AN ASSESSMENTOF GEOMOPHIC PROCESSES RESPONSIBLE FOR THE FORMATION OF TORS IN SEME, KISUMU COUNTY, KENYA.

By

ODHIAMBO MOPHAT CALVINS

RESEARCH PROJECT SUBMITTED IN PARTIAL FULFILLMENT FOR THE REQUIREMENTS OF THEAWARD OF MASTERS DEGREE IN ARTS IN GEOMORPHOLOGY IN THE DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES, UNIVERSITY OF NAIROBI

2019

DECLARATION

This research project is my original work and has never been submitted for examination or approval in any other university.

Signature: …………………………. Date: ………………..…………….

Odhiambo Calvins Mophat

C5O/5894/2017

This Research project has been submitted for examination with our approval as the University Supervisors:

____________________Date___/___/2019	____________________Date___/___/2019
Prof, George Krhoda	Dr. John. Nyangaga
Department of Geography and environmental studies University of Nairobi	Department of Geography and environmental studies University of Nairobi

DEDICATION

To my late mother Dorothy Olivia Onono and Jaqueline Buyayi.

ACKNOWLEGEMENT

I would like to appreciate the following institution for the support I received during my study; The Ministry of Interior and Coordination of Government Affairs, Ministry of Education, National Commission for Science Technology and Innovation for Research Authorization and Permit and Authorization. I am thankful to the University of Nairobi for all the resources used during the course of this project.

My sincere thanks and appreciation to Prof George Krhoda and Dr. Nyangaga my supervisors for providing scholarly guidance and materials for constituting this piece of work, your kind guidance enabled me accomplish my academic work and in time. I would also wish to thank Dr. Nyandega for his kind, continuous and constant guidance during the report writing and the entire staff in the department of Geography and Environmental Studies for all the support you gave during the entire period of my study. M. Juma was a key player in the statistical analysis.

Special thanks to my great friends and colleague scholar Oliver for G.I.S analysis Cecilia and Linda whom I found help from during field work and the edition of my work.

To My family members, you have been very supportive especially my wife for understanding and emotional supports during this tiring and tedious exercise. Thank you all.

Finally, may I declare that I am solely responsible for any errors found in this project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ACRONYMS AND ABBREVIATIONS

BWP	Biological weathering process
GIS	Geographical information systems
GMP	Geomorphic process
GoK	Government of Kenya
MMP	Mass movement
MWP	Mass wasting processes
UNEP	United Nations environmental program
IOG	International Organization of Geomorphosites
NACOSTI	National Commission for Science Technology and Innovation
KARI:	Kenya Agricultural Research Institute.
KSS:	Kenya Soil Survey.

ABSTRACT

The formation of tors has been a major discussion in geomorphology for quite a number of years. According to the old Welsh language tors refers to a heap or pile of rock, tor a free standing residual mass of rock which rises abruptly from the, a surrounding smooth outcrop and gentle slopes of adjacent hills or even ridge crests (Ehlen,2004). Tors in the opinion (Romani, 2005) are conspicuous masses of rock that rise above surface normally common features of elevated granitic terrains. The main objective of this study was to assess the spatial distribution of tors and to determine the geomorphic process that explain the formation and the study was conducted in Seme sub-county, Kisumu County Kenya. Specifically, the study determined the relationship between geomorphic process that is Mass movement, Weathering and Water erosion in the formation of tors.

The study employed non-probability method in getting the population size that has spatial and temporal representation of the area in the form of tor population within the administrative structures in East Seme. The target population was tors of height of 4metres and diameter of 7 metres, captured and spatially referenced, a total of 40 tors that also included geomorphosites such as the Kit-Mikayi, Luanda-Manya, Luanda-Boya, Kidi-Achiel and Kit-Maria were included in the sample. Primary data sets were used Tors sampled depending on different heights, rock samples, rock crevices, slope estimation and observation, the DEM, land use land cover data and weather data.

Data Processing and Analysis involved measurement of tor height, diameter, lengths of cracks and crevices all in meters and tabulated in excel spread sheet and later analyzed to estimate the relationship between variables to be presented in graphical nature. The analysis methods used were both descriptive and inferential analysis techniques.

The results mean of tor diameter 31.4146, mean of tor heights 18.8293 and mean of cracks lengths in tor 0.6129. The cracks were due to thermal variation, mass movement due to tectonic and water erosion is due to high peak of rainfalls in the area. The study established that leading geomorphic process in tor formation therefore are physical weathering, water erosion and to a lesser extent mass movement.

CHAPTER ONE

INTRODUCTION

1.1Background of the Study

A“tor” is a free standing residual mass of rock that rises abruptly from a surrounding that has a smooth outcrop and gentle slopes of surrounded hill summit (Ehlen, 1998,2004; Ehlen ,1998,2004). A tor can also bea ridge that could also be a conspicuous mass of rocks that, rises above a covered surface as depicted by elevated granitic terrains (Romani 2005).

A wide-ranging study of tor development in the world by different scholars, in different relief regions, has identified different processes and factors resulting to; distribution and formation of the rock outcrops. King (1948), in his explanation of the Pedi plain process of scarp retreat, king affirms that tors are formed when scarps retreat backwards leaving a vast Pedi plain in the wake. Initially for scarps to retreat, the upland region separating adjacent valleys or coastal cliffs must be present. Lateral erosion by rivers, sea waves, wind or weathering acts along valley sides and or coastal scarps wearing them backwards leaving a pediment or Pedi plain behind (Lintons, 1952). With time, the interfluves are reduced to an inselbergs called a Monadnock point, which later is referred to as tors. The reduction of interfluves into tors has brought arguments among geomorphologist on which or how the formation of tors could be influenced by different geomorphic processes (weathering, mass movement and erosion) in different climatic regions. These massive blocks of rocks are of different shapes and appearance, different form, length, and even shapes.

The residual bedrock could be produced below the surface level by a phase of underground chemical weathering, affected by ground water as guided by joint system then followed by a phase of profound rock rotting (Cummighm, 1975).These confirms to (Linton,1952) work which also explained that resultant deep weathered regolith, can later undergo mechanical removal which exposes the rock outcrop, mainly affecting gneiss, sandstones, schist, decites and dolerites (Lintons, 1955)

During rainy seasons, water erosion and mass movement strips away the regolith revealing seated basement surfaces or weathered basal surface as tors. Thus, this process implies that, the rate of denudation in stripping, must overtake the process of weathering as initiated by moisture content (Ehlen,1999)

(Ehlen,2006) made it clear that In instances where deep weathering is faster than the basal surface removal, then, rock outcrops will not be exposed to the surface, rather they keep on lowering.

Linton (1955), explains another process of tor formation as etch planation. This is the process by which the bedrock has been subjected to considerable subsurface weathering, especially when explaining inselbergs protrusions such as bornhardts, tors or dwalas (Ollier, 1961).From Davisian approach, the process of slope decline, which forms tors, occurs during the old stages of landscape evolution, where surrounding softer rocks are eroded and denudated**,** thus, protrusions of hard rock are left standing as tors.

Although many processes have been brought forth on tor formation, none has been widely accepted or commonly adopted as each has its own criticism. Disparities have ranged over among geomorphologists on the application and adoption of the processes towards explanation on formation and distribution tors (Ehlen, 2004). For instance, King (1948), in his explanation on tors and inselberg formation as a product of pediplain process of scarp retreat, received much critism, due to the fact that, tors are not only a product of surface planation, but also can result from other geomorphic processes. Slope retreats on landscape development does not always take uniform pattern and process as tectonic activities can equally affect a landscape (Lintons, 1958). Lateral erosion by rivers on valley sides or erosion by sea along cliff foot (Twidale, 1967), may also cause slopes to retreat. In addition, hard resistant rocks may restrict back-wearing than soft rocks, but King (1958) assumed a homogeneous landscape composed of the same rock type which is not always the case as rock structure may vary depending on the basement system. This study seeks to establish other geomorphic factors which affect tor formation in Seme sub-county, Kisumu County which are water erosion, weathering and mass movement.

Globally, the lack of common stand on formation of tors as related to granitic landforms has been a great source of more confusion. For instance, in Brazil tors have been viewed to have resulted from deep chemical weathering and referred to as fingerlike projections and also referred to as sugar loaf tors,(Cotton,1911, 1923). In Allur province in Central Australia they are said to have resulted from slope retreat and termed as bornhardts (Ollier1961), while in Dartmoor Europe (Linton,1955; Thomas,1967), they are formed through multi-cyclic or two stage which involves double surface erosion and referred to them as tors.

In central Africa Zimbabwe and Namibia, it is said to result from surface planation and they are termed as inselbergs, Dwalas, whaleback and Rwares.

1.2 Statement of the Research Problem

Many Researchers have continuously grappled to explain the evolution and development of Tors globally and Kenya in particular (Ojany and Ogendo1973). The contentious issues among geomorphologists and geologist revolves around how and what exactly accounts for the formation and spatial distribution of tors in an area and more so in tropical zones (Thomas, 1967).Most geomorphologist, (Linton 1952), have adopted two-stage model, which is an improvement of (King,1958),one-stage model, where tor formation was within the Ice Age due to a combination of frost-riving, mass movement and water erosion under peri glacial conditions. These views have been criticized by geomorphologist such as (Twidales, 1967; Ehlen1999) In spite of their criticism a more acceptable two stage process was adopted which concluded that tors are as a result of deep chemical weathering process and scarp retreat.

Studies in Africa and East Africa, regard the formation, and spatial location of tors as a product of pasts climatic conditions (Ojany and Ogendo, 1983), but lacks a clear explanation on the geomorphic processes affected by these climatic conditions. The basis of this study therefore involved, the assessment of geomorphic processes initiated by climatic factors and in this case rainfall and temperature variability were the main drivers of the geomorphic processes under the study that is weathering, mass movement and water erosion and how these processes affect formation of tors in Seme Sub County in Kisumu County an area of high and adequate rainfall which influence mass movement and water erosion.

1.2.1. Research Questions

The research project was based on the following questions:

i. What is the role of water erosion in the development of tors?
ii. Does weathering play a significant role in the formation of tors in Seme Sub County?
iii. What is the relationship between mass movement and formation of tors?

1.3 Study Objectives

1.3.1 General Objective

The general objectives of the study were to ascertain the role of weathering, mass movement and water erosion in the formation of tors in Seme, Kisumu County, Kenya.

1.3.2Specific objectives

The Specific objectives in the study were:

i. To establish the role of water erosion in the development of tors.
ii. To account for the role of weathering in the development of tors
iii. To determine the relationship between mass movement and the formation of tors in Seme, Kenya.

1.3.3 Study Hypotheses

This study relied on the following Hypothesis:

i. Water erosion does not initiate the formation of Tors.
ii. Weathering does not influence the formation of tors in Seme sub County.
iii. Mass movement does not have significant influence on tors formation.

All the hypothesis were tested at α 0.5 significant level.

1.4 Justification the Study

Tors are considered as unique landforms that have scientific, cultural, historical, aesthetic, social and economic value as outlined by (Panizza, 2001). Some of the known tors in Seme include Kit-Mikayi, Kidi-Achiel, Luanda-Manya and Luanda-Boya with their origin having been told through myths. A number of studies conducted globally, in Africa and even Kenya have focused on climatic influence and terminologies of granitic landforms tors included. This implies that little has been done to the study and formation of tors in the region.

From the international organization of geomorphologists, (IOG, 2005) that advocates for the preservation of landforms which are considered endangered by human activities. Through the organization an assessment on the mode of formation, mapping, definition and protection of these landforms has been encouraged. Tors can be used as identity landmarks for the locality at the same time they act as home for the wild animals, they are also sources of underground springs that act as sources of streams that are currently disappearing due to human influence in the area.

The County Government of Kisumu where Seme situated together with the Kenya Tourism Board should promote the preservation of tors and possibly gazette the locality for tourism as this can help in generation of the much needed revenue for the locals thus improving their lively hood as the natives can be employed as tour guides, drivers as well as rangers since tors are also home of wild animals.

The locality can also be an important source of knowledge as institutions can use it as a laboratory for studies of geology and even pedology studies. Numerous Tors have been found to be distributed in the larger parts of Seme in Kisumu though the knowledge on how they are formed is scarce thus the need for publication.

Tors have also been found to be important tourist attraction sites which could earn the Country and specifically Kisumu county enough revenue. With the introduction of devolved governance this study could bring to full realization of the tourism sector leading to generation of revenue which will in turn help to alleviate poverty and improves the living standards.

1.5 Scope and Limitation

The study involved spatial identification of tors wildly distributed within undulating terrain and the remote area of Seme. The choice of selection of tors for study was occasioned by their occurrence being that the area is located within the tropic. The spatial distribution of tors within the tropics in the world is an indication that tors are products of climatic influence on the lithology. The rationale of the study was informed by the reduction of tors in size over the decades as observed by a number of scholars and the changes that are posed by human and climatic influence.

Different Tors were identified, named and marked for the purposes of studying. The area covered was expansive and involved coverage of long distances, uneven terrain and poor road network, heavy and thick vegetation, scorching effect of the sun and high temperature, exposed bare rocks of varied types. Language barrier was unavoidable since the study area is inhabited by. Luos peaking community who understand little Swahili, hence there was need for an interpreter as the verbal questionnaires were structured in English.

1.6 Operational Definition

Geomorphic Processes- the products of climatic processes of weathering, mass movement and water erosion

Mass Movement- the processes by which loose and unconsolidated weathered materials are carried down slope either slowly or rapidly when tors are being formed

Pediment: gently sloping and an extension of hill formed when scarps retreat

Pedi plain: this is a vast flat land formed from several merging pediments also known as peneplain

Per glacial Period -processes, conditions, areas, climates, and topographic features occurring at the immediate margins of glaciers and ice sheets, and influenced by cold temperature of the ice.

Regolith. -All unconsolidated earth materials above the solid bedrock. It includes material weathered in place from all kinds of bedrock and alluvial, glacial, eolian, lacustrine, and pyroclastic deposits. Soil scientists regard as soil only that part of the regolith that is modified by organisms and soil-forming processes

Tor Formation-The various processes that leads to existence and occurrence of granitic bosses within an area.

Tor-A high, isolated pinnacle, or rocky peak; or a pile of rocks, much-jointed and usually granitic, exposed to intense weathering, and often assuming peculiar or fantastic shapes.

Water Erosion-the wearing away of the land surface by running water, waves, or moving ice and wind, or by such processes as mass wasting and corrosion (solution and other chemical processes).

Weathering-All physical disintegration, chemical decomposition, and biologically induced changes in rocks or other deposits at or near the earth's surface by atmospheric or biologic agents or circulating surface waters with essentially no transport of the altered material.

CHAPTER TWO

LITERATURE REVIEW AND CONCEPTUALFRAMEWORK

2.0. Introduction

The geomorphic process which include water erosion, mass movement and weathering, are important in influencing tor formation and spatial distribution in globally. These processes are influenced by climatic elements which is mainly thermal variation. Seasonal change in temperature, accelerates geomorphological processes which will lead to surface erosion and sediment transportation leading to exposure of tors from the old bedrocks. Surface erosion affects lithology which is the general structure of the rock and the rate of seasonal denudation process. The study will therefore highlight key scientific research studies relevant in tor formation and distribution globally, in Africa and Kenya. This necessary in revealing trends in the scholarly research on impact of geomorphic process responsible for the formation and distribution of tors. The review is organized in topical way based on the study objective, problem and hypothesis and questions.

2.2. Geomorphic Processes

Landscapes represent dynamic and natural physical processes both endogenic and exogenic, with close interrelationships, they influence variations in tectonism, lithology and climate. Climate is known to change on timescales as a result of human practices for instance population rise and need for expansion will influence and changes in land use and land cover, which may leads to landscapes evolution, (Doranet, 2002). Importantly, climate parameters such as temperature, rainfall, wind velocity and solar radiation, play significant role in shaping landscapes, especially in areas of active tectonism. The factors give yield to diverse geomorphic process, which in turn, produces distinct assemblages of landforms (Romani, 2005).

Several landforms of bedrock, are produced below and above the surface level dominates various locations across the globe (Palmer *et al*, 1955) and these features exhibit an upward projection of granite rocks that could have been left behind when the surrounding bedrock was broken up due to different processes including frost action, and removed by solifluction. The said processes have resulted to formation of various features under different climatic conditions like in Europe along the Dartmoor, South America especially in Brazil and North America Mojave region in California in Allur province of Australia. The processes also have a connection with aeolian erosion facilitated by katabatic winds mainly in arid and semi-arid areas active-layer cryoturbation cold-based glaciations like in the high peak mountains, fluvial activity, salt weathering and mass wasting. These processes vary in intensity across each micro-climate zone which results into the explanation for the existence of features such Tors as they occur in tropical zones Seme region included.

2.3 Tors Shape and Form

A ‘tor’ is a free-standing residual mass of rock that rises abruptly from surrounding smooth outcrop and gentle slopes of surrounded hill summit or ridges (Ehlen,2004).They are also known be conspicuous masses of rocks that rise above covered surface as depicted by elevated granitic terrains (Romani, 2005). Linton (1952) defines tors as granitic residuals equivalent to inselbergs which outcrops and rises suddenly above a plain, hilly country or rainforests. (Twidale,1982) gives a suggestion of granitic landforms especially tors and inselbergs, as genetically related landforms of same formation and origin, he made an assumption that bornhardts (domes), castle koppies, and nubbins develop in massive bedrock on what will be large-radius domes. Nubbins are block- or boulder-strewn residuals that develop on what will be small-radius domes.

Tors forms outcropping landscape elements isolated from each other like oceanic islands. In relation to this study, ‘tors’ is used to illustrate their ecological isolation, and that; there are no ecological similarities between the Inselbergs on the land surface, and the island in the oceans (Migoń, 1997). Tors are globally distributed and more specifically in tropical and sub-tropical climates, or where a tropical climate dominated.

Tors are classified into two broad categories based on rock structure; dome-shaped and steep-sided. The dome-shaped are unsaleable tors formed from course-textured, porphyritic granite gneiss, while the less perfectly shaped, scalable ones formed of other types of gneiss. Linton, (1955), classified tors according to the topography of the place of occurrence and he basically used the altitude, this included summit tors and spur tors. Their formation is determined and controlled by the various environmental determinants especially factors; climate, jointing and the nature of the rock (Osborn, 1985). Jointing occurs on a very large-scale and control geomorphic process especially chemical weathering that occurs along joint. Water erosion and mass movement strip off weathered regolith leaving fresh surface to be attacked later attacked by chemical weathering. Vegetation facilities further chemical weathering by keeping the ground moisture during the dry season for further decay of the rocks (Dormann,2013)resulting long narrow valleys, with steep sided ridges between them, eventually, producing isolated tors and inselbergs.

Gerrard (1978), classification tors into three groups: summit, valley side tors and emergent tors. He emphasized the importance of joints in formation and spatial distribution of tors. Tors are more closely spaced in zones with joint spacing and more variable in summit and valley side tors. In Dartmoor formation, spacing and jointing control the sheeting structure during the formation of tors and nubbins. Orthogonal joints are dominant and few structures when features like kopjes were being formed in some locations. Both castle koppies and nubbins develop on the subsurface, but under slightly different climatic conditions. The Dartmoor tors in Twidale's classification and the Allur dome of central Australia are products of sheeting process aided by the seasonal climatic variation.

2.3.1 Global Distribution of Tors

Geomorphologists and geologist suggest that in the global distribution of landforms that are formed in granitic bedrocks tors are associated with the Precambrian rock formation, the Guianian and Brazilian shields are ideal type of the Precambrian formation (Porembski and Barthlott, 2000). The term ‘Tors’ was coined by Wilhelm Bornhardt in 1900 to refer to rock outcrops rising abruptly above surrounding plains surface, mainly consisting of granite or gneiss in tropical and temperate zones (Porembski&Barthlott, 2000). In the study of granitic inselbergs, Brazil in particular is dominated by granites of different types of rock outcrop, which are well known for their species richness (Safford, 1999). Brazil, inselbergs, bornhurts and tors, mainly occur in highland and lowland areas (Safford&Martinelli, 2000). The term ‘sugar loaf is associated with the lowland group of dome-shaped granitic tors.The Sugar Loaf in Rio de Janeiro is the most famous example of a typical lowland monolithic tors, being the geological postcard of Brazil (Silva and Ramos, 2002). Ab’Sáber (1995), also distinguished two types of granitic and gneissic outcrop the sugar loafs in south-eastern Brazil, especially in the Atlantic Forest domain, and ‘typical inselbergs’the granitic outcrops located in semi-arid north-eastern Brazil, in the Caatinga domain. He argued that sugar loafs had been inselbergs in dry climatic periods in the past and also that inselbergs could become sugar-loaf-like after radical climatic changes towards wet tropical climates (Ab'Sáber, 1994).

In Australia they occur in 3 forms, domical or bornhardts, knolls or block-strewn nubbins and small castle kopjes (Ollier 1963). The domical forms dominates a wide area, the Eyre Peninsula and the Everard Range in the northwest of South Australia, the New England Plateau (Bald Rock) is an ideal example, New South Wales, Wilson Promontory in Victoria and thePorongurup Range in Western Australia. A number of nubbins and inselbergs are common northern Australia mainly in Pilbara, the Mt Bundey area near Darwin, in the Northern Territory, and in northwestern Queensland, near Naraku and Dajarra, and Cathedral Rocks on the New England Plateau (Ollier 1963). Bornhardts are known to be in massive bedrock with very few open joints, likein the case of Organ Mountains of New Mexico (Seager, 1981) the Cathedral Rocks of the Yosemite region in the Sierra Nevada of California (Huber, 1987). The Needles of South Dakota (Twidale, 1971), and similar acicular forms reported from the Sierra Guadarrama of central Spain are ideal examples of tors or inselbergs of granite or gneiss. They meet the adjacent plains in a sharp slope break, called a piedmont angle, their flanks being steep-sided. Granitic landforms like borhurts tors and castle tors easily and dramatically found in both hot and cold desert landscapes as evidence in the Sahara, and in the Mojave Oberlander (1972).

2.3.2 Tor Distribution in Africa

African Continent is rich of and has wide geographical physical features tors and inselberg among them. According to Doornkamp(1963), some of the most impressive inselbergs have been sighted in different locations Africa. The Tors have been recorded in countries including South, Namibia, Burkina Faso, Tanzania, Angola, Nigeria Uganda and Kenya. In West Africa they exist in the semi-arid region of northern Nigeria Hausa land, (Falconer, 1911; Bain, 1923) and being residuals of former periods of humid climate, evident in the Sahara. In Zimbabwe Tors are known as Whalebacks or Dwalas, gently sloping granitic inselbergs and unweathered basal surfaces of old climatic origins and inHarare, Zimbabwe Tors are known as Balancing Rocks in Epworth, these granitic features are usually emerging as residuals of bornhardts. Dwalas can be seen protruding in areas such as the Matoposan area located in the savanna tropical region. In theSouth West Africa the Spitzkoppie,inselbergs in Namibia, rises 3,600 feet in the Namib Desert, is the tallest of this landform in Africa.

Along the East Africa and the Lake Victoria region and in southern Uganda the exposures on the higher slopes and hill crests are frequently seen as tors. Where the exposure is near, or within, the valley floor, its outcrop has the form of a low mound rising almost imperceptibly as a low swell just above the surface of the adjacent vegetated slope. Although inselbergs, tors, bornhardts and Castle Koppies are typical of the savanna and granite areas, they are found in many different environments globally, according to (Ojany and Ogendo, 1983), In some parts of East Africa Tor are found especially in Kakamega and more specifically in Seme County. These granitic landforms are situated in southern region that borders Kenya having the similar lithology as these found in Kakamega, Kisian, Asembo, Seme and Central Tanzania, areas whose surface has experienced uplift and warping in the recent past. These surface deformations are the result of faulting since the end of the Oligocene, have produced the Western Rift Valley. They may be composed of well-jointed granite and consist of blocks standing one upon the other, in which case they are akin to tors .On the other hand, they may consist of one solid, virtually unjointed, rock mass standing in isolation above the adjacent slopes, in which case they resemble bornhardts, but in these examples their limited size frequently suggests that the term massive tor, is more appropriate. Tors occur globally in different climatic environments and a controversy remains unresolved as far as formation and distribution of tors is concerned hence the basis of this study.

2.4 Tor Formation processes

Tors formation involved several mechanisms and process which include; weathering process, denudation, chronology or by morphogenetic region (Cummingham, 1969). Linton, 1955) asserted that the concept of deep weathering of tors and inselbergs formation has never been appreciated by many scholars (Palmer and Radley 1961; Palmer and Neilson, 1962; Thomas, 1974) . In the tropical region the features are commonly referred to as Tors and have been experienced in Southern Africa Zimbabwe, Namibia, Kenya and Tanzania in East Africa. According to Linton (1952), recently, tor formation involves different processes which include;

2.4.1. Linton's Theory of Tor Formation

The two stage process was Linton preposition in his study in Dartmoor in 1952, the preposition received support from Twidale, (1967) and Thomas (1966). Linton (1955) suggest that tors are masses of bedrock produced below the surface level by a phase of profound rock decay, decomposition and disintegration effected by ground water and guided by joint system. This is followed by a phase of mechanical stripping from a basal platform of bedrock which may be flat or inclined and interpreted as representing the position of the water table during the period of rock decomposition so that tor height cannot exceed the depth of the vadose zone of that period (Linton, 1955). Most studies in Dart moor Scotland postulated that, tors are products of two stage process which involves the subsurface chemical weathering process along joints of massive rocks, mostly of granitic origin and structure, followed by deep chemical weathering (Pallister, 1960). Further investigations in Dart moor, suggested that, climate experienced in the past which was warmer and humid during the Peri-glacial and interglacial periods. They further argued that the process of deep weathering is facilitated by rock structure which was affected by climatic factors thus initiating process of deep chemical weathering, water erosion and mass movement. This type and nature of joints which was influenced by the uplift of Godwana surface during the period of tectonic uplift combined with climatic conditions of the past initiated geomorphic processes of chemical weathering, rapid mass movement and then quick flow mainly done by water erosion during the high peak rainy seasons.

The second stage of the process involved the action of geomorphic processes where the exhumation of the weathered roots granitic residuals was exposed by water erosion and mass moment processes. Solifluxtion was active and effective process while mass movement was involved in the removal of the loose materials from the upland and the slopes in the Dartmoor.

According to (Linton, 1955) the granitic land forms like tors are likely to be the products of structure, process, climate and time. He further noted that the rock had to be resistant and jointed to form the surface. On the matter of process, Linton affirms that deep chemical weathering which is aided by the ground moisture occurring along a joint was largely the real course for tor formation. The findings are in line with those of (Thomas, 1974) who asserted that weathering is rapid where distance between joints and cracks in the granite is narrow than where distance is wide. Once this weathered material is removed by erosion a rock outcrop with widely spaced joints remains and this is referred to as a tor.

(Gilbert, 1877) ;(Thomas, 1965) ;(Carson and Kirkby, 1972) ;(Twidale and Bourne,1998) all suggest that joints in rocks accelerate effect of sediment cover removal and removal of bedrock weathering rates that in a qualitative and functional form of geomorphic processes. This model of tors formation occurs in arid environments and presents possibly transient features related to fluctuations in climate and local transport conditions rather than palimpsests of an ancient landscape derived from differential subsurface weathering followed by regolith stripping. (King, 1949), therefore concluded that, tors as highly steep-sided, isolated hills that rise abruptly above the surrounding plains and show much variety in scale and morphology. They are highly resistant to weathering landforms as they comprise of unjointed rock cores, and are virtually indestructible formed as result of action geomorphic processes acting on granite bedrocks.

Studies by Ollier (1959), in Australia affirms that tors are mostly of different forms such as the inselbergs which are characterized by great elevation known as skyline tors that are averagely 300m and possess near vertical or even overhanging sides. The rounded summit and thick rock sheets are determined by massive sheet jointed in the rock produced by pressure release. These rock sheets may be curved down sharply at the dome margin to form major vertical joints and they normally range between 0.5 to 1.5m in thickness although sheets as thick as 10m have been observed.

(Mabbut,1961) ;(Linton,1952) argued that granitic landscapes occurred in different climatic conditions and are formed almost in similar ways yet it has been established that the landforms share a lot of similar features in terms of mode of formation as experienced in Seme, Kisian, Kakemega and Asembo western Kenya. Linton's opinion regarding time, there are small tors which were revealed during quarrying operations in Dart moor and others were also exposed in Southern Africa during tectonic occurrence. They were not yet naturally exhumed because of their low-lying position in the landscape. These would be future tors when exposed as time was required for their exhumation. Generally, the opinions of scholars blended that tors were of two types namely skyline tors which were residual granites (monandnocks) named from the U.S.A(Pallister, 1960)

(Elehn, 2004) working in southern Georgia in the USA concludes that tors and inselberg are small rocky hills occupying the granitic landscape. They are thought and are believed to be old stage of the planation surface of ancient mid-centaury. Another type of terminology was the Sub-skyline tors –resulting from deep sub-surface weathering on jointed rocks which form the basic requirement for exhumation of the sub-skyline tors. They are thought to be youthful based on the Davisian approach of explaining evolution and development of landscapes which are believed to have been rejuvenated from the erosion.

2.4.2. The King's Theory of Tor formation

King (1958) in his studies in southern Africa region presents a model of tor formation which largely depends on fluvial processes as the main mechanism in the process of their evolution of landscape and inselbergs, tor and related landforms formation. Formation of Inselbergs through the process of Parallel Slope Retreat entails a chronological and sequential development and evolution of the landscape that may lead to occurrence of inselbergs, tors, castlekoppies. (King, 1948) postulated that land forms like inselbergs are a result of Pedi planation, a process which involves parallel scarp retreat. Pedi planation is sometimes referred to as circum-denudation. Pediplanation involves sequential erosion periods which date back from the Jurassic period (King, 1948). Pediplanation cycle is phases where, slope retreat results in the formation of inselbergs (Ollier, 1961).. The first phase involves initial stream incision and valley widening process.

Africa, inselbergs were formed through joint controlled drainage incision in the surface of low-relief. Incision would only be possible in well and heavily jointed structures which result from first valley formation and then in sedimentation or in parallel slope retreat: (Ojany and Ogendo, 1983). The end products of slope retreat are the remnants of the old peneplain which are massively jointed areas which rise above the lower pediplain as either bornhardts, inselbergs, tors or castle tor. It is from this preposition that it is believed that tors in East Africa, Uganda, central Tanzania Western Kenya (Kakamega, Kisian, Maragoli, Asembo and Seme) are believed to have been formed (Ollier,1961). (King, 1958) disregards Lintons (1955) model and process of tor formation pointing out that many Inselbergs stands higher than known depth of subsurface weathering. Together with other critics of deep chemical and surface stripping process of surface evolution got response from (Thomas, 1966) and (Savigear, 1960). Both agreed that the irregularly distribution of tors has no common relation with drainage system or erosion escarpments.

Tors, inselbergs and other granitic landforms as products of Godwan surface is enough reason to suggest that weathering is the main origin of these landforms (Ollier, 1961). In his argument Ollier (1961) believed that, where deep chemical weathering is not possible due to constant and high drainage incision and erosion. Tors are not common in such localities. Consequently, both (Ollier and Tuddenham, 1961) suggested that in Australia tors might have also been formed through King's process though the process is in conjunction with deep chemical weathering, mass movement and water erosion. Their ideas were also confirmed by (Hilton, 1966) working in the upper province of Ghana, Guyan and Ojany, (1969) in Western Kenya. In all the cases slope retreat is favored and is regarded as process which might have occurred under deep mantle but not under sub-surface aerial condition. Tors therefore can occur in different climatic conditions. Thus this study seek to demonstrate the role of climate as the key driver of geomorphic process that is mass movement, water erosion and weathering responsible for the formation of tors in the study area,

2.4.3. Process of Equifinality

The term "equifinality" in geomorphology is the conclusion that similar structures of landforms are formed as a result of very different processes. In some cases, also referred to as a multi working hypotheses where several approaches my lead and can be used in explaining occurrence of similar landforms as used in description and occurrence of tors. This concept was first used by (Chorley, 1962) among others. The process revolves around the ideas of similar granitic landforms (inselbergs, bornhardts, tors, kopjes and castle tors) which may have resulted from different rock types and from altogether different processes. Since our understanding of various processes is limited, processes and mechanisms which appear to be quite different may, in fact, be one and the same thing. Landforms which appear very similar, may in reality be very different and reflect diverse origins thus similar landforms may have been formed by different processes due to location differences. It is true that the history of the formation of features is often unrecorded and so not understood.

Chorley's (1962) reveals that, exhaustive testing of every possibility is necessary in the process equifinality. However, equifinality is generally against the adoption of a single universal process in geomorphology. Therefore, in building up process for geomorphology, during research, there should be an encouragement for using multiple working hypotheses. Multiple working hypotheses involve the formulation of several hypotheses in an attempt to seek explanation of the same phenomena, (Moller and Dowling 2015). However, according to (Cooke and Reeves 1976), the multiple working hypotheses concept calls for crude testing of each theory and the elimination of weaker models or process. (Ely et al. 2016) suggest that, the main aim of employing this methodology is to counter the natural scientists, geomorphologists and geologist, bias to propagate and protect well known preferred and established processes, without subjecting them to critical evaluation.

Though equifinality employs a methodology of multiple working hypotheses, the relationship is a paradox. It is a paradox in the sense that in geomorphology, Equifinality aims to explain the existence of the same landforms through various processes and yet the aim of the methodology it employs is to ultimately eliminate all the other process and remain with one general universal process. Equifinality would call for the co-existence of Process and yet the multiple working hypotheses would call for the elimination of one of them.

Probably the fact that,(Linton1958and King1948) fail to understand that there are different explanations for the formation of Tors as granite features: Their failure to recognize that different processes may have been responsible for the formation of tors; and that probably what they term the same feature, inselberg maybe two different landforms:(Cooke and Reeves,1976). In fact, each inselbergs is unique in its own form and composition and there is no standard example of an inselbergs. Thus the formation of these feature is an open argument. Equifinality allows the co-existence of different process. This literature reviews therefore give a detailed explanation on the assessment of geomorphic process responsible for tor formation and distribution within the Seme region, there are various process put forward to explain the spatial occurrence of tors and related landforms and most of them tend to point out that tors are products of action of both endogenic and exogenic to what extent geomorphic products and how are they influenced by environmental factors like climatic products.

2.4.4 Weathering and Tor Formation

The process of weathering involves the disintegration decomposition and alteration of rocks to more stable material from their exposure to the action of agents erosive agents such as air, water and organic fluids. This could also be related to the two-stage model of tor form breakdown of rock materials followed by regolith stripping exposing the granitic masses of low joint density. The main process of weathering that involves tor formation is as mentioned by Linton 1952, (Twidale, 1967) and (Ollier, 1984) and thus provides good general discussions of physical and chemical processes of weathering on granitic rocks. In the opinion of (Ehlen and Gerrard 1988) more analysis of chemical weathering of granitic rocks should be carried out to further expound on the early work of (Morris, 1934) on landscape evolution through weathering of granitic rocks while investigating the process of exfoliation and insolation as possible weathering agents. (Ollier,1971) on the other hand discusses a number of different hypotheses for the origin of spheroidal forms, and also addresses induced fracture as a form of physical weathering (Ollier,1978) which could have had a relationship with tor formation in Seme. In the opinion of (Crickmay,1935) regarding the southern Appalachians and (Blank,1951) in Texas , the main process acting on granitic rocks is granular disintegration and is often cited as the major cause for tafoni which is small (less than 1 cm (0.39 in)) to some extent are (greater than 1 meter (3.3 ft)) cave-like features that develop in either natural or manmade, vertical to steeply sloping, exposures of granular rock as explained (Dragovich,1969) (Bradley,1978). (Kesel,1977) also cited sheeting and spalling as the major process in central Arizona as geomorphic process responsible for tor formation, inselbergs and other related granitic landforms and that Crystal growth, usually salt or ice, is also a common form of physical weathering. (Palmer and Raddley,1961) ; Palmer and Neilson (1962) suggested that freeze /thaw is largely responsible for the formation of granite tors in England though (Kelly and Zumberge,1961) found salt weathering in conjunction with freeze/thaw as the major processes involved in forming tors in the Dry Valleys of Antarctica. (King, 1975), of course, strongly supporting the physical processes for the origin of granite landforms in southern Africa, as does (Mabbutt, 1952).

The processes involving tor formation through conditions of landforms associated with cold environments which are non-glacial (Harris, 1988) are also cited. The Periglacial environments are those found within cold climates and nonglacial produces distinctive landforms and deposits, often as a result of ground freezing. Periglacial geomorphology is concerned with the understanding of the landforms, deposits and processes of cold nonglacial environment, (Harris,1988).According to (Peltier,1950) the one stage process explains areas that under went periglacial erosion process in Pleistocene periods, Tors are thus isolated granitic remnants which are indicators of geomorphic cycles (Palmer and Ruddley,1961);(Palmer and Nielson,1962)being the key proponents argued that the one stage process of tor formation is a product of two stage process. The Pleistocene glacial activities and condition partially modifies the already existing landscape and the landforms including the granitic rocks in existence.

The one stage process is not common though normally used to explain the assumptions of periglacial processes in modifying the granitic landscape leading to formation of tors in specific climatic condition, much as 'glaciation' describes the general effects of glacial action. Despite the fact that glaciations affect the granite uplands (Ormerod, 1869) evidences of geomorphological studies of peripheral regions according to (Evans, 2016) has contributed to glaciations being underestimated in the formation of tors.

Most explanation indicates therefore that climatic control is a key processes of tor formation and resulting tor formed have rounded and angular forms, this shows the dominating effects of chemical and physical weathering (Ballantyne and Harris, 1994) However because tors occur across a broad climatic range and similar tor morphologies may develop under differing climates and weathering processes, a climate control on tor formation remains uncertain (Ballantyne and Harris; Migoń2006).

(Demek, 1964)(Czuduk,1964) argues that the angular Tor as those found in Seme are products of general process of the periglacial slope development including altiplanation terraces, felsenmeer, solifluction and escapement retreat whereas In the opinion of (Czudek,1964)the role of lateral rather than vertical planation which occurred during the periglacial period, contrasting the slow process lowering the planation terraces with the comparability rapid scarp retreat process is linked to the permafrost as a basal point of limit to frost action on the exposed microclimate and rapid frost cycling on the cliff faces.

In his opinion (Derbyshire, 1972), Tors as products of landforms formed as a result of chemical weathering. This is in contrast with angularity of periglacial tor formation contrasts sharply with rounded tors formation hypothesis as tors produced by subsurface Chemical weathering process the difference is always attributed to the markedly difference behavior and nature of the frost attack especially the selectivity of the frost attack compared to subsurface weathering process initiated by the thermal variation and other climatic elements.

According to (Nielsen,1962) Tors form due to single stage processes where the bedrock is exposed sub aerially through the process of weathering either mechanically then transported by agents of erosion especially running water. Granitic land forms like tors may also be formed structurally as a result of physical activities taking place on the crust. According to (Cotton, 1911), one stage mode of tor formation has been experienced in Ghana, Nigeria and in the Tanzanian belt of East Africa. It is thus a possibility that tors found in Seme region in Kisumu County could have also been formed by the one stage process. Other prior publications that supported the two stage model including those favoring the two-stage etching hypothesis were for (Gilbert 1877; Thomas, 1965; Carson and Kirkby 1972; Twidale and Bourne, 1998), they together appreciated the accelerating effect that sediment cover has on bedrock weathering rates and affirmed that in a qualitative and functional form showing that weathering could as well be responsible for the formation of Tors as exhibited in Seme region.

2.4.5. Mass wasting and Tor Formation

This is the movement of large mass of rock ,soil debris downward due to gravitational pull, it is commonly associated with climatic periods and the Structural process which is majorly based on rock structural components and formation thus an initiation of the climatic conditions and due to deep differential chemical weathering of bedrock by ground moisture, mechanical stripping of the weathered overburden n rocks exposing the tors, which then represent the more resistant and less weathered bedrock knobs of granitic residuals(Heimsath,2000).The process describes and presents suitable models for the investigation of landscape in granitic regions for evolution and formation of the tors and occurrence. In several cases the origin is inscribed to the key processes of weathering, erosion and mass movement associated to their occurrence. A structural consideration influences the weathering processes but differs from the other theories because the leading role of the rock structure is the major component which determines geomorphic processes. (Twidale,1969, 1971) consider structure especially the joints and the location of tectonic stress in the rock mass as being the key components in the evolution of the torand landforms.

(Cunnigham,1971) further proposed that tors in an area may occur in copula structure originating from the emplacement of plutonic and further explains that the interactions between magma and the county rock can occur when the geomorphic evolution of the landscape affect the plutonic roofing structure which is always eroded by water.

(Volborth,1962)indicated that both granite cupolas which are having a roof top like structure and readily weathered in the roof areas of especially granite plotons and placed their development at the time of emplacement. (Cunningham, 1971) opined that the wide range of application of the theory on tor formation and occurrence.

Tors are also known to be the key residual displaying the points of convergence in geomorphological thinking patterns when dealing with landscape evolution though with diverse lithology. They present similar features in terms of their mode of formation especially through the surface and subsurface stripping of regolith. Tors may also grow along the ridge crest or near mountain cores when increased rainfall and runoff rates induce a decline in pediment slopes that cause head ward thinning of regolith profiles, inducing the regolith thickness instability. In these cases, the regolith thickness instability is not associated with localized areas of concentrated fluvial incision.

The rainfall rate favors pediment denudation rates above the bare bedrock weathering rate, causing initial bedrock irregularities near the exposed bedrock crest to grow relative to mantled areas once they became exposed (Prick, 2004) erosion on the other hand is a general term for the removal of loose unconsolidated rock or soil particles from exposed surfaces by water, air or ice, or by other particles carried by these agents. In order for erosion to occur, loose rock or mineral particles have to come from elsewhere. The main processes that produce these particles are first weathering where particles are broken into smaller particles primarily by weathering (Prick, 2004)

Weathered materials, especially fine materials like soil, sand, and silt are very susceptible to erosion. In general, the smaller or lighter the particle, the more easily it is eroded and transport in solution. When ice freezes to a surface, especially in cracks, it expands and removes weak fragments of rock. Rapidly running water and strong winds are also able to remove particles (Strudley, 2006).

Running water causes friction or collusion of materials being transported with other materials and cause particles to detach, this is known as abrasion. The major erosive agents in most streams and rivers are the suspended sediment, pebbles and other material carried along (Strudley, 2006).The effectiveness of erosion agents in eroding material is related to the size of the particles being carried: the bigger the particle, the more erosive it is a boulder pushed by a stream is more erosive than a small grain of sand, the number of particles in the running water. Once particles are loosened, they are able to be moved. Forces which encourage particles to move include gravity and fluid forces. Wit gravity particles on a slope tend to move down slope. There is a “critical angle of sliding” at which point the forces of gravity overcome the forces of friction, and a particle moves down slope. Fluid forces relate to water and air. Water and air exert both a horizontal “drag” force on a particle, as well as a vertical lift. The horizontal drag or “push” force, if it is sufficient to overcome the resistance of friction and cohesion, will cause the particle to move. The strength of this force is directly related to the velocity of the water, the density of the medium and the sediment load.

The vertical lift force is directly related to the amount of turbulence and buoyancy in the water and air. Turbulence causes the particles to rise off the surface, minimizing the effects of friction and cohesion, allowing the particle to float and be carried along easily. Irregular or rough surfaces tend to cause more eddies and turbulence. Mediums moving at high velocities are also usually more turbulent (Heimsath, 2000). Particles can be transported in a number of ways. In suspension particles are carried along by the agent such as water, air or ice and do not touch the bed. Particles are not dissolved, but carried along in a river. In solution Particles are dissolved in water and carried along as chemical compounds in the water such as salt in the ocean.

Particles are also moved by saltation where particles bounce along the bed. This often causes more erosion by causing other particles to be detached and entrained, both from the bed and from the particle itself. Pebble transport by rivers, sand drift over desert surfaces, soil blowing over fields, or even snow drift over smooth surfaces such as those in other factor is particle shape where smooth particles tend to travel faster and further than irregular or rough one called friction. Thus previously eroded material for example a smooth stone beach is more easily eroded than newly weathered material. The other one is nature of the agent where air tends to move only smaller, lighter particles, but quickly and great distances.

Many positive relief elements arise from tectonic activity or by differential weathering and erosion enhanced by the lithologic and mineralogical variability, this in the opinion of (Twidale and Bourne, 1998);(Twidale and Romani,1994)leads to the formation of tors though still contestable since there exist a number of different processes leading to disintegration of rocks. Tors are form during periods of higher effective moisture, resulting in local base level incision and regolith thinning on pediments, invoking a transition in which mantled surfaces lower at rates exceeding the bare bedrock weathering rate.

The above conditions enhance the emergence, growth and exposer of tors in areas covered by regolith thickness less than a threshold value. Subsequent shifts in climate or local base level that restore sediment surface lowering rates less than the bare bedrock weathering rate which lead to a progressive decrease in tor height and, ultimately, their disappearance.

2.4.6. Water Erosion and Tor Formation

Water erosion is the washing away and removal of soil materials by moving water ,the process my natural of can also be triggered by man's activities its rate may be slow or rapid depending on the ground obstacles and prevailing weather conditions. Water moves particles of all sizes; small ones quickly and long distances; larger ones slowly, for shorter distances while ice tends to move sediments all sizes at equal speed usually very slowly (Thomas,1989). Eventually, materials transported by the stream eventually deposited due to various factors such change in velocity and gradient where if the velocity of water drops, the ability of the medium to transport particles drop. Strong wind carrying dirt deposits the sediment when the wind speed drops. Rivers carrying sediment deposit it when the water velocity decelerates. The other reason for deposition of sediments transported by running water is change in friction where if the roughness of the surface increases, the ability of the medium to transport particles drops. But the sediments will deposit if there is an obstacle which can either be vegetation. A change in the effect of gravity where if the slope of a surface decreases so does the ability of running water to transport particles. Steep, fast-flowing rivers can carry much sediment with little deposition. However, when the slope decreases, the river velocity decreases, and deposition occurs (Strudley,2006).

Change in cohesiveness where dry particles are moistened, the ability of air to transport particles is reduced. Really dry soil is more easily eroded than moist soil. Fifth reason for deposition of eroded matter is flocculation which occurs when fresh water rivers carrying much silt and clay mix with salt water (at the river mouth), the salt chemically reacts with the fine mud and clay particles transported by the fresh water rivers. The mud and clay particles glom together into larger particles which settle out. Thus, where rivers drain into oceans there are often huge sediment deposits (islands, sand bars, deltas) (Strudley, 2006).

These deposits are partly the result of the fact that the river's velocity is decreased and partly the result of this chemical process of flocculation. Most deposited material is sorted by weight and size because of the relative ease with which it can be transported. For example in most river systems large rocks are found near the headwaters, fine sediments near the mouth (Dohrenwend,1994). Landforms of Erosion and Deposition cause different erosional landforms and dispositional landforms. When this occurs, erosion granitic landscape tends to leave behind residual pillars like features granitic tors. Erosion tends to accentuate joints and weaknesses in rocks, creating larger cracks or gullies. Depositional Landforms are landforms created by deposited materials are classified as either. Active Landforms are in the process of being created at the present time (Thomas,1989).Relict Landforms are created by processes in the past which are no longer actively affecting them and in other circumstances erosional processes because since depositional features have become stabilized as in the case of a river terraces that is a flat step above a river which were once flood plains.

Much human activity increases erosion land use and practices for instance clearing natural vegetation for agriculture, forestry, residences among others. In some instances, people have actually reduced erosion. For instance, on many coastal areas, beach/cliff erosion have been reduced by engineering projects (Anderson, 2002).Mass wasting is a downward movement of soil, regolith and/or bedrock under the influence of gravity. Mass movement processes occur due to slope failure and also provide debris for erosion, transportation and deposition. All mass movement happens on slopes and are driven by the gravity are usually balanced by the resisting forces of friction and shearing stress (Heimsath, 1999).

The resisting force depends on the cohesiveness/ strength of the slope material. Sand has little cohesiveness. Soil/clay has moderate cohesiveness, depending on moisture and mineral content. Rocks range from shale and mudstones (low cohesiveness) to granites and basalts (high cohesiveness) This means that sand will move on very shallow slopes. In contrast, rocks like granite can be stable on vertical slopes due to the alignment of the stratus. Resistance is also related to rock structure. Strata parallel to the slope may shear more easily than strata at right angles (Anderson, 2002).

There are various types of mass movement. On steep rock cliffs are created by faulting or erosion, pieces of rock may simply fall and accumulate at the foot of the slope as talus or creep slopes. Freeze-thaw weathering processes, in particular, are responsible for freeing fragments or large blocks which fall as rock falls. Rock falls are dry just rock. Talus slopes tend to be sorted with larger blocks at the bottom and smaller fragments at the top. These talus slopes are very common in the Rockies (Strudley et al, 2006).

According to (Twidale, 1998) when rock, debris, and soil move downhill at high speed they are called debris avalanches. Often these are associated with ice, water or snow that provides lubrication for debris movement. They include rock, water, snow and debris. In alpine areas, avalanches can be caused by a sudden release of melting snow and ice, mixed together with rock material.

The other landform is earthflow which occurs when a mass of soil, regolith or weak clay or shale become saturated with water (heavy rain, snowmelt, flood), it may move downhill relatively rapidly (over the course of a few hours); but not as a sudden, destructive avalanche. The material moves sluggishly, leaving step-like scarps (low cliffs) and terraces at the head, and a bulging toe.

Earthflows are most common on grass or forest covered slopes that have been saturated by heavy rains, snowmelt, or ground water. The vegetation roots help to control the flow by holding the soil together. Earthflows frequently block road/railway lines, destroy buildings, or at least dislodge foundations. For example Palos Verdes Hills, L.A. County where 160 hectares of land moved 20 meters over 3 years, causing $10 million damage. The saturated soil caused by watering gardens and the use of cesspools. The 150 homes affected discharged 115,000 liters of water per day (Anderson, 2002).

Mudflows happen when certain materials become saturated (especially very fine-grained clays and silts). These sediments, when saturated, behave almost like a liquid, flowing downhill rapidly like a river of mud. Mudflows are most common in deserts and arid areas, where vegetation does not protect soil on slopes and local, very intense rainstorms provide water faster than the ground can absorb it. Surface water runoff mixes with sediment to form mud, which moves downhill quickly. They are also common in areas of active volcanoes, where rain or melting snow turn ash into mud (Heimsath, 2000).

In many alpine areas, a land form called talus (loose rock) accumulates rapidly on top of small masses of glacial ice. Ice moves slowly downhill, carrying the talus with it. These rock glaciers can carry tremendous quantities of rock downhill. Soil creep is the slowdown slope flow of surface soil, saturated with water. Saturated soil can move very slowly downhill simply as the result of gravity if the surface is not protected by vegetation.

Typically, soil happens because of the influence of animals or deforestation. A specific form of soil creep is solifluction which happens in environments that experience freeze-thaw action. As soil freezes it rises at right angles to the slope surface and as it thaws it fails straight down because of gravity. Gradually it moves downhill. It is characterized by the slow movement of soil material down slope and the formation of lobe-shaped features (Strudley, 2006).

Human induced mass movement is referred to as scarification. Every human slope disturbance such as a highway cut, housing construction, subdivisions, mining, even school construction affects weathering. Large open pit mines are among the most substantial mass movement effects of humans, called scarification.

The Earth's crust hosts different types of rocks which have one thing in common that they are all made up of minerals. Minerals are a solid chemical or compound which forms naturally in the earth. Some of these minerals are rare such as diamond, rubies and opals while others are common such as quartz or talc used in making talcum powder. When several minerals occur together they make up a rock (Gunnel et al, 2013).

According to (Twidale, 2005) rocks differ because of the existence of the very many types of minerals in the Earth. The minerals come together in lots of different combinations and quantities which leads to the wide range of rocks. On the other hand only about 30 minerals are the ones that are common thus making their grouping by geologists much easier. They are normally grouped based on how they were formed namely igneous, metamorphic and sedimentary.

Igneous rocks are formed by magma from the molten interior of the Earth. When magma erupts, it cools to form volcanic type of landforms. If the magma cools inside the earth it forms intrusive rocks which may later be exposed by erosion and weathering. Examples of these include granite and basalt. Metamorphic rocks are those which have been subjected to tremendous heat and pressure causing them to change into another type of rock.

This type of rocks is normally resistant to erosion and weathering thus making their weathering to be very hard. Examples include marble which comes from limestone, slate coming from clay and sandstone. (Ehlen, 2004)Sedimentary rocks are formed from sediments already settled at the bottom of a lake, ocean or sea and have been compressed over millions of years. Sediment comes from rocks that have been eroded and carried away by ice, river water and from sea creature skeletons. Examples include sandstone, limestone, clay and chalk.

Granite is a type of rock that contains accessory minerals most of which are precious gems such as tourmaline, beryl, topaz, zircon and apatite. Other economically important accessory minerals that occur in granites are phosphates and rare earth Oxides. Related to the rare earth elements is a significant concentration of element uranium in granites. Some rocks are incorrectly referred to as granites such as the coarse-grained metamorphic rocks. In the opinion of (Ojany and Ogendo, 1983), Tor in Eastern Kenya were formed as a result of the one stage process though features of structurally formation could be evident in regions along the western part of Kenya such as Seme, Kakamega and Maragoli .This literature review therefore gives a detailed explanation on the processes explaining the distribution and formation of Tors.

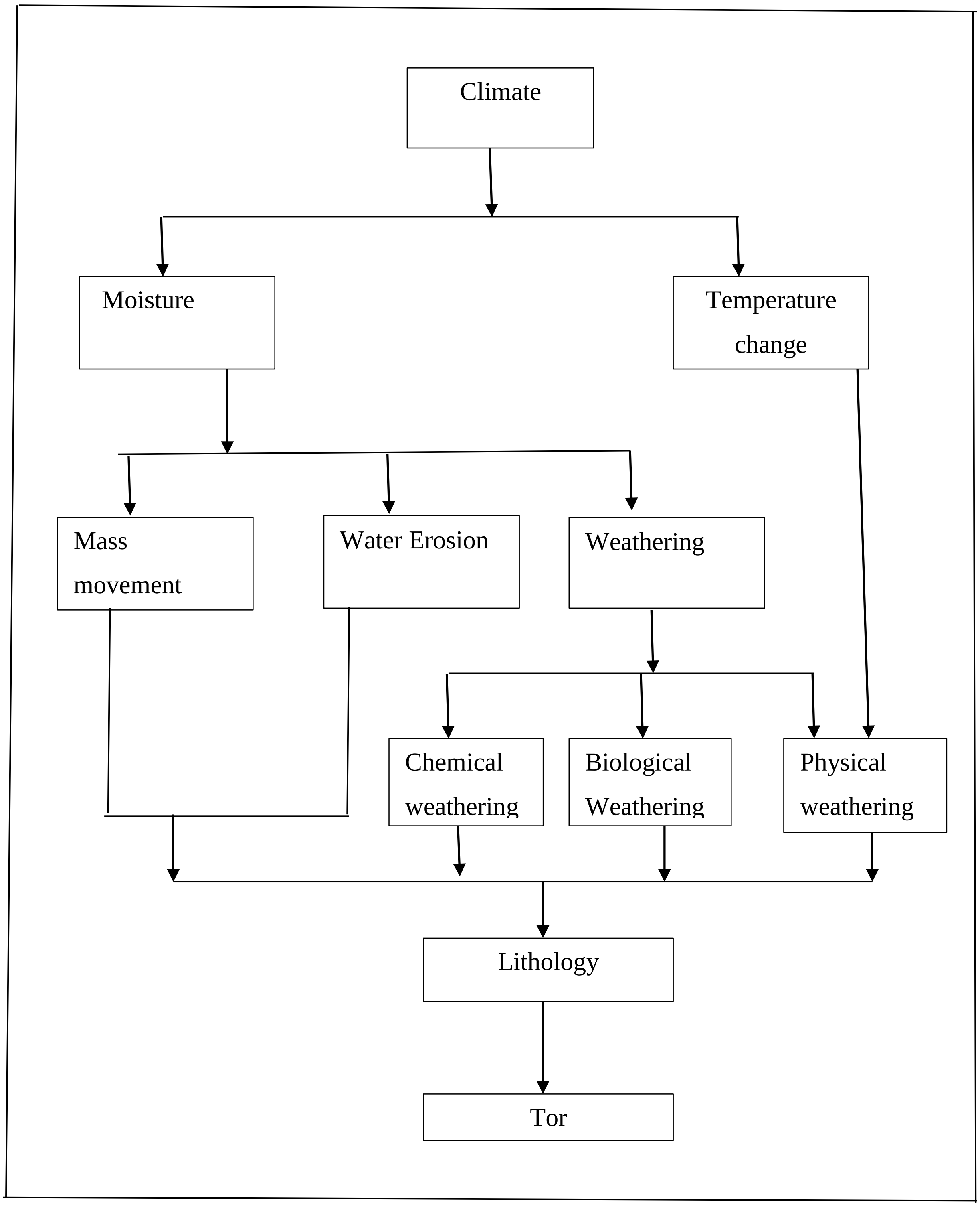
2.4.7. Conceptual Framework of Tor Formation

The conceptual framework provides a basis showing the connection between factors influencing the formation of tors. In (figure2.2), indicates climate as the main driving force. Climate initiates the geomorphic processes through its elements of thermal variation and precipitation. It is being considered as driving force because it’s elements such as rainfall, temperature and their effects on moisture will influence the process of deep chemical weathering on the rock structural components leading to underground decay and disintegration of the top layer of the basement granitic system. This triggers the formation of ground regolith which can be stripped off by surface run off in the process of water erosion and mass movement. The materials then expose the granite content leading to formation of tors, inselbergs, ruwares, kopjes, castle tors and other related landforms.

Seasonal thermal variation can also lead to the formation of tors especially when thawing process occurs in the temperate areas as proposed by Linton. A wide diurnal temperatures range of the day can also cause the stress in the rocks leading to the process of exfoliation, process of mechanical or physical weathering leading to exposer of tors in the tropical regions. The presence moisture in environment can also influence the growth of plants on tor surfaces when this occurs the roots will penetrate into the cracks leading to their expansion and eventual disintegration.

The weathering process lead to formation of tors in areas where trees are more common. Barrowing animals can also initiate the process of physical breakdown of soil as this will influence weathering leaving the soil loose for the agents of erosion once this happen the loose surface soil will be removed exposing the tors .Water erosion which is a product of surface runoff may lead to removal of surface debris when wearing occurs in the area thus leading to formation of the tor of. Mass movement as a process aided by the availability of moisture also causes tor formation especially when the tors are exposed by either a sudden or slow process of mass movement.

Figure2.1: Conceptual framework of Tor Formation



Source: Author (2019)

CHAPTER THREE

THE STUDY AREA

3.1 Location and Size

Seme East is located is located in Kisumu County within longitude 34^0, 30 minutes and 34^045 minutes and latitude0015, 0^0,05^0s.The area is bordered to the south by Lake Victoria and Kendu Bay on the Southwestern side of Kisumu west sub county, Siaya county to the West Vihiga county to the North west (map 3.1). The scope of this study covered; Kaila, Kit-Mikayi and Kakello approximate area of 7556ha.

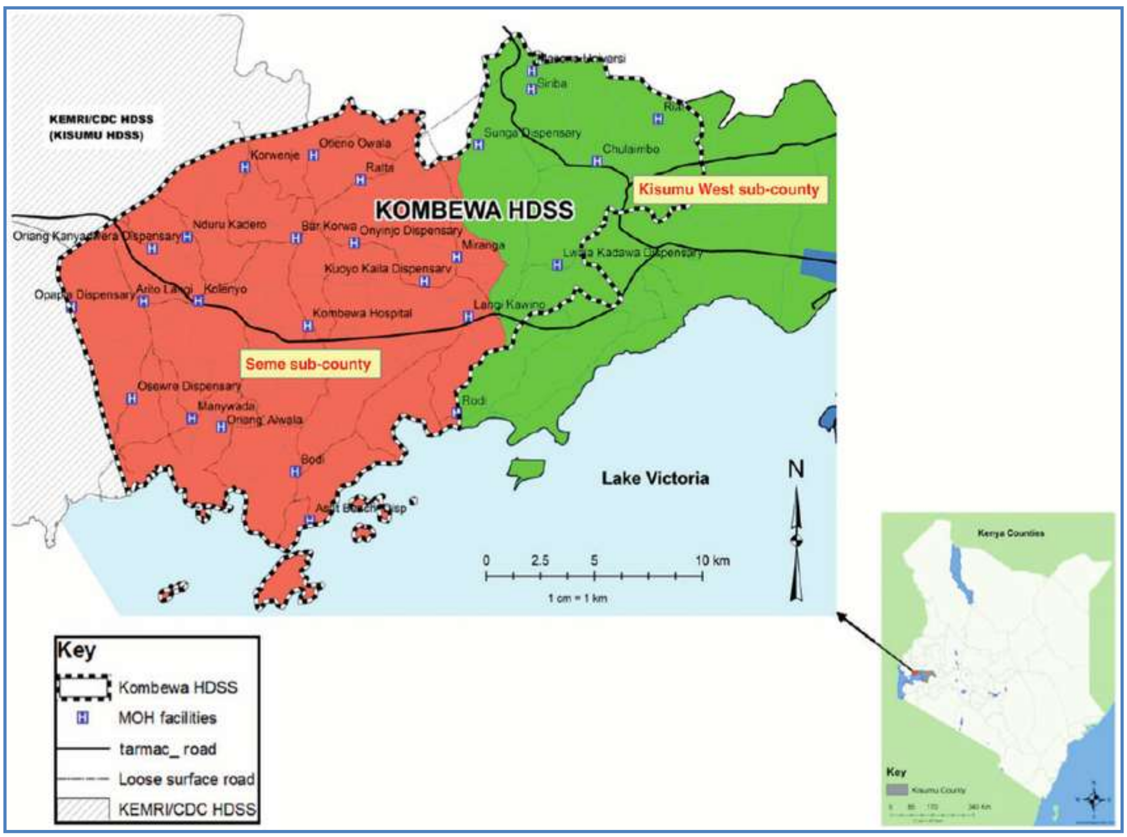
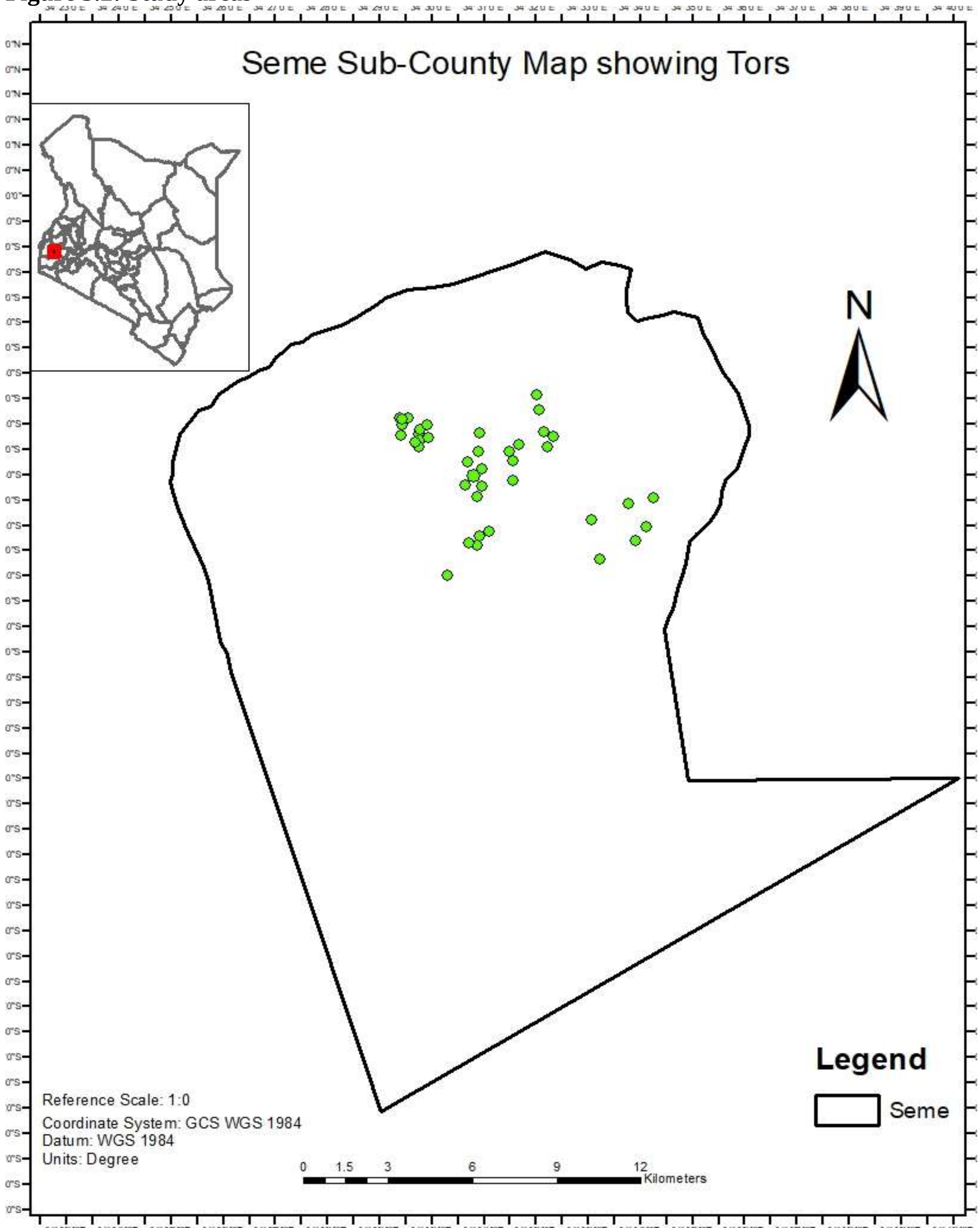


Figure 3.1: The location of Seme

Source: (The independent electoral boundary commission,2007)

Figure 3.2: Study areas



Source (Researcher, 2019)

3.2. Geology and Soils

Seme area covers part of the eastern flank of the Seme fault line. Its geology is dominated by widespread granite majorly in the Kit-Mikayi and Kaila Sub-locations which are believed to have occurred during the activity of the Cainozoic age Lavas and other pyroclastics which cover nearly the entire area (the geology map fig 3.3).The andesine, trichyte and phonolytes overlie a foundation of folded and metamorphosed Precambrian rock of Nyanzian and the Kavirondian belt. Gneise and Magmatte deposits found in Kit-Mikayi and parts of Kakello are of Pleistocene and Recent Age.(Saggerson, 1953).

The rock beneath East Seme and the Maseno forests is the Kavirondian basement system is porous and more permeable and is more suitable in allowing water to the downward horizons to facilitate leaching process which is a key form of chemical weathering process. This series is composed of sandy sediments, gravel or pebble beds, tuffs and pyroclastic sediments. In Ogal area stream deposits occur. The Lake bed deposits are characterized by course, intermediate igneous near the Kaloka beach to the Othany dam sand Saggerson,(1953). A section of the Kaila area is covered by granite and trachytes, (UNEP, 2003).

Soils in Seme are also well drained, moderately deep to very deep dark brown and to yellow brown friable clay over petrolithic. There is also shallow brown to dark brown, friable sandy clay with loam petrolinth above 30% ironstone. Along the Kit-Mikayi area towards of Othany are found alluvial clays and swamp soils in nature. Areas underlain by ironstone soils with lithosols, the soils are gravely whose clay content ranges from 60 % to 70%. Areas underlain by vertisols and verticgleysols the soil is composed of cracking clay, dark brown to very dark grayish brown, are mottled, firm to very firm, deep to very deep and poorly drained (Kenya Soil Survey,2013).

From East Kombewa towards the Lake. Victoria to some parts of Kaila sub location, the main top soil formation is the orthicferralsols, partly petroferric phase with orthicacrisols. The soils are boulder and stony with some places especially in the slopes having cracking clay dark grey to black in colour, firm to very firm, very deep and imperfectly drained. Soil characteristics influence infiltration capacity of rainwater, soil water storage and ground water recharge through percolation into the aquifers which consequently becomes baseline of ground moisture for the process of deep chemical weathering and ground runoff initiating water erosion. In the opinion of (Nyangaga,2010) infiltration capacity of rainwater relies on the classification was based on rate of infiltration and soil permeability he grouped them in (A, B, C, and D)

Group A Soils: These have high infiltration at the rate of > 0.78 cm/hr when wet. These soils have low runoff. Soils in this group are Sand, loamy sand or sandy loam.

Group B Soils: These soils have moderate infiltration at a rate of 0.43 to 0.82 cm/hr when wet. They have moderate runoff. Soils in this group are silt loam or loam.

Group C Soils**:** Have low infiltration at a rate of 0.14 to 0.40 cm /hr when wet. They have moderate to low runoff. Soil in this group is sandy clay loam.
Group D Soils: have very low infiltration at a rate of 0 to 0.12 cm/hr when wet. They generate high runoff. Such soils are clay loam, silt clay loam, sandy clay, silt clay, or clay (Table1.1).

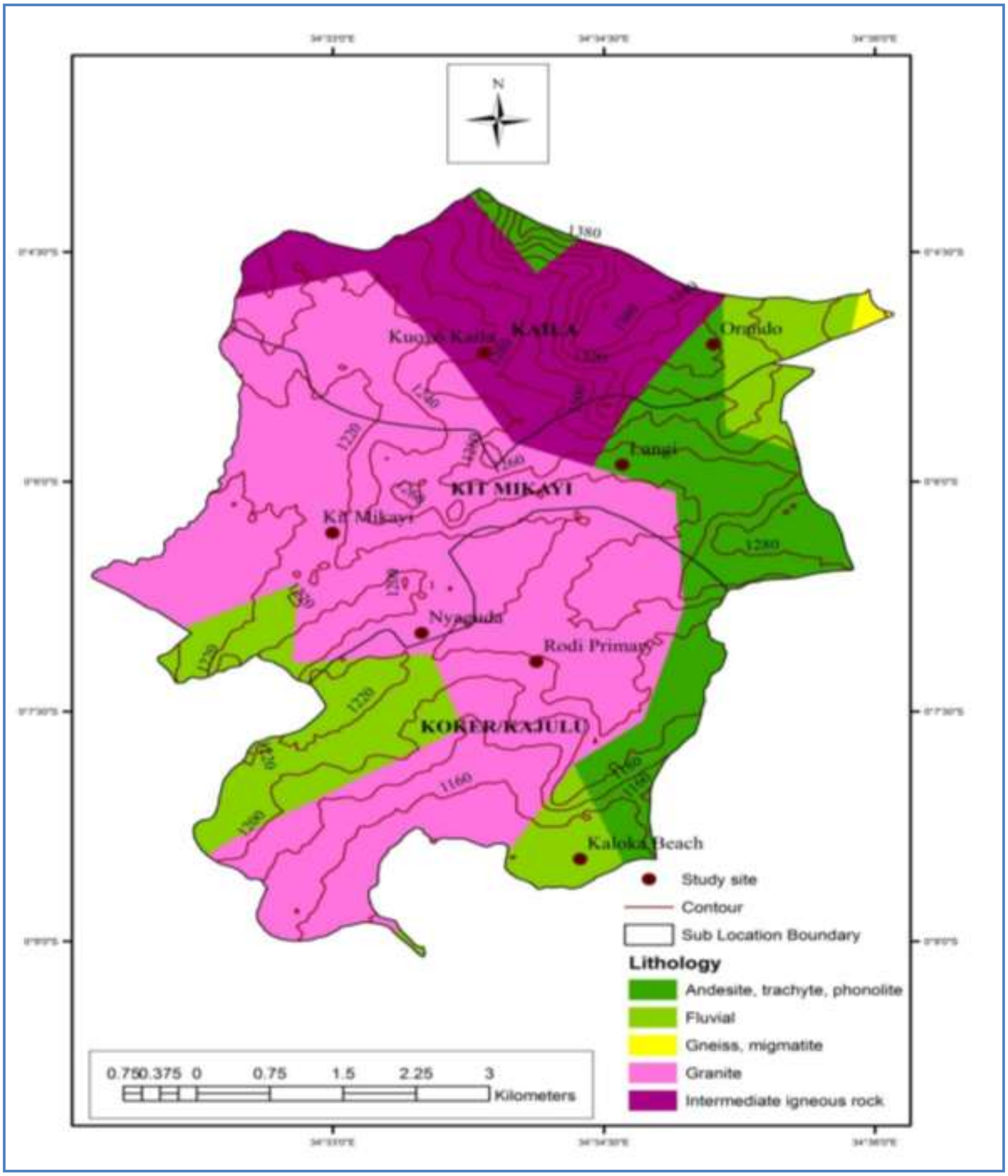
Table 3.1: Basic Infiltration rates for various soils

Soil Type	**Range of Basic Infiltration Rate (mm/hr)**
Sand	>32
Sandy Loam	25 to 35
Loam	15 to 25
Clay Loam	10 to 15
Clay	5 to 10

Source: (Nyangaga, 2010)

Figure 3.3: Geology of Seme

Source : Researcher (2018)



3.3 Topography

The rugged and undulating hills and valleys mostly consist of numerous rock outcrops of granitic origin are found within the area of study. There are also granitic elevations of volcanic origin especially the Orando hills and Akonya hills in East Kombewa where the tors occur. The Lake Victoria low altitudes runs from Kaloka beach to Nanga beach and extend to Ogal beach where it borders Kisumu West Constituency in this region the low altitude and stream valleys allows continuous and seasonal depositions of sediments which is believed to be originating from the high altitudes of the tor's regions. Plains, valleys and occasional volcanic hills residuals which ranges from an altitude of 800 meters above sea level from the Lake Victoria to 1800 meters above sea level in Meseno at the slopes of Maragoli Hills. It is made up of undulating topography giving rise to plateau, scarps and structural hills. This kind of terrain encourages the geomorphic process like weathering, erosion and mass movement as slope is known to be influencing denudational process.

3.4Climate

The climate of the Northern region of Seme (Rata) is modified equatorial that is experienced in the Maseno region and the Maragoli hills. Seme–Sub County rainfall amount ranges from as low as 800mm in the lake altitude of 1100m basin to as high as 1950mm in the slopes of Maseno 1700m. Seme Sub-County specifically receives an average annual rainfall of 1600mm annually (United Nations Environment Programme (UNEP), 2003). The rainfall distribution varies gradually from south to north between March and May while the short rains occur in September to November. During the short rains the average annual rainfall ranges between 450mm and 600mm. Rainfall data from the Kenya Meteorological Department indicates that the county largely receives substantial rainfall.

Maseno has a mean annual rainfall of1630mm, Kisumu 1,280 mm (FAO, CLIMWATE 2011). The areas neighboring Lake Victoria like the lower Kit-Mikayi near Othany, Kaloka and Ogal beach receive very light showers from the lake but generally the area is currently considered to be an area due to the lake influence. The rainfall pattern in the location plays a key role in influencing the rate of geomorphic process that is weathering, mass movement and water erosion, the process are key in influencing the process of rock decay for instance the process of leaching will initiate the rooting process in rock then the process of erosion and mass movement sets in and eventually the surface of the granite rocks will be exposed to the surface as tors.

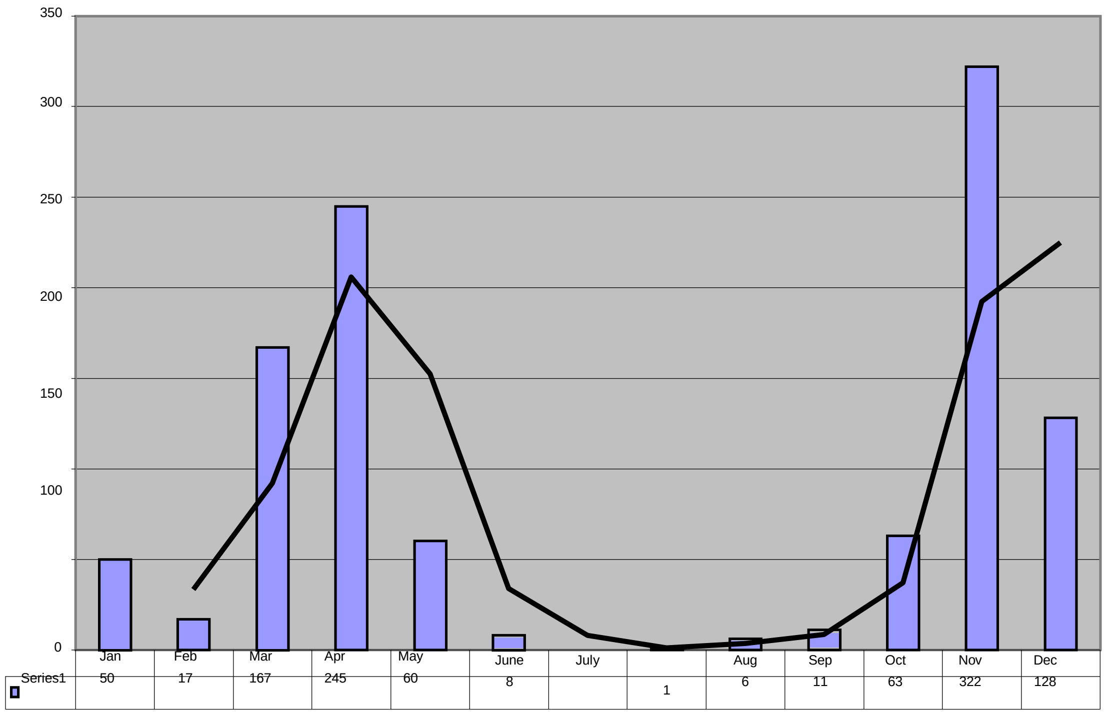
Table 3.2: Climatic Data for Kisumu Station within the Catchment

Station: Seme-Kisumu			Altitude:	1498 m		**Position:**1.30 S, 36.75 E		
Month	Min Temp[°C]	Max Temp [°C]	Humidity [%]	Wind [km/day]	Sun [hours]	Rad [MJ/m²/day]	ETo[mm/day]	Rain [mm]
January	12.5	23.4	69	200	8.1	23	3.54	48.3
February	11.5	24.3	65	210	9.8	22.5	5.97	4.8
March	9.1	27.0	68	198	8.4	24	3.8	92.2
April	10.4	23	71	166	6	20.5	3.3	241.1
May	8.1	24.6	76	112	6.8	18.2	3.21	187.3
June	11	22.5	70	98	5.8	15.4	2.02	37.5
July	8.6	20	72	90	3.4	14.8	2	16.5
August	7.4	23.6	66	110	4.3	15.7	2.81	25
September	8.7	26	69	132	5.8	17.8	4.4	30.1
October	13.4	26.1	65	168	8.8	21	4.5	61.4
November	13.6	25	73	192	6.6	18.6	3.8	148.4
December	10.72	23.5	74	189	7	19.8	3.1	105.6
Average	11.9	25.3	72	161	7.2	19.3	3.93	89.46
Totals								1061.5

Source: FAO, CLIMWATE Database

Figure2.5: Rainfall Regime at East Seme Agr. Office (9138000Altitude 1400M) for 67 Years up to1986

(Source: Maseno Agricultural Office, 1986)



3.5. Hydrological Characteristics

The hydrology of Seme consist of both permanent and seasonal rivers and streams namely including River Magada Rata and River Awach with their origin from Maseno and Maragoli spring system. Some minor streams also originate form Orando hills and Maseno escarpments where tor are spatially located. The flow of the river is mainly sub-surface through the Forest for a considerable distance. Runoff is slow due to the undulating nature of its water head. Discharge of the river varies from one point to another along its course (UNEP, 2003). There is an assumption that the presence of black cotton soil in the area neighboring Lake. Victoria encourages the high siltation in the region sandy soils derived from volcanic activities result into good infiltration.

Most streams that flows from Maseno escarpments have their sources form Maragoli hills where there are several springs in Vihiga County 1,850and drains into the plains of Kaila and Kakello area. Other streams that flow into the slopes from the hilly include Ndiru also from Maseno and Apindo from Lunga springs. Numerous natural springs also contribute significant quantities of water into the plians where pundo swamp is situated this helps in creating the process of erosion and during high rainfall peak will influence rateof runoff thus promoting erosion thus exposing old bedding plains. Man-made dams namely: Othany and Kadongo dams, have been constructed along the Awach valley to detain surface flow.

3.6. Socio-Economic Activities

The area of study has numerous tourist attractions including diversity of landscapes, wildlife, culture and the many historical sites and suitable beaches like Kaloka, Ogal along Lake Victoria provide enormous potential for tourism growth in the region. The Ndere Island National Park in Seme Sub-county, Kit-Mikayi and others which have not been documented as documents monument, recreational sailing and sport fishing on Lake Victoria provide attractive sites.

Fishing is the main economic activity for the people who live near the lake, the fishing is mainly done for substance and also cash when in surplus to generate income for the native. Seme Sub County is endowed with a wide range of minerals such as soda ash, fluorspar, limestone, barite, gypsum, salt, dimension stone, silica sand, soapstone, manganese, copper, zinc, titanium, lead, nickel, chromite, pyrite, rare earth elements and pyrochlore. Most of these minerals still remain unexploited due to inadequate knowledge on their status, economic viability and appropriate mining technologies however mining is being practiced in small scale in upland region of North Kaila towards Maseno .There is subsistence agriculture being practiced in Seme Sub County which include growing the cereals like maize and millet in area of Kakello, Kit-Mikayi and Kaila. In Kaila sub location legume crops dominates like groundnuts and beans are being produce for both cash and subsistence consumption.

3.7Vegetation and land use land cover

The area is covered by mixture of vegetation ranging from grass and shrubs at the lake region to forest land in the Maseno region in the sub locations of Kit-Mikayi, Kaila and Kakello where tors are located the area has mostly fig trees and guava trees that mostly grow in the cracks aiding the biological weathering process. Land use in Seme area has changed due to the expansion of human settlement and urbanization since the early 1900s (UNEP, 2001).

The increase Human population from 100,000 in 1975 total most 200,000 in 1999 has resulted in there reduction of vegetation cover land (HABITAT, 2002). The greatest expansion of human settlement area was recorded between the years 1985 and 2005 (Tibaijuka, 2007). Various activities such as dam construction, vegetable farming and urbanization and urban farming are undertaken in the area such as in Kombewa, Hollo,Ngere, Maseno and Obambo area. The presence of thick vegetation within the area of study in an indication of high infiltration as these plant cover tends to reduce the rate of ran off thus encouraging initiating the process of erosion. The plant cover also encourages infiltration thus causing the leaching process which influence chemical weathering when water washed mineral as it percolates in the lower horizons thus causing chemical reactions leading to underground decomposition and disintegration of rocks which when washed away during erosion will pave way for bedrock exposure as ator.

3.8. Population

The population of the county according to the 2009 Population and Housing Census estimated at 968,909 persons with 474,687 males and 494,222 females. The map below shows population distribution of the Seme region, Population by age groups as at 2009 and projections for 2015 and 2017.Based on the Kenya national bureau of statistics projection of 2013, Seme has a population of 98,634 persons with children, males and females combined. The constant and rapidly increasing population in Seme has created a great impact in the tor's location. Due to the demand of land the native has converted the areas where tors are located into farms and this further leads to disintegration of rocks into fragments and pebbles this affect the sizes and shapes of tors.

Table 3.3: Population of Seme (1962-2009)

Year	**Area (hectares)**	**Population**	**% increase in population**	**Density (persons/ha)**
1962	75,945	136,795	121.5	5
1969	75,945	199,286	80.1	8
1979	75,945	287,775	61.4	11
1989	75,945	324,570	71.3	18
1999	75,945	443,254	62.4	33
2009	75,945	568,909	54.6	48

Source: (K.N.B.S2009), Table 1 and Government of Kenya, (2010).

CHAPTER FOUR
METHODOLOGY

4.1 Study Design

The study basically relied on non-probability sampling technique where the samples are gathered in a process that do not give all the individuals in the population equal chances of being selected this is attributed to the spatial occurrence and distribution of the tor. The physical identification was guided by the objectives of the study where the researcher considered tor heights, diameter lengths of cracks and the number of boulders present near each tor from all the three location thus giving fair representation of each Sub-location. This was particularly useful for determining the relationship between weathering, mass movement and water erosion as factors responsible for tor formation and their spatial distribution.

4.2 Data Types and Sources

The source of data for the study was mainly primary data which was collected directly from the area of study. The primary data was obtained by measuring tor heights, lengths of cracks in the tors, diameters of the tors and boulders, physical counting of a number of boulders in which photography was also used. Terrain data was obtained through a GPS receiver. Data on weathering and mass movement was obtained on inventory of landforms developed during the period when pre-visit was conducted. Data on water erosion was obtained through the observation of processes of erosion and measurements of the gullies. More data on soil erosion was on what the natives were doing with the aim of reducing soil erosion. Additional data was also by interviewing the residents. The data collected was adequate for analysis.

4.3. Pilot Survey

A preliminary survey was conducted to enable the research team to get to learn the potential threats and challenges expected during the actual field activities in the study area and also to meet the administrative officers of area. The team also identified tors that were used to form the sample size to meet the target population in order to establish the needs and expectations of the study. The visit enabled the better revision of objectives, research questions and hypothesis. The survey also helped in the assemblage of tools and equipment's which were used to meet the research objectives and hypotheses. The visit was not without challenges, to mention but a few language barrier, improper roads and paths that led to thickets and steep slopes to where the tors were located. An induction training session was carried out for a period of three days due to limited time to enable the team to familiarize themselves with the type of study that was done. The sampling frame included all tors of height of 4m and above and diameter of 7m. This was helpful in determining the rate of action of geomorphic processes. The cracks of approximately 0.5m was considered as these would represent a population that had with stand several geomorphic cycles and could therefore give a clear evidence of erosion, mass movement and weathering of tors which occurred randomly in the study area. These cracks also were to ensure that the sample had adequate proportion of tors that met the criteria of research. Using a GPS, all the spatially identified tors were located and the coordinates recorded based on altitude. The administrative boundaries including Kaila, Kakello, and Kit-Mikayi were used as the basic frame and unit.40 tors were selected.

4.3.1 Data Collection

4.3.2 Target Population

The sample size included spatially identified tors in three administrative regions; Kaila, Kakello and Kit-Mikayi from which, a total number of (40) tors were sampled randomly based on the three objectives of study and their GPS locations recorded .The study involved measuring and estimation of Tor heights, Diameter, Crevices all in (m), Counting the number of boulders gathered around the Tor and the various Tor shapes.

All tors within the study area of the three sub locations were initially considered due to their spatial occurrence and distribution within the area of study but much focus was on tors that were 4metres high and above , 7 meters in diameter and at the same time had cracks of 2mm and above as they could help in addressing the study objectives which included establishing the role of water erosion in the development of tors, accounting for the role of weathering in the development of tors and determining the relationship between mass movement. The specific tor height diameter and cracks lengths measurements were taken using a tape measure and a string and recorded in an excel spread sheet, coded and analyzed.

4.3.3. Data Collection Instruments

To collect the data different tools including, notebooks, digital camera, meter rule protractors, string, notebooks

Digital camera was helpful when capturing the images and videos during the study as well as data recording. This could enable the researcher in fulfilling the demands of the objective of water erosion, weathering and mass movement.

Plate 1: Digital camera

The Global Positioning System (G.P.S) receiverwas used to determine the coordinates of the tors under investigation. This was also helpful in determining the spatial distribution of tors within the study area as this could reveal the extent of geomorphic process which were under investigation and their influence on tor formation and in obtaining Terrain data was obtained through measurements using GPS receivers.

Plate 2: Global Positioning System Receiver

The protractor was useful when measuringthe angelof cracksto determining the cracks extents as this was used in addressing the objective of physical weathering.

Plate 3: Protractor

A biro pen and piece of stick of length 15cm were also used in determining the length and extent of cracks as it could give a standard measurement and more accurate lengths being that its length could be easily established.

Biro Pen Standard piece of stick

Plate 4: Biro Pen and standard stick

The string was used in measuring the heights and the diameters of the tors after which the string lengths were computed using the tape measure which was also necessary in determining the rate of erosion and mass movement.

The internet helped in obtaining secondary weather data of thermal variability and rainfall. Thiswas useful in establishing the various objectives of study like the temperature change leading to various processes of weathering and also to establish the amount of sediments that might have been displaced down slope.

4.3.4. Sampling Procedure

During the process of preparation for the actual study the research team carried out aprevisit twice in the area of study with an aim of obtaining the suitability of all the study tools and objectives satisfaction. This enabled the team in establishing contact with the relevant bodies and authorities like the administrative, and natives who had lived in the area for enough period which could be useful in provision of relevant knowledge on tors. Relevant secondary information was obtained from the past literature sources of tors occurrence and distribution. The study employed non probability sampling procedure to acquire the necessary data. At the onset of the study the area was first marked and subdivided as per the administrative units where each unit was treated as a stratum. In each sub location or stratum tors were identified randomly and marked for study. The data was collected using measurement, estimation of tor heights counting number of boulders near the tors and measurement of lengths and depths of cracks.

4.3.5 Measurement of the Gully Depth, Width and Length

During data collection regarding the role of water erosion as per the first objective of the study on tor formation the research team was able to identify areas where erosion process was pronounced in each sub-location for instance in Kaila sub location the team observed that gully erosion seemed to be more pronounced than any other types of erosion which was facilitated majorly by the surface run off and the change of land use activities. The width and depth of the gullies were measured and recorded, in all areas where the tors were spatially identified. The measurement was done using the string and meter rule. The string was stretched from the banks of the gullies and then the lengths of the string were measured using a meter rule and recorded in meters. To determine the depth of the gullies the string was tied in each bank of the gully and then readings taken using meter rule. The procedure was then repeated in all the three sub-locations of Kaila, Kit-Mikayi and Kakello sub locations. Sheet erosion was recorded using digital camera and images later transferred. The sediments were deposited in sequential pattern at the foot of the tors where the team observed that the heavy deposits of the sediments were near the slope whereas those sediments that seemed lighter were deposited a far off the slope.

The boulders in the gullies were also identified and counted physically, their diameters measured in meters and recorded. The team also observed and recorded the shape and sizes of the boulders in the area. The distance of the boulders from the tors under investigation were also determined in meters as this was important in determining and establishing the impact of transportation by the agent of erosion especially water erosion in the area of study in all the three sub locations.

Boulders rolled due to mass movement in a valley

Plate 5: Measurement of death, width and lengths of gullies

Plate 6: Measurement depth of gully

4.3.6 Measurement of the Tor Height

The estimation of tor height involved first the random identification of tors using a global positioning system (G.P.S).with the use of a string, tors of approximate height of 4m and above were selected randomly since they were visible from a distance and could as well be captured through photo imagery for spatial mapping. most tors were found to be of an average height of 5 to 25 m high as shown in the later pages The team also observed and recorded the coloration of the tors where they were trying to establish the more dominant type of colour and the impact of water in the coloration. The shapes and surface texture of the tors were also observed and recorded as this was important in establishing the time frame of which the process of weathering might have occurred.

4.3.7 Measurement of widths of Cracks in the tors

Cracks are small and medium spaces that have been created in the tors as a result of different weathering processes. Cracks on tors show the degree and intensity of products of weathering as influenced by temperature changes, plants and animals and chemical reactions with tors. By use of a pen and a stick whose lengths added up to 15cm, the lengths of the cracks were obtained as the meter rule could not provide very accurate measurement in some cases a digital camera was used to capture the image then serialized and stored.

In cases of biological weathering process which is basically aided by plants growing on top of tors and roots penetrating into the cracks a digital camera was used. This procedure was repeated in all the three sub locations of the study which was Kaila, Kakello and Kit-Mikayi.

(a) **(b)**

Plate 7: Measuring the widths of cracks

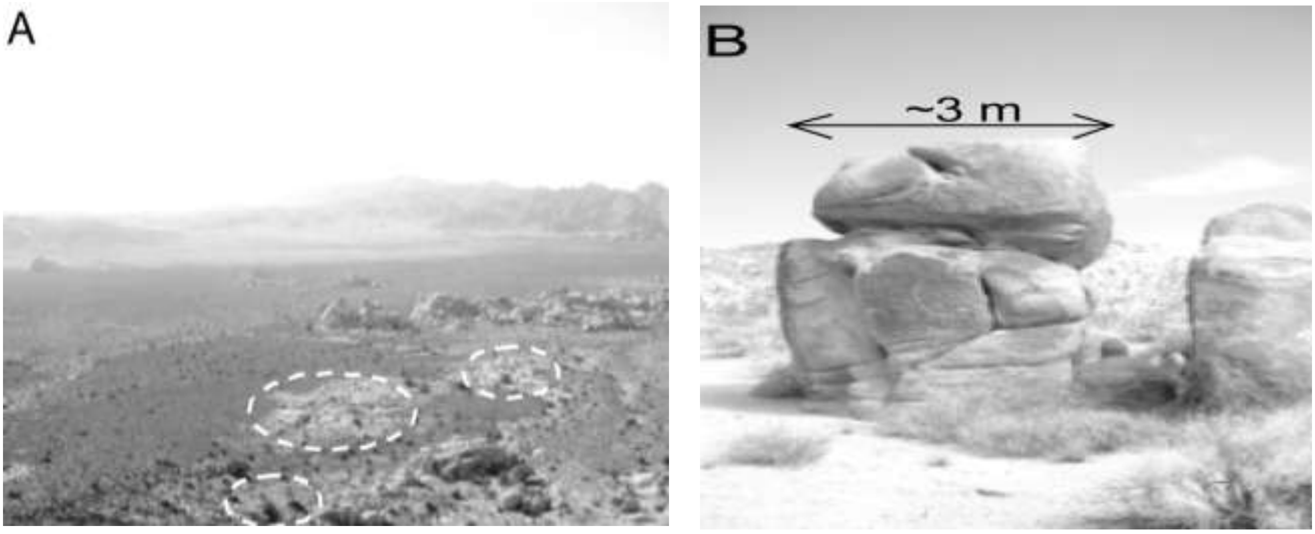
The angles of the cracks were obtained using a protractor. This was necessary in determining the extent and level of process of weathering within the area of which conforms to the third objective which was aimed at determining the rate of weathering and its relevance in tor formation, geometrical fittingwas also used which involved piecing together 3D surfaces of component to establish the commonness of once existing structure. This was done by collection and estimation of the rock fragments and fitting them with the main rock surfaces where they might have split due to different processes, this was done using the measurement of the angles and shapes as well as structural similarities of the pieces of fragments in relation to the main rocks.

Plate 7: Measurement of angles of cracks

Source: Researcher (2019)

4.3.8. Measurement of Tor Diameters

Diameter is the distance across the tor's circumference. Tor diameter was important in estimating the amount of soil and rock fragments gathered around the tor as a result of mass movement. The estimation of tor diameter involved first spatial and random tors location using a global positioning system (G.P.S). The diameters of the tors identified were approximately 7m. The Diameter was estimated by circumnavigating a string round the specific tor then using a ruler to measure the distance covered by the string in m and then recording in a pre-determined excel table this was later transferred to SPSS for analysis. The number of boulders near the tor were also counted physically and recorded to help in establishing the rate of mass movement in the three sub-locations in seme sub-county



Source : Researcher (2019)

Plate 8: Measurement of tor diameter

4.4. Data Processing and Analysis

4.4.1. Data Processing

The data collected from the field was compiled and then merged into a common code book which was generated. The information was then transferred into a digital file and SPSS software. The file generated was edited and revised of errors and where there were omissions the data was used for filling in. In some cases, a frequency distribution table was used in the identification of outliers and missing entries in the database.

4.4.2Data analysis

After the data was processed, filed and compiled preliminary analysis were then undertaken where all variables and indicators were determined, this was necessary in attaining measures of central tendencies and possibly dispersion which were to establish the most accurate method of determining sample data and the appropriate inferential methods to be used in measuring the extents, differences and associations on research variables of interests. Correlation analysis was also used to examine the relationship between the variables used as shown in formula 1. The frequency results were then tested for significance to show whether the observed occurrence was chance event or a significant event in the tor formation in Seme Sub County. A regression analysis was also done to establish how these variables had influence on each other. The statistical tool employed was correlation and reggration analysis and the formula below was used for calculations.

Formula …………..(i)

$$r = \frac{N\sum xy-(\sum x)(\sum y)}{\sqrt{[N\sum x^2-(x)^2][N\sum y^2-(\sum y)^2]}}$$

Formula ………….. (ii)

$$y=a+bx$$

$$b== \frac{N\sum xy-(\sum x)(\sum y)}{N\sum x^2-(x)^2}$$

The expected observations were later subjected to an analysis through various calculations which included single variables by the procedure of row times column total divided by the total observations in the test of independent and the row proportions divided by the column totals in the single variable contingency.

The factors that were correlated included tor height, or diameter, lengths of cracks in the tors, number of boulders and their distance from the tor , the valley characteristics for example the volume of debris that were eroded, gully depth, width and lengths .

The test in all cases were at α 0.05 = 95% level of confidence

CHAPTER FIVE
RESULTS AND DISCUSSIONS

5.1 Introduction

This chapter is concerned with the discussion of assessment of results of geomorphic processes on tor formation based on specific objectives of the study; it also describes the statistical nature of the results obtained.

5.2 Distribution Tendencies of tors

The data on tors distribution was subjected to descriptive statistical analyses as exploratory measure to reveal the distribution tendencies. The summary statistics (the mean, standard deviation (SD), minimum, maximum, median, skewness, kurtosis are given in table 5.1. they have been used to describe the basic features of the data in the study areas. they provide simple summaries about the sample and the measures to allow simple interpretation of the data.

Table 5.1 : Summary statistics of Diameter, Height and Cracks in (m)

		Diameter(m)	Height(m)	Cracks(m)
N	Valid	40	40	40
Mean		31.4146	18.8293	.6129
Std. Error of Mean		2.97612	1.88961	.14514
Median		28.0000	16.0000	.4100
Mode		30.00	15.00	.20[a]
Std. Deviation		19.05646	12.09939	.92932
Variance		363.149	146.395	.864
Skewness		2.603	2.448	5.343
Std.ErrorofSkewness		.369	.369	.369
Kurtosis		8.927	7.852	30.983
Std.ErrorofKurtosis		.724	.724	.724
Sum		1288.00	772.00	25.13
a. Multiple modes exist. The smallest value is shown				

The mean of the tor height tor diameter and the cracks were 31.41,18.82 and o.61 respectively. There was a high variance in the diameter of the tors as compared to the height and the cracks indicating high rates of erosion as mentioned in Ehlens (1999,2004)work on tors in Mojave province in California. The maximum diameter of the tor was given as 115 as the minimum was 13,the results gave the highest of the tors to be 70m and the minimum 6m this is attributed to the difference in modes of formation and time frame .as depicted in the work (Ojany and Ogendo 1973).

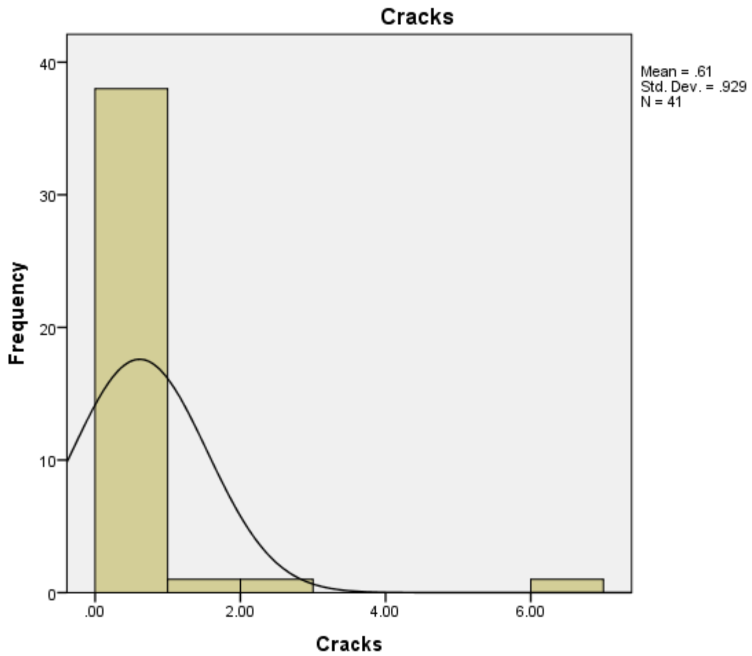
5.3. Determining the Role of Weathering in Tor Formation.

Another objective of the study was to establish the role of weathering in the formation of tors. This study collected data on the indicators of weathering which included widths of cracks, tor height, colour and surface texture. The pronounced type of weathering within the study areas was physical weathering, however there was an aspect of chemical weathering which was depicted by multiple coloration in tors as indicated in the (table 5.2) and cracks that were dominant where most tors the level of cracks were so pronounced and wide with most tors having high percentage of 75.8 Tors distribution by cracks and the minimum being 0.0 percent.

Table 5.2: Tor spatial distribution by cracks

Crackswidths(m)	No of tors	Percentage
0.1-0.5	13	75.8
0.6-1.0	26	12.4
1.0-1.5	1	4.9
1.6-2.0	0	0
2.5-3.0	0	0
3.0 above	1	2.4
Total	40	100

Figure 5.1 Tor spartial width by cracks(m)

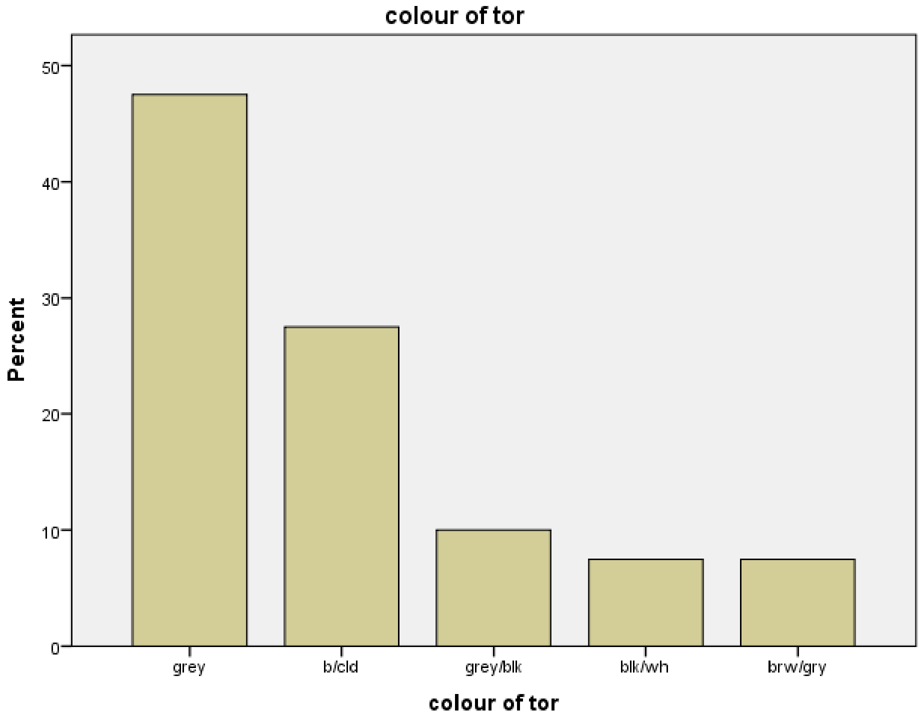


Source: Researcher (2019)

Table 5.3: Tor spartial distribution by colour

Colour of tors	No of tors	Percentage
Grey	19	47.5
Black	11	27.5
Grey strip black	4	10
Black strip white	3	7.5
Brown and grey	3	7.5
Total	40	100

Figure 5.2: Tor spatial distribution by colour



When a correlation analysis was undertaken the relationship between diameter and the cracks within the tor gave a correlation coefficient value r =0.828 with the p value of 0.000 this suggested that there was a relationship between the size of the diameter and the length of the crack which meant that the wider the tor, the larger the crack hence the wider the diameter and so the more periods of geomorphic cycles in particular physical weathering. When the cracks of the tor and the height of the tor were correlated the results revealed that there was no significant relationship between the indicators since the p value was greater than 0.05. This was an indication of wide range of temperature within the regions as earlier stated in the literature review

Table 5.4: Correlations analysis of tor Diameter, Heights and widths of cracks

Tor characteristics		Diameter	Height	Cracks
Diameter	Pearson Correlation	1	.828**	-.010
	Sig. (2-tailed)		.000	.950
	N	41	41	41
Height	Pearson Correlation	.828**	1	-.065
	Sig. (2-tailed)	.000		.685
	N	41	41	41
Cracks	Pearson Correlation	-.010	-.065	1
	Sig. (2-tailed)	.950	.685	
	N	41	41	41

A correlation analysis was done and it was found out that there was a . The weak correlation between the cracks and the diameter of tors, and then a strong correlation was noted between tor diameters and height, whereas the regression analysis showed that diameter had a greater influence in the role of weathering in the tor formation.

Table 5.5: Reggration analysis of Diameters and cracks in tors

Model		Sumof Squares	df	Mean Square	F	Sig.
1	Regression	1.476	1	1.476	.004	.950[b]
	Residual	14524.476	39	372.422		
	Total	14525.951	40			

a. Dependent Variable: Diameter
Predictors: (Constant), Cracks

The regression analysis between cracks and diameter revealed a significant influence which meant that tors that have large diameter have wide and long the crack. The large cracks are attributed to the high rate of weathering process which is associated to high rates of water erosion and weathering as confirmed by (Ollier,1960) in the tropical regions of Central Australian in the Allur bournhurts and (Cummighn,1975) in tropical Mojave Province in the U.S.A. and both suggested action longer period of geomorphic cycles

Table 5.6: Reggration analysis of diameters and cracks

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	31.541	3.624		8.703	.000
	Cracks	-.207	3.283	-.010	-.063	.950

Dependent Variable: Diameter

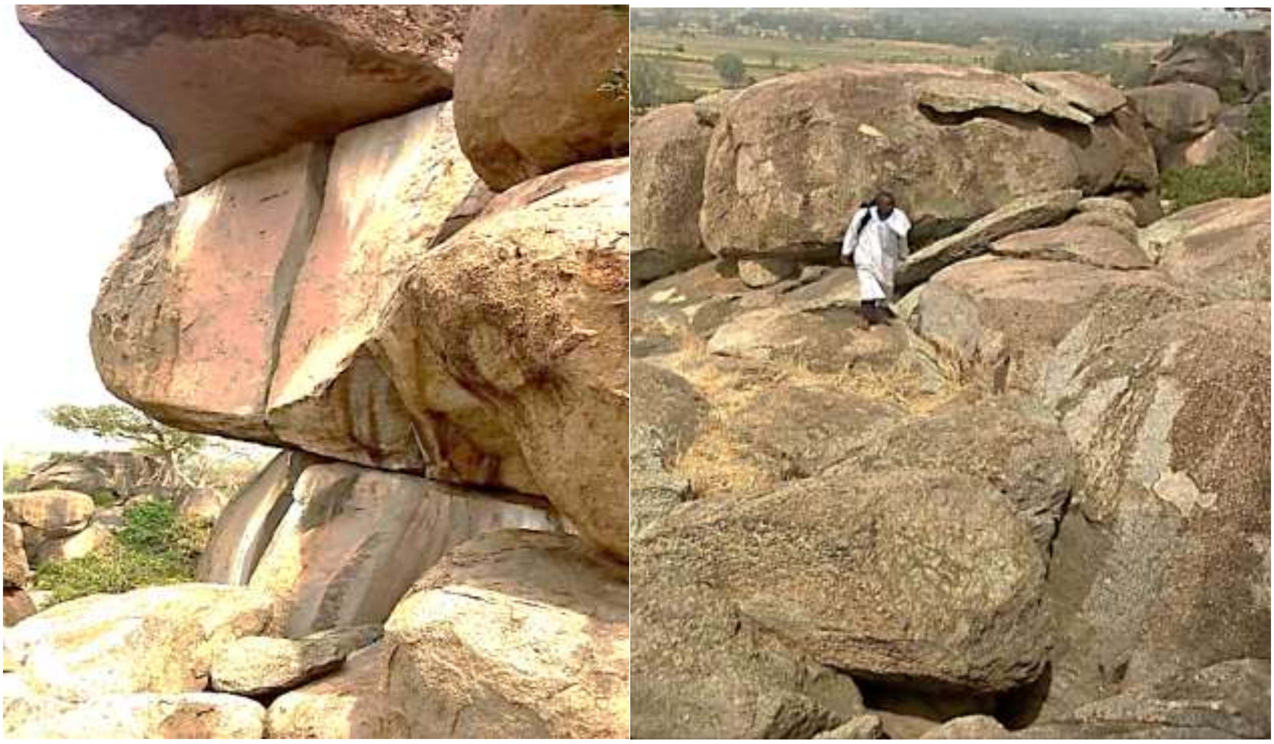
Source: Researcher (2019)

Biological Weathering

Plate 9: Biological Weathering

Source: Researcher (2019)

Mechanical or Physical weathering process



Source: Researcher (2019)

Plate 10: Mechanical or physical weathering process

5.4 Determining the Impact of Water Erosion In tor formation

The first objective of the study was to establish the role of water erosion in determining the rate of tor formation in the area. This was done by observing the rate of soil erosion in the areas under the study where several types of erosion were noted with gully erosion being the most pronounced type and therefore the study considered measuring the lengths widths and depths of gullies. The lengths, widths and depths of the gullies were correlated with the diameter, height and the cracks of the tor and a significant relationship was obtained since the correlation coefficient value r was at 0.916 and the p value was at 0.000, indicating that the p value was less than 0.005. The relationship further revealed that when diameter was correlated against a diameter a perfect correlation occurred whereas diameter against height gave an insignificant correlation it was further noted that diameter against depth was significant and diameter against length was insignificant as indicated in appendix 1.When diameter height and cracks were regressed the results showed that cracks was the least factor in explaining the impact of water erosion in the exposure of tors whereas the height had a higher percentage in explaining the impact of water erosion in the exposure of tors.. The conclusion therefore was the larger the diameter of the tor, the higher the tor the wider the gully, the longer the valley hence the higher the rate of water erosion and the higher the chances of the tor being exposed.

Table 5.7 Correlations analysis between lengths, width and depth of gullies

		GULLIES		COORDINATES		DISTANCE
		width	length	depth	lat	
D	Pearson Correlation	.000	-.021*	.395**	-.031**	-.069
	Sig. (2-tailed)	.998	.901	.012	.850	.674
	N	37	37	40	40	40
cr	Pearson Correlation	.123*	.130	.787	-.116**	-.215
	Sig. (2-tailed)	.468	.443	.000	.476	.183
	N	37	37	40	40	40
H	Pearson Correlation	-.003**	-.037	.390	.001*	-.049
	Sig. (2-tailed)	.986	.827	.013	.995	.762
	N	37	37	40	40	40
nb	Pearson Correlation	-.171**	-.139**	.299*	-.042	-.175
	Sig. (2-tailed)	.319	.419	.065	.800	.286
	N	36	36	39	39	39
md_bls	Pearson Correlation	-.014	-.105	.132	.007	.207
	Sig. (2-tailed)	.933	.535	.417	.965	.201
	N	37	37	40	40	40
vol	Pearson Correlation	.638	.432*	.314	-.080	-.083
	Sig. (2-tailed)	.000	.008	.048	.622	.609
	N	37	37	40	40	40
depth	Pearson Correlation	.468*	.344	.217	-.208	-.171
	Sig. (2-tailed)	.003	.037	.196	.217	.311
	N	37	37	37	37	37
width	Pearson Correlation	1	.249	.134	-.036	-.122
	Sig. (2-tailed)		.137	.430	.831	.473
	N	37	37	37	37	37
length	Pearson Correlation	.249	1	.157	.001	-.142
	Sig. (2-tailed)	.137		.353	.997	.401
	N	37	37	37	37	37
long	Pearson Correlation	.134*	.157**	1*	-.076	-.253
	Sig. (2-tailed)	.430	.353		.642	.115
	N	37	37	40	40	40
lat	Pearson Correlation	-.036	.001	-.076	1	.190
	Sig. (2-tailed)	.831	.997	.642		.240
	N	37	37	40	40	40
distance	Pearson Correlation	-.122	-.142	-.253	.190	1
	Sig. (2-tailed)	.473	.401	.115	.240	
	N	37	37	40	40	40

The result of regressing height with cracks showed that there was no notable influence of the height on the crack and likewise cracks on the height as exhibited in the table 5.8

Table 5. 8: Regression analysis of cracks and heights

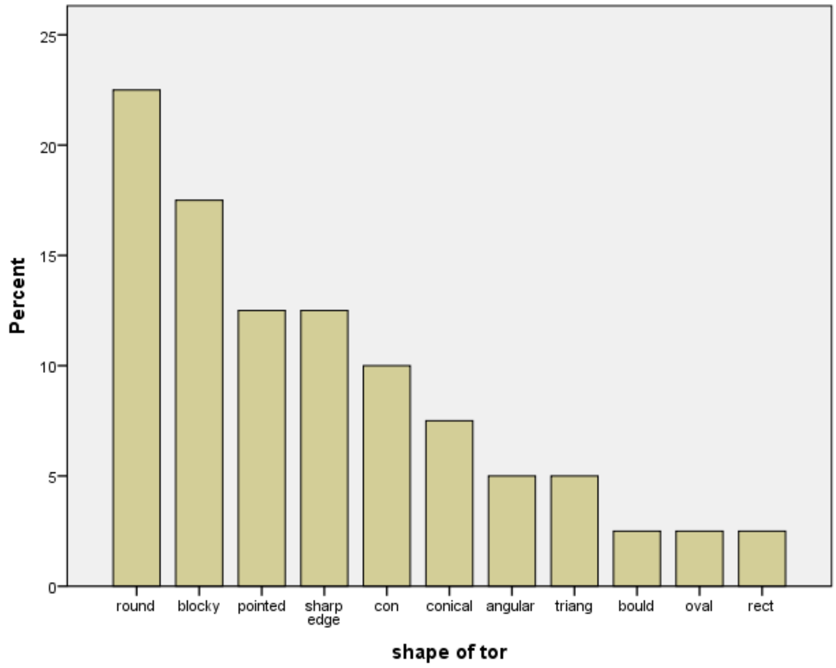
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	.148	1	.148	.168	.685[b]
	Residual	34.398	39	.882		
	Total	34.546	40			

The shapes of the tors were also an important indicator of how erosion influences the formation of tors since erosion is known to wear out the surfaces of tors giving them the current shape. within the study area it was observed that the most common shape was the round shape which had a percentage of 22.5% with the least percentage on the pointed shape as indicated in (table) conical shaped tors was also noticed but with a lesser percentage which is a product of tectonic eruptions as suggested by (Ojany and Ogendo,1973)

Table 5.9 Tor spartial distribution by shape

Shape of tors	**No of tors**	**Percentage**
Round	9	22.5
Blocky	7	17.5
Pointed	5	12.5
Sharp edge	5	12.5
Conical	4	10.5
Angular	3	7.5
Triangular	2	5.0
Bould	2	5.0
Oval	1	2.5
Rectangular	1	2.5
Total	**40**	**100.0**

Figure 5.3 Tor spartial distribution by shape



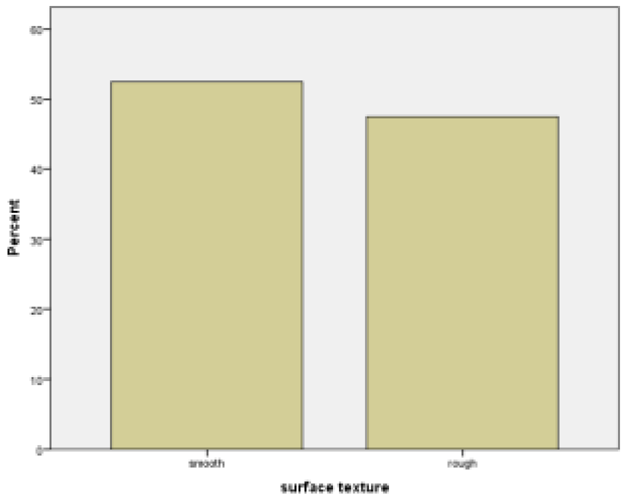
Source: Researcher (2019)

Table 6.0: Tor distribution by texture

Tors shape	No of tors	Percentages
Smooth	21	52.5
Rough	19	47.5
Total	**40**	**100**

Source: Researcher (2019)

Figure 5.4: Tor distribution by texture



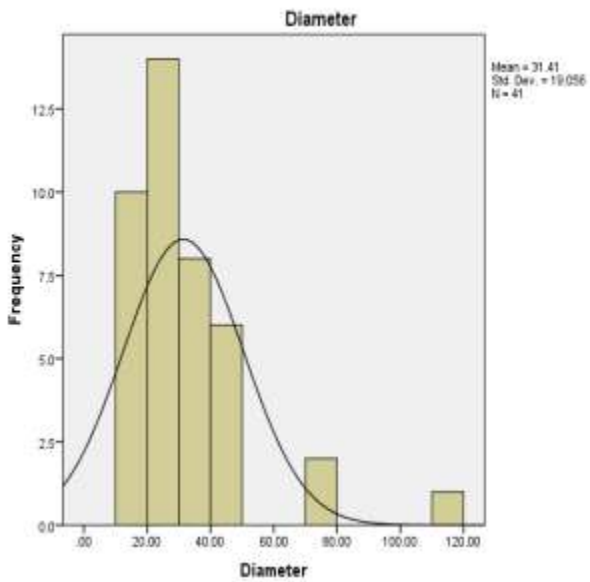
Source: Researcher (2019)

The tor diameters were also observed as being large medium or small. The tors with medium diameters were the least the least at 0 percent and with wide diameter at 26.9 percent this has no reflection of geomorphic process influence in the area but it could be attributed to chemical process as they also had multiple coloration and indication of chemical weathering process.

Table 5.10: Tor spatial distribution by diameters

Interval of diameter(m)	No of tors	Percentage
11-20	10	26.9
21-30	18	43.8
31-40	5	12.2
41-50	4	9.8
51-60	2	4.9
61-70	0	0
71-80	0	0
81-90	0	0
91-100	0	0
101-110	0	0
110-121	1	2.4
Total	40	100

Figure 5.5: Tor spatial distribution by diameter



5.11 Tor spatial distribution by height

Class interval	No of tors(m)	Percentage
1-10	8	19.6
11-20	23	56
21-30	7	12.1
31-40	1	17
41-50	1	2.4
51-60	0	0
61-70	1	2.4
Total	41	100

Source: Researcher (2019)

(a) Rills developing into gullies (b) Gully measurement (c) Boulders within a gully

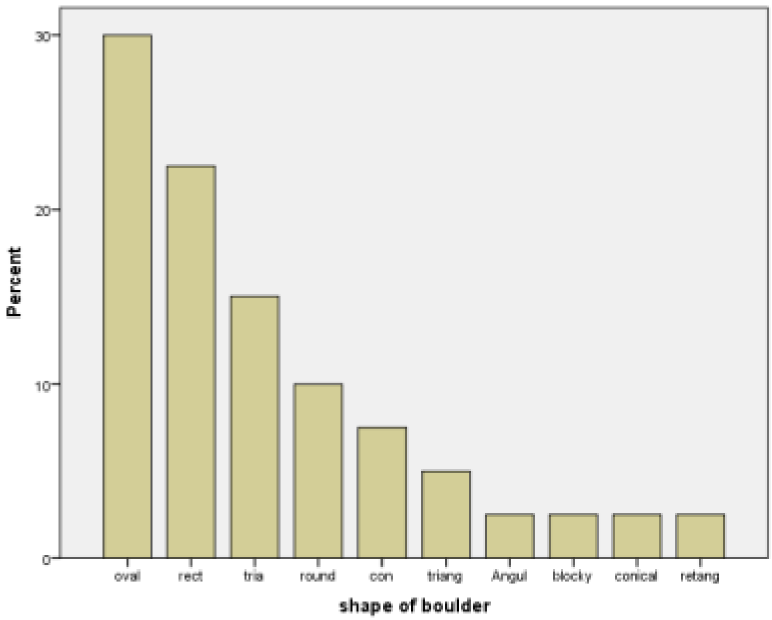
Plate 11: Water Erosion

Source : (Researcher 2019)

5.4.4 Determining the Role of Mass Movement in Tor Formation.

Since mass movement had been noticed as a key process also in the formation of tors in our literature review and being one of the objectives of the study. It was therefore crucial to establish the types of mass movement occurring within the areas of study which leads to tor formation. However there was inconsistent data that could reveal the type of mass movement involved in the tor formation within the study areas, never the less we noted that there were hanging boulders in between the tors and rolled boulders at the foot of the tors which was a clear indication of a rapid type of mass movement. When a regression analysis was run the results showed that height, cracks and the diameter had no influence on the role that mass movement plays in the formation of tors.

Figure 5.5: Tor spatial distribution by shapes of boulders



Source: (Researcher 2019)

(a) **(b)**

Figure (a) shows a boulder hnging between tors (b) boulders distributed near tors

Plate: 12: hanging rock between and boulders

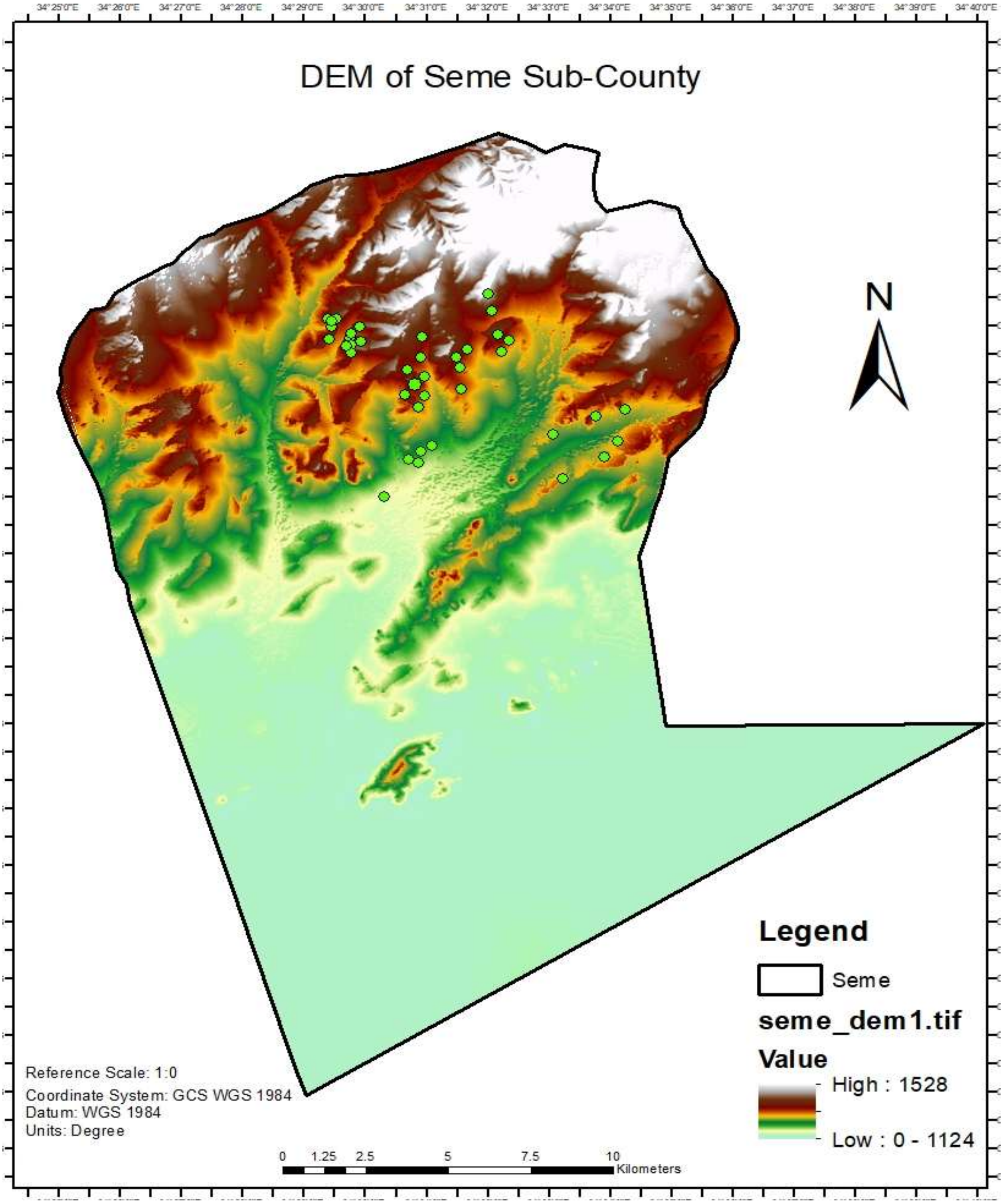
Source : (Researcher 2019)

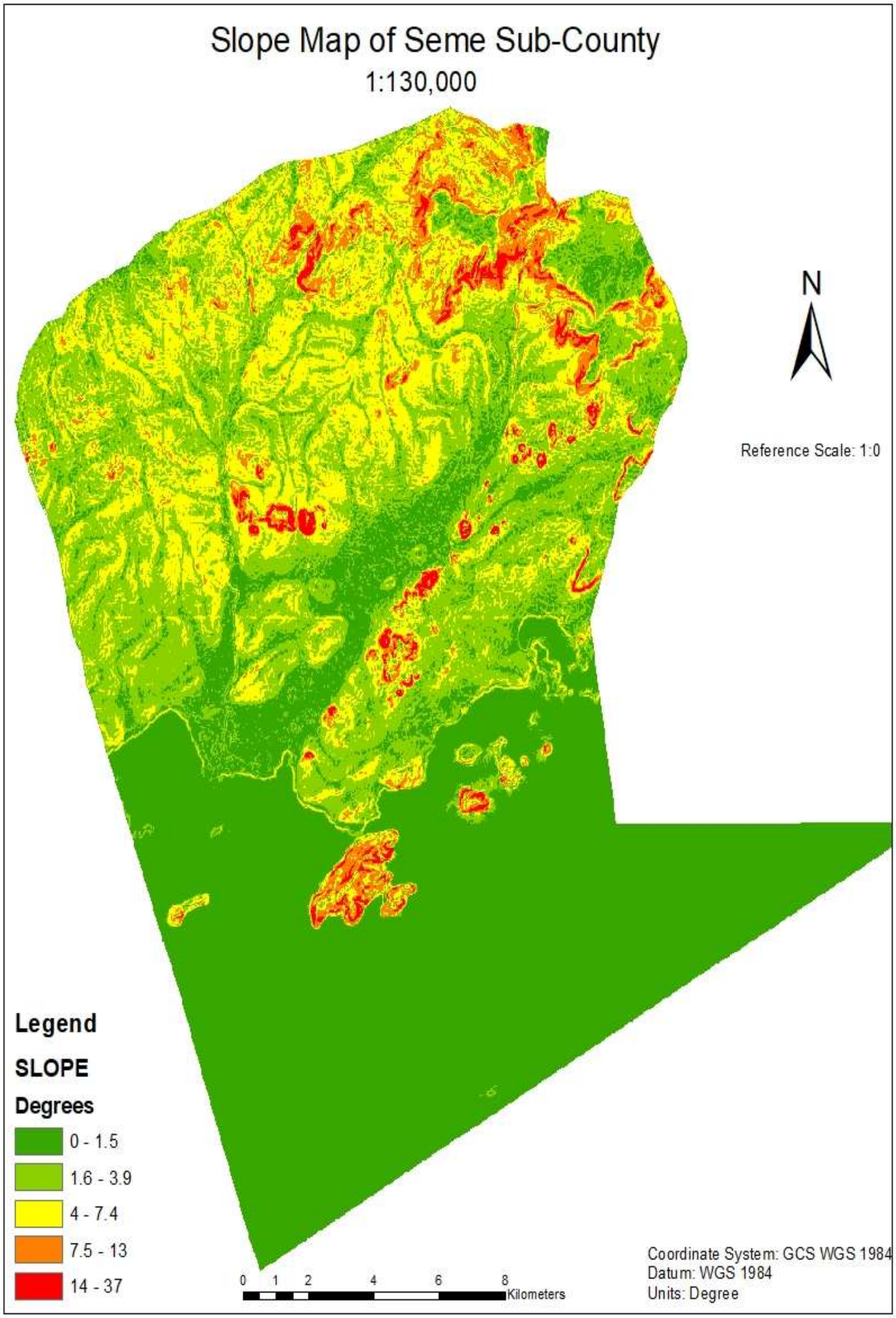
The Terrain of the area

A Digital Elevation Model (DEM), also known as the Digital Terrain Model (DTM), is a representation of the earth's topography used to derive topographic attributes, geomorphometric parameters, morphometric variables or terrain information in general. The Seme terrain as illustrated in the DEM map below shows points where tors predominantly for, the randomly picked tors within the areas of study was marked in green (fig 5.56) using GPS device.

The terrain where tors form is characterized by a relative change in altitude as illustrated in the map, tors mainly occur at mid to high altitude ranging from 900m to 1528m. This is due to the action of geomorphic process especially weathering and water erosion within the area. Tors in the area of Seme are located within the Seme fault line and Kisian fault line, this is due to the process of down warping followed by the action of water as caused by excessive rainfall and deep chemical weathering which are processes that lead to the exposure of the tors within the mid to high altitude areas of Orando, Akonya hills and the slopes of Maseno areas.

Figure 5.56: Tors distribution in relation to the terrain





Slope Map of Seme Sub-County
1:130,000
N
Reference Scale: 1:0
Legend
SLOPE
Degrees
0 - 1.5
1.6 - 3.9
4 - 7.4
7.5 - 13
14 - 37
0 1 2 4 6 8
Kilometers
Coordinate System: GCS WGS 1984
Datum: WGS 1984
Units: Degree

CHAPTER SIX

SUMMURY CONCLUSIONS, AND RECOMMENDATIONS

6.1 Conclusion

The summary of the findings were done according to the specific findings guided by the objectives of the study obtained from the previous chapter. After the processing and the analysis of the data collected the following results were arrived at:

Tor formation is influenced by geomorphic processes which are initiated by climatic conditions and the main elements of climate being thermal variation and precipitation. The time factor was also an important element as tor formation involves processes which undergo lengthy period of time as far as decades. Rock structure and the minberal components of rocks cannot be underated since they are the main determinant in the weathering processes.

The study sought to assess and establish the role of geomorphic process that is weathering, mass movement and water erosion in formation and distribution of tors in Seme sub-county where it was established that tors were formed as a result of two stage or multi cyclic processes which is preposition of Linton 1955 when studying tors in Dart moor. From the findings the region under the study, initially suffered from down warping leading to the exposure of tors as a result of mass wasting, water erosion and weathering which in the literature review it was established that they the major geomorphic factors that leads to tor formation within seme sub county.

Weathering being the most dominant geomorphic process in the three sub location plays a significant role in the formation of tors in the region being that all areas within the area experience all the three forms of weathering with mechanical (physical) weathering being the most dominant. The impact of mass movement might have been experienced during the tectonic process that resulted into the formation of Lake Victoria depression and the Seme and the Kisian fault line as most of the tors occurred in a linear pattern within the two fault lines although in the study it was a challenge to establish whether the boulders were a product of mass movement.

The study area also experienced high rate of erosion as indicated by deep valleys which also guided the streams and rivers that flows within the Seme sub-county

6.2 Recommendations

Tors are of very important economic value and the more study should be encouraged from the elementary levels of education as this will help shaping careers in the region

6.2.1 Policy Recommendations

The study arrived at the following recommendations

a. Policy makers should establish an institution that can help in the study of this region which can act as a research laboratory for pedologists and geologist to promote more research in tors thus bringing out the real economic aspects of tors and can also promote the learning of physical Geography.
b. The County Government of Kisumu should work on making the region a tourist site through Gazzeting the area as this will promote the economy of the area as it can change the native's fortunes of economic abilities and general life style.
c. Tor should be preserved to improve the economic and aesthetic value within the source regions as they can be used as the economic identity of the area.

6.2.2 Recommendations for Further researches

To provide an in-depth understanding of the Seme tors, the recommendations below should be considered for further research:

a) More research should be done to establish the right terminology being that there are several terminologies used when referring to tors that are located in other parts of the world and the confusing structure.
b) Study should be conducted to establish the most dominant geomorphic processes that can lead to formation of tor.
c) Detailed research should be carried out to establish whether tors are products of endogenic processes or geomorphic process.
d) More research to establish whether Sometors are product of time, structure or climatic activity.

REFERENCES

Campbell, S., Garrard, A. J., Green, C. P., Scourse, J. D., Davey, N. D. W., & Cattle, R. (1998). Granite landscapes. In *Quaternary of South-West England* (pp. 71-127). Springer, Dordrecht.

Carson, M. A. & Kirby, M. J. 1972. Hill slope Form and Process. Cambridge. *Geographical Studies No. 3. Viii* +475 pp., 195 figs, 20 tables. Cambridge University.

Condon, R. W., Newman, J. C., & Cummingham, G. M. (1969). Soil erosion and pasture degeneration in central Australia. III.

Cooke, R. U., & Reeves, R. W. (1976). *Arroyos and environmental change.* Oxford, 328, 520-557.

Cunnigham(1971). *The talking penguin's guide to climate change.*

Darmody, R., Thorn, C., Seppälä, M., Campbell, S., Li, Y., & Harbor, J. (2008). Global applicability of landscape evolution. *Archaeological landscape evolution, climatic geomorphology*.

Demek, J. (1964). Slope development in granite areas of Bohemian massif (Czechoslovakia). Zeist. *Geomorphic,* 8: 82-106.

Derbyshire, E. (1972). Pleistocene Glaciation of Tasmania: Review and Speculations. Australian Geographical Studies, 10(1), 79-94.

Ehlen, M. A. (2004, June). An agent-based simulation laboratory for economics and infrastructure interdependency. In *Proceedings of the 2004 American (control conference* (Vol. 2, pp. 1295-1300). IEEE.

Ehlen, J., & Gerrard, A. J. (1988). Pediments in arid environments. *geomorphology of desert environments.*

Evans, D. J., Kalyan, R., & Orton, C. (2017). Periglacial geomorphology of summit tors on bodmin moor, cornwall, swengland. *Journal of maps.*Eyles, N., Putkinen, N. &Arbelaez-

Moreno, L., 2016: Erosional origin of drumlins and megaridges. Sedimentary Geology 238, 2–23

Gilbert (1877). Report on the geology of the Henry Mountains. Washington government, Printing Office.

Heimsath, A. M., Chappell, J., Dietrich, W. E., Nishiizumi, K., &Finkel, R. C. (2000). Soil production on a retreating escarpment in southeastern Australia. Geology, 28(9), 787-790.

Huggett, R. (2016). *Fundamentals of geomorphology*.Routledge. Heimsath, A. M., Dietrich, W. E., Nishiizumi, K., &Finkel, R. C. (1999). Cosmogenic nuclides, topography, and the spatial variation of soil depth. *Geomorphology*, *27*(1-2), 151-172

Ivosevic, S. W. (1976). Geology and ore deposits of the Johnnie District, Nye County, Nevada.

Kennedy, D. M., Ierodiaconou, D., &Schimel, A. (2014). *Earth surface processes and landforms.*

King, L. C., & Fair, T. J. D. (1944). Hillslopes and dongas. *South African Journal of Geology*, *47*(1), 1-4.

King, L., & Linton, D. L. (1958). The problem of tors. *The geographical journal, 124*(2)

Kirkby, M. J. (1972). *The physical environment of the Nochixtlan Valley*, Oaxaca (No. 2). Vanderbilt University.

Linton (1955), The problem of tors, *Geographical Journal 121*(4), 470-487.

Linton, D. L. (1952). The significance of tors in glaciated lands. In *17th International Congress* (pp. 354-357)

Litchfield, W. H., &Mabbutt, J. A. (1962). Hardpan in soils of semi-arid Western Australia. *Journal of Soil Science*, *13*(2), 148-159.

Mabbutt, J. A. (1961). The assessment of grazing capacity. New S Wales Soil ConservServ:A stripped land surface in Western Australia. *Transactions and Papers* (Institute of British Geographers), (29), 101-114.

Migoń, P., & Thomas, M. F. (2002). Grus weathering mantles—problems of interpretation. *Catena*, *49*(1-2), 5-24

Möller, P. & Dowling, T.P.F., 2016: Streamlined subglacialbedforms on the Närke plain, south-central Sweden – areal distribution, morphometrics, internal architecture and formation. Quaternary Science Reviews 146, 182–215.

Oilier and Tuddenham (1961). *ETL-0566 "The landforms of granitic rocks : an annotated bibliography."* Australia

Oilier, C. D. (1982). The Great Escarpment of eastern Australia: tectonic and geomorphic significance. *Journal of the Geological Society of Australia*, *29*(1-2), 13-23.

Ojany, F. F. (1969). The inselbergs of Eastern Kenya with special reference to the Ukambani area. Z. fur Geomorphic, 13, 196-206.

Ollier, C. D. (1961). Lag deposits at Coober Pedy, South Australia. *Aust. J. Sci*, 24, 84-5.

Ollier, C. D. (1965). Some features of granite weathering in Australia. *Zeitschriftfür Geomorphologies,* 9, 285-304.

Ollier, F. (1961). Xénophon:" Banquet";". *Apologie de So-crate"*(Paris, 1961), 98-99.

Ollier, C. D. (1959).A two-cycle theory of tropical pedology. *Journal of soil science,*

Ollier, C.(1995).Tectonics and landscape evolution in southeast Australia. *Geomorphology.*

Ollier, C., Calcaterra, D., &Parise, M. (2007). Studies in weathering and slope movements—an introduction. *Geomorphology.*

Palmer and Radley (1961), Cristone tors of the English Pennines. *Zeitschrift fur Geomorphologies,* 5, 1.s. 37-52.

Palmer C. E. &Ohmstede, W. D. (1956).The Simultaneous Oscillation of Barometers along and near the Equator. https://doi.org/10.1111/j.2153-3490.1956.tb0125

Palmer,J. and Neilson, R. A.(1962) Proceedings of the Yorkshire Geological Society, 33, 315-340, 1 April1962, https://doi.org/10.1144/pygs.33.3.315

Panizza, M. (2001). Geomorphosites: concepts, methods and examples of geomorphological survey. *Chinese science bulletin, 46*(1), 4-5.

Peltier, L. C. (1950). The geographic cycle in periglacial regions as it is related to climatic geomorphology. *Annals of the association of American Geographers, 40*(3), 214-236.

Phillips, J. D.(2005).Weatheringinstability and landscape evolution. *Geomorphology,*

Pinderhughes, R. (2004). *Alternative urban futures: Planning for sustainable development in cities throughout the world*. Rowman& Littlefield

Pulfrey, W. (1952). Concentric structures in the Archean of central Kenya. Int. Geol. Cong., 19th Session, Algiers (1952), pp. 203-207.

Rollin, E., Milton, E., & Roche, P. (1994). The influence of weathering and lichen cover on the reflectance spectra of granitic rocks. Remote sensing of environment.

Safford, H. D., &Martinelli, G. (2000). Southeast Brazil. In *Inselbergs* (pp. 339-389). Springer, Berlin, Heidelberg.

Schoenwald, D. A., Barton, D. C., &….A Bibliography on the chemical weathering of granitic rocks. the role of biological weathering in periglacial areas: a study of weathering rinds in south Iceland. *Geomorphology*

Strudley, M. W., Murray, A. B., &Haff, P. K. (2006). *Emergence of pediments, tors, and piedmont.*

Strudley, M. W., Murray, A. B., &Haff, P. (2006). Emergence of pediments, tors, and piedmont junctions from a bedrock weathering–regolith thickness feedback. *Geology*

Tierney, R., & Glass, H. (2016). Modelling the structural controls of primary kaolinite formation. *geomorphology,* Titan's atmospheric temperatures, winds, and composition. Science, 308(5724), 975-978. Gerrard, A. J. W. (1974). The geomorphological importance of jointing in the Dartmoor granite. *Progress in geomorphology*, 39-50.

Twidale C R & Bourne J A (1998a) Flared slopes revisited. Physical Geography 19: 110–133.

Twidale C R & Bourne J A 1998b Origin and age of bornhardts, southwest Western Australia. *Australian Journal of Earth Sciences*, 45: 903–914.

Twidale C R (1968). Origin of Wave Rock, Hyden, Western Australia. Transactions of the Royal Society of South Australia 92: 115–123.

Twidale, C. R., &RomaniWeathering with particular reference to granitic rocks. Granite landforms

Twidale, C. (1982). Price, D. G. (1995). Weathering and weathering processes. *Quarterly journal of engineering geology and hydrogeology,* 28

Twidale, C., & Vidal Romani, J. (1994). On the multistage development of etch forms. *Geomorphology*.

Volborth, A. (1962). Allanitepegmatites, Red Rock, Nevada compared with allanitepegmatites in southern Nevada and California. *Economic Geology, 57*(2), 209-216.

Weathering rinds: formation processes and weathering rates. Treatise on geomorphology. Linton, D. L. (1955). The problem of tors. *The Geographical Journal, 121*(4), 470-487.

William Davis Morris (1933) *The History of the study of Landforms or the Development of Geomorpholgy.* Vol 2 Methuen & Co. Ltd. London.

Measurements of diameters, heights and lengths angles of cracks

Location	Diameter m	Height m	Average cracks
34.4901 -0.0788	29	16	0.3
34.4948 -0.081	32	25	0.4
34.4961 -0.0828	45	30	0.6
34.4962 -0.0805	40	28	0.75
34.499 -0.0796	30	18	0.45
34.4958 -0.0784	28	15	0.3
34.4963 -0.0771	72	50	0.5
34.4986 -0.0754	48	40	0.15
34.4923 -0.073	17	10	0.6
34.49 -0.073	27	18	0.3
34.4907 -0.0737	16	7	0.2
34.5108 -0.0953	23	14	0.4
34.5156 -0.0782	30	15	0.4
34.5151 -0.0842	26	16	0.4
34.5115 -0.0878	14	9	0.5
34.5162 -0.09	14	6	0.3
34.5135 -0.0921	16	7	0.6
34.5108 -0.0953	23	33	0.2
34.5163 -0.0955	20	13	0.55
34.5145 -0.0989	28	15	0.2
34.526 -0.0936	25	12	0.6
34.5259 -0.0872	16	10	0.25
34.5247 -0.0842	29	20	0.3
34.5279 -0.082	115	70	0.7
34.5335 -0.0655	30	9	0.4
34.5345 -0.0707	30	12	0.25
34.5361 -0.0777	30	20	0.35
34.5391 -0.0793	45	16	0.6
34.5371 -0.0826	40	25	0.3
34.5513 -0.1068	29	20	1.1
34.5629 -0.1014	23	25	2
34.5513 -0.1068	48	16	0.3
34.5538 -0.1198	28	18	1.1
34.5052 -0.1251	16	15	1.3

Source: Researcher (2018)

		Diameter	Cracks	Height	BOULDERS		GULLIES	
					Number	Diameter	Volume	Depth
d	Pearson Correlation	1	.372*	.916**	.500**	-.182	.119	.349*
	Sig. (2-tailed)		.018	.000	.001	.260	.463	.034
	N	40	40	40	39	40	40	37
cr	Pearson Correlation	.372*	1	.286	.546**	.042	.368*	.306
	Sig. (2-tailed)	.018		.074	.000	.796	.019	.065
	N	40	40	40	39	40	40	37
h	Pearson Correlation	.916**	.286	1	.386*	-.118	.084	.311
	Sig. (2-tailed)	.000	.074		.015	.468	.605	.061
	N	40	40	40	39	40	40	37
nb	Pearson Correlation	.500**	.546**	.386*	1	-.098	-.048	.059
	Sig. (2-tailed)	.001	.000	.015		.554	.770	.731
	N	39	39	39	39	39	39	36
md_bls	Pearson Correlation	-.182	.042	-.118	-.098	1	-.056	-.161
	Sig. (2-tailed)	.260	.796	.468	.554		.729	.342
	N	40	40	40	39	40	40	37
vol	Pearson Correlation	.119	.368*	.084	-.048	-.056	1	.743**
	Sig. (2-tailed)	.463	.019	.605	.770	.729		.000
	N	40	40	40	39	40	40	37
depth	Pearson Correlation	.349*	.306	.311	.059	-.161	.743**	1
	Sig. (2-tailed)	.034	.065	.061	.731	.342	.000	
	N	37	37	37	36	37	37	37
width	Pearson Correlation	.000	.123	-.003	-.171	-.014	.638**	.468**
	Sig. (2-tailed)	.998	.468	.986	.319	.933	.000	.003
	N	37	37	37	36	37	37	37
length	Pearson Correlation	-.021	.130	-.037	-.139	-.105	.432**	.344*
	Sig. (2-tailed)	.901	.443	.827	.419	.535	.008	.037
	N	37	37	37	36	37	37	37
long	Pearson Correlation	.395*	.787**	.390*	.299	.132	.314*	.217
	Sig. (2-tailed)	.012	.000	.013	.065	.417	.048	.196
	N	40	40	40	39	40	40	37
lat	Pearson Correlation	-.031	-.116	.001	-.042	.007	-.080	-.208
	Sig. (2-tailed)	.850	.476	.995	.800	.965	.622	.217
	N	40	40	40	39	40	40	37
distance	Pearson Correlation	-.069	-.215	-.049	-.175	.207	-.083	-.171
	Sig. (2-tailed)	.674	.183	.762	.286	.201	.609	.311
	N	40	40	40	39	40	40	37

Appendix II: Introductory Letter from University of Nairobi

UNIVERSITY OF NAIROBI

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

Telephone: +254 2 318262
Extension: 28016
Fax: +254 2 245566
Email-geography@uonbi.ac.ke

P.O. BOX 30197-00100
NAIROBI
KENYA

September 5, 2018

The Director,
National Commission for Science & Technology
Nairobi
Kenya.

Dear Sir/Madam,

RESEARCH PERMIT: ODHIAMBO MOPHAT CALVINS

This is to confirm that the above named is a Master of Arts student (Registration Number – C50/5894/2017) at the Department of Geography and Environmental Studies, University of Nairobi registered .

Mr. Odhiambo is currently undertaking research on a topic titled: **Topic Assessment of Geomorphic Processes Responsible for the Formation of TORs in Seme Sub-county –Kisumu County.**

Any assistance accorded to him will be highly appreciated.

CHAIRMAN
Department Of Geography
and Environmental Studies
UNIVERSITY OF NAIROBI

Dr. Boniface Wambua
Chairman, Department of Geography & Environmental Studies

Appendix III: Research Authorization Letter

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471,
2241349,3310571,2219420
Fax:+254-20-318245,318249
Email: dg@nacosti.go.ke
Website : www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref. No. **NACOSTI/P/18/71210/25464**

Date: **12th October, 2018**

Calvins Mophat Odhiambo
University of Nairobi
P.O. Box 30197-00100
NAIROBI.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Assessment of geomophic processes responsible for the formation of TORs in Seme Sub County, Kisumu County"*** I am pleased to inform you that you have been authorized to undertake research in **Kisumu County** for the period ending **11th October, 2019.**

You are advised to report to **the County Commissioner and the County Director of Education, Kisumu County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

GODFREY P. KALERWA MSc., MBA, MKIM
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Kisumu County.

The County Director of Education
Kisumu County.

Appendix IV: Research permit

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

The Grant of Research Licenses is guided by the Science, Technology and Innovation (Research Licensing) Regulations, 2014.

CONDITIONS

1. The License is valid for the proposed research, location and specified period.
2. The License and any rights thereunder are non-transferable.
3. The Licensee shall inform the County Governor before commencement of the research.
4. Excavation, filming and collection of specimens are subject to further necessary clearance from relevant Government Agencies.
5. The License does not give authority to transfer research materials.
6. NACOSTI may monitor and evaluate the licensed research project.
7. The Licensee shall submit one hard copy and upload a soft copy of their final report within one year of completion of the research.
8. NACOSTI reserves the right to modify the conditions of the License including cancellation without prior notice.

National Commission for Science, Technology and innovation
P.O. Box 30623 - 00100, Nairobi, Kenya
TEL: 020 400 7000, 0713 788787, 0735 404245
Email: dg@nacosti.go.ke, registry@nacosti.go.ke
Website: www.nacosti.go.ke

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

RESEARCH LICENSE

Serial No.A 21132

CONDITIONS: see back page

THIS IS TO CERTIFY THAT:
MR. CALVINS MOPHAT ODHIAMBO
of UNIVERSITY OF NAIROBI, 19676-200
NAIROBI,has been permitted to conduct
research in *Kisumu County*

on the topic: *ASSESSMENT OF GEOMOPHIC PROCESSES RESPONSIBLE FOR THE FORMATION OF TORS IN SEME SUB COUNTY, KISUMU COUNTY*

for the period ending:
11th October,2019

Permit No : NACOSTI/P/18/71210/25464
Date Of Issue : 12th October,2018
Fee Recieved :Ksh 1000

....
Applicant's Signature

....
Director General
National Commission for Science, Technology & Innovation

AppendixV: The geology map of Kisumu showing the Seme and Kisian fault line where tors are spatially located