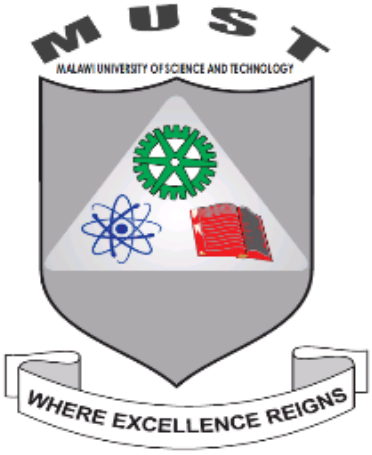
GEOLOGICAL ASSESSMENT OF BLANTYRE DISTRICT TO IDENTIFY SUITABLE AREAS FOR QUARRY SITES



GEOLOGICAL ASSESSMENT OF BLANTYRE DISTRICT TO IDENTIFY SUITABLE AREAS FOR QUARRY SITES

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Dissertation submitted to Ndata School of Climate and Earth Sciences of the Malawi University of Science and Technology in partial fulfilment of the requirements for the Bachelor of Science degree in Earth Sciences

JULY, 2021

DISSERTATION APPROVED BY:

GEOLOGICAL ASSESSMENT OF BLANTYRE DISTRICT TO IDENTIFY SUITABLE AREAS FOR QUARRY SITES

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DECLARATION

I Dereck Makowa declare that this research project represents my own work and that it has never submitted to this institution and any other institution for any academic

purpose, all sources of information have been appropriately acknowledged.

SIGNATURE: 

DATE: 20 JULY 2021

DISCLAIMER

This document describes work undertaken as part of a programme of study at Ndata

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ABSTRACT

This research was carried out to identify suitable areas for quarry stones occurrence in Blantyre district using GIS tools. The WOE method was used in this study where by Blantyre map with sample points was crossed with the landslide controlling factors map to come up with the suitability map. The methodology began with the collection of the sample points through satellite image. Then desk work for preparation of the thematic maps using ArcGIS. The WOE method was applied in ILWIS to come up with the Suitability map of the area. Slopeness of soil, elevation and type of geology were used as the quarry stones controlling factors in this study. The most controlling factor to the quarry stones occurrence was identified to be the type of geology.

ACKNOWLEDGEMENTS

Firstly, I would like to thank God Almighty for a gracious life given to me. Thanks to my supervisor Mr. F. Josiya for all the efforts he invested to this project. Much appreciations should also go to GSD for other data sets that were provided to use in this research. Deep thanks to my mum and my late father for all support rendered to me throughout my upbringing and studies. I would like to appreciate my sister, Lonney for all the financial support she has been providing for my studies. Finally, thanks to my classmates for all supports showed during our life time at school.

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ACRONYMS/ABBREVIATIONS

Char: Charnockitic

Cw: Contrast weight

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DEM: Digital Elevation Model

GIS: Geographic Information System

Gr: Granulite

GSD: Geological Survey Department

ILWIS: Integrated Land and Water Information System

Pg: Perthite

Pr: Perthitc

W+: Positive weight

W-: Negative weight

WOE: Weight of Evidence

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1. INTRODUCTION

1.1. BACKGROUND OF THE STUDY

In its effort to attain environmental sustainability ahead of the year 2020, the government of Malawi in 2018 banned the use of the fire cured bricks in all construction projects (Government., 2018). This followed the gazzetting of the use of sustainable construction materials regulations of 2018. Major construction works in most cities all over the world depend much on the use of river sand production of concrete and sandcrete blocks. This over dependence on river sand has impacted the environment negatively and contributed to high cost of building and construction. In order to reduce over dependence on river sand for concrete and block work, alternative materials like laterite, quarry dust and recycled aggregate etc. are being sourced for as partial or full replacement for river sand for blocks production without altering the strength and quality of the blocks (Mithanthaya I.R., 2002). Full replacement of river sand with a blend of quarry dust and laterite in the production of blocks is a growing phenomenon in most cities across Africa.

DFID have been funding infrastructure improvements in Malawi for many years. Substantial experience has been gained in appropriate building techniques. These include environmentally friendly technologies such as cement stabilized soil blocks, economically beneficial materials produced in Malawi and durable low maintenance detailing to produce long lasting buildings. Cement stabilized soil Blocks (SSBs) were introduced into Malawi by DFID in 1998 primarily because of the deforestation caused by burning clay bricks. SSBs are made from sub-soil and cement using a manual press manufactured in Kenya. Despite the order of the government in banning the use of fire cured bricks in construction projects and the introduction of cement stabilized soil blocks, it has been hard for most people to adopt the use of blocks since they find them to be more expensive compared to fire cured bricks. So, this among others is one of the

factor frustrating the achievement of environmental sustainability in Malawi because most of the inc

(Mira, 2015) Through other studies made previously, it was found that the blocks are expensive because of the overdependence on the river sand which is one of the important materials for the blocks production, since there is pressure on sand; the price of sand is costly hence making the blocks to be expensive for construction projects. Since some researchers discovered an alternative of quarry dust for blocks production in place of sand, this could ease the pressure on sand, hence reducing the cost of blocks production that lead to affordability of blocks for construction projects in the country.

So, this study aimed at coming up with a map indicating the potential areas of quarry stone within the district of Blantyre, in order to increase the availability of quarry dust from the quarry mining sites, so that the quarry dust would be used as a partial or full replacement of sand in blocks production.

1.2. PROBLEM STATEMENT

Due to the government ban on the use of fire cured bricks in construction projects to achieve environmental sustainability, there is a pressure on sand which is one of the important raw materials for the production of blocks, this result in sand being costly available, hence making the blocks to be expensive for construction projects. In order to ease the pressure on sand and also making the blocks affordable for construction projects, there is a need of having alternative to the use of sand in blocks production. Through some researches it was discovered that quarry dust could be used as a partial or full replacement of sand in blocks production.

So, in order to have enough quarry dust for the production of blocks, there is a need of having more quarry stone mining sites. Currently, there is no map showing the suitable areas for quarry stone within Blantyre district, hence this study was conducted to close the gap by making a geological assessment in identifying and coming up with a clear map indicating the potential areas of quarry stone within the district.

1.3. RESEARCH QUESTIONS

- What is the most influencing factor to the occurrence of quarry stone?
- Where do more quarry stone occur in Blantyre?

1.4. OBJECTIVES

1.4.1. Main Objective

The main objective of this research was to produce the map of potential sites for quarry stone in Blantyre which will help investors to locate suitable sites for quarry mining, hence obtaining enough quarry dust for production of blocks. This objective will be achieved by application of GIS.

1.4.2. Specific Objectives

- To map the observable quarry stone sites in the study area (Blantyre)
- To determine the most controlling factor to the occurrence of quarry stone in the study area

1.5. SIGNIFICANCE OF THE STUDY

The essence for conducting the study was to increase the use of quarry dust in the production of construction blocks; this was done by identifying the potential sites for quarry stones. Since, the availability of enough quarry dust which could be used as a

partial or full replacement of river sand would reduce the pressure which is on sand for blocks prod

2. LITERATURE REVIEW

This chapter presents a review of literature related to the study. The review covered various issues on quarry stone dust and its relation to production of blocks for construction projects. Materials were drawn from several sources which are closely related to theme and objectives of the study.

The chapter deals with production of blocks, geological rock types associated with quarry, policies of construction in Malawi, statistics of quarry dust use and quarry dust as a partial or full replacement of sand in blocks production.

2.1. Production of Blocks

According to (Koski, 1992) the concrete commonly used to make concrete blocks is a mixture of powdered Portland cement, water, sand and gravel. This produces a light gray block with a fine surface texture and a high compressive strength. A typical concrete block weighs 17.2-19.5kg. In general, the concrete mixture used for blocks has a higher percentage of sand and a lower percentage of gravel and water than the concrete mixture used for general construction purposes. This produces a very dry, stiff mixture that holds its shape when it is removed from the block mold.

In addition to the basic components, as taken from (Schierhom, 1996) the concrete mixture used to make blocks may also contain various chemicals, called admixtures, to alter curing time, increase compressive strength, or improve workability. The mixture may have pigments added to give the blocks a uniform colour throughout, or the surface of the blocks may be coated with a baked-on glaze to give a decorative effect or to provide protection against chemical attack. The glazes are usually made with a thermosetting resinous blinder, silica sand and colour pigment.

Based on (ASTM, 2003) the shapes and sizes of most common concrete blocks have been standardized to ensure uniform building construction. The common block size in the United States is referred to as an 8-by-8-by-16 block, with the nominal measurements of 8 in (20.3 cm) high by 8 in (20.3 cm) deep by 16 in (40.6 cm) wide. This nominal measurement includes room for a bead of mortar, and the block itself

actually measures 7.63 in (19.4 cm) high by 7.63 in (19.4 cm) deep by 15.63 in (38.8 cm) wide (AS
The production of concrete blocks consists of four basic processes: mixing, moulding, curing and cubing. Some manufacturing plants produce only concrete blocks, while others may produce wide variety of precast concrete products including blocks, flat paver stones, and decorative landscaping pieces such as lawn edging. Some plants are capable of producing 2,000 or more blocks per hour (Koski, 1992).

2.2. Geological rock types associated with quarry

A quarry is a type of open-pit mine in which dimension stone, rock, construction aggregate, riprap, sand, gravel or slate is excavated from the ground (National geographic, 2003). The operation of quarries is regulated in some jurisdictions to reduce their environmental impact. Different types of stones are mined for different purposes. The most common types of quarry material are dimension stones and aggregate.

(National geographic, 2003) Large, precisely cut stones excavated from a quarry are called dimension stones. Dimension stones are used for constructing buildings and monuments, or for decorating the outside of buildings. They are also used for kitchen counters and roofing shingles

Sand, gravel or crushed rock excavated from a quarry is called aggregate. Aggregate is used in construction to create stable foundations for things like roads and railroad tracks (National geographic, 2003). Aggregate is also used to make concrete and asphalt. For this reason, asphalt and concrete plants are often built next to quarries. Asphalt is an oily substance that is mixed with aggregate for road construction.

Charnockite is any orthopyroxene bearing quartz-feldspar rock formed at high temperature and pressure, commonly found in granulite facies, metamorphic regions. Charnockite gneiss are the most common quarry types of rocks (Geological Survey of India, 2009).

2.3. Quarries and Environment

According to (National geographic, 2003) Quarries change their environment. They displace huge amounts of soil and plants, and force animals out of the area. Abandoned quarries rarely leave enough soil to allow life to return to the soil.

Some abandoned quarries can fill with water, creating artificial lakes. Many of these lakes are clear and deep, creating a safe swimming environment for people and some aquatic animals, such as frogs and birds. Sometimes, however, lakes created by abandoned quarries have mining equipment left on the bottom, making them unsafe for swimming. Toxic materials exposed by mining activities can also leak into water at abandoned quarries (National geographic, 2003).

(National geographic, 2003) Quarries are prone to flooding because they are sometimes dug below the water table. Environmentalists fear the toxic materials could seep into groundwater if an abandoned quarry's water reaches an areas of water table. To avoid contaminants miners, must sometimes pump water out of quarries.

2.4. Policies of construction in Malawi

In June 18, 2018, the National Construction Industry Council announced to all the consultant and local councils that the Government of Malawi had published in the Gazette the use of sustainable construction materials regulations, 2018. These regulations were set to promote the use of sustainable and environmentally friendly construction materials in the construction industry (Government., 2018).

The regulations require that every public or commercial project be executed using approved, energy efficient, sustainable and environmentally friendly construction materials and technologies in all the phases of the project as appropriate. As such the traditionally fire cured bricks in the execution of such projects is prohibited (Government., 2018).

The regulation requires Consultants to ensure that the design for, and specify, sustainable construction methods and materials for their clients in addition to

appropriately advising the clients on the benefits, cost effectiveness and value addition of such met

Based on (Government., 2018) the regulations also require the City, Town and District Councils to approve only such projects that specify and utilize construction materials that are sustainable, environmentally friendly and energy efficient.

So, failure to comply with any provision of these regulations is constituted an offence. The regulations became in force in 2018.

2.5. Statistics of Quarry dust use

The amount of industrial waste is increasing year by year. Industrial waste is defined as waste generated by manufacturing or industrial processes. One types of industrial waste is quarry dust. During the production of aggregates through the crushing process of rocks in rubble crusher units, quarry dust is obtained as a by-product.

(Galetakis M, 2004) Quarry dust waste has been used for different activities in the construction, such as road construction and building materials. Quarry dust waste act as lightweight aggregates, bricks, tiles and autoclave blocks.

Quarry dust waste also a waste material that is generated from the stone crushing industry which is abundantly available to the extent of 200 million tonnes per annum. This will lead to landfill disposal problem, health and environmental pollution (Galetakis M, 2004) .

In addition, environmental pollution caused by quarry dust waste and heavy metals has been a problem for many years in the world. Dust from quarrying has been reported to stall the growth and flowering of crops, because it settles on surfaces of leaves thereby interfering with the normal photosynthetic and other exchanges that take place at the leaf and atmosphere interface.

This quarry dust is considered as solid waste material. The problem of its disposal could

be solved, if it is possible to utilize it for alternative purposes. Recycling is a worthwhile activity with many benefits to humans and the environment. Recycling such wastes by incorporating them into building materials is a practical solution for pollution problem (Safiuddin M.D., 2007).

2.6. Quarry dust as a partial or full replacement of sand in blocks production

(Md.Safiuddin, 2007) The concept of replacement of natural fine aggregate by quarry dust which is highlighted in the study could boost the consumption of quarry dust generated from quarries. By replacement of quarry dust, the requirement of land fill area can be reduced and can also solve the problem of natural sand scarcity.

The availability of sand at high cost as a fine aggregate in concrete is not suitable and that is the reason to search for an alternative material. Quarry dust satisfies the reason behind the alternative material as a substitute for sand at very low cost. It even causes burden to dump the crusher dust at one place which causes environmental pollution.

From the results of experimental investigations conducted, it is concluded that the quarry dust can be used as a replacement for fine aggregate like sand in the blocks production (Sahu A.K., 2003).

The suitability of quarry dust as a sand replacement material shows that the mechanical properties are improved and also elastic modulus. The compressive strength achieved optimum by replacing fine aggregate with quarry dust in ratio of 60:40.

3. METHODOLOGY

3.1. STUDY AREA

The study area for this research project is the Blantyre district. It is located in southern region of the country. The district has a lot of mountains/hills and it is one of the districts which have a highest population density in the country. Some of the hills/mountains in this district are Ndilande, Soche, Mvula, Mpingwe, Nthawira, Nthandizi and Michiru.

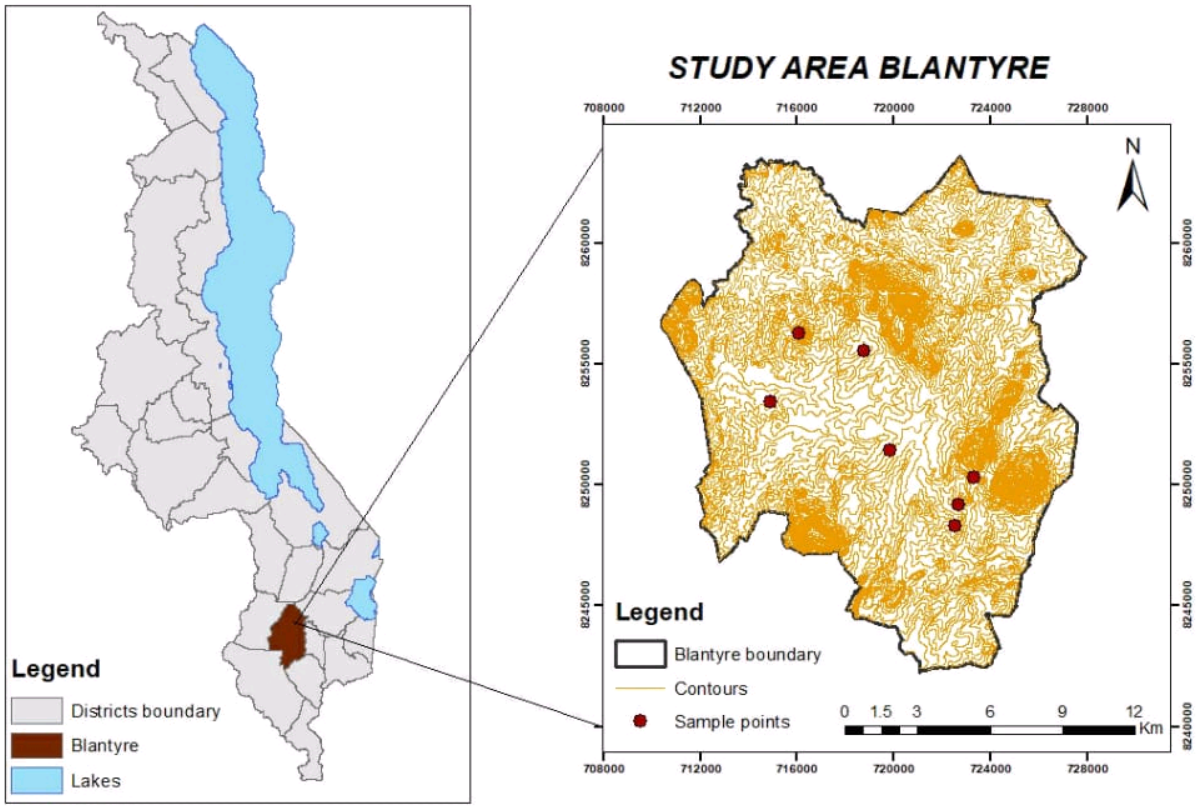


Figure 1: Map of Malawi showing the study area Blantyre

3.1.1. 1.6.1 The General Geology of the Study Area

According to (Keith, 1965) the area around Blantyre City to Limbe was firstly discovered to be consisting of the basement complex rocks which were mostly hornblende and hypersthene gneisses and granulites. The synites intruded the contacts between these basement rocks and they were observed to be rich in potash feldspar. Then potash metamorphism played part in the formation of syenites which improved the content of perthitite and oligoclase. South West of Bangwe Hill is one of the igneous syenite basement complex contact that was initially observed (Keith, 1965).

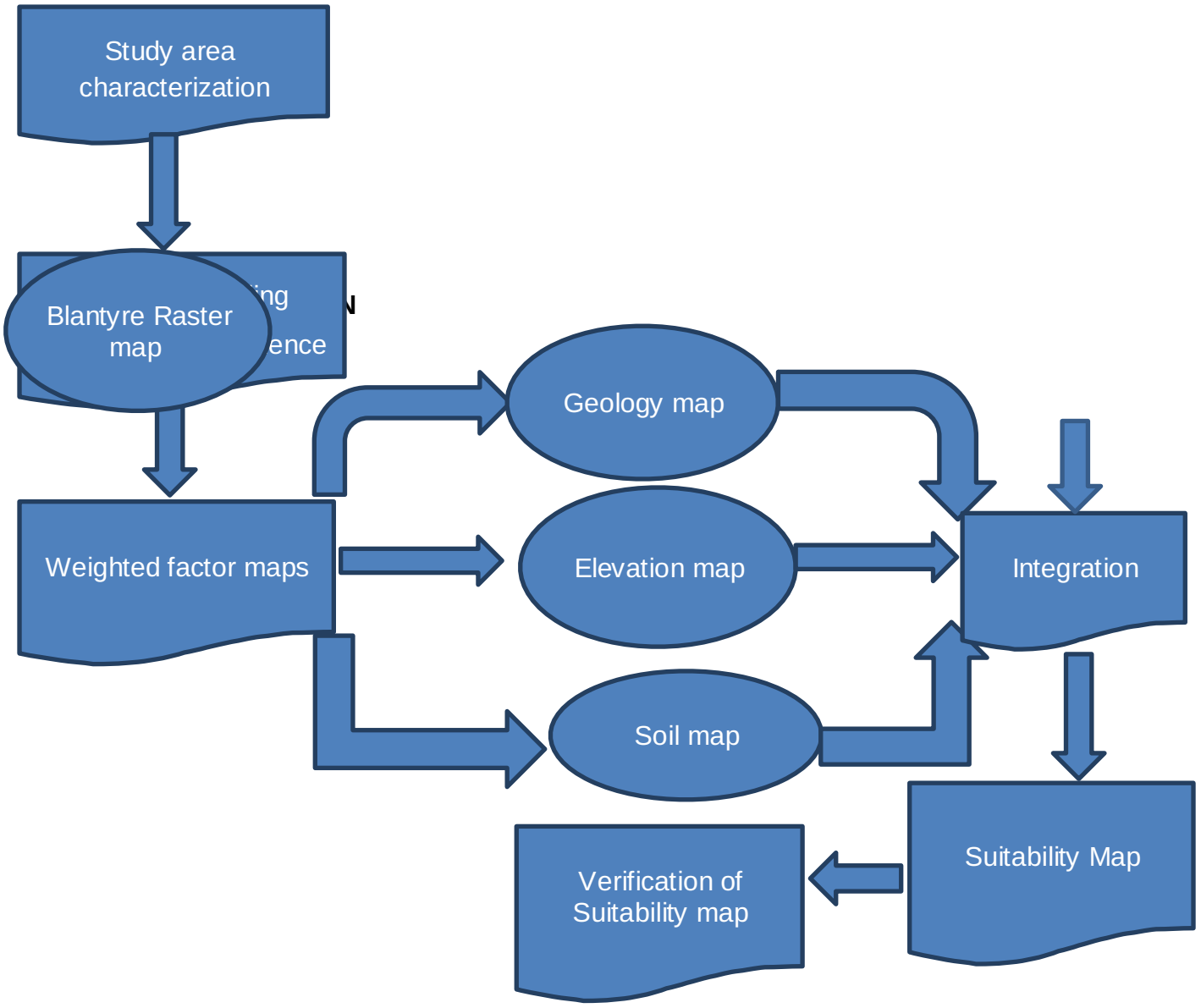
The perthosites and perthite gneisses are found in Ndilande, Soche, Mpingwe and Bangwe Hills. Few charnockitic granulite happen within the perthite gneisses of Mpingwe Hill. The perthite gneisses are also observed in hills of Lunzu and Lirangwe. The dykes of south of Mpingwe hill are observed to consist of anhedral olivine. This type of olivine is also found within Soche Township. The perthitized charnockitic granulites are found in Kanjedza and the charnockitic granulite-intermediate are found in Chileka. The Njuli area is composed of felsic intermediate charnockitic granulite, basic intermediate charnockitic granulite, garnetferous charnotic granulite and garnet-biotite gneiss (Keith, 1965).

3.2. RESEARCH DESIGN

The study employed the use of GIS tools in order to come up with the suitability map of Blantyre showing potential areas for occurrence of quarry stone. The method which was used in this study is called Weight of Evidence (WOE). This method was firstly developed to find out areas of gold mineralization; nowadays it is being applied in many fields.

The method utilizes past data events to gain patterns parameters that control and influence the occurrence of quarry stones; it uses the rule that the present and past is the key to the future. In other words, it applies the concepts of prior and posterior

probability, for assessing the relations between the spatial distribution of the areas associated with



3.3.1. The Geology Map

The geology map of Shire Highlands was accessed from GSD. This map covers a lot of districts such as Phalombe, Mulanje, Thyolo, Blantyre, Chikwawa and Nsanje. This map was obtained as a picture. So the picture was imported into ArcGIS. Then it was georeferenced so that it was given coordinates as exactly as on the actual ground. Georeferencing is done when digitising so that the final digitised map should have actual coordinates as exactly on the actual ground and also to enable overlay with other

factor maps of the same area. This picture was digitised and the result was the map of Blantyre geo

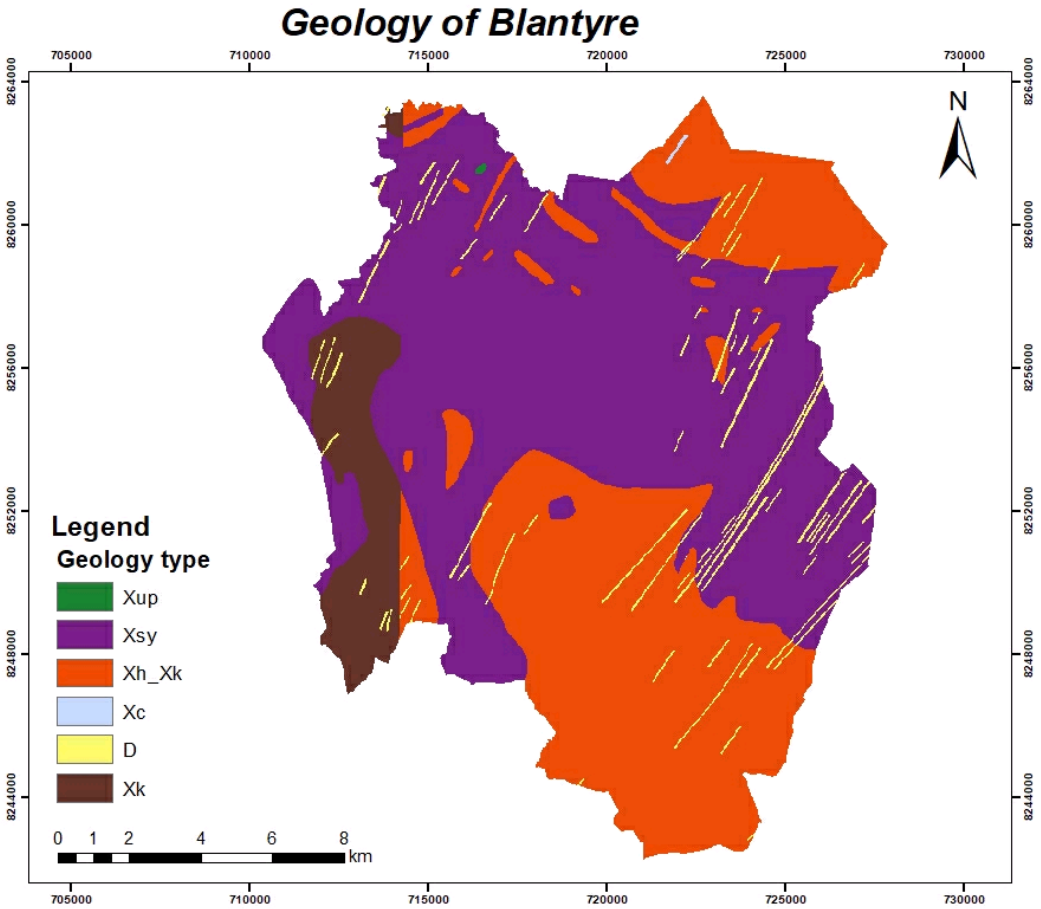


Figure 3: Map of Blantyre showing Geology

3.3.2. The Soil Map

The soil map of Blantyre was extracted from the soil map of the whole Malawi using clipping ArcGIS tool. This soil map was also accessed from GSD. Just as the geology map, digitization was also performed and later the vector polygons were converted to raster dataset.

The geology map and the soil map were all created in ArcGIS and later they were exported as TIFF files for conversion into ILWIS format. They were then reclassified. The reclassification is performed by firstly creating a domain, then using image operation; the created domain is used to slice the desired map into classes based on the created domain.

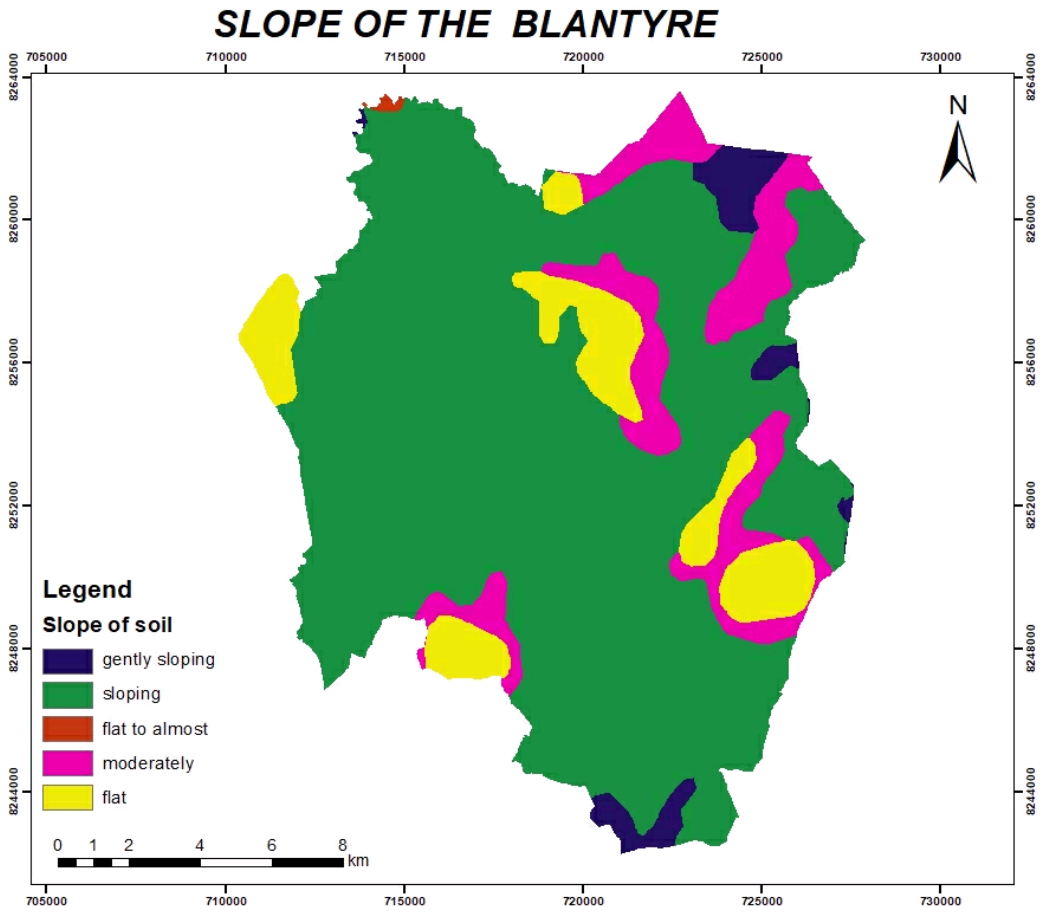


Figure 4: Map of Blantyre showing slopeness

3.3.3. Preparation of the Aspect Map from DEM

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Digital Elevation Model is the digital representation of the land surface elevation with respect to any

The shape file of Blantyre was then added into the ArcGIS. This shape file was used to extract a Blantyre DEM based on a selected extent. The merged and clipped DEM was then imported into ILWIS where the elevation map was prepared by just reclassifying the DEM. A domain was created and the DEM was sliced by the created domain values and the result was the reclassified elevation map (DEM Map).

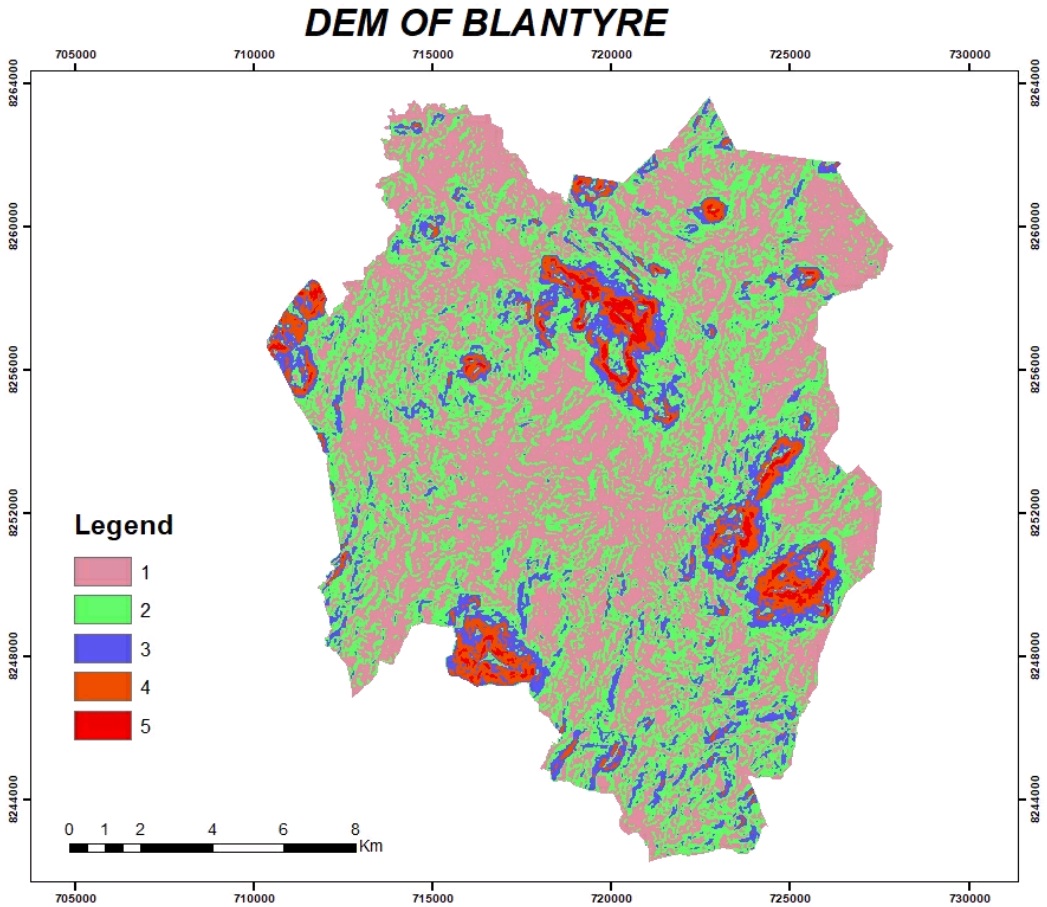


Figure 5: Map of Blantyre showing Elevation

4. RESULTS AND DISCUSSIONS

4.1. Analysis of Controlling Factors

WOE was used to produce quarry sites suitability map. The input parameters in the analysis are the thematic maps and their domains. Each thematic map was crossed with map of Blantyre with sample points, this crossing produces a weight map of each causative factor with its attribute table. This table has the calculated weights of the parameter and its contribution to the quarry stone occurrence.

The significance of the controlling factor in influencing the occurrence of the quarry stones is defined by the contrast of the weight (Cw). This is the difference between the positive and the negative weights that are formed when the controlling factor map is crossed with the Blantyre map. Thus Cw= W+ - W-.

4.1.1. Elevation

Values of 1 to 5 were assigned to represent elevation of Blantyre, in which the highest value of 5 represent areas with highest elevation. So based on the analysis, the results showed that quarry stones have a positive relationship with the high areas which are represented by 5 and 4. While the lowest areas have negative relationship with quarry stones, this was determined by the negative contrast weight values of these areas, as shown on the table below;

Table 1: Showing contrast weights of elevation

ELEVATION	CONTRAST WEIGHT
1	-1.74
2	-1.27
3	-0.1
4	0.59
5	0.77

This showed that based on the factor of elevation, it is more likely to have existence of quarry stones in high areas of Blantyre district than in the lower areas of the district.

4.1.2. Type of Geology

According to the results, it showed that there is high positive relationship of Charnockitic gneiss and granulite with the existence of quarry stones, this is so due to high positive contrast weight as shown in the table below.

Table 2: showing contrast weights of Geology

TYPE OF GEOLOGY	CONTRAST WEIGHT
CHAR GNEISS & GR	2.37
PG GNEISS & SYNETITE	-1.53
MET D, CHAR GNEISS & GR	0.17

As shown above, quarry stones occur mostly in areas with charnockitic gneiss and granulite; and in low proportion in areas with the composition of metadolerite, charnockitic gneiss and granulite.

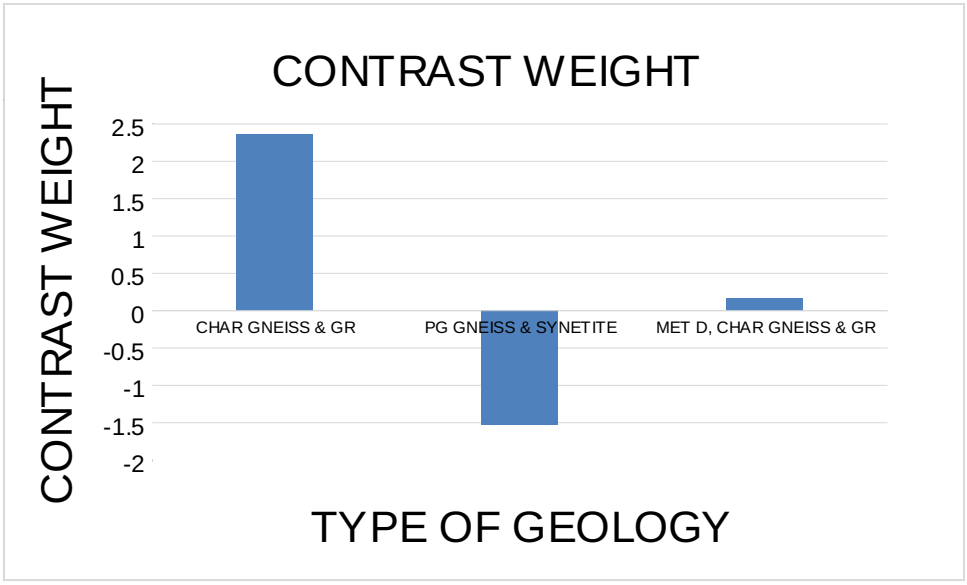


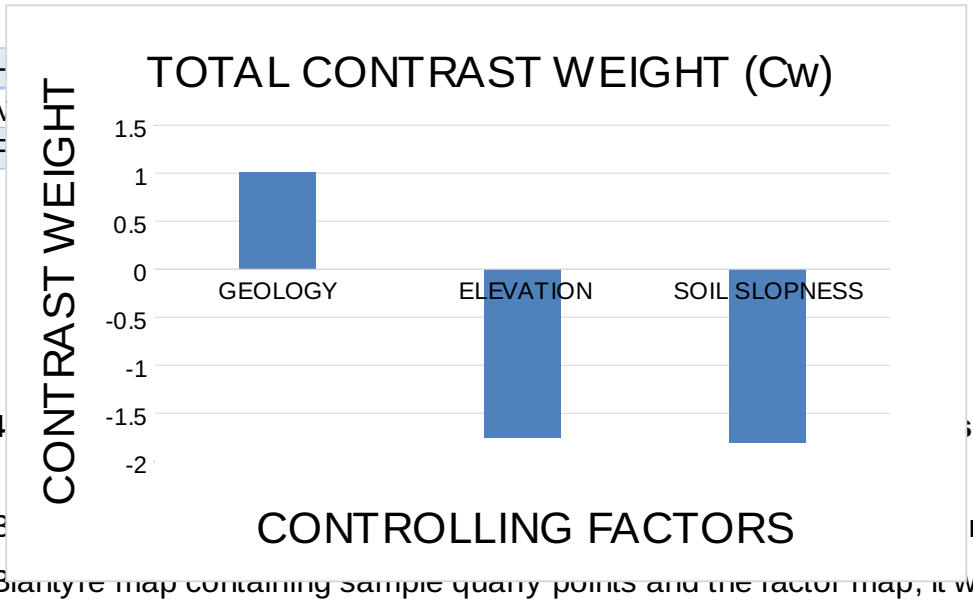
Figure 6: Graph showing Contrast Weights of Geology

4.1.3. Slopeness of soil

According to the results, there is a negative relationship between areas with flat soil in Blantyre district and existence of quarry stones. This is determined by negative contrast weight value. While areas with high slopeness tends to show positive relationship with quarry stones existence as shown in the table below;

Table 3: showing contrast weights of slopeness

SOIL SLOPENESS	CONTRAST WEIGHT



4

B r crossing Blantyre map containing sample quarry points and the factor map, it was observed that the most influencing factor to quarry stones occurrences is the type of geology because it showed highest Contrast weight than the other factors. Table below shows the sum of the Contrast weights for each factor.

Table 4: Showing contrast weights of contreolling factors

FACTOR	CONTRAST WEIGHT
GEOLOGY	1.01
ELEVATION	-1.75
SOIL SLOPENESS	-1.81

Geology is ranked first because quarry stones are rocks, so the type of geology in a place is directly connected to the kinds of rocks which can be available in that particular area. Hence,

regardless of elevation and soil slopeness of the area, geology is the most controlling factor to the

4.3. Suitability Map

The suitability map was generated by combining all the weighted maps. This was performed by writing an addition syntax of all the weighted maps.

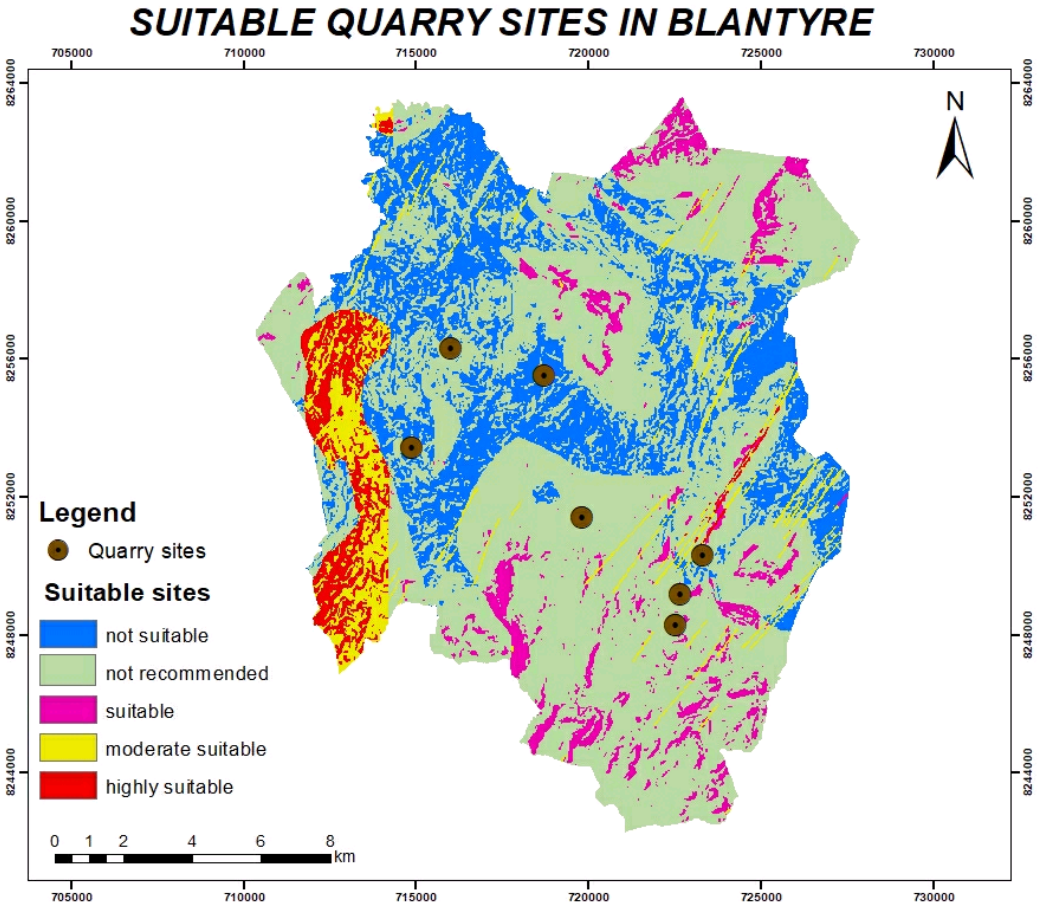


Figure 8: Quarry Sites Suitability Map of Blantyre

The quarry stones suitability map of Blantyre shows that most areas of Blantyre district are not suitable for quarry occurrence, but some areas of the western side of the district is highly suitable for occurrence of quarry stones due to more availability of charnockitic gneiss and granulite geology within this side while some few areas of Southern and North-Eastern parts are moderately to suitable for quarry stones occurrence.

The sample points that were randomly collected were overlaid with the Suitability map. It was observed that few sample points fall within the moderate and suitable areas as shown in the figure above.

Out of the 7 sample points, 3 were observed to fall within moderate and suitable areas for quarry stones occurrence, while 4 fall within areas which are not recommended or not suitable for quarry stones occurrence. In percentages, 42.9% mapped sample points were in moderate and suitable areas and 57.1% mapped sample points were in areas which are not recommended or not suitable for quarry occurrence.

5. CONCLUSIONS AND RECOMMENDATION

In conclusion, the study has come out with the quarry stones Suitability map of Blantyre using GIS tools. The WOE methodology for quarry stones suitability assessment has been used to achieve the main objective of the study. It has also identified the geology as the most influencing factor to the quarry stones occurrence among elevation and slope aspect of soil. The suitability map is very vital to those interested in operation of quarry mining to easily identify areas which are suitable to be quarry mining sites, hence easing the pressure of time and resources used for exploration. In addition, this will contribute to the increase of quarry mining operations, that lead to more availability of quarry dust as by a product of quarry mining within the district. Quarry dust would be used as one of the raw materials for the production of construction blocks, hence shifting from environmentally destructive burned bricks to environmentally friendly construction blocks.

5.1. Limitation of the Study

Lack of enough time for data collection. There was need to visits most of the areas of the district from north to south and east to west. This was not achieved due to lack of enough time and also funds to conduct the field visits.

5.2. For Further Study

There is need to update the suitability map that has been produced in this research project. This is because the controlling factors of quarry stones occurrence might be many. So it is recommended that all the influencing factors should further be incorporated with the ones that were used in this study, this will help to identify all the

suitable areas with the highest percentage of accuracy. Therefore, there is need to add other contr

6. REFERENCE

ASTM. (2003). *Concrete and Mineral aggregates .* Philadelphia: Am. Soc. Testing and Materials (ASTM).

Galetakis M, R. S. (2004). *Utilization of limestone dust for artificial: an experimental approach.* Miner. Eng.

Geological Survey of India. (2009). *Charnockite.* India: Geological survey.

Government., M. (2018). *Use of Sustainable Construction Materials Regulations.* Lilongwe: Malawi Government.

Keith, E. (1965). *The Geology of Shire Highlands.*

Koski, J. A. (1992, October). How concrete block are made. *Masonry Construction*, pp. 374-377.

Leopold, P. (2013). *Susceptibility Maps for Landslides Using Different Modelling .*

Md.Safiuddin, S. &. (2007). Utilization of Quarry waste fine Aggregate inconcrete mixures. *Journal of Applied sciences research 3(3)*, 202-208.

Mira, H. (2015). Improved concrete properties using quarry. *International Journal of Engineering Research and Development*, pp. 46–52.

Mithanthaya I.R., N. J. (2002, December 20-21). Replacement of Sand by Quarry Dust for Plastering and in the Pavement Design. *Proceedings of national Symposium at Karunya Institute of Technology*, pp. pp 9-15.

National geographic. (2003). *engineering geography.* washington, DC: National geographic society.

Rakesh, L. (2015). Landslide Hazard Zonation Using Remote Sensing and GIS. *ernational Journal of Engineering Research and General*.

Safiuddin M.D., R. S. (2007). Utilization of Quarry waste fine Aggregate inconcrete mixures. *Journal of Applied sciences research 3(3)* , 202-208.

Sahu A.K., k. &. (2003). Crushed stone waste as fine aggregate for concrete. *The Indian Concrete Journal*, pp845-847.

Schierhom, C. (1996, February). Producing Structural Lightweight Concrete Block.

Concrete Journal, pp. 92-94, 96, 98, 100-101.