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Hill slope housing development in Vinikilang, Yola, Nigeria: A geo-disaster risk

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Abstract

This work is a community development based research meant for awareness and response. Due to population increase in Yola and environs, Nigeria, settlements have expanded into some unsafe grounds. An example is Vinikilang, a fast growing residential/commercial suburb of Yola. This work shows that the town has been developed on a tectonically evolving rocky, fractured and geologically unstable hill slope. The instability is a function of lithological, structural, topographic and climatic factors which work synergistically. Field observations reveal two fracture/tectonic directions namely NE-SW and NW-SE which are conjugational, dominant on the slope and control the channel of the Benue River in the area. Evidences of mass wasting are shown in this work in order to discourage further housing development. Seepage forces especially during heavy rains constitute a major agent of rock fracture. Geodetic monitoring of slope and resettlement of inhabitants are among the recommendations made to forestall losses in the event of rock fall/slope failure which are sure to occur but uncertain in time.

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1 Introduction

This work is part of a community development based research meant for communal awareness and response. Geologically related disasters or geo-disasters are common occurrences on our planet. Such geo-disasters include earthquakes, tsunamis, river floods, volcanic eruptions, mass wasting etc.

People often assume that the earth beneath them is *terra firma* , a solid foundation on which they can build their lives, but history has shown this is not exactly so. Much of the earth's surface is an unstable ground, land capable of moving down slope in a matter of seconds to weeks. Geologist refers to gravity induced transport of rock or soil as mass movement or mass wasting. It's a typical form of natural hazard, meaning a natural feature of the environment that can cause damage to houses, farmlands, roads, utility lines and even loss of human lives. Vinikilang is an expanding community in the suburb of Yola the capital of Adamawa State, Nigeria and part of its settlements has developed on unsafe grounds.

While it is not the intention of the authors to cause panic, we feel it is our professional responsibility and obligation to alert citizens and regulatory agencies on the danger or potential hazard of building settlements on hill slopes, as the following historical records show. It will be recalled that in Oct 9 1963 after two weeks of heavy rainfall and subsequent rise in the water table, pore pressure built up and dramatically caused a landslide in Italy at the Vaiont Dam leading to the death of 2600 people (Deming, 2002). In 1970 May, the town of Yungay, Peru in South America was buried by debris triggered by earthquake that produced landslide (Marshak, 2001). In 1988 in Brazil's Rio de Janeiro whole communities that were built up on steep mountain slopes disappeared overnight due to mass wasting on the mountain slopes triggered by heavy tropical rains (Marshak op. cit.). On Monday 19th September 2011 international news agencies namely CNN and Aljazeera reported landslide occurrence in China after heavy rains.

It is hoped that this work will enlighten the residents of the study area, and the relevant government agency/functionaries that this built up/expanding area is disaster prone. There are no reports of mass wasting in the area possibly because Vinikilang is relatively a newly built-up/expanding area. However evidences of rock fall (displaced boulders now found at ground positions) and soil creep lends credence to the point that the area is disaster prone. Besides, the River Benue which flows through the area overflows its bank annually causing flooding and disrupting economic activities. This work is important and timely because as the saying goes "to be forewarned is to be forearmed", and "prevention is better than cure". Timely action in the right direction can avert future losses of lives, properties and disruption of economic activities.

Holmes (1981) enumerated some conditions which trigger mass wasting. These include;

a. Lithological factors (unconsolidated or weak material or those which become slippery when wet)
b. Structural factors (closely spaced joints or faults crushed zones etc.)
c. Topographic factors (steep slopes or vertical cliffs)
d. Climatic factors (abundant precipitation or torrential rain)
e. Organic factor (scarcity of vegetation)

Besides the above, anthropogenic activities of farming and construction of buildings on slopes, can contribute to mass wasting. In the case of farming the rock and/or soil is affected by constant tilling/plowing making them amenable to slide. While in the latter case buildings increase the weight (stress) on the rocks which can initiate slide.

This work is based on structural data/field observations made at Vinikilang. It examines the possibility of rock fall in the light of physiographic and field structural data. Its objective is that through an environmental journal awareness would be created on the possibility and negative impacts of mass wasting. Suggestions are made on minimizing its negative impact. Rock fall is the free fall of masses of rock or individual boulders from cliff faces or down steep slopes (Potter and Robinson, 1975). Few examples of devastating mass wasting events reported in Nigeria are hill slope wash and rock avalanche in Nandu, Jama'a Kaduna State, (Oluyide and Okunola, 1993), rock avalanche in Imo state (Okagbue, 1988), rock fall in Song Local Government area Adamawa State (Bassey, 2007). Besides these, there are numerous reports in the airwaves of landslides etc. in Akwa Ibom State, Anambra State etc. in Nigeria.

1.1 Geography

Vinikilang is a fast growing community located on the slope of Bagale hill and close to River Benue (Figure 1), one of Nigeria's longest rivers. It is a residential and commercial area with social amenities like schools, motor Park, market, police station etc. It also plays host to electronic media corporations such as Adamawa Television, Radio Gotel and Television, and Radio Nigeria. These corporations exploit the topographic features of the place to erect their high rise transmission masts. Other facilities such as the National Youth Service Corp orientation camp and an Industrial complex are located here.

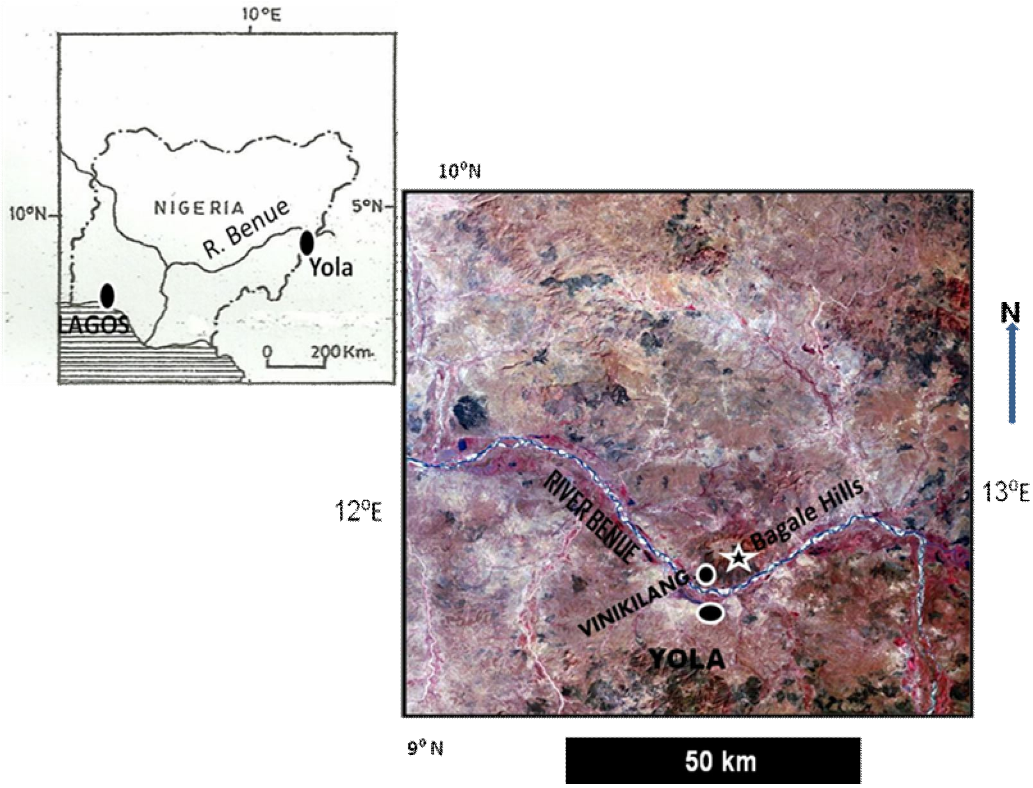

Figure 1: Location of Vinikilang on satellite imagery of Yola area. River Benue exhibits ''V'' shaped channel due to control by conjugate NE-SW and NW-SE fractures (source of imagery: Federal Dept of Forestry, Abuja. Vintage: Jan 1993).Upper left is map of Nigeria showing location of Yola.

1.2 Climate

The two main climatic seasons in the area is the hot/dry season and rainy season, each lasts for about five to six months of the year. The rainy season comes with high precipitation from early April to October, with a peak period from July to September. While the dry hot and dusty harmattan period commences from November to April.

1.3 Relief and Vegetation

The study area is bounded to the east by the Bagale hills which constitute a major anticlinal feature within the Benue Valley. The hills reach a peak at about 2000 m above mean sea level, and serve as water shed to several streams some which drain southwards into the Benue. The area is rocky and highly fractured having evolved through denudation and tectonism. Prominent rock boulders accumulate on the slopes and foot of the hills. The boulders measure several meters across and weigh several tones. The vegetation is grassland with few trees supported by the thin soil or scree from the rocky slopes. Often times the trees grow through cracks or fractures in rocks enhancing their disintegration.

2 Geology

The study area is underlain by the Bima Sandstone, a Cretaceous sedimentary unit of Yola Arm of the Benue Rift valley. Stratigraphically, the Bima Sandstone consist of alternating layers of poorly to moderately consolidated, fine to coarse grained sandstones, clay-shales, siltstone and mudstone with average thickness of 250 m (Obiefuna and Orazuklike, 2011). In the study area, the rock varies in colour from light brown to reddish brown because of its high ferrogenous content. The rock occurs bedded and commonly with cross stratification. It is highly crystalline and cemented in places especially within the study area and environs. The Yola Rift Valley is believed to have formed by wrench fault tectonics (Braide, 1992) and has an easterly trend of over 250 km in length and about 75 km in width.

3 Materials and methods

The work was accomplished mainly by field observations. Structural observations and measurements were made with the compass clinometer, photographs were taken using a digital camera and oral interview of some inhabitants of the study area was done. Topographic and satellite maps of the area and environs were studied to compliment the field work. Position location and elevation data were acquired with the use of *e-trex* GPS device.

4 Results and discussion

The study area is highly tectonized as indicated from the structural measurements and photographs taken (see: Figure 2 and the Plates 1-6). Ninety seven structural features namely faults and joints and other fractures were observed and their strikes and dips measured.

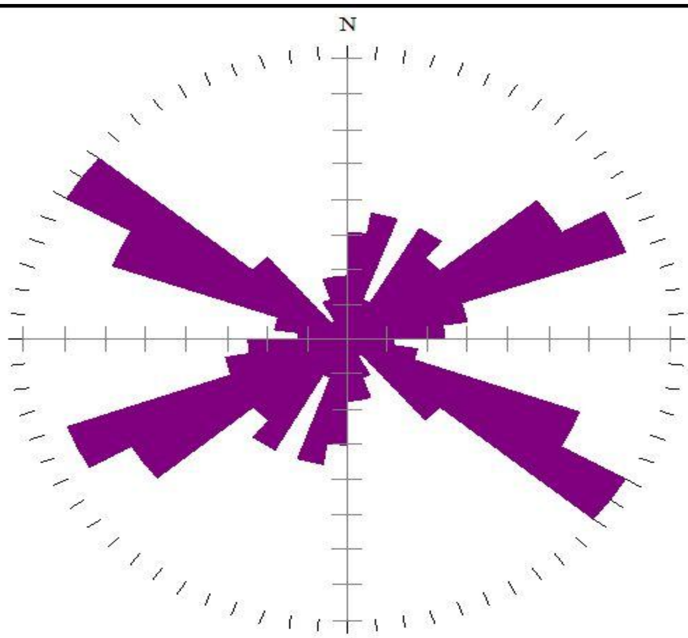

Fig.2 Rose diagram plot of structures (faults, joints and other fractures) in Vinikilang, NE-SW, NW-SE directions are dominant (n=97).

Photograph 1: Part of a heavily fractured slope in study area,buildings at background are part of a school compound.

Photograph 2: Boulders sliding down slope due to soil creep placing the building shown at risk. At background is Jimeta bridge over the Benue, the bridge spans 1.4 km.

Photograph 3: Displaced boulders on hill slope

puts buildings at the background at risk.

Photograph 4: Dipping strata of Bima Sandstone in study area (arrow shows direction of dip), magnitude of dip is 12^{o} NW, strike is N68^{o}.
Location: N 09 18.521', E 012 29.387'.
Dipping surfaces such as shown serve as avenue for soil creep, and potential slide surfaces.

Photograph 5: Wall of building constructed over a fault zone. The wall has cracked at position indicated by broken line over fault trend. Fault trend is N50^{o}E.

Plate 6: Composite scenes of some hill slope houses in Vinikilang.

The faults were identified based on features such as striations and slicken sides. A rose plot of the strikes of the structures is presented in Figure 2. Northeast-southwest and northwest-southeast trends are dominant. They constitute part of a conjugate set of lineaments which control the flow direction of the Benue in the area (see: Fig.1). Benkhelil (1986) and Guiraud (1989) observed the occurrence of strike slip faults conjugated around compressive directions of 60^o and 50^o reverse to thrust faults in the upper Benue Trough. Minor structural directions are N-S, while NNE trend is complimentary. Field photographs show the highly fractured nature of the area (see Photographs 1, 3 and 6). Benkhelil (op cit) showed that Bima Sandstone has the highest density of fractures in the upper Benue trough. He also reported that Bagale hill is an anticlinal structure with a north east axis.

The study area is part of an evolving tectonic slope. Evidence for this are the numerous boulders that litter the base of the hills possibly due to rock fall, while some are in sliding positions on the hills (Photograph 2).

Any moderate slope experiences soil creep (Potter and Robinson, 1975). This is observed in Vinikilang and environs. The topographic height difference between the River Benue valley floor (under the Jimeta Bridge) and some of the highest built up areas is 48 and 61m respectively. Hence soil creep is an on-going mass wasting process in the area. This is evident from features observed at some locations during the study (Photograph 2). Some boulders are found at heights or positions that appear unstable; this puts some buildings at risk (Photograph 3).

The stratification exhibited by the Bima sandstone make the rocks liable to mass wasting. This is because the stratum planes (bedding planes) are potential slip planes in the event of mass movement, especially where the strata are dipping (Photograph 4). By implication, houses in the study area are built on a heavily fractured and sloppy terrain. This can affect the foundation and walls with time. Photograph 5 shows the wall of a building constructed over a 50^o trending fault zones. The fault has initiated a crack (indicated by broken line) on the wall. The

location of this structure is at N 09 18.300’ and E 012 29.227’.
During the rainy season, the water that infiltrates the rocks of the area help boosts groundwater system. The presence of groundwater in the rocks reduces their cohesion due to excessive pore pressure, which can cause rock failure (Hobbs et al., 1976). Such loss in cohesion can trigger rock slide when the cohesion becomes zero. Annual flood by the Benue occasioned by heavy rainfall may lead to rise in ground water level in the area. Subsequently pore pressure will build up in rocks thereby weakening them/expanding existing fractures. Ultimately rock/slope failure will result. It will be recalled that in Oct 9 1963 after two weeks of heavy rainfall and subsequent rise in the water table, pore pressure built up and dramatically caused a landslide in Italy at the Vaiont Dam leading to the death of 2600 people (Deming, 2002). Ishaku (2011) demonstrated that stream channels in the study area and environs are structurally controlled. These streams help to expand existing fractures thereby increasing slope instability.
Building construction in the study area constitutes a load on an already heavily fractured and unstable rocky slope. This increases the stresses on the rocks and can initiate slope failure at any time. Photograph 6 is composite scenery of buildings on the fractured slopes in the area.

5 Conclusions

The study area is underlain by highly fractured rocks produced by denudation and tectonism. The tectonic trends NE-SW, NW-SE constitute a conjugate fracture set, this conjugate directions control the flow of the River Benue as evident on satellite imagery (Fig.1). Soil creep in the area is a precursor to higher grade of mass wasting. Abundance of displaced boulders in the area especially at the base of the hills indicates the possibility of rock fall or landslide occurrence in the past. The area appears to be a potential site for geo-disaster as seepage forces are naturally at work especially during the rainy season. Also the buildings constructed on the slopes increases the stresses on the rocks thereby raising their instability. Slope failure may be spontaneous or gradual and can be initiated by natural phenomenon such as heavy rains, anthropogenic activities (mechanical vibration, heavy traffic etc.). It can result in losses of lives and property.

The following recommendations are made and their implementation should be effected without delay. The land use authorities (Ministry of environment) should put a stop to further construction of houses in the area. Occupants of buildings near overhanging boulders should be made to relocate to safer grounds. Operations of heavy vibrating machines on the hills should not be allowed. The best solution to a threatening geo-disaster is to evacuate or relocate the citizens. This is strongly suggested. Geodetic monitoring scheme should be set up without delay and sustained to study and advise on soil creep and slope movements in the area. The Survey and Informatics dept of Modibbo Adama University of Technology can be consulted to undertake this. These recommendations are important considering the calamities that may result in the event of mass wasting.

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