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Lineament Analysis and Inference of Geological Structures in Bansara-Boki Area, Southeastern Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author MAA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author NE managed the analyses of the study, managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

The purpose of this study is to extract lineaments from satellite images in order to contribute to the understanding of the structural geology of parts of Boki and its environs. Shuttle Radar Topographic Mission (SRTM) and Landsat 7 ETM images of path 187 and row 056 were used for the analysis which is processed for automated extraction, validated through ground-truthing of planar and linear geological features displaying altitude of about 233 for Bansara sheet 304. Lineament extraction processing was done using PCI Geomatica version 2016 for Landsat imagery and ArcGIS 10.5 used to generate Digital Elevation Model (DEM) and Slope Map for SRTM imagery. Statistically a total of 3191 count of highly dense lineament were generated ranging between 0.86 to 4.33 km in length with the mean of 1.22 and a standard deviation of 0.83 intersecting at low percentage of 3-6%. The DEM display a range of 1335 to -1335 m sloping in the range of 0-2.81 and 61.224-89.725 m for topographic analysis. The lineament extracted were trending majorly in NW/SE and other minor ones in NE/SW directions some which were agreement with the altitude of the ground-truth data. The variation is possibly as a result of influence from regional process such as deformation,

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metamorphism, magmatism and method of data acquisition and analysis. Lineament analysis are profound index parameters for engineering of dams, economic mineral and water resources exploration, exploitation, planning and development. It is also useful in geohazard studies and its mitigation as the areas are prone to rockfalls, rockslides, landslides, mudslides and flooding due to high rainfall and human activities at the foot of the highlands.

Keywords: Lineament; topography; planar and linear structures; index parameters SE; Nigeria.

1. INTRODUCTION

Boki belongs to the Basement Complex of the Southeastern Nigeria which is regionally part of the Precambrian Pan-African tectonothermal belt of the West African Craton (WCC) to the left and Gabon-Congo Craton (GCC), to the east [1]. It lies at a latitude of 06° 05' to 06° 30' N and longitude 008° 40' to 009° 00' E Fig. 1. It is administratively divided into two arms Eastern and Western Boki, (Mukuru sheet 305 and Bansara sheet 304). Obudu and Obalinku Local Government Areas LGAs lies to the North, Etung and Ikom to the South, Ogoja LGA to the West, while the East is the prominent Bamenda highlands of Cameroon. On the Nigerian survey map sheet it is divided into Bansara 304 and Mukuru 305 in Cross River State Nigeria. The area consists of migmatites, gneisses, schists, amphibolites, quartzies, phyllites and metasediments and intrusives granites, charnockites, dolerites and granodiorites [2,3]. Lineament are significant lines of landscape revealing the architecture of the rocks like faults and joints in the basement. O'Leary et al. [4] described lineament as a mappable linear feature aligning in a rectilinear or slightly curvilinear relationship and presumably reflect some subsurface phenomenon. Syed and Saied [5], applied Satellite imagery of Lansat Enhanced Thematic Mapper (ETM) data and Geographic Information System (GIS) in mapping structures in Zagros Structural Belt, Southwest Iran. This research attempts to use satellite remote sensing imagery and GIS to extract lineament and contribute to the understanding of the Structural Geology of parts of Boki and its environs. The spatial properties are presented as histograms for each azimuth set together with the mode, mean, standard deviation, and number of involved lineaments [6].

1.1 Geological Setting

The Boki area has benefited from regional studies such as the regional magnetic study of Oban and Obudu Precambrian Massifs [7] and lineament analysis and groundwater exploration in Precambrian Oban Massif and Obudu Plateau [8]. They observed that lineaments are high in areas of outcropping bedrock and thin overburden while the magnetic analysis indicates a preponderance of NE trending anomalies. The Nigerian Geological Survey Agency [9] described the area as granulites terrain without ground-truthing to define the boundaries of the rocks outcrop in the area. More recently [2,3] have differentiated the rocks into migmatites, gneisses, schists, amphibolites, quartzites, phyllites and metasediments and the intrusive rocks are granites, charnockites, dolerites and granodiorites. Elsewhere in Afikpo area [10] have identified some linear density and regional features using Remote Sensing techniques. However, they were unable to access and identify rocks at highly inclined dangerous cliffs. Thus, the need to study the lineaments to bridge the gap in such areas. Fig. 1 is the geological map of the study area showing Bansara to the west and Mukuru to the east of Boki Local Government Area in Cross River State, Nigeria.

Most of the applications of lineaments in the literature are performed using this image Landsat ETM and SRTM image is selected for this study [11,12,13,14,15,16,17]. Lower resolution satellite image (e.g. 80 m and larger cell size) may not be suitable to detect the lineaments.

2. METHODOLOGY

The methods include data sourcing imagery and software. Field structural features modelling and analysis, ground-truthing and lineament and structural interpretation. The materials acquired are Shuttle Radar Topographic Mission (SRTM) 30m x 30m, Landsat 8 Pixel size: 1 – 7.9: 30 m and shape files Nigerian shape files 2015. The PCI GEOMATICA 16 was used for lineament mapping, ARCGIS 10.5 for Cartography and spatial analysis while Grapher 12.1.2 and Rockworks 16 were used for altitude analysis. A total of 288 altitudes in Bansara sheet 304.

The conception of lineament analysis and inference of geologic structures came with an

inspiration of contributing to the understanding of structural geology through lineament extraction from satellites imageries which have not been given little or no attention in the study area. Three procedures were applied in this research to infer geologic structures in Boki to evaluate the nature and distribution of the lineaments. These are: density and intersection density, length, and orientation analyses. All the analyses are illustrated as maps of the study area. Fig. 2 is the research design chart of the study.

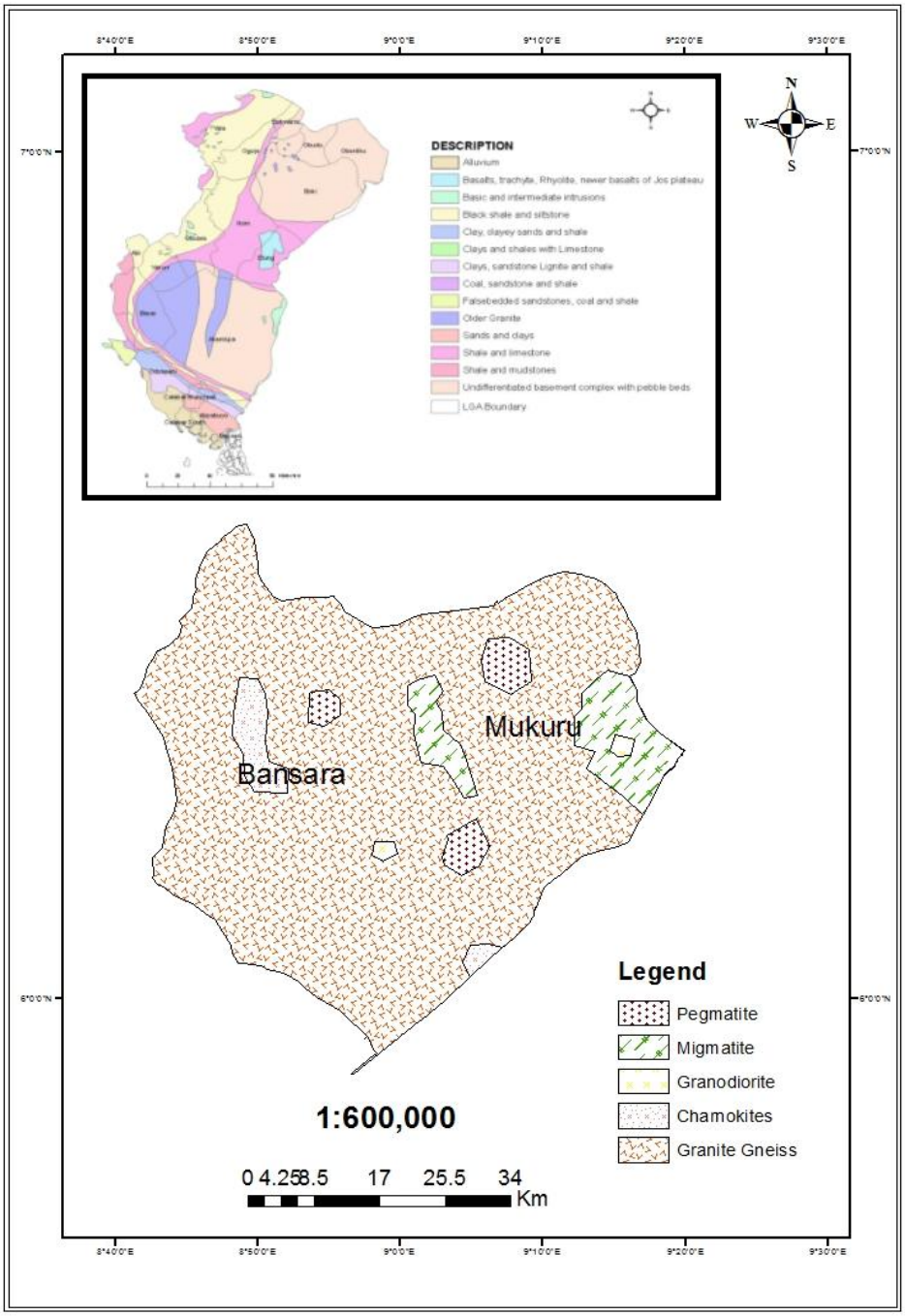


Fig. 1. Geologic map showing Boki the study area

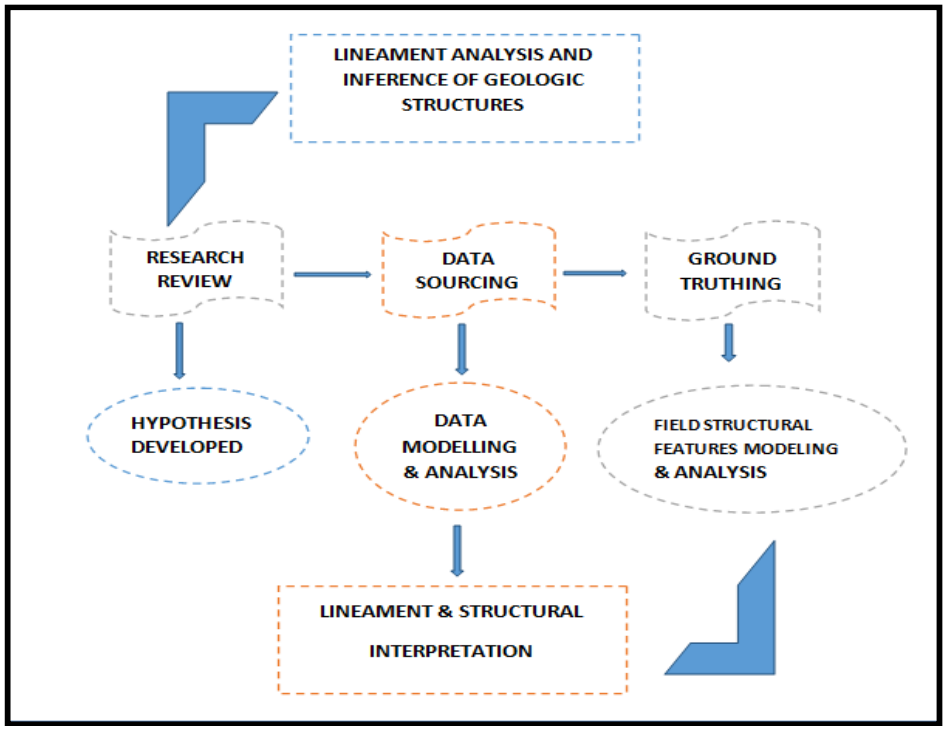


Fig. 2. Research design chart for the study

Table 1. List of secondary data sources with their functions in the research

S/N	Data name & specification	Data class	Data source	Functions for this research
1	LandSat-7 OLI 2016, Path 187, Row 056	Image	USGS-GLOVIS(www.nasa.gov)	Extraction of lineaments
2	SRTM (Shuttle Radar Topographic Mission), Path 187, Row,056	Image	USGS-GLOVIS (www.nasa.gov)	Extraction of topographic features
3	Nigerian Shape Files NigeriaSat-X	Images	Esri/ASTAL	Producing boundary study maps
4	PCI Geomatica 2016	Software	Pcigeomatics (www.pcigeomatics)	Modelling Lineament
5	ArcGIS 10.5	Software	Esri (www.esri)	Cartography and Spatial Analysis
6	Rockworks 2016	Software	Rockwares (www.rockwares.com)	Altitude Analysis
7	Stereonet 9	Software	geo.cornell.edu (www.geo.cornel.edu)	Altitude Analysis
8	GeoRose 0.4.1	Software	Yongtechnologyinc (www.Yongtechnologyinc)	Altitude Analysis

3. RESULTS AND DISCUSSION

The lineaments data presentation includes the description of the dataset disseminated with the main variables covered, the classifications and breakdowns used, the reference area, summary information on the time period covered and, if applicable, the base period used. Data collected for this research work was sourced primarily and secondarily therefore, the presentation is also done separately as below:

Ground-truthed data of the study area were made to cover linear and planar features as well

as photographs of bigger lineament structures such as extensive mountainous ridges. Northeastern and Southeastern part of the study area (Bansara sheet 304), a total of two hundred and thirty-three (233) attitudes (Tables 2, 3, 4, and 5 & Plates 1 and 2). were measured at Agba-Osokom, Kekibe Hills, Katabang, Katchuan-Iruan and Ebok. Forty-four (44) altitudes of planar and eight (8) of linear features were measured in Katabang, thirty-six (36) altitudes of planar and six (6) of linear in Katchuan, forty-seven (47) altitudes of planar and eleven (11) of linear in Ebok, seventeen (17) of planar and fourteen (14) of linear in Kekibe and forty (40) altitudes of planar and ten (10) of linear features in Agba-Osokom.

Two data sets are used in this study:

1. The Landsat ETM satellite image of the area to extract the lineaments,
2. The SRTM satellite image of the study area to generate DEM.

Satellite image of the area is the main data used in this study. It is used for the extraction of lineaments. Considering spatial resolution of the available satellite images and the size of the study area, This image has a resolution of 30 m which can easily detect the lineaments. Higher resolution images, on the other hand, may complicate the process and can detect minor lineaments not interested in.

The data set of images were acquired on 26/8/2017, Path 187 and row 056, USGS GLOVIS is used in this study. Image is composed of 3432 rows and 4022 columns. It has nine bands sensitive to different wavelengths. Six of these bands detect visible (1, 2, 3), near infrared “NIR” (4), short wave infrared “SWIR” (5, 7), one thermal and one panchromatic.

Table 2. Altitude of structures measured at Katabang area

S/N	Strike	DIP	DIP direction	S/N	Strike	DIP	DIP direction
1	352	34	98	31	330	45	110
2	330	45	112	32	334	42	77
3	334	42	76	33	320	65	66
4	320	65	67	34	310	56	74
5	310	56	77	35	320	56	82
6	320	56	87	36	314	43	44
7	315	43	46	37	305	65	61
8	305	65	65	38	322	32	82
9	322	32	87	39	318	31	88
10	317	31	88	40	341	21	60
11	341	21	65	41	342	43	42
12	342	43	42	42	312	36	34
13	312	36	34	43	336	42	37
14	336	42	37	44	330	45	112
15	347	32	45				
16	187	43	88	**S/N**	**Trend**	**Plunge**	
17	143	32	76				
18	176	43	57	1	277	32	
19	153	56	86	2	276	31	
20	161	33	264	3	282	21	
21	143	64	58	4	281	34	
22	132	43	87	5	284	43	
23	154	52	54	6	274	23	
24	143	76	76	7	254	43	
25	324	53	58	8	289	23	
26	154	53	65				
27	354	44	76				
28	355	32	54				
29	312	23	88				
30	143	34	86				

Plate 1. Field Photograph showing access through Ikom – Ogoja Road shot at Alok

Plate 2. Afi river at Katabang area

The attitudes of the planar and linear features of the different locations mapped were model using GeoRose 0.4.1, Stereonet 9 and Rockworks 2016. These softwares are window based and simply attitude data of planar or linear features can either be typed directly on the softwares spreadsheet or typed in excel and loaded on the softwares and plots generated. The models give leading ways in determining the orientation of the structural features.

A total of two hundred and thirty-three (233) altitudes were mapped in the western part of the study area to be striking and trending in NW-SE direction area also trending in the same direction

confirming a common geological setting N-S for linear features. Egesi and Ukaegbu [18], observed in ground truthing in the area that Bansara area planar features are in agreement NW-SE at Agba Osokom, Katchuan-Iruan, Kekibe hills but the linear features are mostly in N-S to the NE-SW.

In Mukuru area at Kanyang, Bukalum and Bumaji area in N-S to NE-SW plane and linear features, while Owambe/Otanchi is NW-SE trends for Planar features

Lineament intersection density is a map showing the frequency of intersections that occur in a unit cell. The procedure is the same as the previous density map. The purpose of using intersection density map is to estimate the areas of diverse lineament orientations. If the lineaments do not intersect in an area, the resultant map will be represented by a plain map with almost no density contours. That means the lineaments are almost parallel to sub-parallel in this area if they are not short in length.

Visual comparison of density and intersection density maps indicates that although the density is very high, the intersection density about 3 to 6 %. That means in spite of the abundance of the faults in this section, because most of the faults are parallel to each other they do not intersect and therefore the intersection density is low.

The regions characterized by high intersection densities are the southwestern parts of the study area, the SE of Bansara.

The density of lineaments intersection is produced by counting the number of lineament intersections per unit area. The search radius is taken as 8 km. The result of the analysis of intersection is shown in Fig. 9.

Table 3. Altitude of structures measured at Katchuan-Irruan area

S/N	Strike	DIP	DIP direction	S/N	Strike	DIP	DIP direction
1	336	42	37	31	143	34	86
2	347	32	45	32	336	42	37
3	187	43	88	33	314	43	44
4	143	32	76	34	305	65	61
5	176	43	57	35	322	32	82
6	153	56	86	36	318	31	88
7	161	33	264				
8	143	64	58				
9	132	43	87				
10	154	52	54				
11	143	76	76				
12	324	53	58				
13	154	53	65				
14	354	44	76				
15	355	32	54				
16	312	23	88	**S/N**	**Trend**	**Plunge**	
17	143	34	86				
18	336	42	37	1	292	43	
19	314	43	44	2	287	54	
20	305	65	61	3	284	34	
21	322	32	82	4	285	62	
22	318	31	88	5	274	32	
23	341	21	60	6	284	43	
24	342	43	42				
25	312	36	34				
26	336	42	37				
27	330	45	112				
28	314	43	44				
29	305	65	61				
30	322	32	82				

Table 4. Altitude of structures measured at Agba-Osokom area

S/N	Strike	DIP	DIP direction	S/N	Strike	DIP	DIP direction
1	334	42	76	31	143	34	86
2	320	65	67	32	336	42	37
3	310	56	77	33	314	43	44
4	320	56	87	34	305	65	61
5	315	43	46	35	322	32	82
6	305	65	65	36	318	31	88
7	322	32	87	37	143	34	86
8	317	31	88	38	336	42	37
9	341	21	65	39	314	43	44
10	342	43	42	40	305	65	61
11	312	36	34				
12	336	42	37				
13	334	42	76				
14	320	65	67				
15	310	56	77				
16	320	56	87				
17	187	43	88				
18	143	32	76				
19	176	43	57	**S/N**	**Trend**	**Plunge**	
20	153	56	86				
21	161	33	264				
22	143	64	58	1	294	30	
23	132	43	87	2	287	76	
24	154	52	54	3	277	67	
25	143	76	76	4	310	77	
26	324	53	58	5	284	30	
27	154	53	65	6	290	76	
28	354	44	76	7	294	30	
29	187	43	88	8	287	76	
30	143	32	76	9	277	67	

Table 5. Altitude of structures measured at Kekibe Hills area

S/N	Strike	DIP	DIP direction	S/N	Trend	Plunge	DIP direction
1	324	53	58	1	294	30	54
2	154	53	65	2	287	76	76
3	354	44	76	3	277	67	58
4	355	32	54	4	310	77	65
5	312	23	88	5	284	30	76
6	143	34	86	6	290	76	54
7	336	42	37	7	294	30	88
8	314	43	44	8	287	76	86
9	305	65	61	9	277	67	37
10	322	32	82	10	310	77	44
11	318	31	88	11	284	30	
12	341	21	60	12	290	76	
13	342	43	42	13	294	30	
14	312	36	34	14	287	76	
15	336	42	37				
16	324	53	58				
17	154	53	65				

Table 6. Altitude of structures measured at Olum area

S/N	Strike	DIP	DIP direction	S/N	Trend	Plunge
1	153	52	54	1	284	30
2	142	76	76	2	290	76
3	321	53	58	3	294	30
4	151	53	65	4	287	76
5	354	44	76	5	277	67
6	355	32	54	6	310	77
7	312	23	88	7	284	30
8	143	34	86	8	284	30
9	187	43	88			
10	143	32	76			
11	176	43	57			
12	153	56	86			
13	161	33	64			
14	143	64	58			
15	132	43	87			
16	154	52	54			
17	154	52	54			
18	143	76	76			
19	324	53	58			
20	154	53	65			
21	354	44	76			
22	355	32	54			

Table 7. Altitude of structures measured at Ebok area

S/N	Strike	DIP	DIP direction	S/N	Strike	DIP	DIP Direction
1	334	42	76	31	332	42	73
2	320	65	67	32	321	61	61
3	310	56	77	33	311	56	73
4	320	56	87	34	314	56	87
5	315	43	46	35	305	43	46
6	305	65	65	36	166	65	65
7	322	32	87	37	172	32	87
8	317	31	88	38	152	31	88
9	341	21	65	39	152	21	65
10	342	43	42	40	154	43	42
11	312	36	34	41	146	36	34
12	336	42	37	42	330	42	30
13	334	42	76	43	154	42	76
14	320	65	67	44	173	65	67
15	310	56	77	45	310	56	77
16	320	56	87	46	320	56	87
17	153	56	86	47	315	43	46
18	161	33	264				
19	143	64	58	**S/N**	**Trend**	**Plunge**	
20	132	43	87				
21	154	52	54				
22	143	76	76	1	294	30	
23	324	53	58	2	287	76	
24	154	53	65	3	277	67	
25	354	44	76	4	310	77	
26	355	32	54	5	284	30	
27	153	56	86	6	290	76	
28	161	33	264				
29	143	64	58				
30	132	43	87				

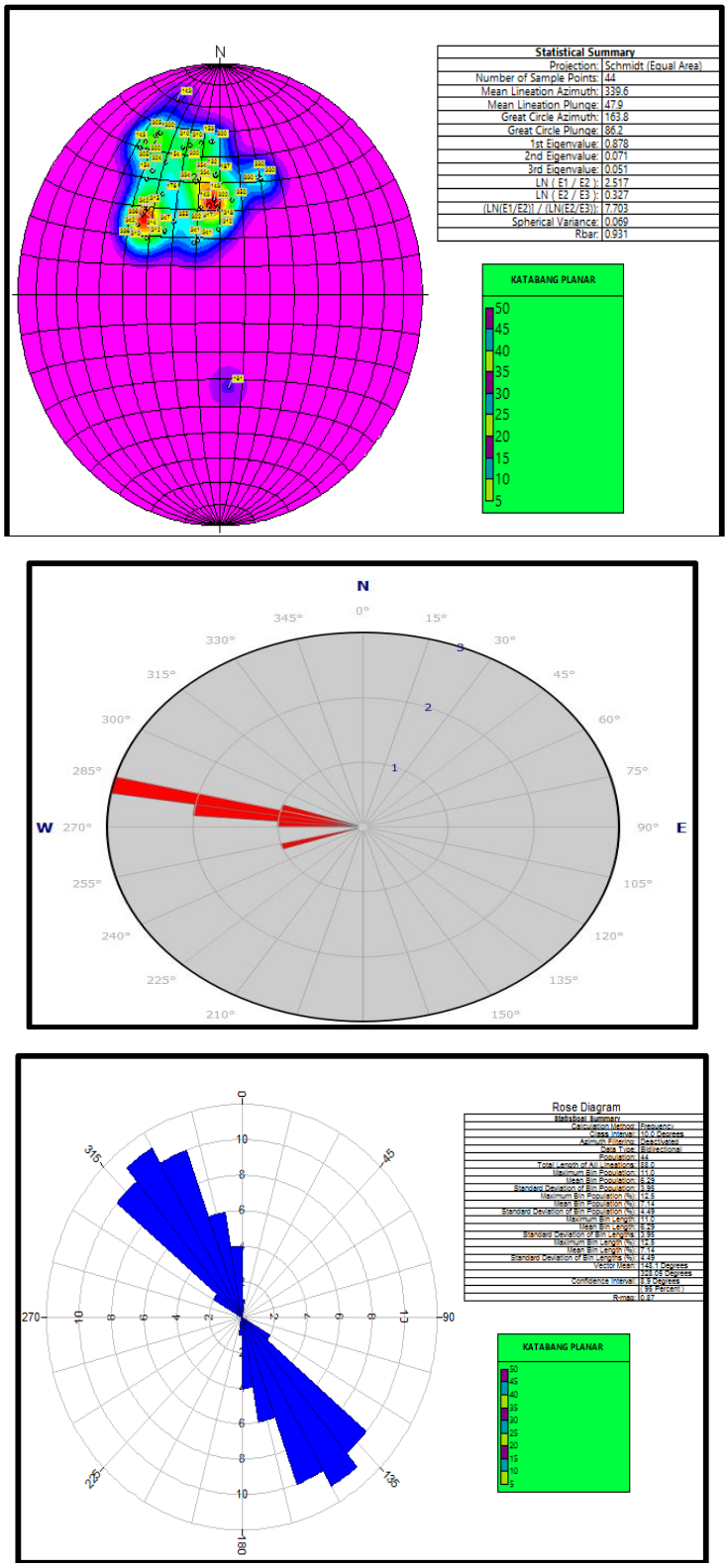


Fig. 3. A- Planar Stereonet plot, B- Planar rose plot and C- Linear rosette plot of the attitudes of Katabang

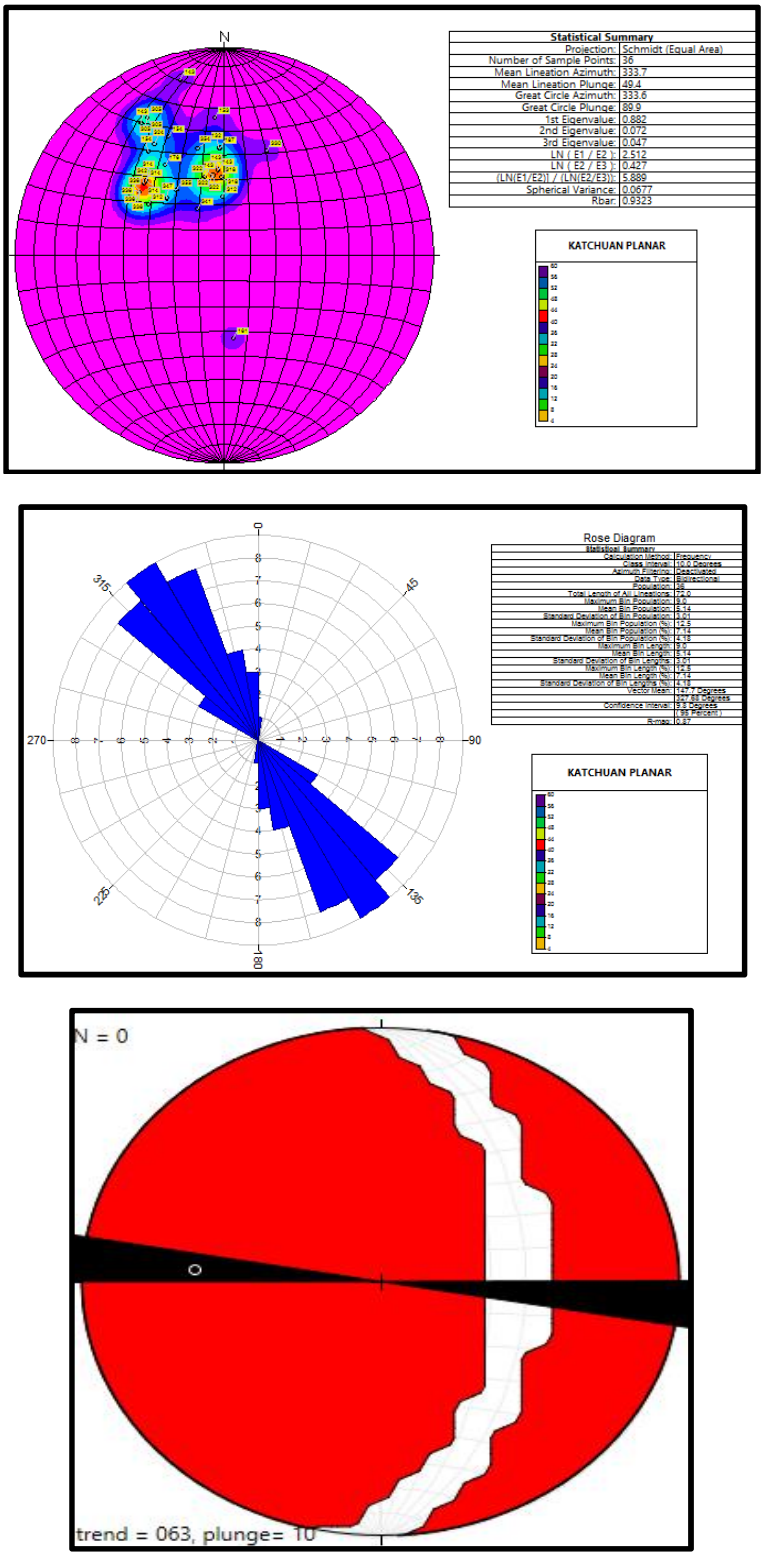


Fig. 4. A- Planar stereonet plot, B- Planar rose plot and C- Attitude linear rosette plot of the attitudes of Katchuan Iruan area

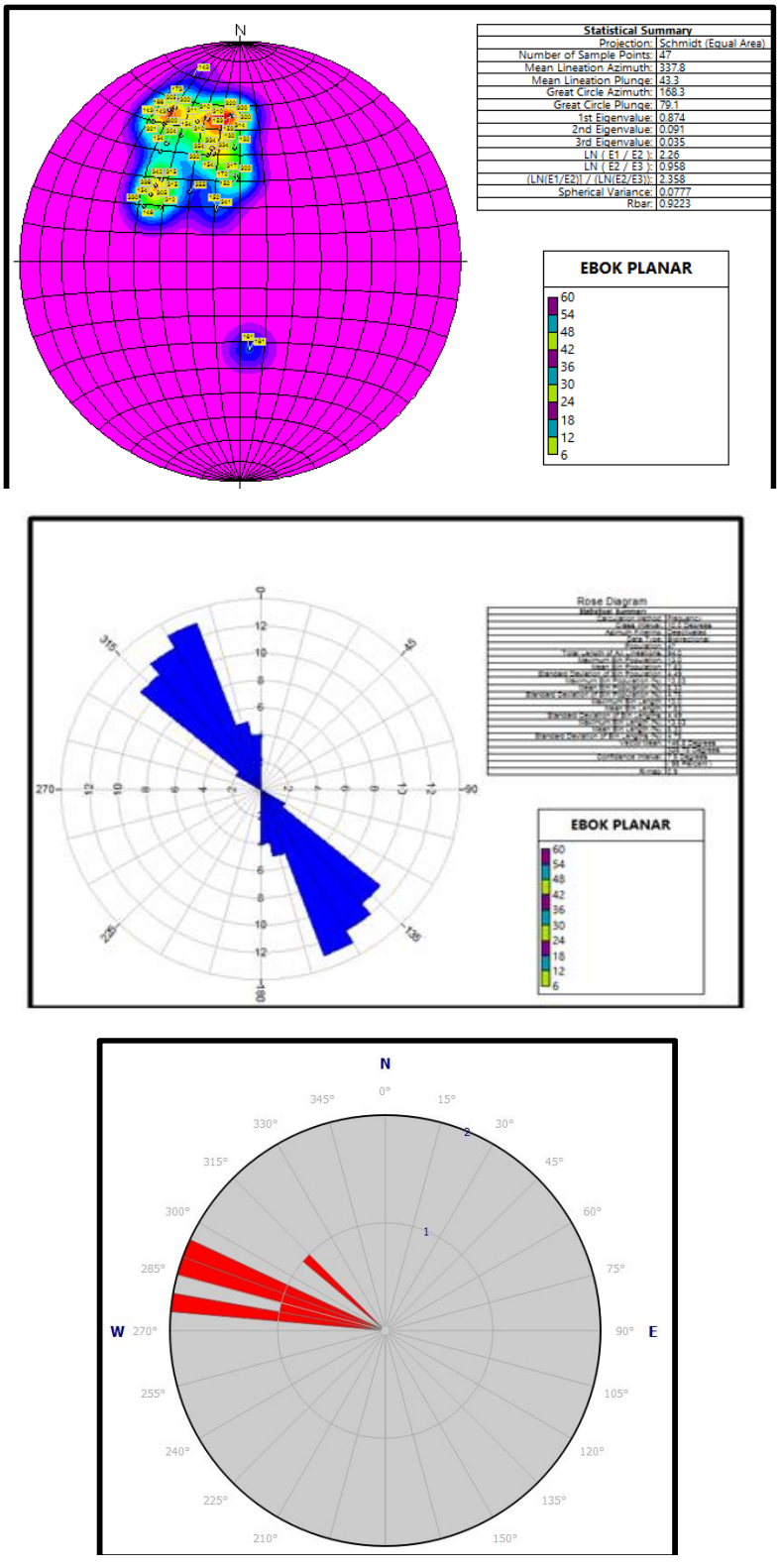


Fig. 5. A- Planar stereonet plot, B- Planar rose plot and C- Linear rosette plot of the attitudes of Ebok area

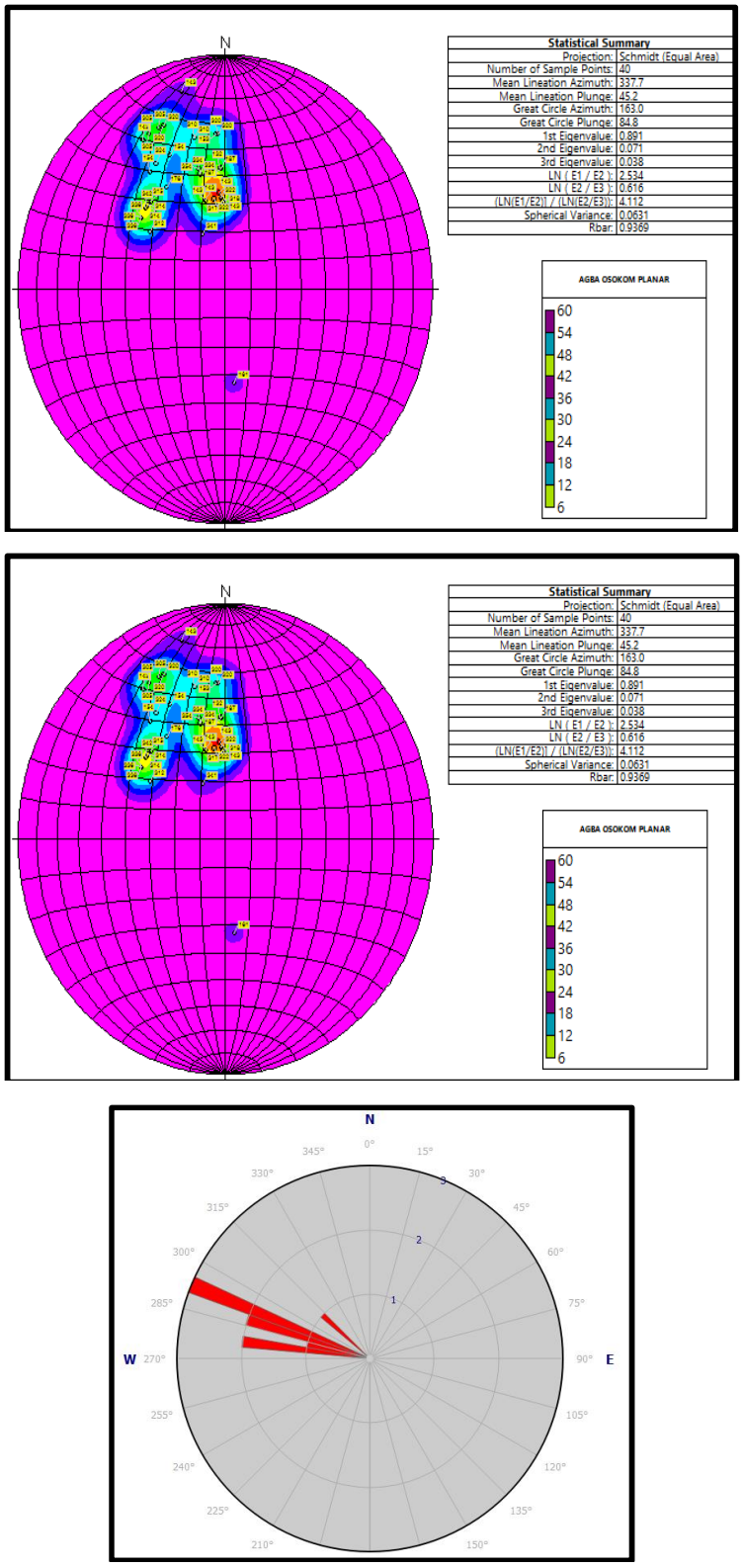
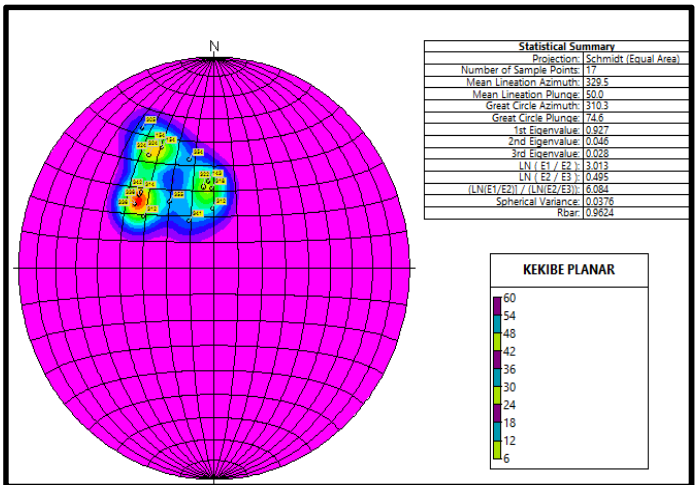
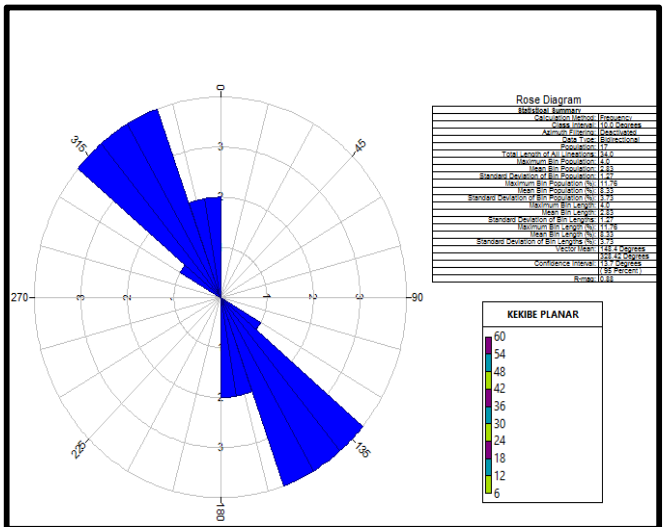


Fig. 6. A- Planar stereonet plot, B- Planar rose plot and C- Linear rosette plot of the attitudes of Agba Osokom





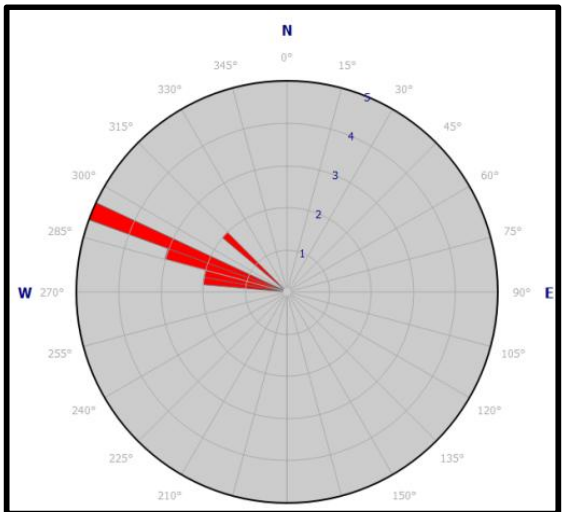


Fig. 7. A- Planar stereonet plot, B- Planar rose plot and C- Linear rosette plot of the attitudes of Kekibe

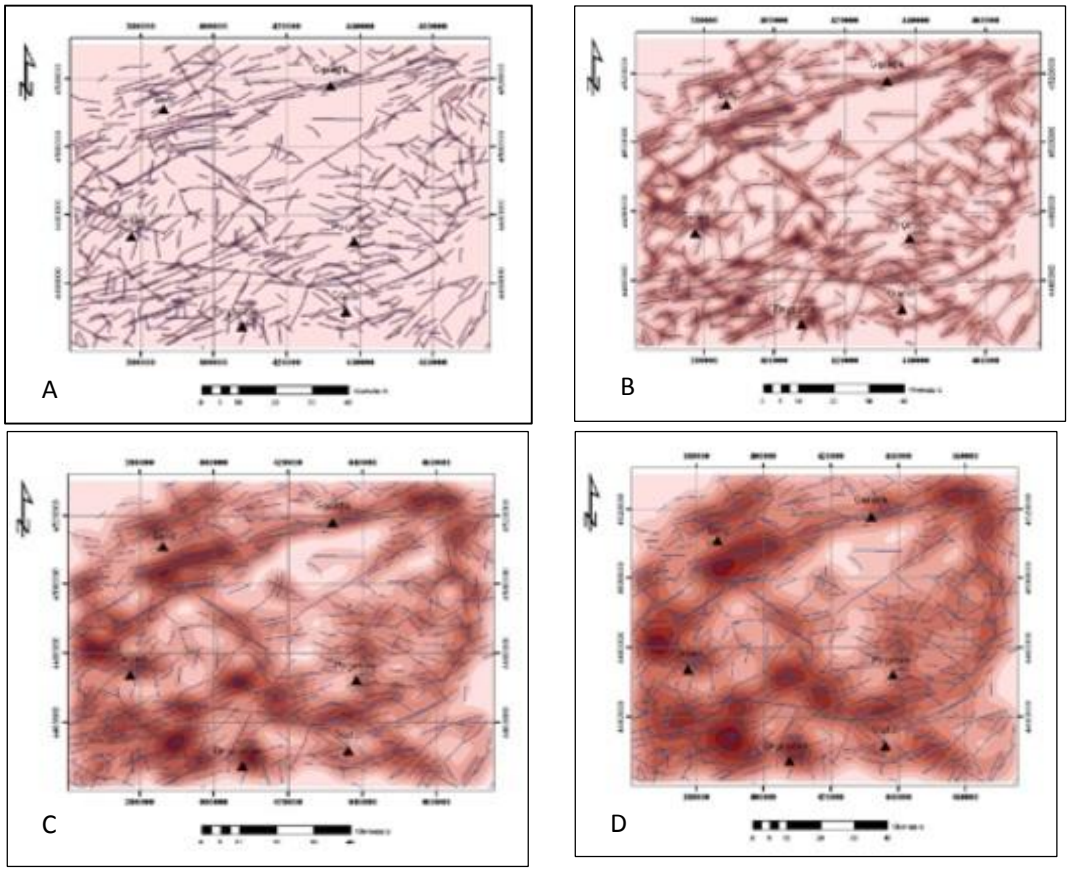


Fig. 8. Density of lineaments with different search radius (A) 1 km, (B) 3 km, (C) 6 km, and (D) 8 km

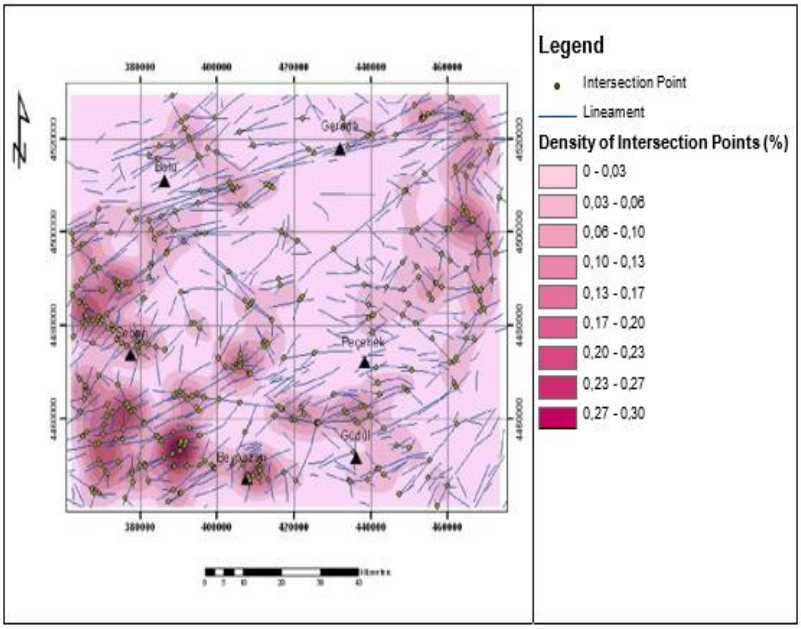


Fig. 9. Lineament intersection density map with a search radius of 8 km

4. CONCLUSION

Structural lineament map of Boki was decided after a combination approach of models generated using satellite images such as Landsat EMT and ground-truth of the study area. Lineament extracted with the following statistics: lineament count of 3191, with length range of 0.86 – 4.33 km, mean of 1.22 km, and standard deviation of o.83. A total of two hundred and thirty-three (233) altitudes were mapped in the western part of the study area. Lineaments extracted were plotted to be trending in NE/SW direction whereas mapped data were modelled to be striking in NW-SE direction for planar structures with linear trending NE/SW. This is in agreement with ground-truthed data in most area.The lineament density is high but with low intersection of 3 to 5%.

Lineament analysis and inference of geologic structures in Boki area has the following contributions to knowledge. The lineaments extracted are first of its kind from satellite imagery of Landsat in the study area and therefore will serve as reference materials to earth and environmental sciences. This research work will serve as index parameter for economic geologist with interest in mineral exploration and exploitation.This research work will also serve as index parameter for hydrogeologist for groundwater exploration and exploitation. Lineament will help decision makers to build a good development policy for geohazards studies, because the areas are prone to rockfalls, rockslides, landslides and mudslides.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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