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Application of Lineament Analysis in Geohazard Studies in Mukuru Area Boki Lga Cross River State Nigeria

By Egesi, N. & Agbebia, M. A.
University of Port Harcourt

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APPLICATIONOFLINEAMENTANALYSISINGEOHAZARDSTUDIESINMUKURUAREABOKILGACROSSRIVERSTATENIGERIA

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Keywords: rockfalls, lineaments mapping, geohazards prevention, mukuru-boki area, nigeria.

I. Introduction

The petrology and structural features of Uwet area parts of Oban massif and southern Obudu has been studied by Ekwueme, (1987, 1990). He observed orientations of planar, linear and small-scale geological structures. These features are consistent with the isotopic data results, indicate that the area was subjected to poly-phase deformation, poly-metamorphism and magmatism during the Precambrian period. Ukaegbu, (2003) identified pressure-temperature distribution and linear structures as the centre of the geotectonic features of southern Obalinku area. Boki area, which is in the south of Obudu and Obalinku Local Government Areas, contains sheets 304 Bansara and 305 Mukuru and has received attention recently, Egesi and Ukaegbu (2010, 2013), Egesi, (2015), which identified the rock types in the area, while Agbebia and Egesi (2019), carried preliminary lineament survey Figs.1 and 2. This paper is an attempt to use lineament analysis to investigate the geology of the area particularly hazardous zones that may put the lives and properties of the inhabitants at great risks if unchecked and control measures put in place.

Author: Department of Geology, Faculty of Science, University of Port Harcourt. e-mail: ndukauba.egesi@uniport.edu.ng

II. Geological Setting

Edet *et al.,* (1994) observed that lineament density are high in areas of outcropping bedrock, overburden and thin cover in parts of Oban and Obudu areas. The Nigerian Geological Survey Agency NGSA (2010) described the study area as granulites terrain using aeromagnetic survey data only. We carried out detailed field investigations, ground-truth, lineament analysis and confirmed the presence of granulites at Kanyang, Wula, Afi River area between Katabang and Kanyang, Bamba and Abuogbagante; other rock types identified are migmatites, eclogites, schists, amphibolites, granites and dolerites Egesi, (2015). Field observations show fracturing increases from Bansara in the west to Mukuru in the east as shown in the terrain Fig.2. It has been observed that the eastern Nigeria terrain is overlain by high grade, migmatitic, metasediments intruded by several voluminous proterozoic, plutonic, hyperbyssal and volcanic suites. In comparison to western Nigeria or western Cameroon, field observations made by Fèrrè *et al.* (1995) indicate no basement-cover relationship within these rock units. Most rock types they identified are coarse grained and include banded migmatites, paragneiss, anatectic granite, granitic gneiss, kinzigites, charnockites, diorites, amphibolites, quartzites and calc-silicate rocks. The calc-silicate forms boudins within the gneisses and migmatites. In addition, lenses of almost pure sillimanite and garnet occur conformably with the layering of the migmatites. These features are also present in Bansara and Mukuru Boki area.

In comparison with Ekwueme (1990), there is indication that metamorphism reached grades higher than upper amphibolites facie, like the granulites facie at Kanyang and Wula, with the formation of abundant metatexites and diatexites (Fèrrè *et al.* 1995). All the metamorphic rocks identified are coarse grained gneisses or anatexites (grain size commonly, 0.5 – 1cm). The observation of orthopyroxene and mesoperthite, in leptynites and its associated leucosomes, are typical minerals of the granulites facie, which is a characteristic of deep-seated regional metamorphism, suggesting peak temperatures well above 650^{o} C for granulites formation (Fèrrè *et al.* 1996). Figures 1 and 2 are the satellite terrain map of Boki showing the Mukuru area and the topographical map with Cameroon boundary in the east.

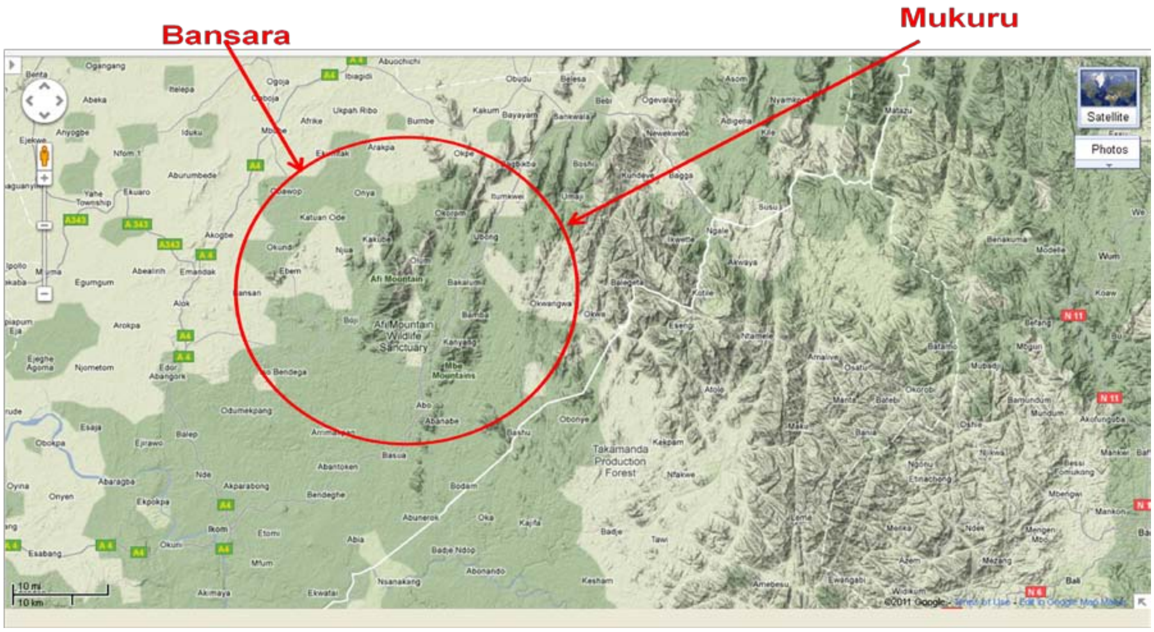

Figure 1: Satellite terrain map showing fractures in Boki, increasing towards the east in the Bamenda massif of Cameroon area (Source: Google Earth 2020)

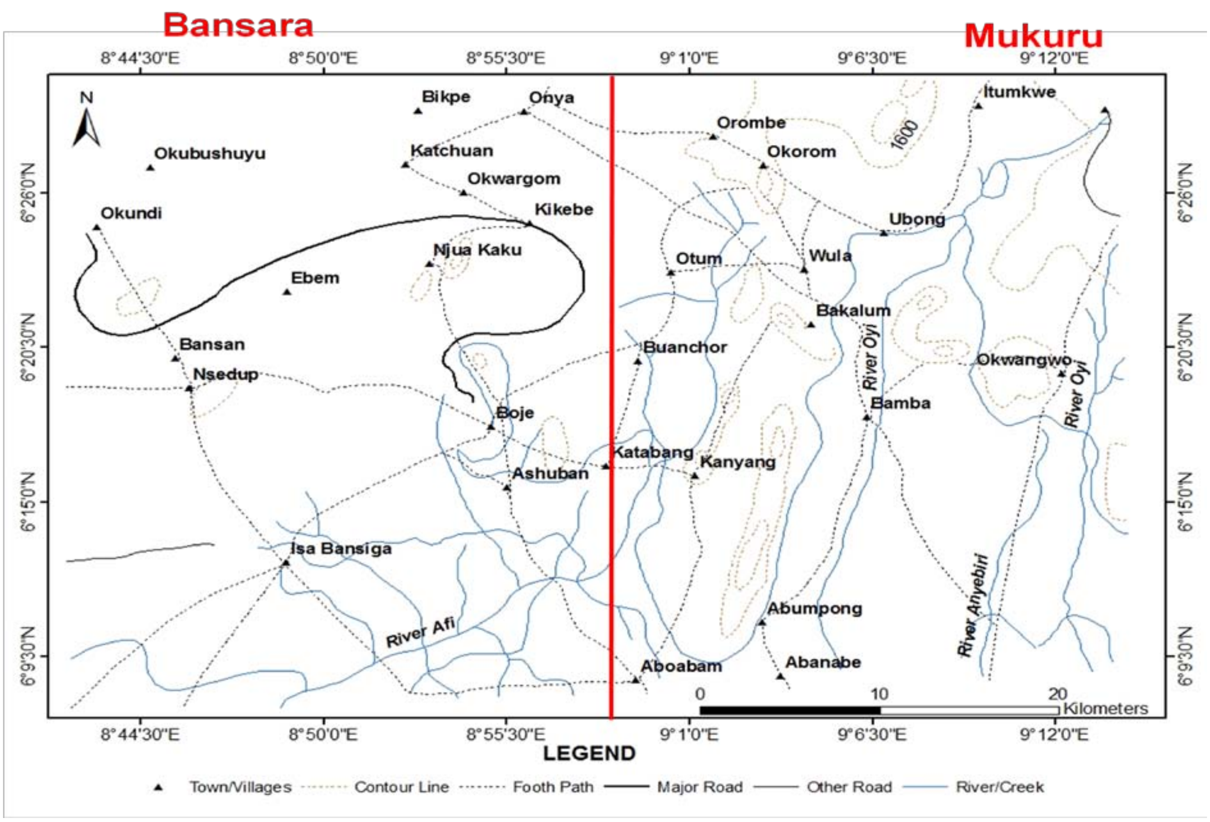

Figure 2: Location map of parts of the study area

Rockfalls or rockslides can occur when a stable slope becomes unstable due a discontinuity. There are a number of factors which can lead to this situation. They can be group into Natural factors and Human activities. Using a sketch for a channel morphology of fluvial systems Ibisate *et al.*(2011), showed the main factors that determines the effectiveness of the resultant features human activities and natural factors can produce (Figure 3). It should be noted that human activity is the main driver for such a geohazard occurrence. Plate 1 is part of massive charnockitic rocks in Buanchor area before the rockfalls and rockslides which occurred in the area due to human activities at the foot of the highlands after a heavy rainfall and storm.

Channel Morphology

↑

Basin external factors → Main drivers → Boundary conditions

↑ ↑ ↑

Climate | Flow discharge & Floods | Sediment yield | River characteristics

Tectonics | Fluvial Territory

Base Level

Metrological and climatic

Past Environmental Conditions

↑ ↑

Metrological and climatic conditions | Slope

Physiographic characteristics | Confinement

Geology and Lithology | Substrate

Vegetation and Others | River bank

↑

Human Activity

Figure 3: A sketch showing the main factors that determine channel morphology (Ibisate *et al*. 2011)

Plate 1: Field photograph of massive charnockitic rocks at Buanchor hills before the rockfalls and rockslides

Mouri *et al.* (2011), carried out a study in the mountainous granitoids terrain in Japan, they found that extreme events such as large storms and floods due to heavy precipitation can trigger off rockfalls, rockslides,

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landslides and mudslides, that can carry large volumes of rock materials for fluvial relocation. Thus, the geology of a locality, can fundamentally influence the hydrology and the morphology that can be transformed. Umeuduji, (2019), using an illustration on Man, Rivers and Morphological transformation and safety, observed that an increasing order of magnitude can occur beyond the annual mean rainfall floods, the 5-year floods with a 20% chance, 50-year floods with a 2% chance and 100-year floods with 1% chance of occurring which may pose threat to safety of lives and properties. The plate 2, below is a lake on top of biotite granite rock which if it is large enough, under large storms favourable conditions can release the water and other rock materials contained after a heavy rainfall to the lowlands where communities are residing. The effect which may be hazardous, will be similar to the collapse or failure of a water dam. There is need for a controlled release of the water in the pond to safeguard inhabitants living at the lowlands.

Plate 2: Field photograph showing a 3m deep lake on top of biotite granite a potential geohazard feature

III. Materials and Methods

The Buanchor highlands are part of the source of Afi River which is a tributary to the Cross River. The methods used includes data sourcing, imagery and software. Field investigations, structural features modelling and analysis, ground-truth and lineament and structural interpretation. The materials acquired are Shuttle Radar Topographic Mission (SRTM) 30 x 30m, LandSat 8 Pixel size: 1 – 7.9: 30m and Nigerian shape files 2019. The PCI GEOMATICA 19 was used for lineament mapping, ARCGIS 10.5 for Cartography and spatial analysis while Grapher 12 and Rockworks 19 were used for altitude analysis. A total number of 265 altitudes were measured in Mukuru sheet 305. As result of the colour differences lineaments appear as lines or edges on the images. Their identification is by observing straight rock boundaries, valleys, tone variations and vegetation cover alignments.

Table 1: List of data and method of acquisition

S/N	Data	Method of Acquisition	COST(NGN)
1	LandSat-ETM 2019, Path 187, Row 056	Purchase through Agents	-
2	SRTM (Shuttle Radar Topographic Mission), Path 187, Row,056	Purchase through Agents	-
3	Nigerian Shape Files Nigeria Sat-X	Given at ASTAL Uyo	-
4	PCI Geomatica 19	Purchase Online	350,000
5	Arc GIS 10.5	Purchase Online	75,000
6	Rockworks 19	Purchase Online	50,000
7	Stereonet 9	Purchase Online	15,000
8	GeoRose 0.4.1	Purchase Online	10,000

Table 2: Parameters of structures measured at Owambe/Otanchi/Bibo area.

S/N	Strike	DIP	DIP Direction	S/N	Strike	DIP	DIP Direction
1	324	53	58	43	324	53	58
2	154	53	65	44	154	53	65
3	354	44	76	45	354	44	76
4	355	32	54	46	355	32	54
5	312	23	88	47	312	23	88
6	143	34	86	48	143	34	86
7	336	42	37	49	336	42	37
8	314	43	44	50	314	43	44
9	305	65	61	51	305	65	61
10	322	32	82	52	322	32	82
11	318	31	88	53	318	31	88
12	341	21	60	54	341	21	60
13	342	43	42	55	342	43	42
14	312	36	34	56	312	36	34
15	336	42	37	57	336	42	37
16	324	53	58	58	324	53	58
17	154	53	65	59	154	53	65
18	354	44	76	60	354	44	76
19	355	32	54	61	355	32	54
20	312	23	88	62	312	23	88
21	143	34	86	63	143	34	86
22	336	42	37	64	336	42	37
23	314	43	44	65	314	43	44
24	305	65	61	66	305	65	61
25	322	32	82	67	322	32	82
26	318	31	88	68	318	31	88
27	341	21	60	69	341	21	60
28	342	43	42	70	321	34	77
29	312	36	34	71	340	40	82
30	336	42	37				
31	324	53	58	S/N	TREND	PLUNGE	
32	154	53	65				
33	354	44	76				
34	355	32	54	1	294	30	
35	312	23	88	2	287	76	
36	143	34	86	3	277	67	
37	336	42	37	4	310	77	
38	314	43	44	5	284	30	
39	305	65	61	6	290	76	
40	322	32	82	7	294	30	
41	318	31	88	8	287	76	
42	341	21	60	9	277	67	

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IV. Results and Discussion

The results are presented as stereonet, rose and rosette plots, tables, maps and ground-truth field photographs. Remote sensing and GIS can be employed for rockfalls and rockslides geohazard analysis and assessment. They are done before the event and after the event. These helps to unveil the topography or how the landscape have changed with time, what triggered the rockfalls and also predict future events. The lineaments indicates a major NW/SE to minor N-S with altitude in NE-SW in Figs.4 and 8 Owambe and Kanyang areas, while Figs.5, 6, and 7, is similar except that the altitudes are in NW/SE direction in Bumaji, Ubong/Olum/Buanchor axis and Bamba areas. Seventy four (74) altitudes of planar and ten (10) of linear features were measured in Owambe/Otanchi/ Bibo, forty six (46) of planar and nine (9) of linear in Bumaji, sixty (60) of planar and sixteen (16) of linear in Ubong/Olum/Buanchor, eighteen (18) of planar and six (6) of linear in Bemi, fourteen (14) of planar and four (4) of linear in Bamba, and four (4) altitudes of planar and four (4) of linear features in Kanyang area.

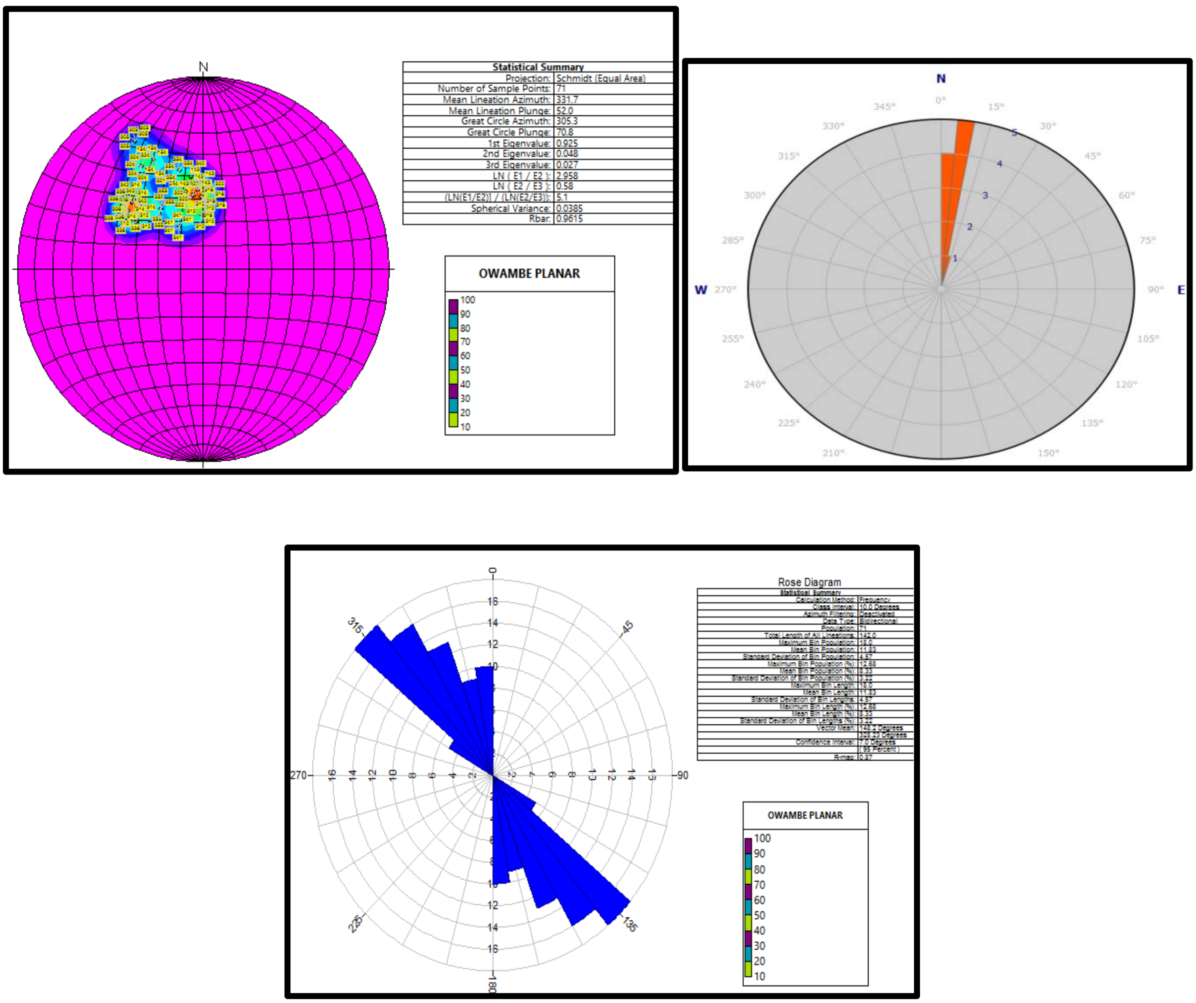

Figure 4: A- Planar Stereonet plot, B- Planar Rose Plot and C- Linear Rosette Plot of the altitudes of Owambe/Otanchi/ Bibo Striking NW/SE to N-S and Trending NE/SW

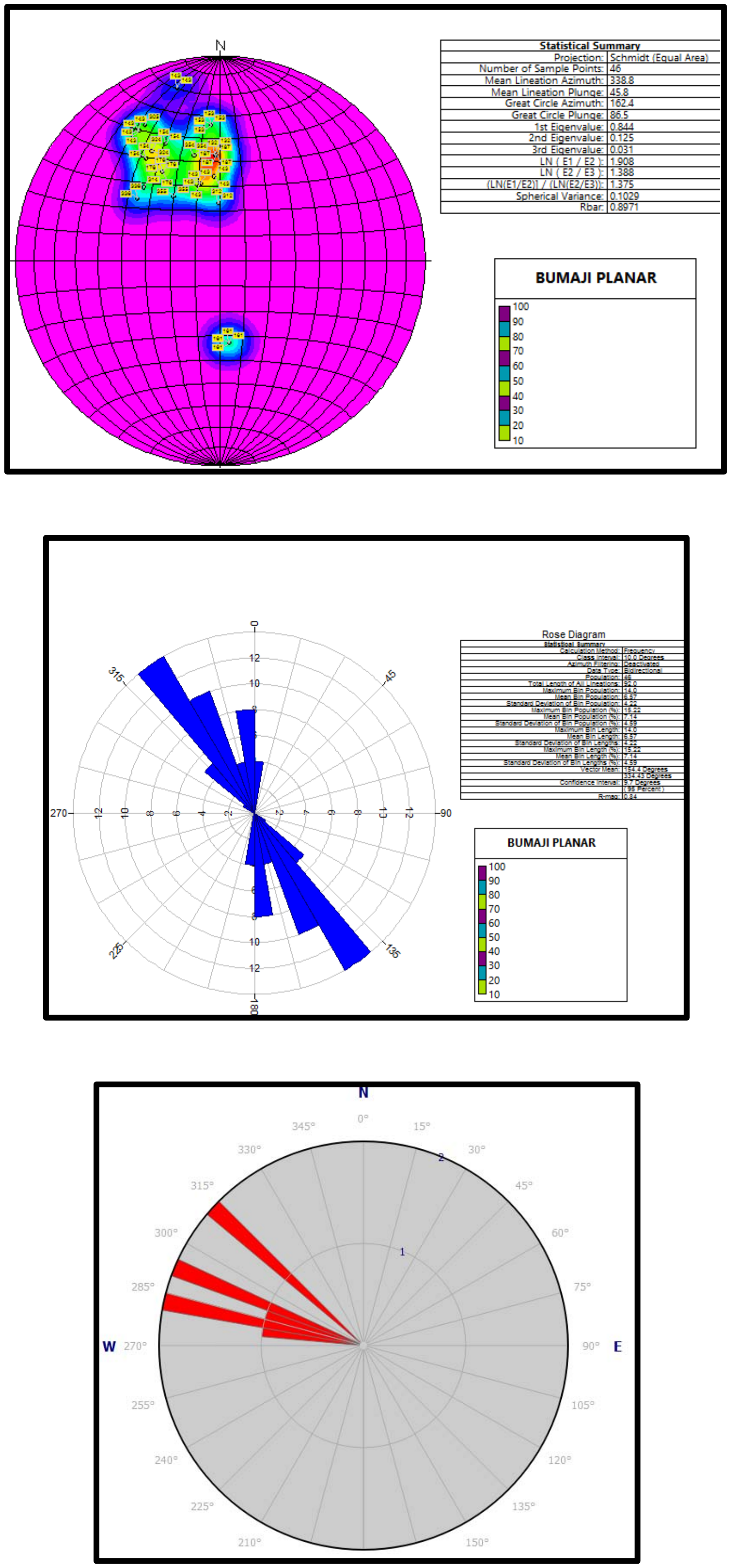

Figure 5: A- Planar Stereonet plot, B- Planar Rose Plot and C- Linear Rosette Plot of the altitudes of Bumaji Striking NW/SE to N-S and Trending NW/SE.

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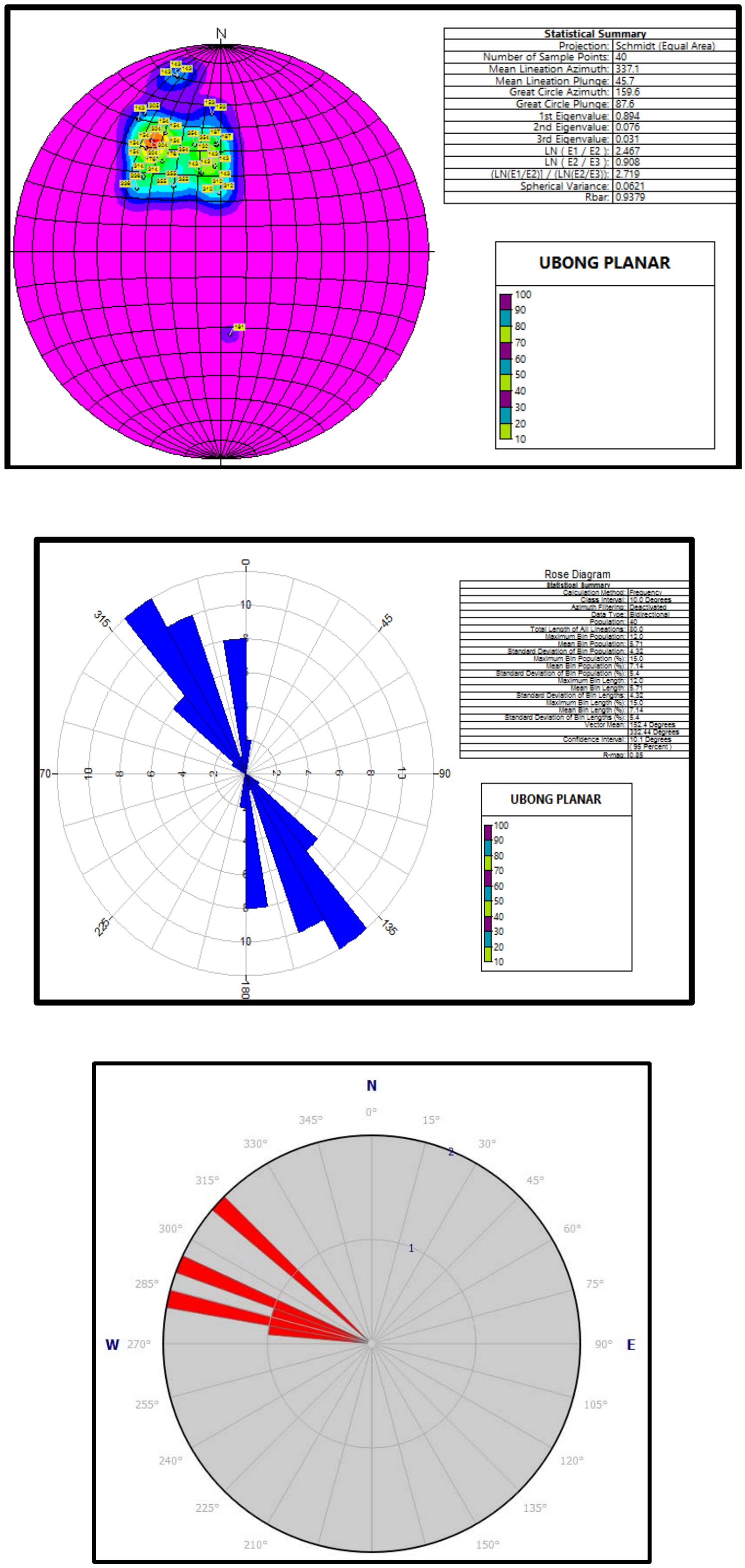

Figure 6: A- Planar Stereonet plot, B- Planar Rose Plot and C- Linear Rosette Plot of the altitudes of Ubong/Olum/Buanchor area Striking NW/SE to N-S and Trending NW/SE

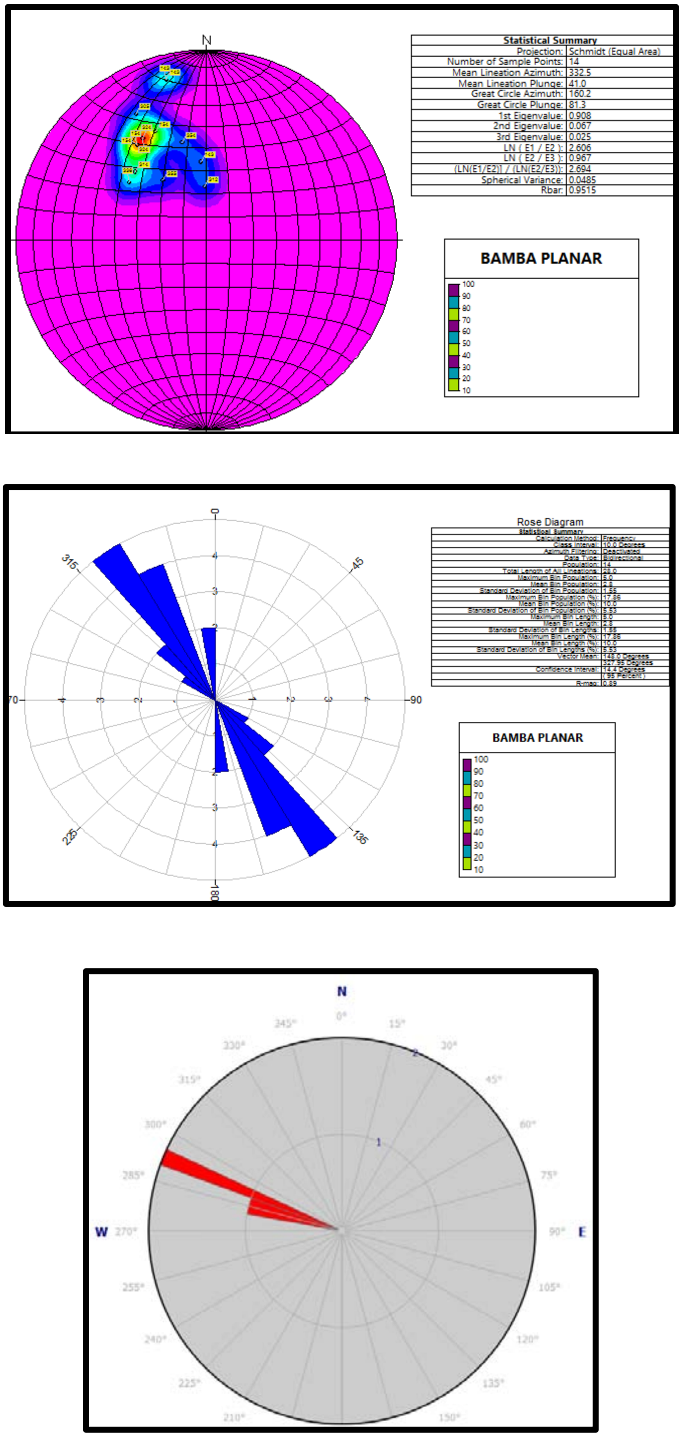

Figure7: A- Planar Stereonet plot, B- Planar Rose Plot and C- Linear Rosette Plot of the attitudes of Bamba area Striking NW/SE to N-S and Trending NW/SE

Table 3: Altitude of structures measured at Kanyang area.

S/N	Strike	DIP	DIP Direction	S/N	Trend	Plunge
1	154	52	54	1	274	38
2	143	76	76	2	280	78
3	324	53	58	3	294	30
4	154	53	65	4	277	70

The Digital Elevation Model (DEM) is use Remote Sensing for the determination of characteristics of an area such as highlands and lowlands, slope and intersection density maps (Figs 9-11), while the groudtruth field photographs after the geohazard event is on plate 3, compared with plate 1 before the event (Okeke *et al.* 2019). The slope values range between 0 - 2.8m and 61.224 – 89.725m also displaying aspect of high intensity.

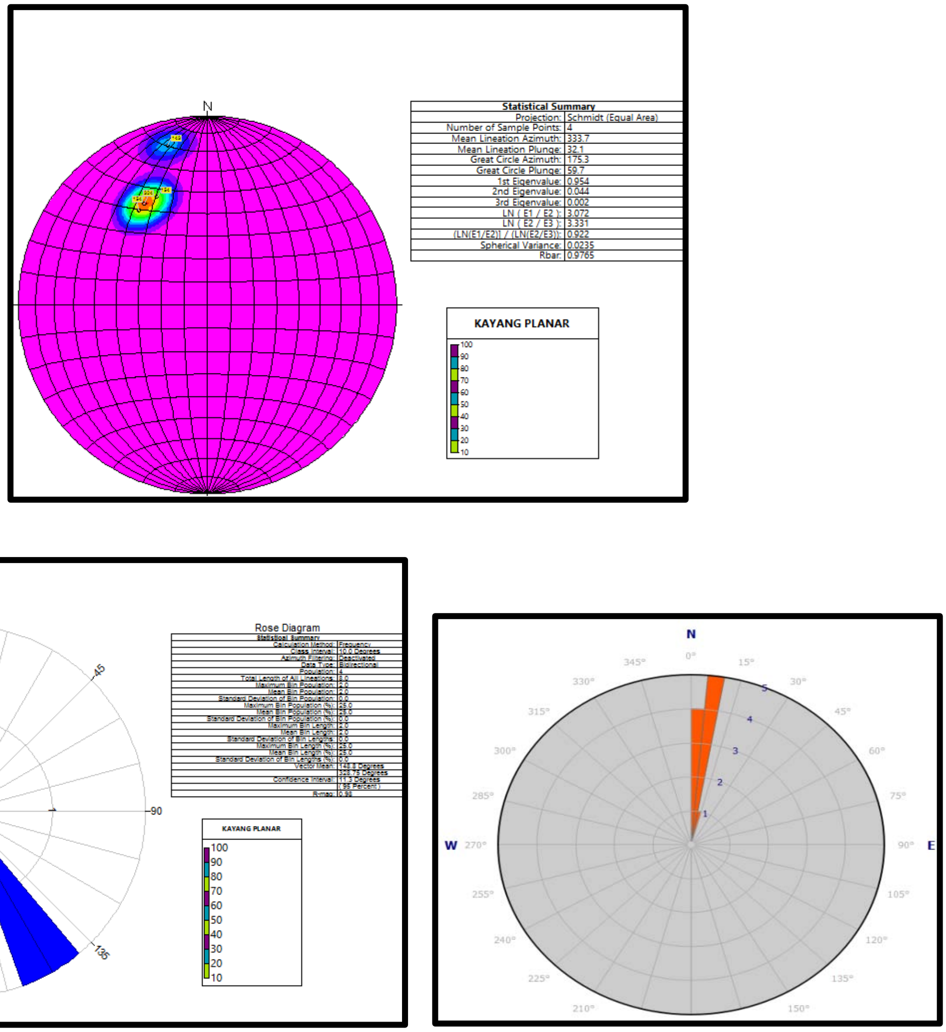

Figure 8: A- Planar Stereonet plot, B- Planar Rose Plot and C- Linear Rosette Plot of the altitudes of Kanyang area Striking NW/SE snd Trending NW/SE.

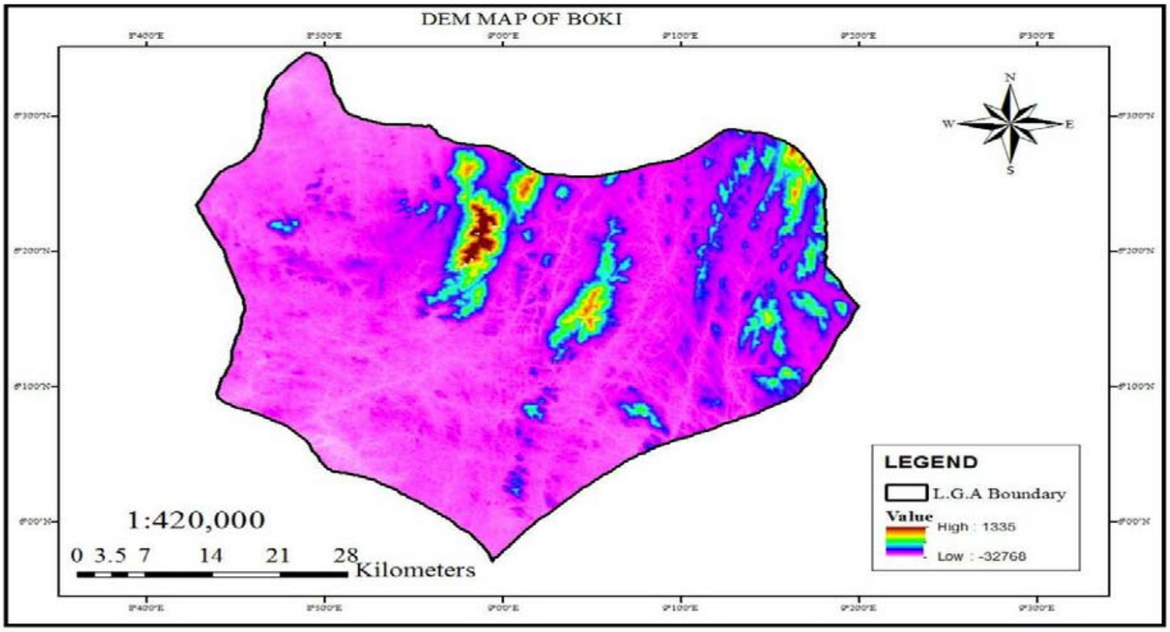

Figure 9: Digital Elevation Model map of Boki, the study area

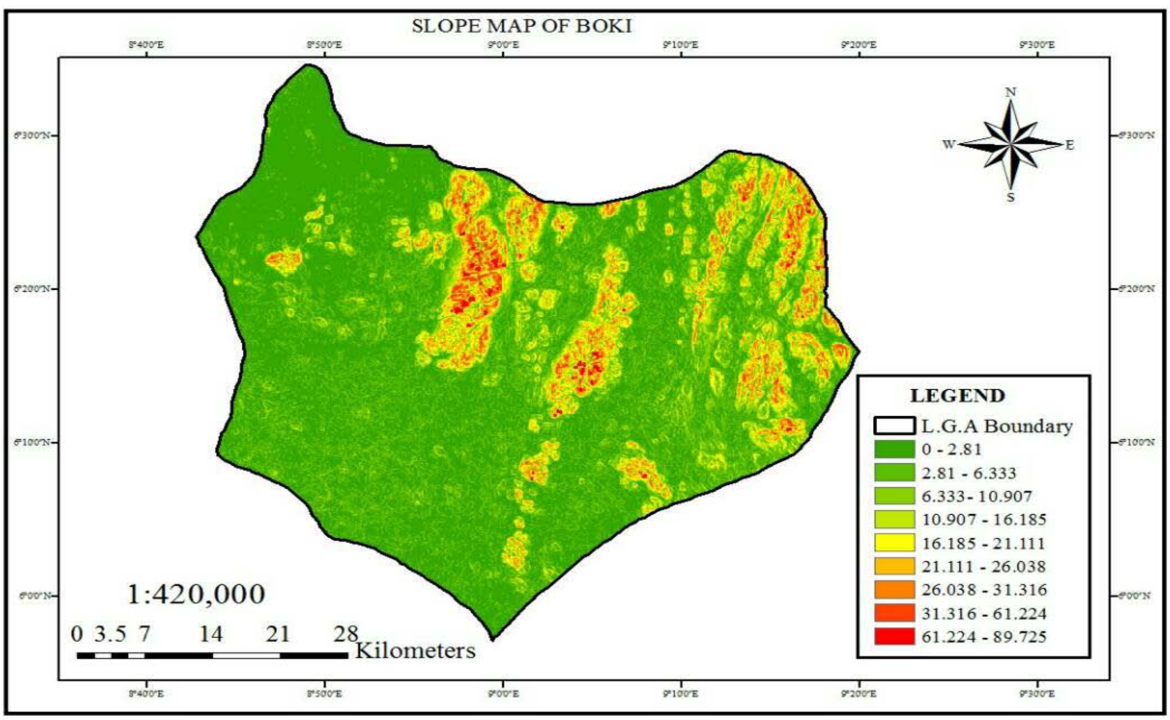

Figure 10: Slope Model of map Boki, the study area

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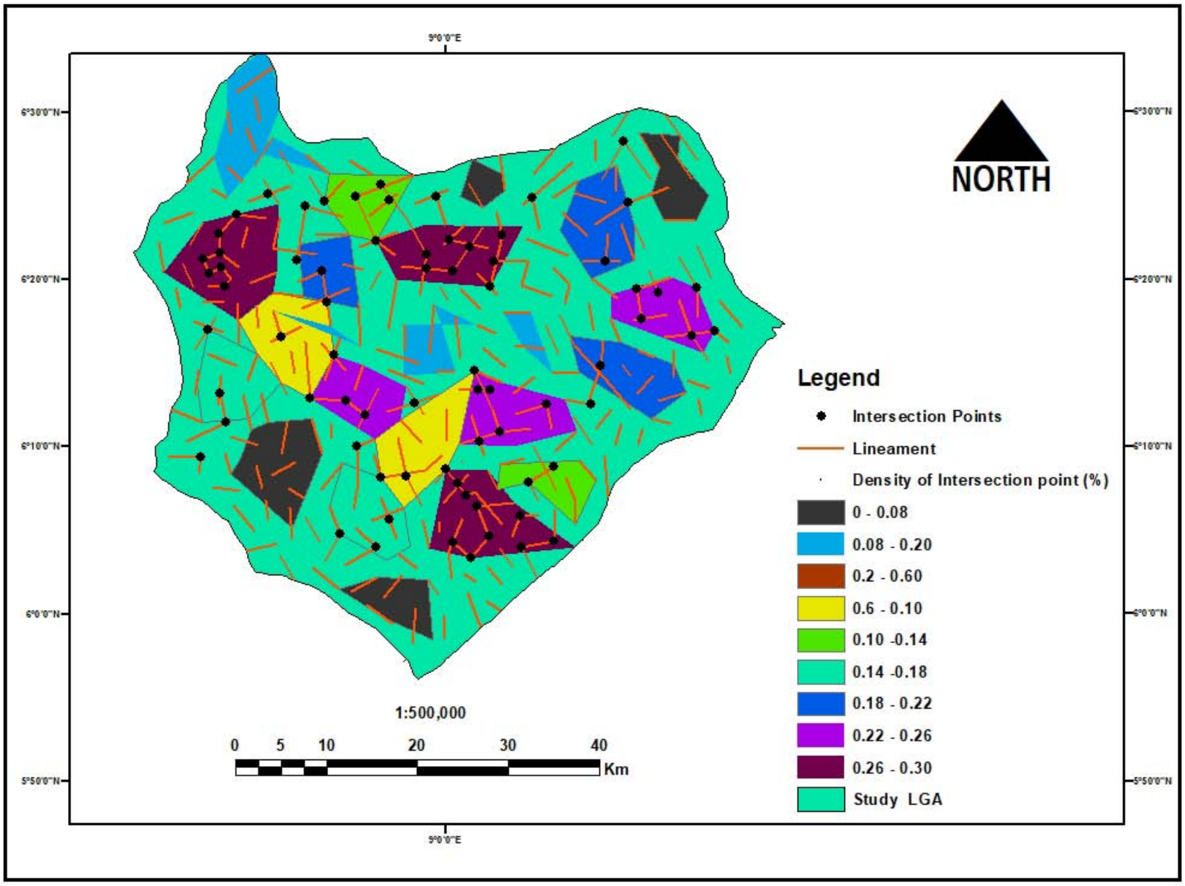

Figure 11: Lineament intersection density map with a search radius of 8 km

Plate 3a: Field photograph near the foot of Buanchor hills after the rockfalls and rockslides

Plate 3b: Field photograph showing geosciences students accessing the foot of the highlands flow route of the rockslides about 2km.

Plate 4, is a damaged six class room block of Community Secondary School Buanchor which is about 1km from the foot of the highlands after the rockfalls and rockslides in the area, while plate 5 is the Walkaway part which are usually connected to trees, was also damaged as the trees were equally affected at about 2km from the highlands. The farmlands were also washed off and filled with sands and gravels (plate 6). The methods of controls on any identified slope prone to rockfalls and rockslides or have been affected by such geohazards are protected with rock netting as shown on plate 7.

Plate 4: Field photograph showing what is left of the damaged six classroom block at Community Secondary School Buanchor after the rockslides.

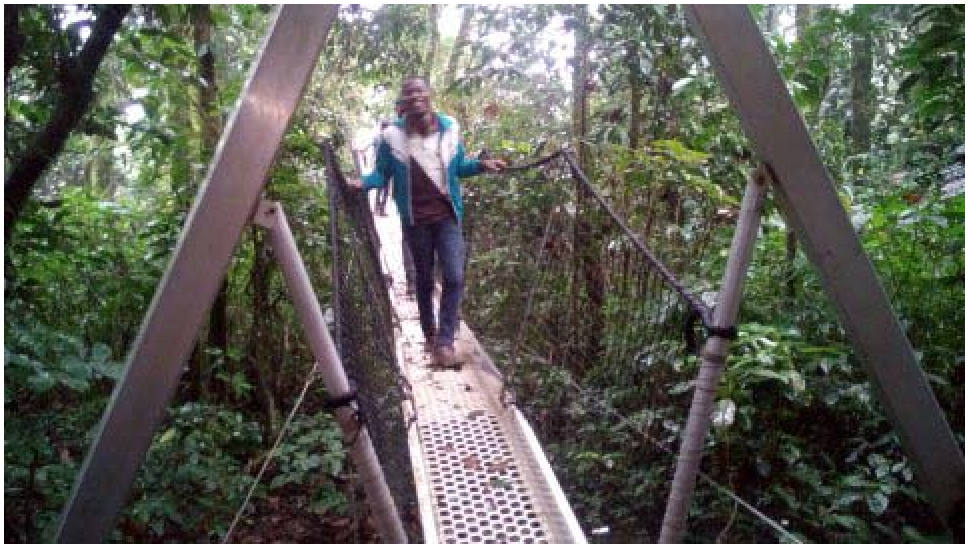

Plate 5: Walkway part before the rockfalls and rockslides at Buanchor

Plate 6: Field photograph of the damage to farmlands and a 400m Walkway at Buanchor

Plate 7: Rock netting a method for protecting critical infrastructure like road and human settlements near Obudu Plateau cattle ranch gate

Rockfalls and rockslides are geohazards features, their mapping and analysis can provide valuable information to mitigate or prevent the catastrophic loss and provide guidelines for a sustainable planning and development (Agbebia and Egesi, 2019). In the Northwestern part of Cameroon, the Lake Nyos which is part of the Cameroon Volcanic Line (CVL), about 190 km from Buanchor-Boki area has been identified as active and violent Ebeniro (2012). The lake is located at a height of about 1.34km above mean sea level. It has previously, released large volumes of carbon dioxide CO_2 and other gases into the atmosphere and has capacity to do more. In 1986, the lake activity led to the release of poisonous gases which killed over 1,000 people, about 2000 livestock and numerous wild animals which were uncountable. The Lake Nyos Dam contains CO_2-rich water at this height and has been eroding at a fast rate with more than 600m of its area already eroded off. Presently, less than 35m of the dam is left and evidence of its weakness can be observe as water spews out from different points around the dam that is not the spillway created at the lowest part of the dam.

If the dam collapses or fails it will release several tons of CO_2-rich water from its high elevation through the northeast to the southeast parts of Nigeria in areas like Kumbi, Mbum and Katsina Ala Rivers drainage system and contributes to issues of Climate Change in the region. The resultant effect may cause flooding in all the drainage channels particularly low-lying areas and towns in Cameroon as well as densely populated areas like Katsina Ala and Adikpo in Benue State, Ogoja, Obudu and Boki towns in Cross River State which are about 155km, 150km, 160km and 165km away from Lake Nyos respectively (Ebeniro, 2012). To determine the lithology of the area, geo-electric study of the structure and its Geological implications of lake Nyos indicated a shallow basement at 113m depth, saturated pyroclastic rocks and weathered basement at 110m, with probably 10m thick agglomerate occurring at about 6m depth from the surface. This result is an indication that there is a need to either strengthen the dam at its lowest point to protect it from failure or alternatively to carry out a controlled release of the lake waters to reduce its level and potential strength (Okwueze *et al*., 1995). In Mineral Exploration surveys, lineament density and intersections are pointers to possible mineralization and mostly target for search for minerals (Ashano and Olasehinde, 2010).

Available data indicates Nigeria may not be on any location considered to be at danger of any powerful earthquake (Ebeniro, 2012). However, it can never be ruled out that a much smaller earthquake can cause a lot of damage to the national psyche, as we are close to the Cameroon Volcanic Line (CVL) which is known to be active both onshore and offshore. It is in our interest to identify lineaments and lakes that are hazardous on top of highlands and appropriately advise the government of today at Federal, State, Local and initiate the processes of taking safety first. We should learn from the experiences of other countries rather others using our own experiences to solve their problems, as I witnessed in Cape Town South Africa, during America Association of Petroleum Explorationists AAPG Cape Town 2018 conference, where Nigeria was given as a bad example of oil wealth management and no country wants to copy that type of example.

V. Conclusion

The use of lineaments in geohazard surveys is important and requires ground-truth to ensure accuracy. A personal communication on the reasons for the rockfalls and rockslides from Peter Jekings the Director of the Wildlife Santuary and Walkaway at Buanchor area, Boki Cross River State indicated that one of the major causes or main drivers of the disaster is human farming activities at the base of the hills which exposes the rocks to massive erosion, by the citizens who are primarily farmers. There is need to identify lakes or ponds, establish protected areas and buffer zones in the area and other highlands within the residential areas in

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Boki, Obalinku and Obudu Local Government Areas. These highlands particularly those with altitude ranges from about 1,050m to 1,650m. This will help reduce the damage that may be cause by such potential geohazards occurrence, will pose threat to human lives and properties and also caves which are wildlife closet during adverse weather conditions.

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