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ASSESSMENT OF OUTER AND INNER SLOPE PROFILES OF VOLCANIC CRATERS ON BIU PLATEAU, BORNO STATE, NIGERIA

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ABSTRACT

This research examined the outer and inner slope profiles of volcanic craters on the Biu Plateau. The objectives of the study are to identify the types of slopes; examine the types of geomorphic processes in the craters; and determine the socio-economic relevance of the craters. Data used for this study were generated from field observations, topographic map, total station survey and group interview. Three sampled craters namely Kumba, Tilla and Jali Tagurmi were purposively selected for the study. Profiles of each craters were plotted using autoCARD where geomorphic processes, and human activities were observed between the stations in relations to slope gradient. Three group interviews and participatory rural appraisal were conducted in the vicinity of each of the craters on the socio-economic importance. Results showed that there are fourteen craters on the Biu plateau; four large (> 300m) in diameter, five medium (200-300m) and five small (< 200m). The morphology of the Kumba crater is conical with an elevation range of 700m to 765m, Tilla crater is circular with elevation range of 736m to 742m while the Jali crater has an oval shape with spot height of 690m to 740m asl. Denudational processes observed on the rims of the craters include weathering, sheet, rill, gully erosions and mass wasting (rock fall, soil creep, debris creep and slides). Socio-economic activities associated with the craters according to group interview and participatory rural appraisal include livestock watering, market gardening, quarrying, tourism, medication and domestic water supply. Other related negative human activities observed include bush burning, deforestation, accelerated erosion, poaching, hunting, and extraction of fuelwood. From the findings of the research it is recommended that public enlightenment campaign on environmental management be conducted, sustainable environmental management of land based resources be ensured. Access roads, afforestation, beneficial cultural practices and tourism be encouraged.

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1. INTRODUCTION

A volcanic crater is a relatively circular depression on the earth's surface caused by volcanic activity. It is typically a basin, within which a vent is located from which lava erupts in form of gases, and ejecta are emitted. A crater can be of various sizes and sometimes of great depth. During climactic eruptions, the volcano's magma chamber may evacuated for the area above it to subside to form a crater or a caldera. In typical volcanoes, the crater is situated at the top of the cone, formed by pyroclastic materials (or debris). In some, the craters may be situated on the flanks of volcanoes and these are commonly referred to as flank craters. Most volcanic craters may either be fully or partially filled with runoff or melted snow to form a crater lake.

The concept of parallel retreat of slopes came up as one of the first criticisms of the Davisian cycle of erosion from the German School led by Albrecht Penck and Walter Penck (1924) cited by Ofomata [1]. They objected to the cycle of erosion because of its simple assumptions of rapid uplift which they believed was misleading and lacked the evidence of tectonic processes and how it operates. They further observed that landforms depended upon the relative rate of uplift of the landscape and the forces of the processes acting against it.

According to them, the agent which relates these two forces is the river, which controls slope development by the rate at which it cuts down the valley floor. During a period of accelerated uplift when rivers cut down energetically and relief decreases, Penck believes that valley slopes will tend to be replaced and gradually become concave in nature. However, as the rate of down cutting declines, streams become progressively ineffective to transport materials on transit, and deposition will take place. The valley sides will then first tend to be straight (rectilinear) and then later transformed into concave forms. If the river erosion is static, then a state of equilibrium may exist, and valley sides may remain rectilinear [2]. Penck's idea of the evolution of landforms was therefore independent of, any form of cycle of erosion as proposed by Davis but rather related to the energy of a river in relation to the uplift of the land. He suggested that increase or decrease in river energy is controlled by a number of factors like change in climate, change in amount of runoff, rate of uplift and base level. Thus, while Davis was of the opinion that landforms are wearing down; Penck believed that they are wearing back. Davis also believed that the rate of removal of weathered materials from slope depended on the slope rather than the process involved; so that a steep slope would retreat more rapidly than a gentle slope but Penck was of the view that the attainment of the stage of peneplain is most likely through the retreat of slopes and not through slope decline as proposed by the Davisian concept of the cycle of erosion. The understanding of the general configuration of landforms, the surface processes and environmental factors involved in modification is necessary, especially in volcanic landscapes like the Biu plateau.

1.1. Statement of the Problem

Biu is a volcanic plateau, characterized by various spectacular geomorphic features which make the area very unique when compared to its surrounding environment. Some studies consider the Biu plateau as the end of the North-North West (NNW) branch of the continental sector of the

Cameroon Volcanic Line (CVL) [3-6]. It has been observed that the Biu and Jos Plateaux have similar major and trace elements and that the Jos Plateau lavas have similar range of isotopic compositions, overlapping the lava of the CVL as a whole [7]. According to Turner [3] the Biu Plateau evolved in three stages during two periods of volcanism: an early fissure type eruption; formation of relatively large tephra ring volcanoes and building up of localized thick lava piles up to 250m in the southern part of the plateau. According to studies carried out by Barfod, et al. [8]; based on diffusional constraints of "He" in mantle xenoliths of the CVL and pollen dating by Salzmann [9] of maar sediments from the Tilla crater on the Biu Plateau, the rough estimate of the age of the last magmatic period is put at < 50 million and > 25 million years.

A base line socio-economic survey, carried out by Amaza, et al. [10] revealed that about 68% of the people on the Biu Plateau are farmers engaged in various agricultural activities on the plateau. These activities have led to the modification of the plateau [10]. Bwala [11] focused on the availability of water for domestic supply and utilization on the Biu plateau which serves as the major source of both surface and underground water in the area. However, no similar study has focused on the development of the craters as spectacular features on the Biu plateau. Therefore, this study intends to fill this gap by focusing on the analysis of the outer and inner slope profiles of volcanic craters on the Biu Plateau, Borno State.

1.2. Aim and Objectives of the Study

The study examines the analysis of outer and inner slope profiles of the volcanic craters on the Biu Plateau, Borno State. The specific objectives of the study are:

i. to examine the types of slopes in the Craters on the Biu Plateau;
ii. examine the types of geomorphic processes and how they modify the craters; and
iii. observe the types of socio-economic activities going on in the craters;

1.3. Research Questions

i. What are the types of slopes associated with the craters?
ii. What are the geomorphic processes and the changes occurring on the craters?
iii.What are the socio-economic activities taking place in the craters?

1.4. Sources of Data

Both primary and secondary sources of data were used for this study. The primary data include the use of Total Station Survey Instrument was used in generating data for slope profile of the craters. Group interview and participatory rural appraisal (PRA) were used to collect data on the socio-economic importance of the craters to the immediate communities. Secondary sources of data were obtained from the use of the Biu topographic Sheet 133 (1:100,000).

1.5. Sampling Techniques

Using the topographic map of Biu sheet 133 on the scale of 1:100,000 and ground truth, the craters were categorised into three major groups based on the diameter of their rims as follows:

Large (> 300 meters), Medium (200 – 300 meters) and Small (< 200 meters). Purposive sampling technique was used to select one crater from each of the three groups for detailed study.

The respondents for the group interview and PRA were purposively selected in the field while carrying out one socio-economic activity or the other for discussion as shown in Plate1.

Plate-1. Group Discussion at Market Gardening around Tilla Crater Lake

Source: Fieldwork, 2014

1.6. Total Station for Morphology Survey

Total Station is a survey instrument commonly known as electromagnetic distance measurement (EDM). It was used for generating data about the morphology of the three craters. The instrument generated data on the easting, northing and height commonly known as X, Y, Z. that was used in producing the profiles of the craters and slopes angles. The observations were taken at intervals of 10 m from the base across each of the three craters and the X, Y, Z data were recorded as shown in Plate 2.

Plate-2. Total Station at Kumba Crater Generating X, Y, Z Data

Source: Fieldwork, 2014

The data generated from the Total Station Survey instrument were analysed using the AutoCAD and Surfer software. Data on the socio-economic importance of craters were analysed using descriptive statistics. Since their formation, the volcanic craters have changed over time. In this section, the geomorphic processes that have modified them are presented.

(a) Slope as a Factor of Geomorphic Processes

Slope is one of the most conspicuous features associated with craters as shown in Fig.1. The slopes at the three crater sites; Kumba, Tilla and Jali Tagurmi were studied and the roles they played in geomorphic processes were observed and measured through the use of the total station as shown in Plate 2. The slopes in the three craters were analysed from the X, Y, Z data generated through the use of the total station Plate 2 and Appendix 1 that were used in plotting the profiles of the three craters respectively.

The results of the measurements and field observations at the craters show that slope plays an important role in the geomorphic processes at the three craters as explained presently. The sole profiles at the three craters are illustrated in Figure 1. It should be noted that among the three craters only Kumba and Tagurmi are characterized by foot slope segment with a gradient range of 1^o to 6^o as shown in Figure 1.

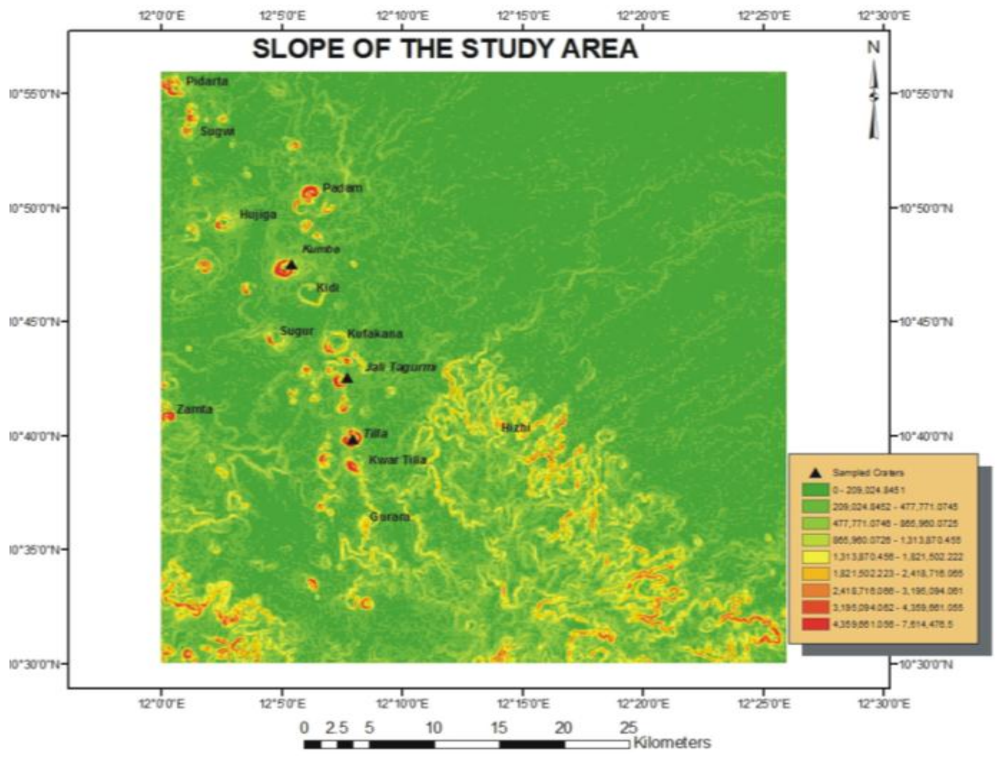

Fig.-1. Slope Map of the Study Area

Source: Generated from SRTM DEM

(i) Kumba Crater Slope Profile

The profile of Kumba crater from the rims down to the floor has eleven segments. At the foot slope segment, the geomorphic processes observed were deposition of materials eroded from the rims. The predominant activity practiced at this point is terrace farming. The vegetation here could be described as denser compared with the upslope. The rim of the Kumba crater serve as the crest or divide that drains or shed water into or outside the crater. The rim of Kumba crater is associated with steep slope with internal gradients ranging from 35^o to 36^o and external gradients range from 36^o to 43^o (Fig.1). This implies that the slope is steeper as one ascends the crater than while descending on the floor. The steep slope displays joints all the way to the floor of the crater with a gentle slope that ranges from 1^o to 3^o as one descends to the floor of the crater.

(ii) Tilla Crater Slope Profile

The Tilla Crater Lake on the other hand has no foot slope and that could be attributed to the nature of its morphology. Tilla crater is the only crater among all the fourteen identified craters in the area that holds water throughout the season. The crest slope (rim) is characterised by a gradient of 21^o (Figure 1) that serves as the watershed that drains water into the crater. Fifty meters from the crest into the crater is characterised by steep slopes with gradient ranging from 35^o to 26^o .The steep slope is followed by a gentle slope with a gradient of 23^o which is characterised by gully erosion as shown in Fig.1. The profile also reveals that materials eroded from the upper parts of the rims are deposited between an angle of 1^o to 5^o as well as on the floor of the crater. Various socio-economic activities are taking place at the shores of the Tilla Lake on gradients ranging from 1^o to 6^o. The economic activities include market gardening, for the cultivation of vegetables such as Tomatoes (*Solanum melongena*), okra (*Abelmoschus esculentus*) and pepper (*Capsicum annuum*) and the grazing of Animals. The geomorphic processes observed include weathering, splash, sheet, rill, and gully erosion and mass wasting (rock fall, soil creep, debris creep and slides). It is evident that the materials deposited on the floor of the crater were eroded from the rims of the crater by these processes. These processes are similar with those of Ebisemiju [12] who carried out a detailed field survey and presented statistical and graphic analyses of 82 slope profiles on fifty hills in the northern Savanna terrain. He found that changes in the slopes seemed to have resulted from the reduction of the laterite boulders and gravels, resulting in their redistribution by creep and sheet wash processes that led to summit lowering and valley aggradation. This is in line with the concept of the dynamic equilibrium in view of the fact that a crater is an open system in which all the component parts are in dynamic equilibrium. Thus, any change in the form of any segment, should be expected to induce change in the other segments.

(iii) Jali Tagurmi Crater Slope Profile

Jali Tagurmi crater which is the smallest of the three sampled craters has a unique oval shape. Its slope profile is shown in Fig.1. It is characterised by a foot slope starting from the main road leading to Miringa with a gradient of 1^o. The gradient keeps increasing from 1^o to 8^o as one ascends to the rim of the crater. The crest (rim) which serves as the water shed or divide is associated with a gradient of 17^o followed by a steep slope with a gradient of 30^o as shown in Fig.1. The eastern side of the crest (rim) which is the highest point on the rim is characterised by steep slopes with gradients of 39^o and 53^o. The floor of the crater is linked to steep slope with gradients of 5^o and $21^{o.}$ This finding agrees with similar work by Sambo [13] on the morphology of Jali Tagurmi where he found that the morphology of the crater is oval in shape not circular in shape like that of Kumba and Tilla. He further observed that the eastern part (rim) rises higher than the western rim.

(iv)The Profiles and Geomorphic Processes

Apart from the rims and the basins of the craters, which are flat and account for some proportion of the total areas of the craters, significant parts are characterised by slopes. By contrast, slopes comprise the greater parts of the landscape and constitute the predominant component of the craters. This finding agrees with the observation by of Faniran and Jeje [14] that flat surface exists mainly only in theory but not in practice; and all landscape comprises some elements of slopes. This is why it is generally believed that an understanding of the form and evolution of the slopes in an area leads to an understanding of the form and evolution of the landform as a whole. As observed in the study area, slope is the link between the surrounding areas as one is ascending the rims and descending into the floor of the craters, so the slope predominantly serves as a transporting surface as well as the major supplier of water and sediments to the floors of the craters. Steep slope characteristics aid fluvial processes in and around the craters, and play a very significant role in the evolution of the craters because of its form, gradient and materials which affect the rate of erosion.

The morphology of any slope is determined by the relationship between the rate of weathered materials generated from the parent rocks and the rate at which the weathered materials are removed from the surface. The generation of the weathered materials involve both physical and chemical weathering, and these are governed by several factors including the composition and structure of the rocks; and the thickness and state of removal of the weathered materials. Structure includes the attitude of the beds, the degree of jointing, the type of deformation, and the geomorphic processes such as sheet, rill and gully erosions. Field survey result reveals that sheet erosion, rill erosion, gully erosion, transportation, deposition, physical, and biological weathering are the most prominent geomorphic processes operating in the area. The rims of the craters that serve as divide, generate run off which tends to increase as it descends the steep slopes that joined the rims and the floor of the crater as shown on Fig.1. It is transformed into sheets erosion and later transformed into rills along the gentle slopes where it is transported and finally deposited on the floors of the craters as shown in Fig.1. This findings agree with a similar statement of Faniran and Jeje [14] that deposition depends on the discharge, stream gradient, channel characteristics and changing pattern of flow. A change from a steep to a low gradient usually leads to a loss of energy in the river or runoff and consequent deposition of sediments. In other words, deposition of materials eroded from the crest of the rims of the craters and transported from the steep slopes will finally be deposited at the gentle slope and foot slopes as observed in the three craters.

1.7. Slope Driven Geomorphic Processes at the craters

The most predominant geomorphic processes observed in the three crater are sheet erosion, rill erosion, gully erosion, transportation and deposition of the eroded materials down slope and influenced by the gradient as indicated above. The most conspicuous form of geomorphic process at the craters is gully erosion. Together, these geomorphic processes have contributed significantly toward the modification of the morphology of the crater since their formation.

2. SUMMARY, CONCLUSION AND RECOMMENDATIONS

2.1. Summary

The observed geomorphic processes modifying the craters (over time) were the physical and chemical weathering processes that set the pace for erosion in form of splash, sheet, rill and gullying. These processes are exacerbated by the socio-economic activities that tend to accelerate them. Socio-economic activities observed around the craters include farming, mining, grazing, deforestation, environmental degradation through bush burning, network of tracts made by man and cattle, fuel wood extraction and settlement expansion around the craters.

2.2. Conclusion

At the rate and manners at which the craters are being modified, if left unchecked, the geomorphic processes will continue to cut down their slopes and both the floors of the craters and their slopes (rims) would become graded very rapidly. At this level, the rates of removal will be equal to the rates of uplift and the craters will be at a state of dynamic equilibrium and consequently will cease to be classified as craters in geomorphic sense. If this happens, the craters will become mere shallow depressions on the landscape.

2.3. Recommendations

Based on the findings of this research, the following recommendations are made:

There is a need for a public enlightenment campaign at the grass root to educate the local communities by the local government authority on the environmental effects of their activities. This is to ensure sustainable use of the crater.

There is also a need to enforce existing laws by the local government authority to ensure controlled exploitation of land and water resources such as mining, cultivation, grazing and land clearing in and around the craters so as to reduce accelerated soil erosion and deforestation.

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