potential solution. A stone can be cushion with aid of inflated pillows, sandbags, woods or wedges. When transporting sandstone into a banker or a truck, the banker or truck compartment should be encased with wood or a carpet, because wood has a natural cushioning effect that can wedge and protect the stone from potential damages caused by movement. Other cushion materials like hay, woodchips or straw can also be used.
Figure 3.20: Handling and transportation techniques applicable to artisanal sandstone mining: (A) Handling and moving posture; (B) Lifting of stone from ground with knees; (C) Lifting of stone from ground with knees; (D) Good resting positions; (E) Manual lifting using clamp; (F) Stone transportation system mounted on vehicle; (G) Use of motorcycle; (H) Transportation using a dolly; (I) Transportation using a dolly; (J) Displacing using three pieces of PVC pipes or wood; (K) Transportation with wheelbarrow; (L) Displacing through flipping; (M) Displacing through flipping.
3.7.2 Handling techniques applicable in basic body-assisted lifting operations

Handling, lifting and transporting sandstone using body mass needs techniques can help to increase safety within the working environment. According to Joseph & Durkin, (2011) incorrect lifting techniques can place undue stress on the lower back. By using the “kinetic method” of manual handling, injuries to the back can be avoided to some extent. The kinetic method is based on two principles:

1. Fully employing strong leg muscles for lifting, rather than the weaker muscles of the back.
2. Using the momentum of the weight of the body to begin horizontal movement.

Safety guidelines in basic lifting operations

Stop and think: Plan the lift, think of where the load has to be placed. Use appropriate handling aids if possible, remove all obstructions surrounding the path. For long lift, consider resting the load midway.

Position the feet: Loss of balance may cause injuries to the back due to walking with feet too close together. It is recommended that the feet be placed about 50cm apart, this distance is suitable for person having a height of about 175cm. The feet should be positioned with one placed in the proposed direction of movement, and the other where it can push the body. During manual handling, at no time should the feet be close together on the ground. The arm and the body ought to be kept as straight as possible when lifting heavy objects, and feet placed close to the object. Knees should be bent, and one should squat and keep the back as straight as possible, lifting with the legs and not the back. If the block is too heavy, it is necessary to get help not to attempt to lift or carry any block alone that exceeds 25kg.

Arms close to the body: When lifting and carrying loads, the arms should be kept close to the body and as straight as possible, so as to avoid unnecessary strain to the upper arm muscles and the chest. In addition, if the load needs to be carried over a long distance, the block can be rested on the thighs.

Correct Hold: An insecure grip may be due to taking the load on the fingertips, caused by a badly designed handle. Greasy surfaces like clay or water on the sandstone block can prevent a secure hold. Whenever possible, a full palm grip ought to be used. This gives a stronger hold and decreases the possibility of the load slipping (Durkin & Joseph, 2011).

Lifting: During lifting, it is necessary to make sure minimum stress is applied to the body by resting the stone against your upper thighs, as shown in Figure 3.20 (D). By doing so, it won’t be
necessary to lift the full weight of the stone for the second time. When in an upright position, one ought to lean back slightly, so that one’s legs do the lifting instead of the back. It is necessary to watch one’s footing as one walks, and be ready to release the load far-off from one’s toes, in case of stumbling.

Flipping: This is an effective method of transporting large stones blocks which cannot fit onto a dolly, and is good for short distances or moving uphill. Preferable the flipping terrain should act as a cushion. It is necessary to lift with one’s arms and legs, and not one’s back, staying behind the stone and making sure one’s hands are clear when it is dropped forward.

Gravity dominates in sandstone mining, where energy sources such as potential, kinetic, and heat energy are likewise applicable. Without going deep on how these laws have been derived, a more common sense will be demonstrated in the next subheading to help explain certain principles for easy understanding. Remember the research is based in a rural community, where working with chisel and hammer on different rock types makes it difficult to obtain uniform results, because many geological, physical, and chemical properties are often ignored. When mining a sandstone block, there is no unique technique, because each block comes with its own challenges due to some geological and physical features of the rock, such as follows;

- The cementing properties between the sand grains;
- Fissure, discontinuities, joints and fault lines;
- Shape, size, and position of the rock mass;
- Chemical composition of the sandstone mass; and
- The quality and type of tools involve during splitting or processing.

3.7.3 Correlation between weight-lifting and moving of sandstone mass against body weight, physical strength and age

In the artisanal mining of sandstone, there is constant handling and transportation of all kinds of sandstone masses within the mine. The lifting and transportation requires fitness and good health. Not everyone can physically lift the same load of sandstones within and around a mine, because each individual has his own limits when it comes to lifting and transporting stones around a mine. The lifting is referred to in this instance as *deadlift in motion*. The deadlift in motion, as described in this section, will correlate your weight lifting and moving of sandstone mass against bodyweight, physical strength and age, and will be modelled below for both genders, male and female. The results will show the average speed, which can be characterised as the relative strength of the individual, depending on your category, whether a beginner, novice, intermediate or expert. According to the South African Mines Health and Safety Act of 1996 (MHSA), no individual should
be allowed to work on a mine without a proper medical examination, therefore in the same way, before any individual is employed in an artisanal mine, the owner must make sure that individual is medically fit to perform his duties.

**Caution:** Despite the calculations below, there are other factors to be considered before lifting a load, because the calculations are only estimates, and do not guarantee lifting. Your health status, steroids or genetics will obviously play an important role during lifting operations, where it is necessary to bear in mind physiological variability amongst individuals. There are many equations for deadlifting, where, according to Brzycki equation used to calculate the 1-RM for a dead lift and a bench lift for competing. As a dead lifter you can use the Brzycki equation to calculate a 1-Maximum Repetition on the deadlift strength calculator (Amarante do Nascimento, et al., 2007). Unfortunately, the equation does not include mobility, and was not suitable for the research purposes. Generally, most of the equations where used for athletic performance, hence why most are termed maximal repetition. For this reason, it is possible to correlate the weight lifting of selected individuals to the lifting and transportation in the artisanal mining of sandstone to have more knowledge as to how the body works when it comes to weight lifting and motion.

### 3.7.3.1 Methodology

The methodology used to achieve a correlation between the weight lifting and moving of a sandstone mass and a person’s age against the average speed, is based on multiple trials of 5-10 individuals of the same age group on a 100 metres normal walk deadlift in motion exercise, performed outdoor on the field, with the aim of knowing which category of persons performed best during lifting and walking. There is a percentage margin applied to compensate any error due to overrating. The researcher considers a maximum of 20kg which is the uncompromised standard (kg) to start with, as a beginner for a male, and a maximum of 15kg for a female both age between 18-40 years old. From 41-65 years old, there is a 15 percent muscle loss every 10 years, calculated as (20 X 0,15). The researcher aimed to ascertain average speed for each age group and plot a bodyweight against average speed graph to determine which age group scores the highest average speed during the research. Moving with a stone at higher speed means good strength or output. The results obtained from the performance of individuals of the three major age groups were illustrated in **Table 3:19, Table 3:20, Table 3:21, and Table 3:22**.

Several assumptions were made due to multiple factors beyond our control, for example, strength has a resilient quality, because strength lost through detraining will be recovered more rapidly than it was first gained. In addition, health and genetics can play a large role, depending on the
individual. It is noticed that performance capacity will be lost after a period of inactivity, and in addition, the research was perform on a particular terrain, whereas each mine has its own particular topography.

3.7.3.2 Terminology

The definition of certain terms used in the research as defined below in the table, are according to Lear, (1989). The terms are in context with deadlift in motion (Lear, 1989).

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Muscular Strength</strong></td>
<td>refers here to the maximal weight that a person can lift i.e., at one repetition maximal or 1-RM. N.B. The research is not interested on the 1-RM.</td>
</tr>
<tr>
<td><strong>Beginner</strong></td>
<td>refers to a person who has not been trained on the exercises before, but can perform because the research is not for a competition and is an activity in motion. A beginner is stronger than 5% of lifters.</td>
</tr>
<tr>
<td><strong>Novice</strong></td>
<td>refers to a person who has been trained regularly for up to several months. A novice is stronger than 20% of lifters.</td>
</tr>
<tr>
<td><strong>Intermediate</strong></td>
<td>refers to a person who has been trained regularly for two years or more. An intermediate is stronger than 50% of lifters.</td>
</tr>
<tr>
<td><strong>Advanced</strong></td>
<td>refers to a person who has been trained and has many years of experience. An advanced lifter is stronger than 80% of lifters.</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>refers to the product of the body mass and gravitational force (g) 9.81m/s².</td>
</tr>
<tr>
<td><strong>Distance</strong></td>
<td>refers to the amount of space between two things measured in meters.</td>
</tr>
<tr>
<td><strong>Time</strong></td>
<td>refers to the continued progress of reality and events, measured in seconds.</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>refers to the rate at which someone or something moves or travels measured in meters per second.</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>refers to the number of years a person has lived in numbers.</td>
</tr>
<tr>
<td><strong>Sarcopenia</strong></td>
<td>refers to a loss of muscle cells, it occurs as humans advance beyond middle age (every 10 years at least 15% of muscle is loss due to sarcopenia).</td>
</tr>
<tr>
<td><strong>Atrophy</strong></td>
<td>refers to a condition which leads to a loss in muscle mass, which happens to inactive older adults.</td>
</tr>
</tbody>
</table>

3.7.3.3 Tools used during Experiment

The following tools were used for the experiment: a stop watch, a weighing scale, and a measuring tape of 100 metres.
BW=Body Weight, BEG=Beginner, NOV=Novice, INT=Intermediate, ADV=Advance, all in kilogrammes.

**Table 3:19:** Males aged 18-40 years lifting and moving a stone mass weighing a maximum of 20kg as a beginner. Novice (20 X 0.20), intermediate (20 X 0.50), advanced (20 X 0.80).

<table>
<thead>
<tr>
<th>BW (kg)</th>
<th>BEG (kg)</th>
<th>NOV (kg)</th>
<th>INT (kg)</th>
<th>ADV (kg)</th>
<th>DIST (m)</th>
<th>Time(s)</th>
<th>Average Speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 – 65</td>
<td>20</td>
<td>24</td>
<td>30</td>
<td>36</td>
<td>100</td>
<td>150</td>
<td>0.67</td>
</tr>
<tr>
<td>66 – 70</td>
<td>20</td>
<td>24</td>
<td>30</td>
<td>36</td>
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<td>71 – 85</td>
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<td>86 – 90</td>
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<td>30</td>
<td>36</td>
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<tr>
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<tr>
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<tr>
<td>106 – 110</td>
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<td>24</td>
<td>30</td>
<td>36</td>
<td>100</td>
<td>150</td>
<td>0.67</td>
</tr>
<tr>
<td>111 – 120</td>
<td>20</td>
<td>24</td>
<td>30</td>
<td>36</td>
<td>100</td>
<td>160</td>
<td>0.62</td>
</tr>
</tbody>
</table>

See graph below
Table 3.20: Males aged 41 – 50 years lifting and moving a stone mass weighing a maximum of 17kg as a Beginner. Due to sarcopenia, every 10 years at least 15% of muscle mass is lost (20 
X 0.15). Novice (17 X 0.20), Intermediate (17 X 0.50), Advance (17 X 0.80).

<table>
<thead>
<tr>
<th>BW (kg)</th>
<th>BEG (kg)</th>
<th>NOV (kg)</th>
<th>INT (kg)</th>
<th>ADV (kg)</th>
<th>DIST (m)</th>
<th>Time(s)</th>
<th>Average Speed (m/s)</th>
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<tr>
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<tr>
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<tr>
<td>86 – 90</td>
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<td>31</td>
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<td>165</td>
<td>0.61</td>
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</tbody>
</table>

See graph below

![Average Speed against Body Weight during Lifting and Transportation](image)
Males aged 66 years and above lifting and moving a stone mass.
For males who are aged 66 years or older, lifting and handling of sandstone will largely depend on the health of the individual, and it is advisable that men older than 66 years should not carry loads weighing more than 15kg or carry loads over long distances.

**Table 3.21:** Females age 18 – 40 years lifting and moving a stone mass weighing a maximum of 15kg as a Beginner. Novice (15 X 0.20), Intermediate (15 X 0.50), Advance (15 X 0.80)

<table>
<thead>
<tr>
<th>BW (kg)</th>
<th>BEG (kg)</th>
<th>NOV (kg)</th>
<th>INT (kg)</th>
<th>ADV (kg)</th>
<th>DIST (m)</th>
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<td>27</td>
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</table>

See graph below
Table 3.22: Females aged between 41 - 50 years lifting and moving a stone mass weighing a maximum of 13kg as a beginner. Due to sarcopenia, every ten years at least 15% of muscles is loss (15 X 0.15). Novice (13 X 0.20), Intermediate (13 X 0.50), Advance (13 X 0.80).

<table>
<thead>
<tr>
<th>BW (kg)</th>
<th>BEG (kg)</th>
<th>NOV (kg)</th>
<th>INT (kg)</th>
<th>ADV (kg)</th>
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<th>Time(s)</th>
<th>Average Speed (m/s)</th>
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</tr>
<tr>
<td>66 – 70</td>
<td>13</td>
<td>16</td>
<td>20</td>
<td>24</td>
<td>100</td>
<td>150</td>
<td>0.67</td>
</tr>
<tr>
<td>71 – 85</td>
<td>13</td>
<td>16</td>
<td>20</td>
<td>24</td>
<td>100</td>
<td>145</td>
<td>0.69</td>
</tr>
<tr>
<td>86 – 90</td>
<td>13</td>
<td>16</td>
<td>20</td>
<td>24</td>
<td>100</td>
<td>150</td>
<td>0.67</td>
</tr>
<tr>
<td>91 – 95</td>
<td>13</td>
<td>16</td>
<td>20</td>
<td>24</td>
<td>100</td>
<td>155</td>
<td>0.66</td>
</tr>
<tr>
<td>96 – 100</td>
<td>13</td>
<td>16</td>
<td>20</td>
<td>24</td>
<td>100</td>
<td>160</td>
<td>0.63</td>
</tr>
<tr>
<td>101 – 105</td>
<td>13</td>
<td>16</td>
<td>20</td>
<td>24</td>
<td>100</td>
<td>175</td>
<td>0.57</td>
</tr>
<tr>
<td>106 – 110</td>
<td>13</td>
<td>16</td>
<td>20</td>
<td>24</td>
<td>100</td>
<td>180</td>
<td>0.56</td>
</tr>
<tr>
<td>111 – 120</td>
<td>13</td>
<td>16</td>
<td>20</td>
<td>24</td>
<td>100</td>
<td>185</td>
<td>0.54</td>
</tr>
</tbody>
</table>

See graph below
Females aged 66 and above lifting and moving a stone mass.
For females aged 66 years or older, lifting and handling of sandstone will largely depend on the health of the individual, and it is advisable that women older than 66 years not carry loads weighing more than 13 kg or carry loads over long distances.

3.7.3.4 Results and conclusions
From the results obtained the researcher concluded that there is a correlation between the age of an individual, bodyweight, and the stone mass he can lift and transport. Persons aged between 18-41 years and 41-50 years of age with an average body weight of 71-85 kg score very high average speeds of 0.9; 0.83; 0.75; and 0.69 m/s, respectively. Persons with a higher body mass score a very low average speed, ranging from 0.62; 0.61; 0.59 to 0.54 m/s, respectively. Results obtained shows young people of average weight can perform very well during manual lifting and transportation of sandstones within and around the mine.
3.7.4 Fundamental Forces Applicable to the Artisanal Mining of Sandstones

The forces to lift or pull a block of sandstone on a plane or an incline as shown below can be determined or calculated if the mass of the block (m) is known.

**Forces and Directions on a Sandstone Block on a Horizontal Plane**

Gravitational acceleration \( g = 9.81 \text{m/s}^2 \)

\[
W = m \times g
\]

Normal reacting force \( N \)

Considering a block of sandstone of mass \( m \) resting on a plane, with a gravitational force \( g \) pulling the mass towards the earth’s centre, \( F \) = frictional force causing a resistance to force \( P_1 \). The resultant forces could be denoted as:

\[
W = m \times g = N
\]

\( W \) = Weight of the stone or downward force in newton (N).

\( N \) = the normal reaction according to newton’s third law of motion.

If \( P > W \), then you can lift the stone vertically.

If \( P_1 > m \times g \), and \( F = 0 \), then you can pull the stone horizontally.

\( P_1 - F = m \times a \), is force necessary to pull that mass of sandstone.

**Forces and Direction of Motion of a Stone Block Mass (m) on an Incline Plane.**

\[
P = m \times g \times \sin \theta + F
\]

\[
N = m \times g \times \cos \theta
\]

\[
F = \mu \times N
\]

Motion up a plane with the pulling force \( P \) parallel to the plane.

3.8 Chemical and physical properties of sandstone

The physical and chemical properties of sandstone are important as they give the miner an indication of what quality and which area the miner can mine a particular type of stone. Below in Table 3.23 are some thermal and chemical properties of sandstones a miner should know about sandstone, according to KOŇÁKOVÁ, (2013). (KOŇÁKOVÁ, et al., 2013).

**Table 3.23: Thermal & chemical properties of sandstones and SI units.**

<table>
<thead>
<tr>
<th>Thermal &amp; chemical properties of sandstones</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific heat capacity (J/kg/K)</td>
<td>646 - 801</td>
</tr>
<tr>
<td>Thermal conductivity (W/m/K)</td>
<td>1.230 - 3.665</td>
</tr>
<tr>
<td>Bulk density (kg/m³)</td>
<td>1868 - 2651</td>
</tr>
<tr>
<td>Porosity (%)</td>
<td>16.44 - 28.64</td>
</tr>
</tbody>
</table>
Hardness of Sandstone
Sandstone is sedimentary rock of medium strength, with a uniaxial compressive strength of 5-100Mpa and measures 6.5-7 on the Mohs scale of hardness (Rustan, 2011).

Uniaxial Compressive Strength (UCS) of Sandstone
A measure of a material's strength is done by averaging the maximum uniaxial compressive strength of several samples of that material. According to Mubiayi, who previously worked on the characterisation of QwaQwa sandstone, he listed three types of sandstones and their UCS as shown in Table 3.24, below Mubiayi, (2009) (Mubiayi, 2009).

Table 3.24: Types of sandstone, coloration and the UCS (MPa)

<table>
<thead>
<tr>
<th>Types of sandstone</th>
<th>coloration</th>
<th>UCS (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grit</td>
<td>White or yellowish</td>
<td>8.28</td>
</tr>
<tr>
<td>Arkose</td>
<td>Reddish brown</td>
<td>22.79</td>
</tr>
<tr>
<td>Greywacke</td>
<td>Grey dark</td>
<td>56.74</td>
</tr>
</tbody>
</table>

3.8.1 Quality Testing
The consumers of sandstones will always demand quality in the final sandstone product. Artisanal miners often ‘test by sight’ i.e., visualising the sandstone for quality, and relying on their past experience in the field. Results obtained from such sight testing are not 100% confident. For example, three properties should be considered before purchasing a stone for paving, which are: water absorbency, flexural strength, and frost resistance.

Analysing of core drilled samples
Make sure samples don’t get contaminated with water, grease, oil, or other chemicals. Samples must not be exposed to air or kept for long before testing. When samples are removed from a drilled core, a representative sample is cut with a chisel or a knife, wrapped in clean plastic bag, and taken to the laboratory for the following tests below to be performed.

Absorbency: refers to the ability of the stone to absorb water. A stone with a high absorbency will turn green i.e., attract algae or be vulnerable to frost.

Flexural Strength: refers to a stone with poor strength can break easily during transportation, installation or everyday use.

Frost resistance: refers to a stone that loses strength due to everyday frost, and is likely to fail. The technical performance of a stone design and installation requires the stone be able to maintain its strength after a freezing weather, as it freezes and defrosts.
Important quality tests on sandstones
There are several quality tests which can be performed on a piece of sandstone to determine certain chemical and physical properties or the suitability of a rock. The researcher recommends at least three major tests to be performed on a stone considered ready for construction or to be used in other applications. The tests include: (1) a water absorption test; (2) a porosity test; and (3) a hardness test. Other tests that may be requested by the miner or a consumer may also include specific gravity, saturation coefficient, impact test, microscopic test, acid test, crystalline test, smiths test, and freezing test. Apart from the natural beauty of sandstone other expected features like cracks, installation process or maintenance play a role in the quality as well, and shall be elaborated on further. The physical and chemical properties of a sandstones gives it the quality it needs for application, where, by conducting a test on the stone, one is able to obtain a picture of the technical qualities of the stone a consumer might need during application. Therefore, a miner might pick-up any of the following quick and easy tests to determine the type of stone he intends to mine or sell, in terms of quality. The tests may include:

Water absorption test: Water absorption is one of the most important tests widely used to determine the durability of sandstone by knowing its absorptive power or porosity. A specimen of about 50 grams is weighed (W₁) for actual weight. The weighed sample is then soak in pure water for at least 48 hours, and when removed from water, the sample surface is wiped with a damp cloth, and then weighed. The weight gain is (W₂). Note that the increase in weighed will be the amount of water absorbed. Any stone that absorbs 10% of its weighed while soaked within 48 hours should be treated with suspicion, unless it is proved otherwise to withstand other desirable conditions. The equations below were derived from documents obtained from the American Society for Testing and Materials (ASTM) (MIA, 2016).

Percentage absorption by weight after 48 hours = \( \frac{W₂ - W₁}{W₁} \times 100 \%) ..........Eq1 

If same 50 grams specimen is suspended freely in water and its weight immediately recorded say (W₃) in grams, therefore:

Percentage absorption by volume after 48 hours = \( \frac{W₂ - W₁}{W₂ - W₃} \times 100 \%) ..........Eq2 

If water is boiled, and the specimen is kept in boiling water for five hours, then removed, and surface water is wiped off with a damp cloth, its weight is recorded as (W₄). The following could be calculated:

Volume of displaced water = \( W₂ - W₃ \)
**Porosity:** refers to the quality of full of tiny holes or being porous i.e., liquids permeate that which has porosity.

\[
\text{Percentage porosity by volume} = \frac{W_4 - W_1}{W_2 - W_3} \times 100 \% \quad \text{Eq 3}
\]

\[
\text{Density} = \frac{W_1}{W_2 - W_3} \quad \text{kg/m}^3 \quad \text{Eq 4}
\]

\[
\text{Specific Gravity} = \frac{W_1}{W_2 - W_3} \quad \text{Eq 5}
\]

\[
\text{Saturation coefficient} = \frac{\text{Water absorption}}{\text{Total porosity}} = \frac{W_2 - W_1}{W_4 - W_1} \quad \text{Eq 6}
\]

**Hardness Test:** A hardness test, also known as resistance to wear, is used to determine the hardness of a stone. This is done by using a Los Angeles machine with a 50cm diameter. The following procedure is observed (Kourd & Hammad, 2010):

- A clean and dried cylinder made of stone specimen of 50cm diameter is prepared and charged into the Los Angeles machine, which is covered and dust tight.
- The machine is rotated at 30rpm for around 1000 revolutions.
- After the desired revolution, the machine is stopped and its content discharged into a 1.7mm LS sieve.
- The crushed particles are separated into two, with the first part from the 1.7mm LS sieve labeled \( W_1 \) and the remaining sample \( W_2 \).
- A Los Angeles Abrasion value can be calculated as:

\[
\text{Percentage wear} = \frac{\text{Loss in weight} \times 100 \%}{\text{Initial weight}} \quad \text{Eq 7}
\]

**Impact Test:** The impact test is done to determine the toughness of the stone. A stone is subjected to an impact test as follows:

- A cylinder is made of stone with a diameter and height of 25mm and 25mm, respectively.
- It is then place on a cast iron anvil of machine.
- A 2 kg hammer is allowed to fall axially and vertically over the specimen.
• With the height of the first blow, say 1 cm, the second blow is 2 cm, third blow 3 cm, and so on.
• The blow at which the specimen will breaks is noted. If it is the n\textsuperscript{th} blow, therefore ‘n’ will represent the toughness index of the stone.

**Microscopic test:** this is done by subjecting a specimen of sandstone under a microscope (Raith, et al., 2012). The various sections of the stone are examine for the following:

• cleavage and fracture;
• textural characteristics and textural variation of the stone;
• structural and macro-discontinuities like existence of pores, veins or fissures;
• deformation and recrystallisation;
• presence of any harmful substance; and
• nature of cementing material.

**Smith’s test:** used by sandstone miners in mining sites in Puma, Cameroon, Smith’s test is used to determine the presence of soluble matter in a stone sample. A few stone chips are placed in a glass tube and the tube is filled with clear water. After approximately one hour, the tube is vigorously stirred or shaken. The presence of earthy matter will convert the clear water to a dirty water, but if the water remains clear, the stone will be durable, and free from any soluble matter.

**Acid test:** an acid test is done by placing a small sample of sandstone of around 50-100 grams into a solution of hydrophobic acid with a strength of 1% for seven days. The stone should be immerse in the acid and should agitated at intervals. A good sandstone will maintain its sharp edges, and its surface will remain free from powder after the seven day period. If powder forms on the surface of the stone, there may be calcium carbonate ($\text{CaCO}_3$) present, and such a sandstone will be vulnerable to weathering. This test is used by sandstone miners in mining sites in Puma-Cameroon.

**Freezing and thawing test:** the sandstone sample is kept immersed in water for 12 hours. The stone is then removed and placed in a freezing machine at -18°C for another 12 hours. It is then removed thawed or warmed at 36°C for at least 8-12 hours. This test should be performed in a shady place to prevent any effect of wind, sun, or rain. The process is repeated several times and the behaviour of the sandstone is observed for any defect (ASTM, 1992).

**Eyesight test:** most artisanal miners of sandstone test stones by sight. They simply visualise a stone with the necked eye as they hold it in their fingers, and say this piece of stone will serve the purpose or not. Though not, it still works well within the mining communities, because of their
accumulated experience and skill. Nevertheless, it will be appropriate for a modern miner to apply a conventional test on a particular sandstone if a miner has to preserve his reputation or credibility in the business of sandstones.

3.8.2 Natural and human-induce problems with sandstone

There are typical problems associated with the deterioration of sandstone. According the technical preservation guidelines from the United States general service administration, the two major problems associated with the deterioration of sandstone have been identified as firstly, natural and inherent problems, and secondly, human-induced problems.

Naturally caused problems and remedies

Normally natural problems like weathering and the effects of moisture occur over a long period of time. Some such problems and their remedies shall be discussed below.

Weathering: sandstone is porous, and highly susceptible to weathering. Disintegration of the stone surface is usually caused by water erosion, wind currents, and other chemical actions. One should avoid pouring soapy water or water containing detergents and other chemicals onto sandstone. Water ways should be diverted away from any sandstone wall, pillars or artefacts. Normally, sandstone objects should be kept dry at all times. Chemicals or contaminated water seeping into the stone should be seriously avoided, as this may cause significant damage to the stone, which might request repair or total replacement.

Moisture or Grease: Moisture can promote algae growth, and moisture freezing in the stone can cause erosion, oxidation, cracking, and flaking. Damp proofing is essential to prevent water seeping or contact with sandstone during construction where sandstone is applicable, and construction should cater for proper water drainage. A contaminated sandstone with algae or grease can be cleaned using a moderate jet of warm water on the affected area until it is free from contaminants.

Cracking: cracks tend to be small and narrow fractures on the stone ranging from as small as 1.5875-12.7 mm. Cracks are caused by the sharp impact of an object or stress on a small area of the stone, due to structural settlement. Before a particular stone is used, it ought to be tested to meet specific strength and quality.

Blistering: refers to airborne chemicals reacting with the stone, forming a hard brittle skin, blisters will often pop when touched. Sandstone and sandstone products should be used in areas with sufficient ventilation, and free from acidic and other oxidising gases.
**Exfoliation**: refers to the separation and loss of large area of stone along the bedding plane, usually caused by stone having been face bedded. The larger side of the stone should face the bed, for more stability.

**Human-induced problems and remedies**

**Painting**: painting, particularly over a deteriorated sandstone surface, can further lead to serious moisture-related problems. Before painting, one should make sure the stone is dry and free from any contaminants.

**Negligence**: while transporting objects or working close to a sandstone wall, floor or artefacts, miners should be careful not to hit the stone surface with any object hard enough to create a crack or damage the stone.

**Vandalism**: during protest, looting and theft of artefacts, the stones easily become damaged or vandalised.

**Sunlight and its effects on Sandstone Deposit**

Sunlight, water and other elements of nature have a huge effects on sandstone properties and quality. High quality sandstone can be mined at a four to six metre depth. This is due to the fact that the deeper you go, the quality of sandstone becomes soft and poor, or otherwise tested contrary. Consider a sandstone ore body divided into four major sections: North, South, East and West. The sun rises from East to West, therefore either the Northeast (NE) or Southeast (SE) section are susceptible to the deliterious effects of the sun. The miner should carefully observe which side of the deposit gets the most sunlight, the side exposed to sunlight will obviously be metamorphosed, and can possibly yield a strong, and less moist sandstone. Therefore, it is preferable to mine sandstones in the NE and SE areas where sunshine is at its peak. A six to eight metre core drill can reveal more about the sandstone as part of a preliminary assessment, as depicted in Figure 3.21(D).
Figure 3:21: (A) A sandstone ore body divided into quadrants N-S, E-W; (B) Shows a metamorphosed sandstone ore body; (C) The mostly affected North-East area; (D) Drill core for further quality testing and analysis.

3.9 Human Elements and Related Ethics

Human elements and ethics are those concerns that are human related, and which pose a major problem in the workplace and the community. The social welfare or well-being of the miner should be a major concern, such as training, health and safety considerations, balancing the workforce, where child or other form of forced labour must be averted through relevant legislation, which ought to be implemented and practiced in conjunction with sustainability.

3.9.1 Skills and Training

Mining sandstone can be very hard and tedious work, you need to be very healthy and strong as an artisanal miner, because you obviously work with little or no machinery in hostile environment. Most of the skills the artisans have today were acquired with time and experience, which is often passed down from one generation to the other, bringing new artisans into the sector, which require skills and training. Due to the fact that artisanal mining constitutes a dorm of craftsmanship, transferring the skills can be a difficult task, nevertheless it is possible to derive a means on how to split and cut or process sandstones using basic tools like a chisel and hammer, or an electric cutting machine, as described under the mining techniques. Acquiring the right skills and training will help ease the mining process, and may significantly improve safety. Most of the artisanal miners in QwaQwa can not read, write or understand the English language that tends to be used
by instructors. In South Africa, most basic trainings in mining is done by MINTEK or the MQA. The ABET (Adult Basic Education and Training) pioneered by the MQA has been within the South African mining sector, who have long assisted in training people with very low or no education, to deliver certain services in the mining industry. For the artisanal miners of sandstones in QwaQwa, the ABET Level 1 and 2 are necessary. ABET Level 1 is training in basic literacy in the mother tongue of the learner, often communication can be facilitated by a qualified interpreter, while ABET Level 2 is training in post-literacy and speaking English communication, using elementary notes or documents with drawings and understand warning signs (Tuchten & Nkomo, 2012). The mining community in QwaQwa ought also to make sure knowledge is not lost from one generation to the next, but transferred by bringing young and inexperienced artisans to work side-by-side with the older and more experienced artisans, until the necessary skills are transferred from one person to another. MINTEK and MQA ought not to be the only government institutions training artisans. Artisans themselves can train each other, by sharing ideas and knowledge, and can designate an experience person to teach the younger ones or the new arrivals in the field. Sub-standard artisanal mining should not be tolerated, because proper training and skills improves product quality, increase safety levels, and boost the morale of artisans and teamworkers.

3.9.2 Health and Safety Considerations

Health and safety are one of those factors that if not properly monitored or if neglected, it can become deadly. In the artisanal mining of sandstone, health issues like silicosis, tuberculosis, and HIV, are most common. Silicosis and injuries are predominant in the artisanal mining of sandstone. Silicosis is caused by silica dust from quartzite that can pass through and damage the lungs. The dust is as a result of splitting, cutting or processing of sandstone. Dust particles of 7µm or less will cause damage to the lungs if inhaled, only particles more than 40µm are safe for the lungs to filter. Silica dust cuts the lungs, and destroy it, due to its abrasiveness (NIOSH, 2004). Health and safety aspects are not often taken seriously by artisanal miners, and most often them are unaware of the mining-related diseases they often carry (Ahmad, 2015).

It is previously the case that government waited for accidents to happen before legislation pertaining to safety could be drafted. Today, things have changed, and much is focused on risk assessment. According to the Mines Health and Safety Act (MHSA) on surface collieries, the employer and the employee must assess and respond to risk. Section 11 of the act says every employer must identify all the hazards to the health or safety, to which employees may be exposed while they are at work (Apcor, 2014), including the artisanal mining and small-scale processing of sandstone.
Personal Protective Equipment (PPE)

By law, no person is allowed to do a particular job considered dangerous without wearing appropriate personal protecting equipment. Depending on the type of operation or duty of the person, the PPE may vary from department to department. In a typical artisanal mining operation of sandstone, the following PPE listed below must be used.

- Hard hats should be worn in and around the mine, where falling objects may create hazard.
- A dust mask must be worn when cutting or processing sandstone or whenever dust or fumes are present in air within the vicinity of work.
- Footwear should be worn in and around an area of a mine or plant susceptible to hazard or objects that can cause injury to the feet.
- Glasses should be worn in mine area where splitting or cutting of sandstone is carried out, and in areas where hazards like fumes, dust or sharp light are present.
- A working suit or appropriate clothing should be put on at all times when entering a mining area.
- Appropriate hand gloves should be used with tools like hammers, chisels or a cutting machine, to prevent injuries caused by overexertion.
- Ear plugs ought to be put on where sound levels are high, particularly when cutting or processing sandstone with machines. Other safety wear like knee guards or belts may also be considered.
- A first aid management kit is necessary onsite to treat minor injuries before the patient is sent to the nearest hospital.

3.9.3 Gender Inequality (Women in Artisanal Mining)

There is no longer any law forbidding women in mining in South Africa. There are many women working today in the artisanal and small-scale mining sector who are willing to take the opportunity, since it is a poverty-driven sector, where men and women are fighting for survival. The increase of women in the sector could be attributed to increased job scarcity. In QwaQwa MINTEK has facilitate the obtaining of permit for the artisanal mining of sandstone, including that of one woman, a Ms. Mnisi. MINTEK has also engaged women in beneficiation of waste stones e.g. travertine and granite into cutting boards, headstones, and cobblestones. In recent years, the universities, the ECSA (Engineering Council South Africa), SAIMM (South African Institute of Mining and Metallurgy) and the DMR (Department of Mineral Resources) have all put the women’s agenda in the forefront, and are able to see the presence of women, felt within the institutions, because the number of women in mining is steadily increasing (Cruise, 2011). There is a gender
shift in small-scale mining, which all stakeholders ought to acknowledge, that extends to the artisanal mining and small-scale processing of sandstone in QwaQwa.

3.9.4 Balancing of Work Force (Age Groups)
Many people, especially those in urban areas, often neglect or minimise artisanal mining activities. Some look at it as a dirty, and a less lucrative job, and others see it as very tedious and difficult. Since artisanal mining is so strenuous, children should not be allowed to work in such an environment, and this is considered abuse according to the ILO (International Labour Organization) and the South African MHSA (mines health and safety Act). The work force may vary from one country to another, depending on the HDI (Human Development Index), where, in South Africa, it is mostly the older people who are attracted to the artisanal mining and small scale processing of sandstones, whereas in Cameroon and Lesotho, the same mineral attract the younger generation. That should not be the case, but is a result of economic need that includes all generations. In QwaQwa, even though the youth are not engaged in artisanal mining activities, most still sit at home doing nothing. Whereas current miners ought to ensure knowledge does not die with the present generation, it ought to be transferred to the youths of today, who are going to be miners of the future.

3.9.5 Child Labour and Abuse
A child is understood to be a person considered underage, and must not be allowed to work on the mines. An underage person is someone less than 18 years of age. In QwaQwa, no case of child abuse in the artisanal mining and small-scale processing of sandstones has been reported, all stakeholders must ensure minors are kept save from working in such a hostile environment. A child as young as 16 years old may visit or do only vocational work or study related activities in such an environment, and must not be allowed to work for pay. Child labour is a punishable crime and must be reported, any employer found guilty of employing or engaging an under-aged person to work on a stone mine will be criminally charged.

3.9.6 Remuneration and Fairness
Most artisanal miners work for themselves and rarely account to someone. But in other instances where the mining activity is big, wages and payments are a daily struggle because such activities are not properly regulated. The salaries of the employee should always be negotiated between the employer and the employee, and no amount as salary should be imposed to the employee. In QwaQwa, miners and other employees often get paid on a daily basis, while others get monthly wages. Miners are often paid depending on the square metre mined or processed per day. Salaries or daily wages are not regular or fixed. Concerns about remuneration should be resolved by employers, and the employers should be sensitised about the importance of a good
relationship between the employer and the employee, in order to create a good working atmosphere and to increase safety and productivity. Any dispute between miners and their employers may be referred to a small court or to the CCMA (Commission for Conciliation Mediation and Arbitration).

3.10 Socio Economic and Political Problems
There is still much that needs to be done in South Africa's mineral industry, where government should work hard in dealing with research and development, education, training, aids, labour efficiency infrastructure, and nationalisation-related problems. All these aspects contribute to the sustainability of the mineral industry. Government is responsible to see that the infrastructure and research development programme put in place to develop the artisanal mining of sandstone in QwaQwa is motivated, monitored, and implemented. Education and training is key, locals must be given the opportunity to learn about the mineral, the market, and its applications and how it can be mined safely and economically. Controversial mine nationalisation could be of an advantage to the artisans, because of their immediate needs for the land, but government needs to be very prudent because, as the mines grow, there will be a need for other investors to contribute. The investors have to be assured that their business will be safe, and that nationalisation poses no threat (Cawood, 2011). Any mining activity undertaken by the locals themselves, be it artisanal or small-scale mining, the local community as a whole should benefit from such activities and government should be the referee to make sure the socio-economic advantage is achieved. With mine nationalisation, it will be difficult to achieve a long-term growth trajectory, where each industry stakeholder aims to promote national growth (Du Plessis, 2013). Competition drives economic growth, whereas nationalisation seems to be a policy for those less competitive, and it does not favour competition, which is bad for a country’s economy. Artisanal and small-scale mining mostly attracts black South Africans, considered to be (HDSA) historically disadvantaged South Africans. While black economic empowerment policy has been inconsistent in its outworking thus far, it nevertheless remains the case that its principles, where they are translated into practice, could serve to advance HDSAs in the economy (Thomas, 2014).

3.10.1 Commercialisation of Sandstone Products
Preliminary results from the research work indicates that the commercialisation of sandstone is of a major concern, and in order for a sandstone miner to achieve his goal, he should be knowledgable about the market prices of the different sandstone products. When one visits the artisanal sandstone miners, they say they are strong and energetic, and that despite certain constraints, the can effectively mine sandstone. Miners will show you stockpiles of sandstone they have mined, awaiting entry into the market. This demonstrates that it is crucial to establish a link
between producers and suppliers to complete the business chain and make it successful. Table 3.25, list the approximate prices of sandstone in different geographical locations.

**Table 3:25: Sandstone pricing list at mine gate**

<table>
<thead>
<tr>
<th>Producers</th>
<th>Miner’s Selling Price per m² (ZAR)</th>
<th>Miner’s Selling Price per m² ($)</th>
<th>Main Suppliers</th>
<th>Sales point</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Arica - QwaQwa</td>
<td>R300</td>
<td>$21</td>
<td>Cashbuild &amp; local market</td>
<td>Mine gate</td>
</tr>
<tr>
<td>Cameroon - Puma</td>
<td>R100</td>
<td>$7</td>
<td>Local market</td>
<td>Mine gate</td>
</tr>
<tr>
<td>Lesotho - Lekokoaneng</td>
<td>R150</td>
<td>$10</td>
<td>Export &amp; local market</td>
<td>Lekokoaneng and Maseru</td>
</tr>
</tbody>
</table>

3.10.2 Advertisement and sensitisation about sandstone applications

There is a need for proper marketing for the end product on behalf of the beneficiaries. But the question remains as to who should do the advertisement (publicity) or sensitisation. It should be a collective effort from government and the miners, or other interested parties. The miners should be given the opportunity to use the State’s platforms for advertisement and commercialisation, to distribute information about the various types, shapes, sizes, and applications of sandstone.

Ceramic tiles application versus sandstone applications: Builders or consumers of sandstone should be encouraged in using the product, because it is more environmentally friendly than ceramic tiles, and will maintain its natural beauty for a longer period of time. Government or municipalities awarding contracts may stress the need for sandstone to be used in most building projects. The need to use sandstones will help boost the artisanal mining and small-scale processing of sandstone activities in the rural community.

Quality, price and quantity of sandstone: There are various types of sandstone products, e.g. tiles, cobbles, slabs, strips, bricks, pebbles and raw blocks. Sometimes the stone can be designed depending on the customer’s order. The quality of the stone can be enhanced depending on the processing and polishing techniques applied and a stone is priced based on its quality and market competition. Artisans mine in small quantities, therefore, when there is a big order, which requires a large volume of sandstone, miners can regroup to supply and fill the gap.
Stocking and sales points of sandstone: There is a need for miners to mine and stock good quantities of sandstone to prevent shortages and availability in the market. Stocking can also help miners for contingency planning, and creates resting periods used to fulfil other responsibilities, like meeting with stakeholders, while sales can still be pursued. Sales points should be available it most lucrative areas, or closer to hardware stores in city centres, where a link should be established with franchised stores like Build it, Habitat for Humanity Restores, Builder’s Warehouse and Ace Hardware Stores. These stores can assist in sales and publicity.

Availability and delivery of sandstone to consumers: There should always be enough sandstone product ready for delivery to customers, where the availability can help maintain the trust between the supplier and the consumer. Free delivery could be a key to enhancing delivery to strategic customers, whereas in QwaQwa, miners often wait for an order from a customer before they can start production. This often comes with delay in the delivery of stones to customers.

3.10.3 Mining legislation pertaining to artisanal mining
In South Africa, artisanal mining is often seen as an illegal mining activity, mainly because most artisanal miners don’t have easy access to mining permits, and majority of the land belongs to private owners. There is a need to improve the mining rights of the sandstone miners in QwaQwa for them to be able to access land with greater ease. The Minerals and Petroleum Resources Development Act of 2002 (MPRDA) does not differentiate between artisanal and small-scale mining, often address as artisanal and small-scale mining with no provision made for artisanal mining, the definition of small-scale mining operations in the MPRDA is one where (a) the mineral in question can be mined fully within a period of two years; and (b) the mining area in question does not surpass 1.5 hectares in extent, where most artisanal mining and small scale processing of sandstone occupies 50-200m². In the struggle for mining land and permits, many South Africans might see mine nationalisation as a form of job creation, however South Africa lacks entrepreneurship in its working population. Research has shown that South Africa is not ready for nationalisation. Sergeant, (2013) studied nationalisation in countries like the DRC, Venezuela and Zambia where nationalisation did not succeed, and reasoned that it would not succeed in South Africa at the present moment as one can not see mine nationalisation as a solution to the present economic hardship, there is still a need to create an environment favourable for business (Sergeant, 2013). In recent years, government, through its affiliates like MINTEK, the universities and other research groups like the MPTRC in the University of Johannesburg, are trying to promote artisanal and small-scale mining activities like the artisanal mining and small-scale processing of sandstones in QwaQwa.
3.10.4 Preliminary Studies on Sandstones Resource
According to the South African Mineral Codes, a preliminary study is a comprehensive design and costing study of the selected option for the development of a mineral project in which appropriate assessments have been made of realistically assumed geological, mining, metallurgical, economic, marketing, legal, environmental, social governmental, engineering, operational and all other modifying factors, which are considered in sufficient detail to demonstrate its viability at the time of reporting that extraction is reasonably justified (economically mineable). These factors reasonably serve as the basis for a final decision by a proponent or financial institution to proceed with, or finance the development of the project, with overall confidence of the study should be stated (SAMREC, 2009). In this research, for QwaQwa sandstone, a pre-feasibility study will not receive elaboration, due to the type and size of the deposit, where it is deemed better to directly discuss a feasibility study to convert the resource into a reserve. To conduct a feasibility study is very important, because, before engaging yourself or others in a mining venture, one should be able to know at an early stage whether or not the project is feasible. It is therefore indispensible to carry out such a study, even for a small projects like artisanal mining and the small-scale processing of sandstones. Investors or shareholders should not be misled analysis done by an incompetent individual. It will be embarrassing if money is borrowed from a financial institution or pensioner’s pensions put at risk into an unproductive venture without a proper feasibility study.

Estimated mineral resource and reserve of QwaQwa sandstone
The city of QwaQwa is very rocky, and it is estimated that more than 5% of the 1685km² (650.58 square miles) it covers is made of sandstone, or 84.25km², which is the probable extent of mineral resource indicted insitu. Due to environmental and tourist considerations, sandstone cannot be mined indiscriminately. Therefore the reserve can be further restricted to 3% of the 1685km² that the area of QwaQwa covers. Finally the 3% of the 1685km² reserve is considered a proved mineral formation that can possibly be mined for economic benefit. This gives us an estimated reserve of at least 0.03 x 1685 = 50.55km². Seam thickness can vary from few millimetres up to 10 metres or more in some areas.

A cash flow model on a 100m² QwaQwa sandstone reserve shall be discussed in Chapter 3, 3.12. Based on certain economic factors, the researcher will be able to draw conclusions as to how lucrative the deposits may be in QwaQwa.

Drilling and quantitative survey
Drilling and sampling is the main method used in sandstone exploration. Drilling into a sandstone ore body is necessary to achieve high quality and ultimately cost-effectiveness. Prospective
drilling in sandstone is quiet simple where there is an outcrop, because it requires to drill just 6m, only 4m deep from top is likely to be considered high quality sandstone due to degradation caused by moisture as you mine deeper. In cases where there is an overburden, this has to be cleared before the miner can reach the sandstone deposit. In case where a drill is expensive to explore, a pneumatic rock drill or pick can be used to access at least a metre or more of exposed rock. Samples are collected and taken for a rapid quality test like water absorption, strength and contaminants. On a 100m² deposit, holes or samples should be drilled at approximately 10 metres apart to obtain a representative sample of the deposit. See Figure below.

3.10.5 Rivalry between artisanal miners (competition)
As in most communities, artisanal mining in QwaQwa is not free from conflict and rivalry between the different groups of miners and individuals as they compete for position and hierarchy. According to Forsyth, (2009) conflict occurs between groups, and before the conflicts can be resolved the causes must firstly be identified (Forsth, et al., 2009). If one tries to deal with or manage conflict successfully without identifying the cause of such conflict, this proves to be a lost cause (Havenga & Visagie, 2004). Research conducted within a group of artisans, indicates there is conflict over authority, land and rights. Greed and jealousy are likely to be two major causes, where an artisan or group wants to be known as the ultimate sandstone miner in QwaQwa. Certain groups or persons wish that a stakeholder such as MINTEK, government agencies, universities
or an NGO coming to the area, be contacted first or be the preferred candidate to acquire any benefits brought forth to the artisanal miners of sandstones into the community. All these conflicts ought to be address by a third party stakeholder, mostly the government and the affiliates, through a conflict management team. There is a strong conflict of interest between the artisanal miners of sandstones in QwaQwa and those in neighbouring Lesotho. In Lesotho, artisans are paid less than in QwaQwa, and the Chinese are flooding the market with sandstone products mined with mechanised equipment. For this reason, artisanal miners in QwaQwa find it very difficult to compete with their neighbours from Lesotho, because this sandstone often finds its way into the South African markets. If the border crossing of sandstone from Lesotho to QwaQwa is allowed without proper regulation, it might further jeopardise the fight to alleviate poverty in the rural community. Therefore legislation must be put in place to mitigate cross boundary commercialisation of sandstone products, particularly from neighbouring Lesotho.

3.10.6 Mining transition from artisanal to small-scale mining or progressive mechanisation

The transition from artisanal mining to small-scale mining should be the way forward. As an artisanal miner of sandstone, your vision and focus should be to grow and move to the next level, which is mechanisation and increase productivity. No miner would like to be in the same position for years, where all artisanal miners of sandstone ought to have a medium and long term plan for their business future. Progressive mechanisation could be achieved through savings, or by acquiring finances or loans from financial institutions like banks and other development agencies e.g. the Industrial Development Corporation (IDC), Business Finance Promotion Agency (BFPA) and the National Youth Development Agency (NYDA).
3.11 Environmental concerns
It is often said that our environment is our future, and mining companies are obliged to protect it from unnecessary degradation in the present, such that it serves future generations. In a country like Egypt, with a rich culture in stone mining, there is a great threat to the stones caused by modern environmental changes like acidic rains and salination from industries which erode stones faster than ever (Klemm & Klemm, 2001). Though in QwaQwa, environmental issues are not a major concern, there ought to be initiatives to promote sustainable sandstone mining activities, because this part of the country has a potential reserve of sandstone with a great deal of economic and tourist benefit and enormous biodiversity.

3.11.1 Environmental management
Some people may argue that the destruction caused by artisanal and small-scale mining to the environment by the local population outweighs the benefits, while others disagree (Mutemeri, et al., 2010). Artisanal and small-scale mining has changed the lives of many, and has alleviate poverty in most communities, therefore environmental issues can be dealt with and properly managed in order to have a sound environmental management system where mining of sandstone is carried out. There is lot of debate as to what the concept “environment” encompasses. According to Colby, the environment is a complex of biotic, climatic, soil and conditions, which comprise the immediate habitat of an organism, including the physical, chemical and biological surroundings of an organism at any given point in time (Chandna, 2013). The National Environmental Management Act (NEMA) provides that the “environment” means the surrounding within which humans exist and that are made up of the following:

I. the land, water and the atmosphere of the earth;
II. micro-organisms, plant and animal life;
III. any part of (I) and (II) and the interrelationships among and between them; and
IV. the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influences human health and well-being (Chandna, 2013).

3.11.2 Protection of the flora and fauna
The mountains of QwaQwa, due to their beauty and biodiversity, has attracted local and international visitors. People visit the mountain formations, and take pictures without knowing the biodiversity is fragile, and requires protection. According to a United Nations Educational,
Scientific and Cultural Organization (UNESCO) report, biodiversity is about the number and existence of different species of plant and animal life in that particular area or in the entire earth (Keating, 1998). As a prospective miner, it is necessary to avoid or prevent the loss of biodiversity, mostly due to anthropogenic causes like mining activities, habitat destruction, and pollution through mining activities. In QwaQwa the local authorities prohibit miners from mining on the face of the mountain. Mining activity takes place only in designated areas deemed appropriate, and represents no threat to the biodiversity or environment. In addition, the owner must carry out a justifiable mining activity by rehabilitating already excavated areas with trees or vegetation. No mining activity ought to be carried out in areas considered fragile or prone to erosion, weathering or flooding.

3.11.3 Water pollution and water management
Water is South Africa’s most precious natural resource. The climate of South Africa is semi-arid, with an average rainfall of 475mm per annum, compared to 735mm for the United States and 860mm for the world (Ochieng, et al., 2010). When processing sandstone, particularly when shaping it with the diamond cutting disc, a large amount of water is needed to lubricate the cutting blade. Around 100 to 1000 litres of water is pumped every day to lubricate a single cutting machine used for the small-scale processing of sandstones. Most often, the water is not recycled, however, water is a scarce resource and needs to be controlled. It is also necessary to pump water, and its availability may be very expensive. All water coming from processing must be contained and recycled so as to maintain a proper water management cycle or process.

3.11.4 Air pollution (smoke and dust)
Sandstone processing or cutting generates huge amounts of dust into the environment, even though the artisanal mining of sandstone generates relatively less dust during mining and splitting, and relatively little fumes from firewood and diesel generators. It is estimated that a minute fraction of sandstone pollutes the air in the form of dust, the vegetation and immediate environment. It is advisable for miners to wear dust masks and safety goggles in cases where the dust and fumes are at high levels, and can pose a health hazard to the workers. Also, water can be used to allay dust, or when cutting with a disc blade to prevent dust from spreading into the environment.

3.11.5 Noise pollution
In sandstone mining, most of the noise occurs during processing and cutting. Cutting machines generates noise, while using a chisel and hammer also generates noise. According to the Mines Health & Safety Act (MHSA), no one is allowed to work in an environment where noise levels exceed 85db (decibel). When working with chisel and hammer or a cutting machine, the artisan or worker must ensure he protects his ears with an earplug or protector. The owner must also
ensure that the noise generated from mining activities causes no harm to neighbours or passers by. No mine or mining activity ought to be carried out too close to a residential area, or where it might cause noise pollution.

3.11.6 Waste management
Waste from sandstone also called spoil heaps, vary in their physical or chemical nature. Most often the overburden is clay, laterite or black soil, and it forms parts of the heaps including spoils from the sandstone itself. Wastes generated from sandstone mining are often non-toxic or widely contaminating. The major concern in this instance is the vegetation cover that ought to be replaced after it has been removed during the mining activity. Restoration is then necessary, and ought to be the responsibility of the mine owner to make sure the community still benefit from the beauty of the land before and after the mining activity (Evans & Kemp, 2011). The process of restoration involves refilling the mining pit with leftover rocks, and planting vegetation on it in order to recreate natural beauty and prevent water erosion.

3.11.7 Provision of Green Energy as an Alternative
Green energy may include, solar, wind, hydrothermal, geothermal, and biomass resources. These will obviously be sources of energy for the future. Green energy is an important source of energy, and it is of great interest to the artisanal and small-scale mining activities. The artisanal mining of sandstones requires energy in splitting, cutting and polishing. Most sandstone mines are located in remote areas, where the power grid is not yet available, and therefore having energy autonomy is important, particularly green energy. Green energy is so important for the artisanal mining and small-scale processing of sandstones in QwaQwa because it does not consume too great an amount of kilowatts, most often less than 10kw for lighting and cutting. Green energy is vital for our fragile environment, and most see green energy as the energy of the future in mining. South African coal reserves are progressively depleting, therefore building small renewable energy plants around the country are indispensable for our environment and mining activities (Seeger & Minnitt, 2010). According to Edkins, (2010) There is enough sun and wind to generate renewable energy in the mountain sides of QwaQwa, where most of the sandstone are located (Edkins, et al., 2010). Using green energy is crucial to protecting the fragile environment.
3.12 A Cash Flow Model for an Artisanal Sandstone Mining Reserve in QwaQwa

Establishing a sustainable mini cash-flow model for QwaQwa sandstone was indispensable, because a cash flow model gives us insight into the economics and sustainability for an investor or to the local miners. Actual figures can help assist us in converting the resource into a reserve and guarantee stakeholders that money won’t be lost during the process of investment and mining.

3.12.1 Terminology

**Stripping ratio**: the ratio of the volume of overburden (waste material) removed in order to extract some tonnage of ore. A stripping ratio of 3:1 means for every single ton of ore mined, three tons of waste material is generated.

**Gross revenue**: the total amount of money made before any expenses.

**Operating costs**: expenses related to the operation of a business e.g., diesel, explosives, spares.

**Capital costs**: fixed costs i.e., one-time expenses incurred e.g. purchase of land or equipment.

**Contingency @ 4%**: making provision for an unpredictable event or circumstances.

**Profit before tax (PBT)**: the profit a company makes before it pays any tax.

**Royalty**: a payment made to an owner for the use of property.

**Profit after tax (PAT)**: the net amount earned by a company after all taxation related expenses have been deducted.

**Cash flow**: the difference in the amount of cash available at the beginning (opening balance) to the amount of cash at the end of that period (closing balance). If the closing balance is higher than the opening balance the cash flow is called positive, otherwise it is negative.

**Internal rates of returns (IRR)**: the interest rate at which the net present value of all the cash flow, positive and negative from a project equal zero. The IRR is used to evaluate the attractiveness of a project or investment.
Return on investment (ROI): this value tells the investor how much was profited to the cost saving realised from a project.

Break even (BE): when a business venture reaches a point where the profits are equal the costs.

Discount rate @ 8%: the minimum interest rate set by a government, which assists in determining the present and future value of your cash flow.

Net present value (NPV): also known as net present worth, is the measurement of the profitability calculated by subtracting the present value (PV) of cash outflow including initial costs from the present values of cash inflows over a period of time.

3.12.2 Methodology
The methodology applies the basic economic principle: profit = revenue − total expenditure, to determine whether the business can make a profit or not, and from there one can establish a net present value (NPV) for the cash flow, return on investment (ROI), internal rate of returns (IRR), and break even (BE). Key elements for this cash flow model are the stripping ratio, tons mined in m², tons processed in m², selling price per m², revenue from sandstone, operating costs, capital costs, profit before tax, royalty, profit after tax, discount rate at eight percent.

Calculations on the reserve
The researcher worked on a 100m² sandstone reserve. Most of the mining land around QwaQwa belongs to the local chief, where, as a traditional obligation, permission is required from the local chief in order to commence with any mining activity. The cost to mine a property might vary depending on who needs the land for a mining activity and the size of the land. A royalty sum of R10,000-R20,000 may be requested by the local chief for a 100m² piece of mining land. Mining proceeds in benches at a mining height of four metres, of high quality stone, with a bench height of 1m each. Dimensions of a 100m², a 1m² and a 23cm X 7.5cm X 3cm (tile) of sandstone are shown in the Figures below.
The dimensions of a $100m^2$ reserve at a mining height of 4m

The dimensions of a $100m^2$ reserve at a mining height of 1m

The dimensions of a $1m^2$ of sandstone
The dimensions of a sandstone tile

From Table 3:26 to Table 3:34, is a summary of calculations and estimates of important elements which constitute the core of the cash-flow model displayed in Page 104.

Table 3:26: Calculations on splitting and processing of a (100m² x 4) of sandstone tiles

<table>
<thead>
<tr>
<th>Description</th>
<th>Dimensions</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining height</td>
<td>4m</td>
<td></td>
</tr>
<tr>
<td>Bench height</td>
<td>1m</td>
<td></td>
</tr>
<tr>
<td>Reserve size</td>
<td>100m² x 4</td>
<td>400m²</td>
</tr>
<tr>
<td>Dimensions of one tile</td>
<td>23cm x 7.5cm x 3cm</td>
<td></td>
</tr>
<tr>
<td>No. of tiles in a 1m x 0.03m tile height</td>
<td>13 x 4</td>
<td>52 tiles</td>
</tr>
<tr>
<td>No. of sets of tiles in a 1m thick</td>
<td>100cm + 3cm</td>
<td>33 Sets of tiles</td>
</tr>
<tr>
<td>No. of tiles in a 1m² of sandstone</td>
<td>52 x 33</td>
<td>1716 tiles</td>
</tr>
<tr>
<td>No. of tiles in a 100m² of sandstone</td>
<td>1716 x 100</td>
<td>171,600 tiles</td>
</tr>
<tr>
<td>No. of tiles in a mining height of 4m</td>
<td>171,600 x 4</td>
<td>686,400 tiles</td>
</tr>
<tr>
<td>Total square metres mined</td>
<td>100m² x 33 x 4</td>
<td>13,200m²</td>
</tr>
<tr>
<td>Recovery @ 95%</td>
<td>13,200 x 0.05 (Waste)</td>
<td>660m²</td>
</tr>
<tr>
<td>Effective square metres mined</td>
<td>13,200m² - 660m²</td>
<td>12,540m²</td>
</tr>
</tbody>
</table>

Table 3:27: Revenue on a (100m² x 4) of sandstone tiles

<table>
<thead>
<tr>
<th>Descriptions</th>
<th>Calculations</th>
<th>Amount (ZAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of a metre square at mine gate</td>
<td>R300</td>
<td></td>
</tr>
<tr>
<td>Cost of a metre square of waste + tailings at mine gate</td>
<td>R256.50</td>
<td></td>
</tr>
<tr>
<td>Revenue from 400m² reserve</td>
<td>12,540m² x R300</td>
<td>R3,762,000</td>
</tr>
<tr>
<td>Revenue from waste + Tailings</td>
<td>660m² x R256.50</td>
<td>R169,290</td>
</tr>
<tr>
<td>Gross revenue</td>
<td></td>
<td>R3,931,290</td>
</tr>
</tbody>
</table>
Table 3:28: Mine Life a (100m² x 4) Sandstone Reserve

<table>
<thead>
<tr>
<th>Descriptions</th>
<th>Calculations</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working hours per day</td>
<td>8 Hours per day</td>
<td></td>
</tr>
<tr>
<td>Working shifts per day</td>
<td>Single shift</td>
<td></td>
</tr>
<tr>
<td>Working hours per week</td>
<td>8 x 5 Days</td>
<td>40 hours per week</td>
</tr>
<tr>
<td>Working hours per month</td>
<td>4 x 40 Hours</td>
<td>160 hours per month</td>
</tr>
<tr>
<td>Working hours per year</td>
<td>12 x 160 Hours</td>
<td>1920 hours per year</td>
</tr>
</tbody>
</table>

Assume there is 10 days of holidays a year

| Advance rate per day          | 2m² Per day x 4 Miners              | 8m²/day        |
| Duration to mine a 400m² reserve | 13200m² ÷ 8m²/Day                | 1650 days     |

Assume a year has 267 working days

| Total no. of years to mine the reserve | 1650 ÷ 267 | 6.2 years |

Therefore, it would require approximately 6.5 years to mine a 100m² sandstone reserve

Table 3:29: Mining crew per mine

<table>
<thead>
<tr>
<th>Mining crew</th>
<th>No. of personnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work description</td>
<td></td>
</tr>
<tr>
<td>Rock splitting</td>
<td>4</td>
</tr>
<tr>
<td>Processing plant</td>
<td>2</td>
</tr>
<tr>
<td>Driver</td>
<td>1</td>
</tr>
<tr>
<td>Welder/mechanic</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8</strong></td>
</tr>
</tbody>
</table>

Table 3:30: Mining tonnage per year

<table>
<thead>
<tr>
<th>Years</th>
<th>Effective square meters mined(m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,760</td>
</tr>
<tr>
<td>2</td>
<td>1,980</td>
</tr>
<tr>
<td>3</td>
<td>2,090</td>
</tr>
<tr>
<td>4</td>
<td>2,200</td>
</tr>
<tr>
<td>5</td>
<td>2,420</td>
</tr>
<tr>
<td>6</td>
<td>2,750</td>
</tr>
</tbody>
</table>
### Table 3:31: Operating costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount (ZAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel R12/litre for 267 days @ three litres per day</td>
<td>12,816</td>
</tr>
<tr>
<td>Explosives R1200/kg @ 5kg per year</td>
<td>6000</td>
</tr>
<tr>
<td>Daily labour R20/m², 2m, for four miners @267 days</td>
<td>42,720</td>
</tr>
<tr>
<td>Equipment operation + truck per year ~</td>
<td>103,000</td>
</tr>
<tr>
<td>Salaried labour (8 Crew) per month</td>
<td>25,000 x 12 x 6</td>
</tr>
<tr>
<td>Engineering &amp; fabrication</td>
<td>15,000</td>
</tr>
<tr>
<td>Administration</td>
<td>2,500</td>
</tr>
<tr>
<td>Social</td>
<td>6,000</td>
</tr>
<tr>
<td>Petty cash</td>
<td>5,000</td>
</tr>
<tr>
<td><strong>Total operating costs</strong></td>
<td><strong>2,602,479.60</strong></td>
</tr>
</tbody>
</table>

### Table 3:32: Capital costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount (ZAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment &amp; machinery purchase</td>
<td>72,800</td>
</tr>
<tr>
<td>Roads/site work</td>
<td>4,000</td>
</tr>
<tr>
<td>Stripping of overburden</td>
<td>4,000</td>
</tr>
<tr>
<td>Buildings (makeshift)</td>
<td>8,000</td>
</tr>
<tr>
<td>Royalty &amp; manager pay (year 1)</td>
<td>145,000</td>
</tr>
<tr>
<td>Contingency @10%</td>
<td>23,380</td>
</tr>
<tr>
<td><strong>Total capital costs</strong></td>
<td><strong>257,180</strong></td>
</tr>
</tbody>
</table>

### Table 3:33: Details on equipment purchase for year one.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Quantity</th>
<th>Unit price (ZAR)</th>
<th>Amount (ZAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone cutting machine</td>
<td>1</td>
<td>25,000</td>
<td>20,000</td>
</tr>
<tr>
<td>Truck (initial deposit)</td>
<td>1</td>
<td>18,000</td>
<td>18,000</td>
</tr>
<tr>
<td>Pneumatic rock hammer</td>
<td>1</td>
<td>15,000</td>
<td>15,000</td>
</tr>
<tr>
<td>10 KW Diesel generator</td>
<td>1</td>
<td>12,000</td>
<td>8,000</td>
</tr>
<tr>
<td>Hammers</td>
<td>10</td>
<td>180</td>
<td>1,800</td>
</tr>
<tr>
<td>Chisels</td>
<td>10</td>
<td>150</td>
<td>1,500</td>
</tr>
<tr>
<td>Equipment</td>
<td>Description</td>
<td>Amount (ZAR)</td>
<td></td>
</tr>
<tr>
<td>---------------------------------</td>
<td>----------------------------</td>
<td>--------------</td>
<td></td>
</tr>
<tr>
<td>Picks</td>
<td>4</td>
<td>1,200</td>
<td></td>
</tr>
<tr>
<td>crowbars</td>
<td>3</td>
<td>900</td>
<td></td>
</tr>
<tr>
<td>Measuring tools</td>
<td>8</td>
<td>1,200</td>
<td></td>
</tr>
<tr>
<td>Personal protective equipment</td>
<td>8 sets</td>
<td>4,000</td>
<td></td>
</tr>
<tr>
<td>First aid box</td>
<td>2</td>
<td>1,200</td>
<td></td>
</tr>
<tr>
<td><strong>Total costs on equipment purchase</strong></td>
<td></td>
<td><strong>72,800</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Table 3:34:** Details on equipment operating costs per year

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Description</th>
<th>Amount (ZAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bond for truck</td>
<td>6000 x 12</td>
<td>72,000</td>
</tr>
<tr>
<td>Spares, oil, battery and tyres</td>
<td>5165 x 6</td>
<td>31,000</td>
</tr>
<tr>
<td><strong>Total costs on equipment operation</strong></td>
<td></td>
<td><strong>103,000</strong></td>
</tr>
</tbody>
</table>

*See cash flow spreadsheet below for more details.*
The excel spreadsheet cash flow model for six years to mine a 100m² sandstone property

### Artisanal Sandstone Mining Project

<table>
<thead>
<tr>
<th>Desciptions</th>
<th>Units</th>
<th>Comments</th>
<th>Figures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square metre mined</td>
<td>m²</td>
<td>Tiles only</td>
<td>13,200,00</td>
</tr>
<tr>
<td>Yearly yield</td>
<td>%</td>
<td>0,80</td>
<td>0,90</td>
</tr>
<tr>
<td>Effective square metre</td>
<td>m²</td>
<td>1,760,00</td>
<td>1,980,00</td>
</tr>
<tr>
<td>Recovery rate</td>
<td>%</td>
<td>5% waste</td>
<td>95,00</td>
</tr>
<tr>
<td>Square metre processed</td>
<td>1,672,00</td>
<td>1,881,00</td>
<td>1,985,50</td>
</tr>
<tr>
<td>Price per square metre</td>
<td>R/ m²</td>
<td>Tiles only</td>
<td>300,00</td>
</tr>
<tr>
<td>Exchange rate</td>
<td>(R/US $)</td>
<td>01:14</td>
<td>14,00</td>
</tr>
<tr>
<td>Revenue from tiles</td>
<td>ZAR</td>
<td>501,600,00</td>
<td>564,300,00</td>
</tr>
<tr>
<td>Revenue from waste</td>
<td>R/Year</td>
<td>20,064,00</td>
<td>22,572,00</td>
</tr>
<tr>
<td>Revenue from tailings</td>
<td>R/Year</td>
<td>2,508,00</td>
<td>2,821,50</td>
</tr>
<tr>
<td>Gross Revenue</td>
<td>ZAR</td>
<td>524,172,00</td>
<td>589,693,50</td>
</tr>
<tr>
<td>Operating costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel</td>
<td>R/Ltr</td>
<td>267 days</td>
<td>12,00</td>
</tr>
<tr>
<td>Explosives</td>
<td>ZAR</td>
<td>R/Kg</td>
<td>1,200,00</td>
</tr>
<tr>
<td>Labour per m²</td>
<td>R/m²</td>
<td>20,00</td>
<td>42,720,00</td>
</tr>
<tr>
<td>Equipment Operation + Truck</td>
<td>ZAR</td>
<td>R/Year</td>
<td>103,000,00</td>
</tr>
<tr>
<td>Salaried Labour for 8 crew</td>
<td>ZAR</td>
<td>Monthly</td>
<td>25,000,00</td>
</tr>
<tr>
<td>Engineering &amp; fabrication</td>
<td>ZAR</td>
<td>R/Year</td>
<td>15,000,00</td>
</tr>
<tr>
<td>Administration</td>
<td>ZAR</td>
<td>R/Year</td>
<td>2,500,00</td>
</tr>
<tr>
<td>Social</td>
<td>ZAR</td>
<td>R/Year</td>
<td>6,000,00</td>
</tr>
<tr>
<td>Petty cash</td>
<td>ZAR</td>
<td>R/Year</td>
<td>5,000,00</td>
</tr>
<tr>
<td>Total Operating costs</td>
<td>ZAR</td>
<td>493,036,00</td>
<td>448,667,60</td>
</tr>
<tr>
<td>Cash Operating Profit</td>
<td>ZAR</td>
<td>31,136,00</td>
<td>141,025,90</td>
</tr>
<tr>
<td>Capital costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment &amp; machinery</td>
<td>ZAR</td>
<td>72,800,00</td>
<td>72,800,00</td>
</tr>
<tr>
<td>Stripping of overburden</td>
<td>R/Hour</td>
<td>2hrs</td>
<td>2,000,00</td>
</tr>
<tr>
<td>Building (makeshift)</td>
<td>ZAR</td>
<td>8,000,00</td>
<td>8,000,00</td>
</tr>
<tr>
<td>Royalty &amp; manager pay (year 1)</td>
<td>ZAR</td>
<td>145,000,00</td>
<td>145,000,00</td>
</tr>
<tr>
<td>Contingency @10%</td>
<td>%</td>
<td>0,10</td>
<td>23,380,00</td>
</tr>
<tr>
<td>Total Capital Costs</td>
<td>ZAR</td>
<td>257,180,00</td>
<td>257,180,00</td>
</tr>
<tr>
<td>Profit Before Tax</td>
<td>ZAR</td>
<td>31,136,00</td>
<td>141,025,90</td>
</tr>
<tr>
<td>Royalty</td>
<td>R/Year</td>
<td>Negotiable</td>
<td></td>
</tr>
<tr>
<td>Profit After Tax</td>
<td>ZAR</td>
<td>-226,044,00</td>
<td>106,025,90</td>
</tr>
<tr>
<td>Cash flow</td>
<td>ZAR</td>
<td>-226,044,00</td>
<td>106,025,90</td>
</tr>
<tr>
<td>Interest rate @8%</td>
<td></td>
<td>1,00</td>
<td>0,93</td>
</tr>
<tr>
<td>NPV</td>
<td>ZAR</td>
<td>-226,044,00</td>
<td>98,172,13</td>
</tr>
<tr>
<td>Pay Back Period</td>
<td>Years</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>ROI</td>
<td>%</td>
<td>19,60</td>
<td></td>
</tr>
<tr>
<td>IRR</td>
<td>%</td>
<td>13,83</td>
<td></td>
</tr>
</tbody>
</table>
3.12.3 **Analysis of the Cash Flow Results**

Results obtained from the cash flow model indicates a positive **NPV**, **ROI** and **IRR** respectively for a six (6) years mining period shown in the table below:

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Net present value</strong></td>
<td>560 532,61</td>
<td>ZAR</td>
</tr>
<tr>
<td><strong>Return on investment</strong></td>
<td>19,60</td>
<td>%</td>
</tr>
<tr>
<td><strong>Internal rates of return</strong></td>
<td>13,83</td>
<td>%</td>
</tr>
</tbody>
</table>

Although we have a positive net present value, attention ought to be drawn towards data collected on the field like low salaries which is a dilemma, with the most highly paid personnel earning a maximum of only R5,000 per month. Therefore at high salaries an investor has to re-think or re-shape the project. Also an initial investment (CAPEX) of **R257 180** may be too high for most investors to carry out such a project in a rural community. With a net present value of approximately **R560 532**, after six years in artisanal mining and small-scale processing of sandstone the miners can gradually mechanise the activity to a small-scale mining activity by purchasing mechanised equipment.
3.13 Conclusion on mining concepts

The mining concepts in artisanal mining and small-scale processing of sandstone in QwaQwa was designed to address the needs of artisans both technical and socio economical. Chapter 3 of the research represents the core focus of the project. Being an artisanal miner, mining sandstone, slate, granite or limestone in a rural community, the above mining concepts can assist miners and stakeholders in starting up a new mine. By fully applying the concepts, the activities shall become more sustainable. The concepts can also be used by partners like government agencies, investors, educators or other research interest groups willing to do business with the sandstone miners.
CHAPTER 4
COMPARATIVE ANALYSIS OF CASE STUDIES

4.1 Introduction
During the course of the research, studies were conducted on different sandstones mining sites. The aim of the study was to observe and compare different mining activities, miner’s shortcomings, and mining techniques, for example, the techniques they used, and the socio-economic and political it creates. The research will examine the artisanal mining and small-scale processing of sandstone in local communities in Cameroon and Lesotho and compare with our case study in QwaQwa, South Africa. Gathering data helped us interpret our findings and the results obtained, and generate vital conclusions and recommendations of how to best mine sandstones in QwaQwa. A detailed analysis of data from the mining sites shall be interpreted in Chapter 5 of the dissertation.

4.2 Mining sites of artisanal mining and small-scale processing of sandstones in Cameroon
Puma is a small town in the Littoral province of the Republic of Cameroon with coordinates 3°51'12.2"N 10°31'19.3"E in the UTC +1 timezone, located about 180km away from the capital Yaoundé. The city of Puma is less populated than QwaQwa, and has a population of around 80,000 people. The artisanal mining and small-scale processing of sandstone in Puma sees higher production rates than in QwaQwa, despite particular challenges. There are more than 10 mining and two processing sites in Puma, most of which are closer to the main road to facilitate delivery. In Puma, the youth are fully mobilised in artisanal mining and small-scale processing of sandstone activities, and are desperately in need of the mineral revenue from inside the dense equatorial forest. Some miners spend the night on the mines, living in makeshift shelters with very little comfort, facing high temperatures, mosquitos, poor sanitation, and many other environmental challenges. The artisanal miners work as a team in small groups between two to ten persons at each particular site. They often prefer to mine early in the morning, when temperatures are low, and when mosquitoes and other wild insects are less active. The miners are very active and energetic, since the entire workforce is mostly the youth, while some are students, and often take the advantage during holidays to make money out of mining sandstones and preparing for the following academic year. In Cameroon, the government through its affiliate (CAPAM), which is a division of the ministry of mines and industrial development in charge of artisanal and small-scale mining. CAPAM is responsible for assisting miners to easily mine, process and sell sandstone products. They do so by providing miners with processing or cutting machines, attributing them
with geological assistance in detecting potential and profitable deposits. Government has made most mining sites accessible by grading roads to access sandstone deposits, while electricity polls have been erected to draw the power lines closer to processing sites. There is a bond through CAPAM between government and the artisanal miners, where government has delegated geologists and technicians to directly assist and support the miners.

4.3 Mining sites of artisanal mining and small-scale processing of sandstone in Lesotho

According to a GPS location, Lekokoaneng is a small, mountainous community in the town of Berea, 26km away from the capital of Lesotho, called Maseru, located at 29° 8' 0" South, 27° 41' 0" East. Lesotho is a country sharing its entire border only with the surrounding South Africa, where the sandstone formation in QwaQwa South Africa extends to Lesotho, as they share a common border and geology. In the Lekokoaneng community, sandstone business is booming, and there is no doubt it does contribute to the tiny nation’s economy, and supplies sandstone to the Southern African Development Community (SADC). Mountain Sandstone Mining was establish in 2011, since which it has been booming, and is one of the three major sandstone mining companies in Lesotho. Even though the Lekokoaneng Mountain Sandstone Mining believes much needs to be done to address the challenges of so-called red tape associated with assessing various government services. The artisanal mining and small-scale processing of sandstones in Lekokoaneng still perform better than their neighbours in QwaQwa South Africa. Why is the industry not growing in South Africa QwaQwa? What needs to be done to improve the current situation of the artisanal mining and small-scale processing of sandstones in QwaQwa?

The people of QwaQwa both young and old are still looking for employment, whereas there is an economic opportunity to mine sandstone. Today, the Lesotho government sees artisanal and small-scale mining through the mining policy as something that adds value and reduces poverty, rather than the negative effects it was earlier thought it had on the environment. The Lesotho government and its people can be observed to be more engaged in the artisanal mining and small-scale processing of sandstone in its rural communities.

4.4 Artisanal mining and small-scale processing of sandstone in QwaQwa

The small South African town QwaQwa is our main case study, the location has already been discussed in Chapter 1. According to Jos Lurie, (2008) the geological map of QwaQwa belongs to the Karoo Super Group, which comprises of the Molteno, Eliot and the Clarence formation, and indicates huge sandstone resource of greywacke and quartzite (Lurie, 2008). QwaQwa is still producing far fewer sandstone products, with a population of 736,200 and a population density of 254.2 per km² or 658.4 per square mile. With more than 10% of its working force unemployed, it
is believed there would be a desire to take up small economic activities like mining sandstone. There are more than ten artisanal mining and small-scale sandstone processing clusters, with less than five mining sandstone legally in QwaQwa. Most of the miners are quiet discouraged with the current situation and hope things might improve as soon as possible. They mine mostly with chisel and hammer, crowbars and picks. Whereas one would expect improvement in technique and strategy, the improvement can be achieved if there is a strong desire to seek economic opportunity in the artisanal mining and small-scale processing of sandstones. With the techniques discussed in Chapter 3, there is a possibility the status-quo can be improved if the procedures are applied accordingly. Table 4:1 and Table 4:2 describe major mining sites and estimates the sandstone reserve in QwaQwa respectively.

Table 4:1: Three major operational mining sites in QwaQwa

<table>
<thead>
<tr>
<th>Mining sites</th>
<th>No. of miners</th>
<th>Property size</th>
<th>Type(s) of deposit</th>
<th>No. of years’ operating</th>
</tr>
</thead>
<tbody>
<tr>
<td>PERENG</td>
<td>6</td>
<td>100m²</td>
<td>Greywacke &amp; Arkose</td>
<td>10</td>
</tr>
<tr>
<td>MAKWANE</td>
<td>4</td>
<td>80m²</td>
<td>Grit</td>
<td>20</td>
</tr>
<tr>
<td>MESIMATSO</td>
<td>5</td>
<td>150m²</td>
<td>Greywacke</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 4:2: Estimated overall mining sites in QwaQwa

<table>
<thead>
<tr>
<th>Total Mining Sites</th>
<th>No. of Mine Owners</th>
<th>Estimated No. of Miners</th>
<th>Resource Estimate (km²)</th>
<th>Reserve Estimate (km²)</th>
<th>Reserve being Exploited (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>5</td>
<td>50</td>
<td>84.25</td>
<td>50.55</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Note: seam thickness may vary from few millimetres up to 10metres or more in certain areas.
4.5 Analysis of studies conducted on the mining sites

After researching all three scenarios, it can be summarised that the artisanal mining and small scale processing of sandstone is more developed in Lesotho and Cameroon than in QwaQwa. Lesotho takes the lead based on two major reasons: firstly, the strategic geographical and economical location of Lesotho, and secondly the lower rank of Lesotho’s Human Development Index (HDI). Lesotho is located in the middle of the Southern African Development Community (SADC), which gives the tiny nation a market advantage, and it can easily export its sandstone into neighbouring South Africa, Botswana, Namibia, easily benefitting from the good transportation network within the SADC region. There is also a high purchasing power within the SADC than in other economic communities in Sub-Saharan Africa. The human development index thus justifies the reasons why poorer countries are most likely to engage in artisanal and small-scale mining activities than richer countries where citizens seek more lucrative and stable jobs. Yet, young and older people in Lesotho are less dependent on government, and will see the artisanal mining and small-scale processing of sandstone as a great economic opportunity. In Cameroon, the problem is accessibility to the market. The workforce is solid and produce lots of sandstone products, whereas a poor transportation and road network of the country prevents the sandstone products from accessing the markets around the country. In QwaQwa, the locals show less interest in artisanal mining activities, although they desperately require the money generated from the activity. The South African government is still spending a great deal on social grants, where artisanal mining and small-scale processing of sandstones can help relieve spending.

4.6 Conclusion

About ten mining and three processing sites were visited during the research. Each of these sites possesses different system of work and management, though they all mine sandstone. It was observed that the geographical, political and socio-economical elements thus influence the mining activities on the mining sites. The different activities on the sites have assisted the researcher in establishing proper guidelines, and best practices for mining activity in QwaQwa.
CHAPTER 5

INTERPRETATION OF FINDINGS AND RESULTS

5.1 Introduction to the interpretation of findings and results
This Chapter presents an interpretation of findings and results obtained from the mining concepts in Chapter 3, and studies carried out on mining sites of the artisanal mining and small-scale processing of sandstones in three different countries, namely Lesotho, Cameroon and South Africa, so that the results obtained from these countries can be interpreted towards the improvement of sandstone mining in QwaQwa. The results and findings assisted in the benchmarking of mining activities and address the shortcomings between the miners, government and other stakeholders in QwaQwa.

5.2 Data analysis on findings and results
The findings shall be interpreted under two main subheadings, which are the quantitative and qualitative data analysed from the mining concepts in Chapter 3. Analysis and recommendations on the findings shall be discussed in Section 5.3, 5.4, 6.3 and 6.4 in order to provide an insight as to how to make the artisanal mining and small-scale processing of sandstones sustainable with limited resources within the local community of QwaQwa. The technical and human elements discussed in Chapter 3, which can be applicable to the artisanal mining and small-scale processing of sandstones in QwaQwa, shall be commented upon. The aim is to come out with a new agenda to suit the geographical, technical, and socio-political needs of the miners in the rural community of QwaQwa. Although qualitative research remains reliant on interpretation, it may be improve and remain flexible because a research is a continuous process. Also, the quantitative data obtained from Chapter 3, particularly Sections 3.7.3 and 3.12 shall be interpreted and discussed.

5.2.1 Interpretation of quantitative analysis
The researcher in the end realised a strong need for attention towards artisanal mining and small-scale processing of sandstone, where working with artisans is very difficult because of their status, social life and the nature of their job. Most artisans do their jobs based on a short term plan, not on a medium or long-term plan. Whereas to succeed, miners must focus on the future. In Chapter 3, Section 3.8.1, looked at some quick sandstone testing techniques, which could add value and quality to the final product like the hardness, porosity and water absorption tests. In Section 3.7.3, the correlation between weight lifting and moving of sandstone mass against body weight,
physical strength and age was discussed in order to mitigate the high level of lifting and transporting of sandstone within the mine. The section also describes who and how an individual can adapt and integrate his/her self into such a working environment. The cash flow model in Section 3.12 explains how much it costs and what it takes to kick start an artisanal sandstone mining project in QwaQwa, or elsewhere within South Africa. The results from the findings were based on data collected from miners and owners through interaction, where some data were adjusted, such as remuneration, working hours, working conditions, and other provisions, to best accommodate modern society and its demands. Therefore, precautionary measures ought to be taken into consideration, due to the flexibility of royalty, remunerations and the assimilation of the legislation on the mines health and safety acts.

5.2.2 Interpretation of qualitative analysis
There is no doubt that if all the splitting, processing techniques, ethical considerations, environmental concerns and transportation techniques are fully understood and implemented, the following are likely be achieved through the benchmarking, stakeholder responsibilities and recommendations discussed in the next section and in Chapter 6. By analysing the qualitative analysis the following can be achieved:

**Increased safety:** there will be no injuries or bruise on the body particularly the hands and legs. The contracting of respiratory disease like silicosis and tuberculosis will be reduced. The life span of the artisans will increase as a result. The concerns refers us to Section 3.9.2, advising on the applications of personal protective equipment (PPE) for artisanal miners.

**Increased productivity:** the amount of sandstone split and processed will increase on daily basis. Customer care and delivery will speed up and there will be a good relationship maintained between the miners and their clients. The concerns refers us to Section 3.5, 3.6 and 3.7 on how, if miners apply the splitting, processing, handling and transportation techniques appropriately and relevant to the type of stone mining, productivity will definitely increase. Acquiring light machinery like a front-end loader should in future planning of the miners since there is a need to speed up transportation and production.

**Increased Product Quality:** The quality of the product is likely to increase since the working condition has changed under new rules. By applying the new techniques and processing tools, this will result in producing high quality products. Product quality could also be complement by performing some tests describe in Section 3.8.1. In addition, acquiring more electric tools can be significantly impact the production of high quality sandstone.
Boost the morale of the miner: Working in a more productive and safe environment will absolute boost morale. Remunerations will likely be increased and the community will reap the benefits of good mining practices, such as poverty alleviation and job creation.

Will facilitate rehabilitation of the environment: Mining in benches with a mining height of one metre per bench and proper cleaning of the over burden will facilitate the rehabilitation of the environment. It will be easy to refill displaced soil from previously mined areas and plant back vegetation over previously mined areas, since the mining activity was carried out in a sequential or organised manner as describe in Section 3.11.6.

Provide a better understanding of artisanal mining and small-scale processing of sandstone:

The review in Chapter 2 and the mining concepts in Chapter 3 on the artisanal mining and small-scale processing of sandstone will help artisanal miners gain a better understanding of artisanal mining and the small-scale processing of sandstone. The review and the mining concepts will be a great advantage for the miners, since most of them are remote areas and require exposure to modern techniques, they will now be able to plot their future and create new possibilities, making sure they drive their business to the next level. Chapter 2, also gives us a further understanding of how artisanal mining and small-scale processing of sandstone operates globally, and a vision for the way forward.

Facilitate legalisation and issuing of mining permits: Today, many perceive artisanal and small-scale mining as illegal. With these findings, artisanal mining and small-scale processing of sandstone in QwaQwa is perceived as a vital tool for rural development, and will invite stakeholders to push for the issuing of more permits or mining licenses through the assistance of the Department of Minerals Resources. Miners can also achieve mining permits by regrouping and applying for such as a group rather than as individuals, as this will draw much attention from the DMR. Supportive elements considered indispensable are detailed in Section 3.10.3.

Regulating trade deals and quotas: It is necessary to impose a quota or restrict movement of sandstone products entering into South Africa. By doing so, this will help mitigate conflict of interest between neighbours like Lesotho, where sandstone is cheaply produced. See Chapter 5, Section 5.4.
5.3 Benchmarking in the artisanal mining and small-scale processing of sandstone in QwaQwa

It is necessary to draw the line on the best practices and guidelines in the artisanal mining and small-scale processing of sandstones in QwaQwa. Research would indicate best practice. Analysis from the mining concepts in Chapter 3 helps support all the best practices and guidelines, and should be fully applied in the artisanal mining and small-scale processing of sandstone in the rural community of QwaQwa. Below are a list of best practices and guidelines designed to benefit the artisanal mining and small-scale processing of sandstone in QwaQwa and other local communities involved in sandstone mining. Any group or individual who intends to mine sandstone must take responsibility, and bear the costs of the following regulations:

- It is inappropriate and against the law to mine a piece of land without having the appropriate mining permit or an authorisation from the local authority. Mining activity should not be carried out on a reserved land or in a restricted area.
- Before any mining activity commences, an environmental assessment must be carried out by the owner to make sure the biodiversity is protected.
- A preliminary study on the deposit should be conducted either by a mining consultant or by qualified personnel to ensure money is not wasted on a non-existent mineral resource.
- The employer must take responsibly for the employee’s safety by providing them with a healthy working environment, as well as the correct training, skills, knowledge, supervision and PPE.
- The employee has the right to choose not to work in an environment which is not safe until the employer provides the employee with all safety measures.
- Miners must undergo periodic medical examination and check-up on respiratory diseases like silicosis and lungs infections at the expense of the employer.
- The employer must establish and maintain a system of occupational hygiene measurements of all working places where the following hazard limits prevail.
  a) airborne pollutants;
     i) particulates > or = 1/10 of the occupational exposure limit;
     ii) gases and vapours > or = 1/2 of the occupational exposure limit;
  b) thermal stress;
     i) heat > 25°C wet bulb and/or > 32°C dry bulb and/or > 32°C mean radiant temperature are prohibited;
     ii) cold < 10°C equivalent chill temperature; and
  c) noise levels > or = 85 Decibels should be avoided.
- Miners should periodically undergo a cardio-respiratory examination with a full size chest x-ray using a photographic plate measuring 35cm × 35cm × 35cm × 42cm, or the digital equivalent.
- Any hazard that can cause injury to a person should be mitigated, reported or cleared of by either the employer, the employee or the miner working at that moment.
- Gunpowder, explosive cartridges, flammable liquids, and other dangerous equipment must be kept in a safe place, and should be used only by a well-trained, experience or a qualified person.
- The artisanal miner must make sure he selects the right splitting or processing techniques to avoid wasting of resources.
- No person is allow to negligently cause or permit water supplied from any service pipe for dust allaying or drinking purposes to run to waste.
- All mining of sandstone ore body, no matter the type, should be carried out in benches as mining activity progresses. As mining in benches turn to expose most of the sandstone to sunlight, this increases its quality, as water dries up.
- Artisanal miners of sandstone in QwaQwa should first and foremost consider using one of the nine splitting or seven processing techniques discussed in the mining concepts in Chapter 3. Except another technique is proved appropriate as a substitute.
- Records of all daily and monthly work should be kept. This includes production records, medical records, purchase, and sales records.
- Miners must avoid high walls greater than 2m during mining in order to prevent unprecedented rock fall or injuries to miners.
- Miner should avoid mining quality sandstone at depths greater than 6m, as the quality may be compromised as mining progresses deeper.
- After mining over a particular area, the owner ought to rehabilitate the mined area, either by landfill, planting of vegetation, or levelling.
- Any dispute between miners or between employers and employees should be resolved amicably, or referred to a small claims court or the Court of Conciliation Mediation and Arbitration (CCMA). Mining-related queries like water, land, environment, should be referred to the DMR.
- All miners and staff should strictly adhere to best practices and guidelines.
5.4 Shared responsibility between artisans and various stakeholders

There are five main key players involved in the artisanal mining and small-scale processing of sandstones in QwaQwa, they include the artisans, Government (DMR), MINTEK and MQA. Other stakeholders may be NGOs and willing investors. In recent years, MINTEK has trained successful artisanal miners of sandstone through its artisanal and small-scale mining programme, and the DMR has helped in buying some machinery and assisted with training of miners. Current provisions are not enough, as many miners are still in desperate need to grow their sandstone business, where many say they want government to issue them with mining licences, provide them with basic tools, and electric cutting machines used for processing sandstone. They say selling their product can be problematic, and they want their product to be advertised and purchased by government contractors in the construction industry. In addition, the mining of land becomes a big issue in South Africa, as it is impossible for a miner to walk onto a piece of land and starts to mine without authorisation. In QwaQwa, the miner must get a licence or mining permit to mine the land, or if possible, purchase that piece of land. Artisans are poor and can not afford to buy land to mine, therefore they will desire to acquire a mining license in order to mine the land. The process to obtain legal documents is a tedious and slow process for artisans willing to carry out a subsistence activity. Therefore, government should assist artisans by providing them with licences, or attributing pieces of land to miners for them to mine at reasonable cost. By doing so, it will help reduce the infighting between miners over mining land. In QwaQwa there are already some individuals with a licence to mine, although many still mine illegally.

Government ought also to act as the middle-man between artisanal miners and the consumers of sandstone by regulating the price of sandstone products, making the product more accessible to the public, while imposing a quota on imported sandstone into the country to permit the local industry to grow. There is also a need for miners to easily access finance from financial institutions for loans and other forms of support. The desperate financial need may come from the banks and other development agencies like the Industrial Development Corporation (IDC), Business Finance Promotion Agency (BFPA), and the National Youth Development Agency (NYDA). At moment, most of the processed sandstones used in South Africa come from India and Lesotho, whereas South Africa has a huge resource of sandstone. Also, the most important partner the miners need are those who can assist them in processing and transportation. They require cutting machines and processing tools, which are too expensive for them to invest in. They will highly welcome any partner who brings in resources, provided they can make a profit and a living. There is a problem of infighting in-between the miners of QwaQwa themselves, this comes as a result of jealousy or fighting and competing for limited resources and position. In QwaQwa there are groups of miners
or individuals fighting against a particular group. Many want to portray themselves as the ultimate or legitimate miners of sandstone in the area. All this infightings should be resolved by addressing the root causes of the problem as follows:

- Government ought to organise seminars at least twice a year on the artisanal mining and small-scale processing of sandstone in QwaQwa to meet and discuss the problems they face and how to mitigate them.
- The DMR should move into the area i.e., go to the miners and facilitate them with the attribution of mining permits or mining land, since most of the miners are illiterate.
- A need for serious co-operation between miners by regrouping themselves and bringing unity through a conflict management programme.
- Government, MINTEK, DMR and other stakeholders may assist miners through subsidies. Subsidies can be made by providing miners with equipment they desperately need, ranging from transportation trucks to cutting blades and PPE.
- Implementing a quota from imported sandstones, particularly from Lesotho. The Chinese in Lesotho pose a big threat to the artisanal mining and small-scale processing of sandstone in QwaQwa. The main agreement between the Chinese and the Lesotho government was for the Chinese to mine and process sandstone for international markets. Unfortunately, the sandstones finds its way into neighboring South Africa. Which makes it difficult for the artisanal miners in QwaQwa to compete with them in terms of prices and technology.

5.5 The concept of progressive mechanisation

In the context of the research, the term progressive mechanisation refers to improvement in technique over time. This is a technical, step-by-step process used to assist struggling miners in a rural county, while preserving their bio-diversified ecosystem and the strong social and cultural beliefs. Progressive mechanisation examines subsequent activities, for example if an artisan mines 3m² of sandstones a day while using a chisel and hammer, the same miner can progress to mine 10m² of sandstone a day after purchasing more advanced tools like pneumatic rock hammer (PRH), with the revenue generated. Progressive mechanisation can take many years, and will only depend on the satisfaction of all stakeholders, taking into account socio-political and environmental concerns.
5.6 Conclusion on findings

Sandstone products are becoming more demanding within our communities and abroad. With many countries around the world, increasing production, particularly in Lesotho which is the nearest neighbour to QwaQwa and represents an immediate competitive threat to QwaQwa sandstone, the quantitative and qualitative results of the research are aimed to improve progressive mechanisation, or utilisation of modern tools and machinery. Also they can provide a proper management of resources to secure the future of sandstone mining from the major challenges it faces, such as technical, environmental and waste management.
CHAPTER 6

CONCLUSIONS, RECOMMENDATIONS AND WAY FORWARD

6.1 Introduction to the Conclusion Recommendations and Way Forward

This chapter concludes on the research work on the artisanal mining and small-scale processing of sandstone in QwaQwa (Free State) South Africa, and makes recommendations according to the results and findings. Chapter 6 also guides us on the way forward, as to what has to be done for the activity to become more sustainable.

6.2 Conclusions on Findings

To conclude research on the artisanal mining and small scale processing of sandstones, one needs patience and caution when recommending or implementing new techniques to QwaQwa miners, taking into consideration their socio-cultural background, acknowledging that miners and other community members may be unwilling to accept new mining concepts. A strategy such as described in Section 3.10 must be applied in order convey any message appropriately. Results from the research indicates the artisanal mining and small scale processing of sandstones in QwaQwa faces a major challenge in the need for progressive mechanisation. The application of mining concepts into the artisanal mining and small scale processing of sandstone (AMSPS) has opened a window into a more sustainable application. The research observed: nine (9) splitting and seven (7) processing or cutting techniques; transportation and lifting techniques; a cash-flow model; the physical and chemical properties of sandstones; human elements; ethical concerns; socio-economic and political issues; and environmental concerns. All these techniques and concerns, if addressed properly, will lead to more prosperous artisanal mining and small-scale processing of sandstones in QwaQwa. Nevertheless, government was seen as a key player in addressing all these respective concerns. Most of the miners believed that aspects of underperformance should be ascribed towards government and its institutions. However, the reality is that to initiate a project in artisanal mining and small-scale processing of sandstone in QwaQwa a miner would require just few basic tools, personal protective equipment, and a processing or stone cutting machine for production to start. There is a strong opinion driven by a discussion of the mining concepts in Chapter 3 demonstrating that the artisanal mining and small-scale processing of sandstones in QwaQwa and the entire country can move to the next level of production and delivery, due to the fact that demand for sandstone products within the construction and housing industry in the country and worldwide is on the rise.
Government is obliged to reach out to artisanal miners in South Africa, and in particular the sandstone miners in QwaQwa (Free State). Government in its own capacity, along with other stakeholders, should play an important role in identifying the shortcomings of artisanal miners by addressing, implementing and monitoring its success through subsidies and the provision of equipment. The artisanal mining and small-scale processing of sandstones can sometimes be considered as a subsistence livelihood activity, and will require very little capital to start mining. Therefore there is that urgent need to encourage artisans by providing them with basic tools. Other factors like commercialisation discussed in Chapter 3 must also be considered to ensure the entire process of sandstone mining becomes successful. For artisanal mining of sandstones to be successful, one would agree government should commission research on the mineral and take the lead. According to Paget, (2015) government should also convene a forum specifically on artisanal mining of sandstone with stakeholders involved, and should also be consulting periodically on the matter, with meaningful outcomes made available to the public (Paget, 2015).

6.3 Recommendations on research work
The artisanal mining and the small-scale processing of sandstone should be recognised at all levels of government and its institutions. There is a need to rectify old mining legislation for it to work better for the artisanal and small-scale mining activities in South Africa, no matter what kind of a mineral the miner would like to mine. New legislations ought to be able to facilitate young artisans in obtaining land and permits for future growth and prosperity. From a research perspective, the researcher recommends that artisans regroup in a number of at least two to ten persons so that their difficulties can easily be heard by Government and other institutions. They must take the lead, on behalf of their own future well-being. Miners should seek financial help from any financial institutions, whether in the form of grants, credit or loans. Money well spent will probably yield profit. From the cash-flow detailed in Section 3.12 most of the elements needed to start a new mine are indicated, therefore several steps need to be taken from the time you acquire finances, get the mining permit, procure equipment, and start mining. Activities must commence immediately after the acquisition of finances. During the process, money ought to be well spent, and the time frame set should be respected, so as to avoid losses in resources caused by poor timing and lengthy transactions. The owner must make sure the mine produces marketable sandstone products at least once every week, and ought to ensure that monthly, daily or weekly salaries are paid as agreed between the employer and the employee. The employer should always respect and maintain a workforce in good health and high spirit.
Recommendation to the QwaQwa sandstone miners is to adhere to the practice of progressive mechanisation. Progressive mechanisation is the ability to replace an old technology with a more practical technology, while considering affordability. Progressive mechanisation could also be improving and replacing current work practices, with a better or more practical and affordable concept. As shown in Figure 6.1 (A), an artisanal miner who can afford only a chisel and hammer in the beginning of his activity, should think of saving towards the purchase of wedges and feathers in order to increase production. Production ought not end with wedges and feathers, whereas production has to increase, he ought to think of purchasing explosives, and then a generator with a pneumatic rock hammer so as to ensure the creation of wealth through high production rates. The way forward is to achieve high production machinery, like the multi-blade segment cutters, a load haul dump caterpillar, or hydraulic splitters.

The researcher also recommends that government encourage the contractors, particularly those getting tenders from government, to use sandstone in construction works, since it is sure to accelerate the production and sales of sandstone around the country. There are still windows of opportunities to be exploited, therefore further research must be conducted in related fields which includes strategising, marketing and communication. All the above as mentioned has to be integrated for better results, and the researcher strongly avers that the sandstone industry has its place in modern South Africa, and is likely to prosper.
Figure 6.1: A display of progressive mechanisation in splitting, processing and transportation or handling techniques recommended for QwaQwa sandstones mining: (A) Progressive mechanisation in splitting; (B) Progressive mechanisation in small scale processing; (C) Progressive mechanisation in transporting and handling; (D) Improving work place safety.
6.4 Aspirations and prospects

The aim of the research was to assist the artisanal mining and small-scale processing of sandstone to become mechanise. The profit of an approximate R560 532 made from the first 100m² of mining land should be well spent or reinvested into the business. In the next stage, we should be having a different mining land size of say 500m², with a bigger landscape, where the cash-flow ought to change with an increase in the number of employees and equipment. Expensive mechanised equipment will be required, and obviously our Net Present Value will be huge as compare to the initial 100m² mined during a period of six years. If the second venture is successful, the community will benefit more from the company’s social commitments and the company’s credit profile ranking will increase. The future of mechanised sandstone mining QwaQwa owes its roots from artisanal mining and small-scale processing of sandstones, it is the artisanal mining that will grow to a large-scale or a multinational mining company, capable of exporting sandstone products from QwaQwa. Lesotho is already seizing the opportunity and gaining new markets in the region. In a typical mechanised sandstone mine, one finds heavy duty and precision machines like multi-blade segment cutters, multi-wire saws, diamond-wire saws, double-blade stone cutters, single-blade stone cutters, hydraulic double-column stone cutters, automatic continuous polishing machine, multi-plate cutter, infrared automatic bridge-type stone cutter, water jets, fork lifts, tractor loader backhoe (TLB), load haul dumpers (LHD), bucket wheels, heavy duty trucks, all being used around the clock. These machines are robust and will cut through any sandstone formation at significant speeds. These machines increase the safety of miners as they work, with high tonnages per hour, and will be able to satisfy the growing demand of customers. Mechanisation should be our way forward if the artisanal mining and small-scale processing of sandstones is required to move from current production level to higher production level. See Figure 6.2 below for some mechanised splitting tools (WeiKu, 2011).
Figure 6.2: Mechanised mining and processing of sandstones. (A) Sandstone mining site, mining with a double blade stone cutter; (B) Cutting with a single blade stone cutter; (C) Multi-blade segment cutter with water jet; (D) A heavy duty truck transporting sandstone.
6.5 Conclusion
Despite the need for a progressive mechanisation on QwaQwa sandstone, research activity on artisanal mining and small-scale processing could benefit from more research viz., proper waste management, increase recovery rate, production techniques, and proper resource management. Also, the mining activity has a huge impact on the health and safety of miners and requires further attention (Mezadre & Bianco, 2014). Therefore, health and safety concerns must be taken seriously in rural communities mining sandstone.
REFERENCING


Czekaj, T., 2016. Technologies for stone industry, Opole: ABRA.


APPENDIX

This section contains additional information related to the research, but not considered essential to the main findings. Below are images related to the artisanal mining and small-scale Processing of Sandstones taken from South Africa, Cameroon, Republic of Congo, and Zambia.

Figure 1, illustrates images from the QwaQwa (Free State) and Puma (Cameroon) of sandstone mining community.
Figure 1: (A) QwaQwa rural community; (B) Puma sandstone community near the highway; (C) Puma sandstones; (D) Sandstone processing in QwaQwa; (E) Sandstone processing in QwaQwa.

Figure 2, illustrates images of splitting technique used in the artisanal sandstone mining in Rural Community.
Figure 2: (A) Sandstone splitting in QwaQwa using chisel and hammer; (B) Sandstone splitting in Puma using heat energy from firewood; (C) Sandstone splitting in QwaQwa using crowbars, picks and axes; (D) Sandstone splitting in Cameroon using expansive mortar; (E) An artisanal sandstone miner from QwaQwa; (F) Sandstone splitting in Puma using low energy explosive.

Figure 3, illustrates images of commercialised sandstone products
Figure 3: (A) A stock pile of processed sandstone tiles; (B) Processed sandstone bricks; (C) Carved sandstones into artefacts; (D) Sandstone rectangular bricks; (E) Sandstone hexagonal bricks.
Figure 4, illustrates images of sandstone applications against poor mining facilities.

(A) A four story building in Cameroon built with sandstone; (B) A three story building in Cameroon built with sandstone; (C) A makeshift tent in Puma; (D) Another makeshift tent in Puma; (E) & (F) Depicts poor commercialisation and advertisement of sandstone products in Puma-Cameroon.