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SCULPTURING OF LAPANDIM-TAI INSELBERG IN KALTUNGO LOCAL GOVERNMENT AREA, GOMBE STATE, NIGERIA

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Abstract

This research focused on the sculpturing and modification of Lapandim-Tai, an inselberg, in Kaltungo, Kaltungo Local Government Area of Gombe State, Nigeria. Data collection involved the measurement of angles of the inselberg, which was carried out using Abney Level taken at a 30 metres interval from point A to point B. Two ranging poles and a 100 metre tape were used. The results showed that gradients at the foot of the hill on either side were low, 0.6^{o}-1.3^{o} and 0.3^{oh}-0.9^{o}. Correlation analyses on the two sets of angles were performed and the results showed that there is a correlation to the angles of the slopes of the hill. This implied that there was a uniform stripping of regolith on the hill and is associated with the processes of fluvial erosion, and created rills and gullies that are sculpturing the inselberg and thus rendered its slopes as bad land. Distribution of eroded materials showed that particle sizes of grains were coarse at the top of the hill and got finer farther away. Based on the findings, it was concluded that Lapandim-Tai evolved through the processes of weathering and regolith stripping and that running water was the main agent of erosion of sculpturing the hill. It is recommended that grasses with tufted root systems and fast growing plant species such as Paniculatu/Pitadeniastrum africanum should be planted on the slopes of the hill to prevent further loss of regolith and thus of sculpturing the inselberg.

Key words: Inselberg, Lapandim-Tai, Regolith, Sculpturing and Stripping

Introduction

The term inselberg is German in origin coined from two words: ‘insel’ meaning ‘island’ while ‘berg’ means ‘mountain’ (Barker, 2019) The term is descriptive and it refers to rock hills which occur in isolation or in clusters and rise sharply above the general level of the surrounding (Afolabi and Ogunkoya, 2018). Sculpturing refers to the processes involved in a progression of change of a feature or landform on the surface of the earth. Processes involved in the sculpturing and modification of landform and thus its evolution include exogenous geomorphic processes of weathering, erosion, transportation and deposition. The term erosion refers to the group of natural processes, including corrosion, dissolution, abrasion and removal which material is transported and deposited in other locations (Faniran and Jeje, 2002; Davy, Brow and Mossman, 2011). In other words, erosion is the process by which earth's surface material is worn away by agents of denudation such as running water, wind, glacier and mass wasting under the influence of gravity. Erosion that occurs at irregular or varying rates caused by the differences in the resistance and hardness of surface materials: softer and weaker rocks are rapidly worn away, whereas harder and more resistant rocks remain to form ridges, hills or mountains. Differential erosion along with tectonic settings is one of the most important controls on the evolution of continental landscapes (Monroe, Wicander and Reed, 2006). The feedback of erosion on tectonics is given by the transportation of surface or near surface material, mass of rock, soil particles, sand, etc. to new locations (Godin, Gleeson, Seale, Ulrich, and Parrish, 2006). While erosion in all of its forms wears away materials from the earth's surface, the process of mass wasting as a product of deep fluvial incision has the highest tectonic implications (Van and Arshak, 2004).

Generally, inselbergs are produced by the lowering of the surface around it (de Blij, *et al,* 2005 and Afolabi and Ogunkoya, 2018). In studying the evolution of Anamalai Hill in India, Chakraborty (2019) observed that land use brought about changes in the physical state of the hill. The morphology of inselbergs includes domed inselbergs, castellated inselbergs and bolder inselbergs (Labley, 2019). Domed inselbergs, also called bornhardts, are convex-upward hills and display various curvature and stand at heights above the surrounding. In a study of the evolution of inselbergs near Lake Johnston, Western Australia (Bourne and Twidale, 2002) associated the evolution with removal of regolith thereby exhuming the categories of inselbergs observed in the Lake Region. In studying the evolution of inselbergs in Igbajo District of Central Western Nigeria, Afolabi and Ogunkoya (2018) observed that the Igbajo terrain is deeply weathered covered by a thin layer of soil on the slopes of the inselbergs and that the pediment are well dissected by running water. They concluded that two theories, land denudation associated with pediplanation and the second was that associated with deep weathering followed by multi-cyclic stripping of regolith explained the evolution of inselbergs in Igbajo area. Analyzing the angles up the inselbergs showed close relationship of the possibility of stripping of regolith under the influence of heavy rainfall experienced in the area. Burke (2003) considered global trends and took a landscape view of inselbergs and opined that inselbergs could be habitat to diverse bioclimatic organisms and humans could impact on these features (inselbergs). Inselbergs that are close to settlements, the processes of sculpturing could be accelerated thereby accentuating the modification of the hills. The geomorphic processes involved in the evolution and sculpturing of inselbergs and plains are scarp retreat and the extension of the pediment, a rock-cut surface often observed at the foot of mountains (Young, 1972, Sinha, 2015, Musarurwa and Mandaza (2018) and Chandra (2019). This position was supported by the theory developed in explaining the evolution of plains by Walther Penck who suggested that slopes retreated backwards and in doing so were replaced by less steep slopes (de Blij, *et al,* 2005). Further development on the evolution of plains was that by Alan Wood and Lester C. King as reported by de Blij, *et al*, (2005) argued that slope retreat is the process whereby highlands are reduced to pediplains –not peneplains, and explained further that pediplains are plains at the foot of mountains. Erosion can be regarded as merely a geomorphological process whereby the surface layer of weathering rocks is loosened and carried away by wind, glacier and running water to a lower horizon (Ofomata, 2009). Under natural conditions, transport of materials downslope usually is intermittent, and each movement is so slight that erosive processes are very slow and appear to be continuous. In the absence of vegetation cover, rainfall initiates a set of processes; rain-flash erosion, sheet erosion, rill and gully erosion especially where precipitation is heavy and prolonged. The falling raindrops possess considerable kinetic energy and loosened the soil and initiates erosion processes by depressing the aggregates and splashing them around in the absence of intercepting trees, shrubs, and grasses. The raindrops erosion assumes serious proportions as billions of drops of rainwater beat the surface and splash the particles down slope. When the rainfall becomes heavy or when the soil has lost the capacity to absorb water, the rainwater accumulates on the ground and then flows down the slope in irregular sheet, which is one of threats of erosion by water. Consequently, the depth and the velocity of water progressively increase downslope. The intensity of sheet erosion depends on the steepness of the slope (gradient) and on the volume of water flowing. The sheets denude the soil layers more or less uniformly making it thinner. A threat of sheet erosion is the concentration of water into definite channels or rills that flow downslope-giving rise to gullies in which running water aggravates the power of erosion in the channel.

The physical factors of erosion that affect the sculpturing and evolution of an inselbergs could be divided into four: climate, surface configuration (relief), surface materials and vegetation. The relationship between climate and soil is fairly well known. Surface runoff constitutes the most dominant sub-factor in erosion activities that account for the evolution of inselbergs in tropical and other humid regions. Erosion in upland areas is characterized by mass wasting, a process that occurs on slopes under the influence of gravity. Although water is not a main transporting medium in uplands, mass wasting or land sliding process are very important activities that cause erosion hazard in uplands. The effect of erosion by wind plays only a little role in humid tropical environment. Mountain areas have higher elevation and thus greater potential energy of flowing water than lowlands. This combined with the steeper slope angles, result in more dynamic erosion in upland areas than on the surroundings ground, a process that is responsible for stripping of surface material on slopes of mountainous and highland areas.

Statement of the Research Problem

Erosion, due to fluvial processes, is the major ecological problem facing slopes of highland and hilly areas. Running water is responsible for the exhumation of hills in Western Nigeria (Afolabi and Ogunkoya, 2018) through the process of stripping regolith on the slopes. The problem of weathering and mass wasting is a cogent ecological problem in hilly and mountainous areas in the tropics. The slopes of Lapandim-Tai, being in the tropics, are likely to be undergoing loss of surface material through the processes of stripping and slope retreat. Continued erosion over geologic time frame have resulted into exposing hard resistant rocks thereby creating inselbergs in places as in the case of Anamalai Hill in India, Chakraborty (2019). One is left with the question in mind as to whether or not Lapandim-Tai in Kaltungo evolved because of erosional processes. This study therefore sets to find out the geomorphic processes in the evolution of Lapandim-Tai.

Aim and Objectives

This research aimed at establishing the geomorphic processes that led to the sculpturing of Lapandim-Tai in Kaltungo, Kaltungo LGA of Gombe State, Nigeria. To achieve the aim of the study, the following objectives were set to:

i, establish the geology and relief of the study area,

ii, determine the gradient of the inselberg,

iii, assess the sizes of surface particles down slope of the inselberg and;

iv, establish the geomorphic processes responsible for the sculpturing of Lapandim-Tai.

The Study Area

Kaltungo is one of the eleven LGAs of Gombe State and it is the Headquarters of Kaltungo LGA.The LGA is located between latitudes 9^0 46’ N and 11^0 00’N and longitudes $11^0$15’E and 11^0 30’ E as shown in Fig 1. Lapandim-Tai is an inselberg lying in the southeast of Kaltungo town. The granites of the basement form massive and isolated rocky hills in the western and southern parts of Kaltungo with Bima sandstones forming impressive hills with sharp peaks (Kilang Hill) of about 1,600 m above mean sea level

Geology and Relief

The geological formation of the study area is basically of basement complex rocks consisting of igneous and metamorphic rocks of the Precambrian overlain by Bima sandstones. The basement cretaceous and the volcanic rocks form prominent hill features.

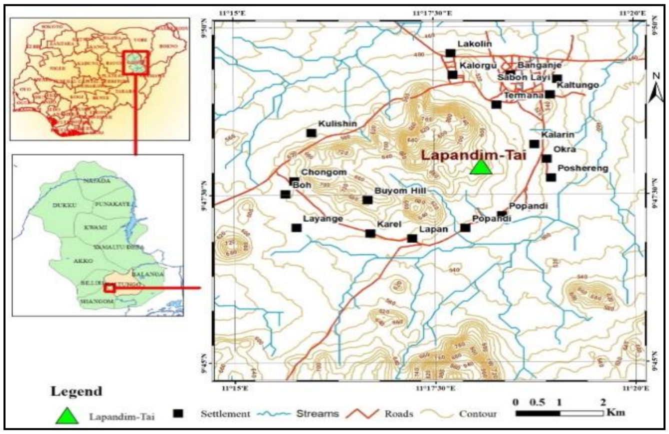

Fig. 1: Kaltungo LGA showing Lapandim-Tai
Source: Digitized from Nigeria Shape-file

Rainfall

The pattern and amount of rainfall received in Lapandim-Tal and its environs are influenced by two air masses: tropical continental (CT) and tropical maritime. The CT originates between latitudes 20^{o} N and 40^{o} N in the Northern Hemisphere and blows from the northeast. The air mass is dry, cold and dusty (Wanah and Mbaya, 2011). The MT originates over the Atlantic Ocean, blows from a south-west direction to the northeast, and is laden with moisture acquired from the ocean. Inter-Topical Continental Zone (ITCZ) separates the two air masses. The zone, according to (Faniran and Jeje, 2002) is characterized by convectional activity with air currents rising to 10,000m leading to the formation of altocumulus and cumulonimbus clouds, which yield torrential rainfall. The two air masses migrate north and south along with the apparent movement of the overhead sun over a year. Between May and October, the overhead sun is in the northern hemisphere during which Lapandim-Tai is in rainy season. There is little or no rainfall in Kaltungo during the dry season when the area is under the influence of CT air mass (Wanah and Mbaya, 2011; Wanah, 2017). The average annual rainfall as extrapolated from long past figures for Gombe and Numan was 850 mm as presented by Udo, 1981 and supported by Wanah and Mbaya (2011) compilation of rainfall totals, Average temperature for the locality is 25.7^{0}C with an annual range of 8.0^{0}C (Wanah and Mbaya, 2011).

Methodology

The following instruments and materials were used in data collection: Global Positioning System (GPS), 100meter measuring tape, Abney level, compass, ranging poles, topographic map, computer, relevant software and field notebook. Reconnaissance survey was conducted for getting familiar with the inselberg (Lapandim-Tai), and for getting specific direction, which the field measurement should start and end. Measurement of angles were taken using Abney level starting from the first point, A, at the northwestern part of the hill to the next point continually at an average interval of 30 m up to the peak of the hill, and down to point B on the other side of the hill. Two ranging poles were used in pecking the points and for reading off angles between two succeeding points.

Results and Discussion

This section presents the results of the study such that each objective is treated under a sub-title.

Geology and Relief of Lapandim- Tai and Environs

The geology of Lapandim-Tai and its environs, as per the mapping of Nigeria Geological Survey Agency (2019), is that of Bima Formation Fig. 2. The formation is the oldest, thickest, and most extensive sandstone formation in the area. Medium-grained porphyritic granites are the source of light coarse and medium-grained soils of the area and have been subdivided into three silica-clastic members of B1, B2, and B3. B1consists of basement derived conglomerates supported in a sandy matrix. B2 is coarse to medium and fine-grained sandstone with good lateral continuity. B3 consists of well-sorted, uniformly fine-grained ferruginous sandstone inter-bedded with more clayey to shale carbonaceous beds. Lapandim-Tai is a broad dome shaped inselberg surrounded by piedmont that spreads gently away from the foot of the hill. The southern side of the inselberg is steeper than the western and northern sides as shown in the DEM of the hill in Fig. 3 and illustrated in Fig. 4 (cross profile of the hill along line A-B) and Fig. 5 (cross profile along line C-D). Lapandim-Tai descends from 580 m to 477 m above mean sea level given an altitude of 50 m above the surrounding ground. Human activities, namely; cultivation of crops such as guinea corn, maize and groundnuts take place on the gentle slopes of the piedmont. Houses could be seen around the hill (Plate 1). Natural vegetation on the hill has been cleared mainly as fuel wood and for farmlands and settlement.

Quick Bird image of the hill was generated (Fig. 6) and it reveals various degrees of degradation that is associated with running water. Gullies could be discerned from the hill downwards each increasing in size as it receives tributaries and thus increase in the volume of water carried. The combine effect of large volume of water and the steep gradient explains the degree of dissection of the slopes on Lapandim-Tai. The gullies in Fig. 6 implied that large quantity of eroded material had been removed from the hill and that it is an on-going geomorphic process that is sculpturing the hill.

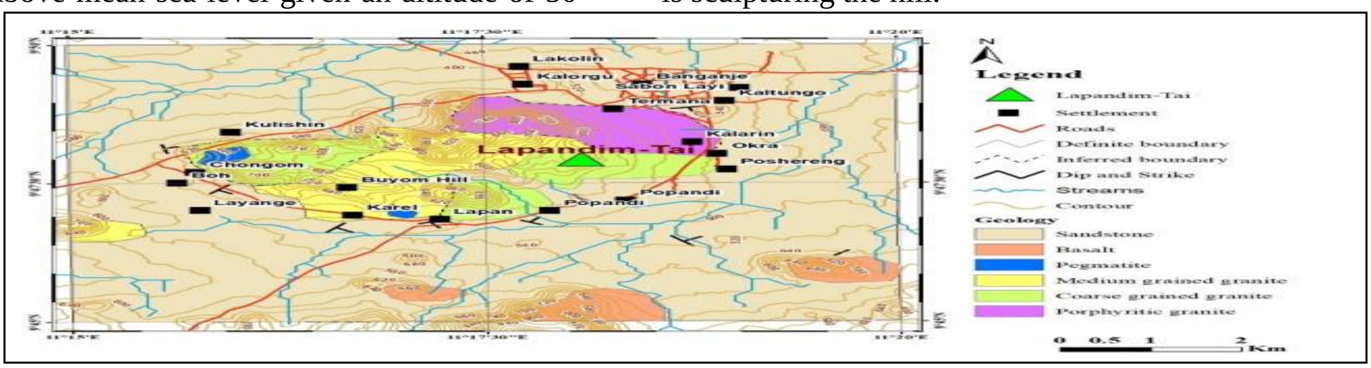

Fig. 2: Geological Map of Kaltungo
Source: Nigeria Geological Survey Agency (2019)

Gradient of Lapandim-Tai

Gradient or slope is the measure of steepness or the degree of inclination of a feature relative to the horizontal plane. In other words, gradient is the steepness of a slope expressed as a proportion between its vertical interval (VI) and its horizontal equivalent (HE) (Ibrahim and El-Tantawi, 2012, and Wanah, 2017) and is calculated by the use of the formula G = VI/HE. The gradient of the hill from point A at the foot of the hill to the highest point on the peak is 29^0 and that which descends to point B is 31^0 as shown in Fig 3 and illustrated in Fig 4 and Fig. 5. The data in Table 1 are succeeding angles up to the top of the hill (X), and those (Y) that descend down. The information was subjected to correlation analysis to study the degree of relationship between the two sides of the inselberg. Generally, the gradient of the hill is steep up to the top of the hill and down the sides of the hill in all directions which could be responsible for fast surface flows accounting for the degree of dissection and thus of sculpturing of the hill. Table 2 resents change in elevations in meters up the hill from point A up to the top of the inselberg and down to point B.

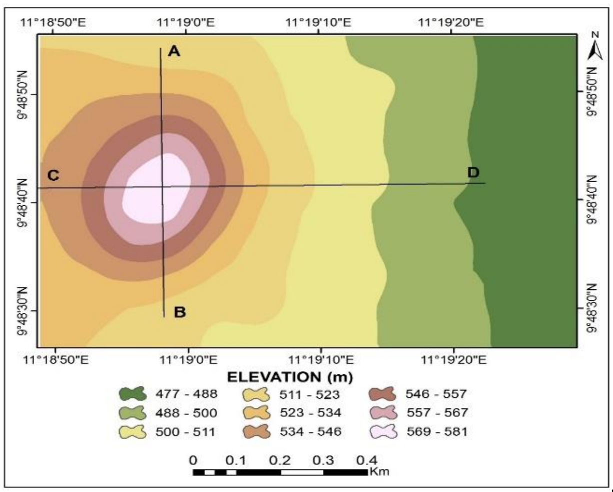

Fig.3: Digital Elevation Model (DEM) of Lapandim-Tai
Source: National Centre for Remote Sensing, Jos, 2019.

Correlation is the degree of association between two variables and it is represented in the form of coefficient known as correlation coefficient. The range of correlation coefficient is between minus one (-1) and plus one (+1). If the correlation coefficient is negative, then the variables are inversely proportional. If the coefficient is 0, there is no association between the variables. If coefficient is positive, then the variables are associated directly and the association is maximum when it is +1. The steep gradient (29^o on the northern side of the hill and 31^o on the south) shows that Lapandim-Tai stands high above the surrounding ground

Table 1: : Angles along Line A-B

S/No	X Angles	Y Angles
1	1.3^0	0.9^0
2	0.6^0	0.3^0
3	10.7^0	10.7^0
4	10.9^0	24.0^0
5	20.0^0	25.0^0
6	23.0^0	27.0^0
7	22.0^0	10.6^0
8	10.6^0	10.1^0
9	10.9^0	0.8^0
10	0.6^0	0.6^0
11	0.2^0	0.4^0

Source**:** Fieldwork, 2019

although it is much lower than the hills west of it. In determining the gradient between the two sides of the hill, correlation analysis was carried out to study the degree of relationship between the two sides of the inselberg. Angles in X and Y are denoted as two independent variables.

Hypotheses were formulated as follows:

H_0 There is no relationship between the angles on side A of the Lapandim-Tai and those on side B.

H_1 There is relationship between angles on one side of the hill and those on the other side

Using SPSS version 2016 software as a statistical tool, Pearson correlation is 0.987 and 0.657 respectively. These show that Y tends to increase as X increases implying that there exists a positive or direct correlation. Therefore, the null hypothesis (H_0) is rejected and accepted the research hypothesis (H_1) and concludes that there is relationship between angles on one side of the hill and those of the other side. This implies that there was a uniform geomorphic wearing process that accounted for stripping of material and thus sculpturing the hill thereby explaining erosional evolutionary trend of the hill.

Table 2: Elevations (m) along Line A-B

	Elevation (m) A	Elevation (m) B
1	514m	507m
2	519m	513m
3	522m	514m
4	533m	525m
5	539m	532m
6	541m	545m
7	554m	561m
8	565m	573m
9	573m	584m
10	579m	581m
11	580m	580m

Source: Fieldwork, 2019.

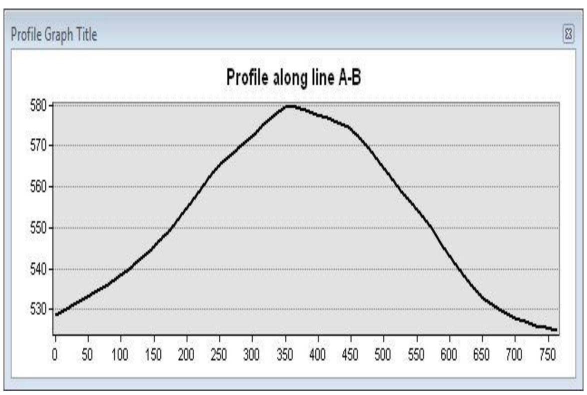

Fig. 4: Cross Profile of Lapandim-Tai along line A-B
Source: Fieldwork, 2019

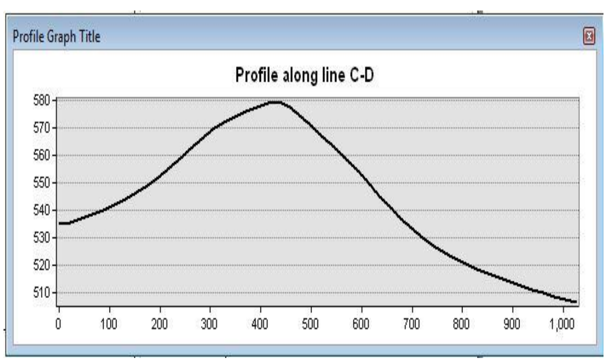

Fig. 5: Cross Profile of Lapandim-Tai along line C-D
Source: Fieldwork, 2019.

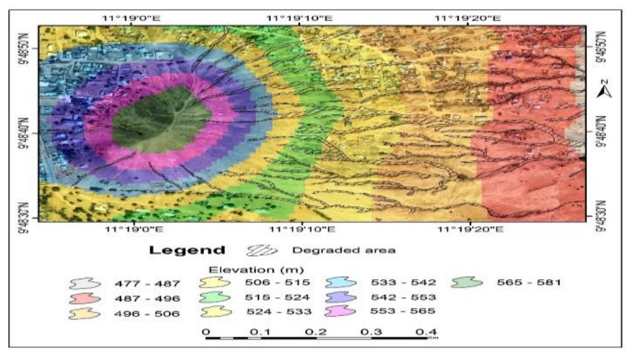

Fig. 6: DTM, Quick-bird image and degraded land
Source; National Centre for Remote Sensing, Jos, 2019

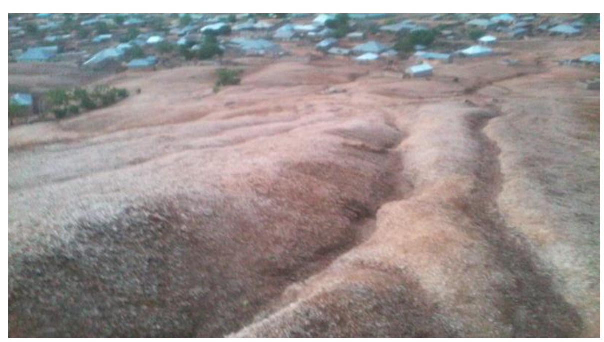

Plate 1: Gullies on eroded hillslope of Lapandim-Tai inselberg.
Source: Fieldwork, 2019.

Assessment of the sizes of surface particles downslope

The soil on Lapandim-Tai consists of sorted coarse grained, medium to fine grained particles as well as silty and clayey lenses as shown in Plate 2. The fine material explains reduced permeability, and therefore generation of flows that carried material down the hill. The soil is unconsolidated and is inter-bedded with a ferruginous reddish brown to yellowish arkosic sandstone alternating with clayey, light grey, carbonaceous, and pyritic beds. Grain sizes on Lapandim-Tai are coarse at the top (Plate 2) and in the middle slope but are much finer farther away from the hill.

Plate 2: Grain sizes in the study area
Source: Fieldwork, 2019.

Geomorphic Processes in Sculpturing Lapandim-Tai

Explanations for the evolution of inselbergs centre around two opposing theories: land denudation associated with pediplanation and that which is associated with deep weathering followed by multi-cyclic stripping of regolith (Young, 1972, Buckle, 1978, Afolabi and Ogunkoya, 2018, Wanah, *et al*, 2019). The application of these geomorphic processes is that inselberg is a remnant of stripping of weathered regolith through the process of parallel slope retreat as postulated by Young (1972), a process referred to as pediplanation, which according to many authorities is limited to arid and semi-arid areas. In savannah regions, according to Buckle (1978), plains are more the result of deep weathering followed by stripping of the weathered layer and scarp retreat. Deep weathering by chemical decomposition in the humid tropics produces a layer of rotten rock up to 60 m thick (de Blij, *et al* 2005) although the depth of the weathered material may vary from place to place and according to mineral composition and jointing of the parent rock (de Blij, 2002). Streams flowing across the plains develop wide shallow channels in which vertical erosion is not great. If, however, regional uplift initiates a new erosion cycle, streams will be rejuvenated and will cut down into the weathered layer thereby stripping off the material. A new layer of plain is formed which is gradually extended by scarp retreat (de Blij, 2002). In those areas where the rock was resistant, inselberg of hard rock will remain above the plain. Accordingly, inselbergs are remnants of resistant rocks and therefore explaining the evolution of inselbergs. Gullies and rills developed on them serve as tools in sculpturing hills that evolved through deep weathering and stripping of the weathered material.

Running water is the most powerful agent of erosion and thus of stripping regolith from the slopes of Lapandim-Tai. This is in line with the fact that continents are mostly eroded primary by running water at an average rate of 2.5 cm in every 750 years (Alexander, Harvey, Calvo, James, and Cedar, 1994). Typically, rivers tend to have old age, mature and youthful ages and the three stages may grade imperceptibly from one stage to the next. The youthful stage is characterized by rapid down cutting, high stream gradient, steep-sided valleys with narrow bottoms. These features can be seen in Plate 1 and in the Quick Bird image in Fig. 6. In general, a stream's gradient decreases from its upper course downslope resulting in a longitudinal concave as can be discerned from the DEM of the hill (Fig. 3) and depicted in the cross profiles in Figs 4 and 5. The uniform steepness in slope on Lapandim-Tai is responsible for uniform rate of runoff, moving sediments and deposition of materials. Erosion by water through its processes of splash, rills and gullies is that considerable quantities of soil may be stripped downslope. Rill and gully erosion are the dominant form of water erosion on Lapandim-Tai thereby explaining its stripping and sculpturing and subsequently its evolution.

Detailed study of the processes of stripping fine to coarse grains downslope of Lapandim-Tai has not been carried out. It is therefore recommended for further studies.

Conclusion

The study found that running water, along with human activities and moderate rainfall over the area are responsible for eroding and thus sculpturing Lapandim-Tai. Since the slopes on the inselberg are uniform and thus giving rise to a conical hill, it means that the hill evolved through uniform slope retreat, a geomorphic process of stripping regolith thereby exhuming resistant rocks, which remained as Lapandim-Tai inselberg. Coarse grain sizes and frequent gullies on the hill point to on-going loss of slope material. The observed erosional processes exhumed resistant rock type forming the hill, which is Bima Sandstone.

Recommendations

Erosional processes going on Lapandim-Tai is a major ecological problem threatening the existence of the hill. It is also an environmental, social and economic problem that needs to be tackled. To forestall the erosional problem and for sustainable utilization of the hill, erosion on the slopes and lower ground surrounding the hill should be controlled through planting fast growing plant species such as *Paniculatu/Pitadeniastrum africanum* and Bahamas grass. Inhabitants of the area should be educated on the consequences of un-informed land use and embark on planting fast growing plant species to anchor and stabilized loss of slope material from being washed away. Erosion control measures should be coordinated such that each erosion hazard should not be considered in isolation but must be seen as a component part of integrated management scheme and be treated within that context. Management of erosional hazards in the local government, state and the federation should finance programs that could assist in minimizing the loss of surface material on hills. Finally, the research report is recommended for students of landform evolution.

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