MAPPING OF GEOLOGICAL FORMATIONS AND LINEAMENTS USING REMOTE SENSING AND GIS TECHNIQUES IN KOLAR RIVER CATCHMENT AREA, MADHYA PRADESH, CENTRAL INDIA

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Abstract

Geology and Lineament mapping was carried out in Kolar River catchment area using Landsat-8 Satellite data. Digital image processing and visual image interpretation method was used to extract lineament in Arc GIS environment. The area comprised of 82 lineaments in the rocks of Alluvium, Deccan trap, and Bhander formation of upper vindhyan group. The extracted lineaments were statistically analyzed by applying Geospatial and Geostatistical analysis for determination of lengths, direction and density of the lineaments. Results show that the extracted lineaments were categorised in two groups on basis of length such as 58 minor less than 3 km and 24 major lineaments present. Lineament density was calculated by line density tool of geospatial analysis and it is categorised into 5 classes namely very good, good, moderate, low and very low density. The extracted lineament identified in this region are mainly parallel to drainage, scarp, fault and joint/ fractures etc. Of the total 82 lineaments in the study area, 57 were found in the basaltic terrain, 20 in Alluvium formation and 5 in Vindhyan formation. The maximum lineament found in basaltic terrain of Deccan trap were parallel to drainage and joints/fractures. It suggests that the trends are N - S, NNE - SSW, ENE - WSW, SE - SW and E - W axis. The principal direction of lineaments in the region are between NE- SW and NW - SE. The calculated lineaments from the study area were utilized for the groundwater recharge potential zone demarcation and characteristics of litho logical formation.

Keywords: *Geology, Lineaments; Remote Sensing; Geographic Information System*

Introduction

The systematic mapping and study of fractures was carried out in the beginning of the 19th century in Great Britain. The term Lineament was introduced by Hobbs In 1903 in his basic work “lineaments of the Atlantic border regions”. The more notable lineaments, according to him, are the crests of ridges or boundaries of elevated places, drainage lines, coast lines, and limits of geological formations of the petrographic type or line of outcrops. He defined lineaments as "significant lines in the Earth's face"(Sankar & S, 2015).

A lineament is a linear landscape feature that represents a fault, fracture, joints and River parallel or other underlying geological structure. The concept of mapping of geology and lineament extraction have been applied throughout the world by several authors using digital satellite images for a variety of objectives, including structural and tectonic study (Won et al., 1997; Kim et al., 1999; Madani, 2001; Sedrettea and Rebaïb, 2016; Si Mhamdi et al., 2017), groundwater exploration (Bruning, 2008; Alonso-Contes, 2011), and mineral prospecting (Lee et al., 2010; Rowan et al., 1991; Mars and Rowan, 2006; Mathew and Ariffin, 2018; Farahbakhsh et al., 2018; Ranli et al., 2010).

The important literature of lineament study was carried out related to the Tapti-Purna lineament, which is a significant part of the ENE-WSE trending SONATA (Son-Narmada-Tapti Lineament).The Salbardi fault is one of the significant structural elements in the region.The well-known Gavilgrah/Elichpur fault is likely the eastern continuation of the Salbardi fault (Rajurkar 1981). According to Auden (1949), the length of this fault, which runs across the Gawilgrah region and to the northeast, is between 1800 and 1400 metres. In different places, it was referred to as the Gawilgrah fault, Ellictipur fault, and Salbardi fault (Rajukar 1992, Saxena, 1994, Tiwari, 1985).

. Mapping of geology and analysis of lineaments help in understanding the site for groundwater recharge of an area. Lineaments, which stand for litho-contacts, joints, shear zones,faults, fractures, dykes etc. can be mapped and analysed easily using remote sensing and GIS techniques. These techniques not only do mapping of geology and lineament but also aid in comprehending an analysis of lithological formation and lineament characteristics. They also help in the exploration of minerals, groundwater, oil, and the seismicity of a particular region.

In this investigation, lineaments' direction, position, length, density and classification on the basis of origin and length are determined from Landsat 8 satellite image. The lithology, classification of lineaments and lineament density were mapped with help of Arc MAP 10.4.

Study Area

The Kolar River is originated from Vindhya mountain ranges of Sehore district which is located in Madhya Pradesh of Central India. It is right-bank tributary of Narmada River which after origin flows in south-west direction and merges with Narmada River near Nasrullahganj in Raisen district. Its total drainage area is about 1300 sq.km. covering two districts of Madhya Pradesh i.e. Sehore and Raisen district. Geographically, it is bounded by latitudes 22º 33" 30' N to 23º 7' 30" N and longitudes 770 2'30" E to 770 28'30" E. Kolar river catchment area lies at an elevation of 350 to 600 meters above msl. The area is covered with tropical deciduous forest. The detailed map of study area is given in Fig. 1.

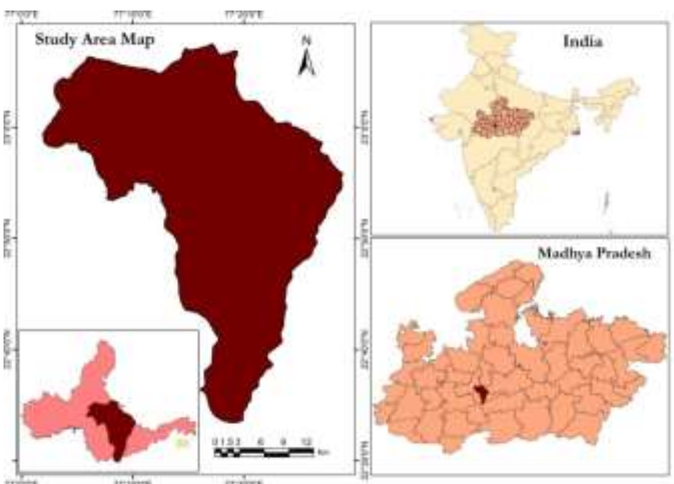

Figure 1: Map of the Study Area

Materials and Methodology

Satellite images of Landsat 8, Digital elevation model (DEM) and district resource map (DRM) were used to identify the linear features and characteristics of the terrain. Geospatial techniques have been applied to map the linear features and geological formation. Landsat 8 satellite have Operational Land Imager (OLI) sensors which have 8 bands for some particular applications: band 7 for geology, band 5 for soil and rock discrimination and band 3 for discrimination of soil from vegetation (Boettinger et al., 2008; Campbell, 2002; Chen and Campagna, 2009). Landsat composite image prepared using image analysis tool and different band composition was used to improve the clarity of the features. Digital image processing were used for some image enhancement techniques to improve the quality of the image such as band rationing, principle components analysis (PCA), False Colour Composite (FCC), independent component analysis (ICA) . True Colour Composite (RGB) techniques were used for eliminating shadowing and topographic effects which is suitable for complex terrain. The description of detailed flow chart of methodology is given in Fig. 2.

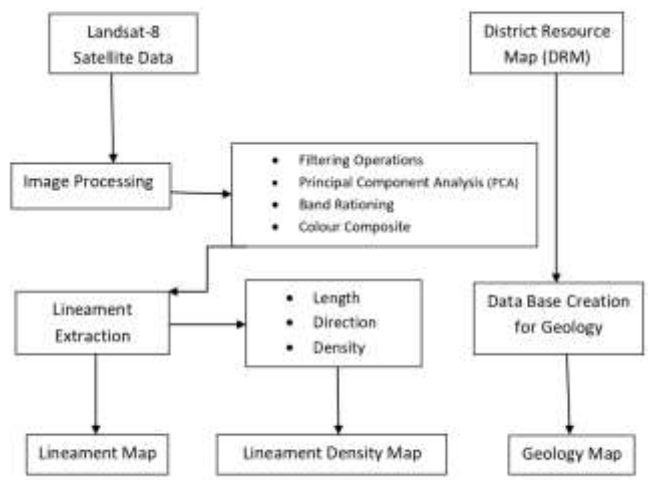

Figure 2: Methodology Flowchart

Digital Image processing

Image processing techniques is an important part of remote sensing and GIS. In this technique number of single Landsat bands was used to create composite bands for true colour composite (RGB) and false colour composite (FCC). In general, combinations of bands from each spectral region (i.e., visible, mid-infrared, and SWIR II) were found to have more contrast on lithological features. For Landsat 8 OLI, RGB bands 7, 5, and 3 were further enhanced using difference stretch, and a resolution merge was created using all Landsat bands. Factor loading was then performed to determine the most suitable RGB bands (7, 5, and 3) that contained information about lineaments. For improvement of lithological features, band ratio combinations (7/5, 6/4, 4/2), principle components analysis, PCA (1, 5, 6), minimal noise feature, MNF (7, 5, 1), and independent component analysis, ICA (1, 5, 7) were carried out to find an easier way to extract the lineaments. A slight variation of the same was made utilising an FCC that included the following: ICA, PCA, MNF, and Band Ratios, with the Red and Green Channels having the

Most Geological Information, and the Blue Channel having the Saturation Band from the IHS Transform of RGB Combinations for Bands (7, 5, and 3). The FCC image is given in Figure 3.

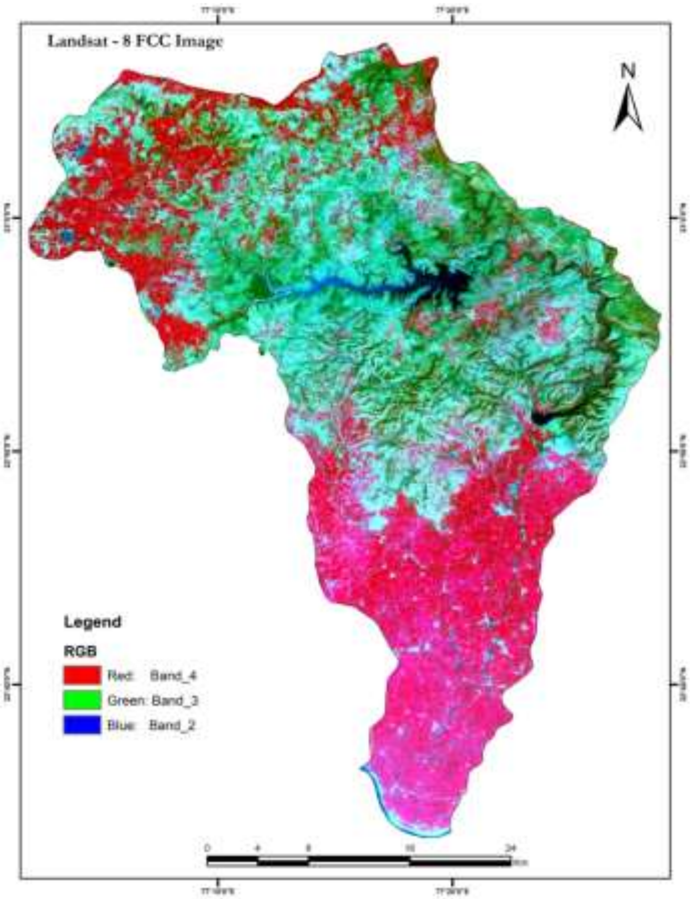

Figure 3: Landsat 8 FCC image

Mapping of Lineament and Geology

Digital image processing and visual image interpretation techniques were used for extraction of lineament via digitizing the line type of geometry from the district resource map of Sehore and satellite image. Lineament map prepared is shown in Fig. 5. Geological formation of the study area was mapped with the help of DRM, satellite image and by field survey (Fig. 4).

Results and Discussion

In the present study remote sensing data and GIS tool has been found very useful in the interpretation of geological formation and lineament analysis. Geology and lineament were individually mapped. Lineaments were classified based on length such as less than 1 Km, 1-2 Km, 2-3 Km,3-5 Km and more than 5 km. In the area 57 lineaments were found at the basaltic terrain, 20 lineaments in Alluvium formation and 5 lineaments in Vindhyan formation. Main lithological units observed are unconsolidated sediments with conglomerate and breccia, basalt and sandstone.

Geological formation

Geologically, the area is occupied mainly by Deccan traps, Bhander formation of upper Vindhyan group and Alluvium.

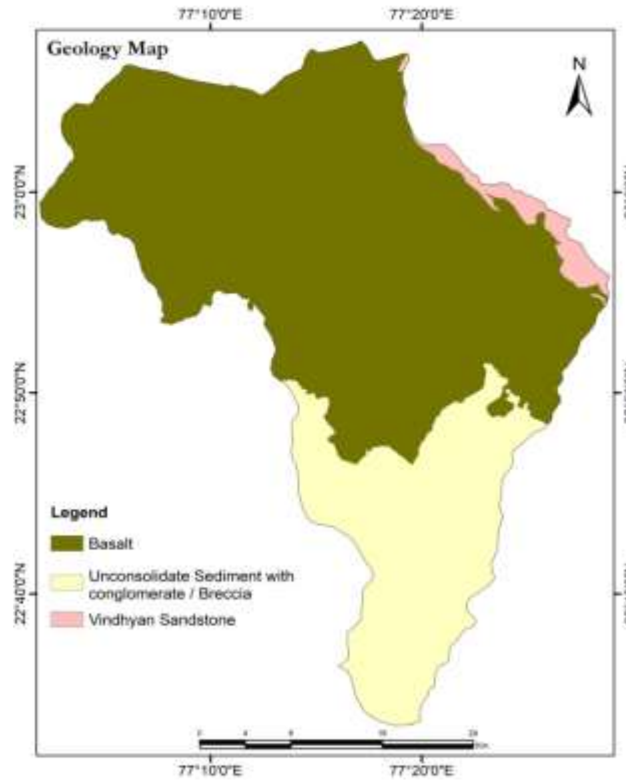

Figure 4: Geology Map of the Study Area

This formation is unconformably overlained by Deccan trap and which in turn is overlain by the alluvium of quaternary period. The geological succession of the lithological units identified in the study area is given in Table 1 and the geological map is shown in Fig. 4. Basalt was the main rock formation exposed over 72.52 % area, other than Basalt, Unconsolidated Sediment with conglomerate / Breccia over 24.94 % area and only 2.54% is Upper Bhander rocks of Vindhyan Sandstone.

Table 1 Geological Succession of the Study Area

S. N.	Lithology	Area in Km^2	Area in Percentage
1	Basalt	939.83	72.52

2	Unconsolidate Sediment with conglomerate / Breccia	323.19	24.94
3	Vindhyan Sandstone	32.94	2.54

Lineament Direction and Length

The trends of the all lineaments of the study area is given in Tables 1-4. Most of the lineaments are minor with some major lineaments. These trends towards NE, ESE, SE, NNE and SSW directions . Lengths are categorised in six classes on the basis of length range, these are less than 1 km, 2 km, 3 km, 5 km and 5 to 20 km. Of the total lineaments identified, the maximum 46 were related to drainage parallel, 31 parallel to joints/ fracture, 4 scarp parallel and 1 found parallel to fault. According to Table 3, 14 lineaments are less than 1 km, 28 are between 1-2 km, 16 are between 2-3 km, and 20 are between 3-5 km. and only 4 lineaments in the study area are longer than 5 km. (Table 2 and 3). This suggests that the trends are N- S, NNE-SSW, ENE-WSW, SE-SW and E-W axis. The principal direction of lineament in the region is between NE-SW and NW-SE (Fig.5).

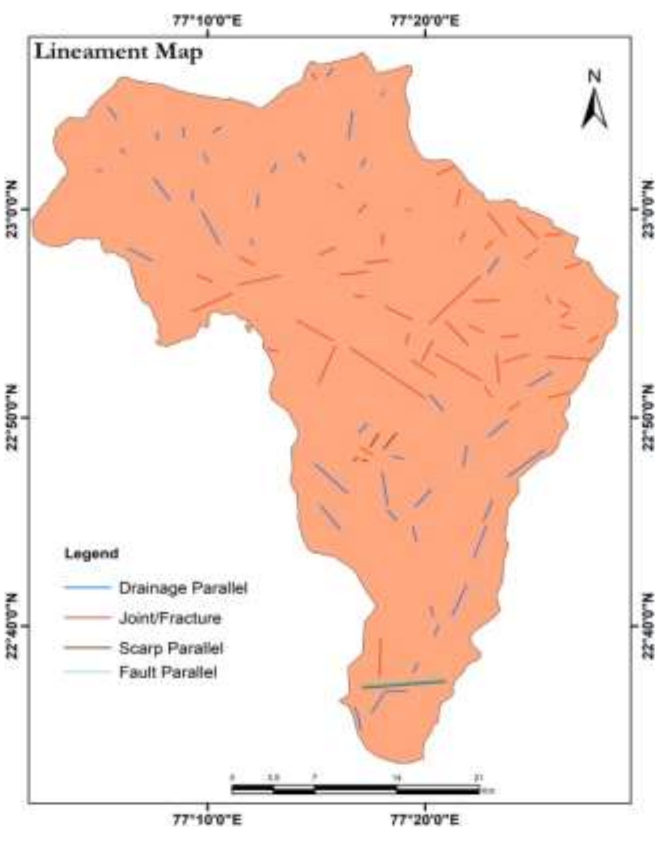

Figure 5: Lineament map of the study area

Table 2: Direction and length of lineaments

S. No	Direction In Degree	Distance In M	S. No	Direction In Degree	Distance In M	S. No	Direction In Degree	Distance In M	S. No	Direction In Degree	Distance In M
1	1.78	2072.27	22	70.82	4011.51	43	249.17	1041.75	64	302.54	522.61
2	2.04	2932.12	23	74.80	3373.08	44	250.82	3221.52	65	302.72	6476.68
3	4.18	3992.78	24	77.77	1191.55	45	255.83	4216.05	66	304.89	3340.58
4	5.86	16698.33	25	81.46	1026.88	46	258.81	1097.94	67	308.82	5327.39
5	5.94	2147.50	26	81.85	421.05	47	260.81	1163.49	68	309.98	4665.40
6	9.31	3832.91	27	95.33	1382.97	48	261.32	1098.62	69	315.20	4170.09
7	18.00	1988.55	28	97.26	890.92	49	265.95	4085.68	70	318.05	720.45
8	27.80	984.95	29	102.87	2307.09	50	269.13	1612.08	71	321.94	2891.58
9	29.62	2978.16	30	109.58	876.19	51	270.44	1702.23	72	322.02	1127.82
10	34.25	2979.60	31	116.89	1965.84	52	271.27	816.93	73	322.21	3623.17
11	39.24	2219.32	32	121.54	1254.25	53	274.70	1640.76	74	322.30	817.65
12	46.00	2427.99	33	137.60	5856.62	54	275.64	2584.27	75	324.26	2472.18
13	47.26	859.94	34	138.10	1301.30	55	277.45	4082.57	76	326.28	1194.00
14	52.66	2694.91	35	170.12	1526.80	56	283.71	397.78	77	327.11	3977.78
15	60.57	2450.51	36	183.20	1897.37	57	285.37	429.28	78	329.64	1392.48
16	62.23	4832.33	37	204.40	1878.71	58	290.94	4294.63	79	330.99	679.41
17	63.69	786.86	38	217.11	1022.53	59	291.65	1947.55	80	342.06	1871.12
18	65.57	2514.0	39	225.30	1512.	60	295.22	3915.	81	352.44	892.5

		2			97			60			2
19	66.08	3022.38	40	236.11	1384.86	61	296.35	2328.34	82	357.57	4841.49
20	67.01	2736.26	41	238.02	1402.38	62	298.46	4583.05			
21	69.88	3917.92	42	238.05	1812.46	63	300.20	1218.77			

Table 3: Number of lineament and Length range in meter

S.N.	Lineament Range in Km	Number of Lineament
1	5-20	4
2	3-5	20
3	2-3	16
4	1-2	28
6	Less than 1	14

Lineament density

The density analysis of lineament is commonly used in combination with the geostatistical and geospatial tool (Epuh et al. 2020; Shandini et al. 2020; Abdelouhed, Ahmed, Abdellah, Mohammed, et al. 2021; Jellouli et al. 2021). The density maps can be prepared utilising this geostatistical and geospatial method with the line density tool that is included into the spatial analyst tool of the Arc GIS 10.4 software environment. This tool calculates the density of the lineaments, which offers helpful knowledge on the geographic distribution of joints/fractures. Many authors have used this tool as an effective method to learn about the lineament density distribution.

The lineament density map was generated for characterizing the spatial patterns of lineaments distribution in order to summarize and verify the identified lineaments. Line density tool was applied separately on every lineament map (including overall lineaments of the four directions) in order to generate the lineament density maps of Landsat-8 derived lineaments as well as the density map of overall drainage, scarp, faults and joint/fractures in the study area. The prepared map is shown in Fig. 6 by grids using natural break method.

Lineament density maps display that the high concentrations of lineaments are prevalent in central part of the study area. It reveals the existence of several joints/fracture and drainage parallel to the lineament in the area. The low-density values were observed in the south east part of area. In the southern part of the area, there is a one fault that are particularly identified in lineament density maps. These densities values are clearly classified in five classes: very low, low, medium, high and very high density area

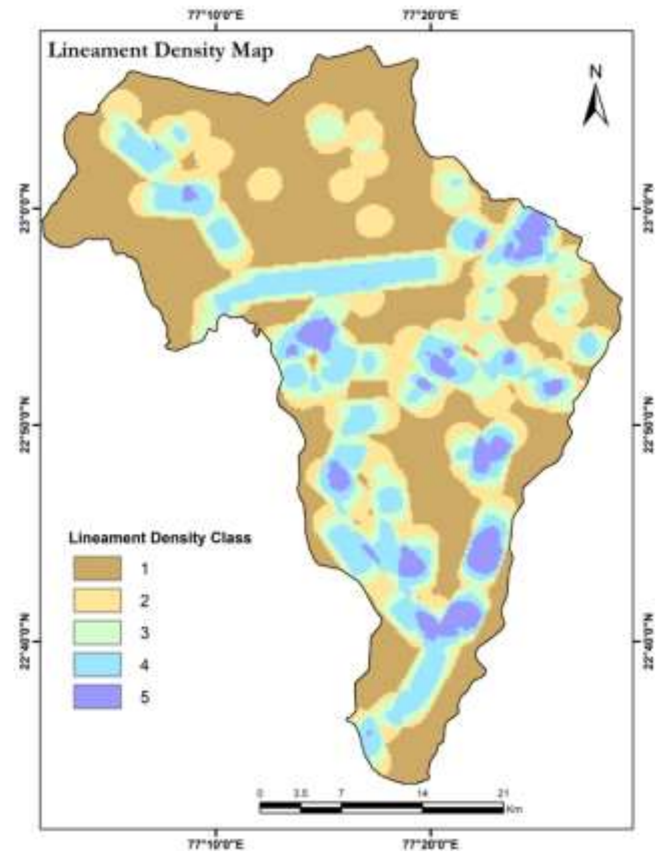

Figure 6: Lineament density map of the Study Area

Conclusion

The application of Remote sensing technology is used in many different areas of study, including structural geology, mineral exploration and the extraction of lineaments and structural characteristics. This study explains how to analyse lineaments from satellite data. The analysis of lineaments and fractures revealed a large number of long and short fractures with primarily trending towards north-east to south-west and north-west to south- east structural trends.. The observations demonstrate the capability of the remote sensing and GIS technique to extract lineament trends for tectonic study. Geo informatics technique is the best strategy for categorising the various type of lineaments on the basis of length and origin.

In the present study 82 lineaments were extracted with a total length of 219415.1 mts and categorized in five classes on the basis of length, 14 lineaments are less than 1 km, 28 are between 1-2 km, 16 lineaments are between 2-3 km, and 20 lineaments are between 3-5 km. and 4 lineaments more than 5 km. The lineaments trend towards N- S, NNE-SSW, ENE-WSW, SE-SW and E-W axis. The principal direction of lineament in the region between NE- SW and NW-SE. Lineament density maps displayed that the high concentrations of lineaments occupied the central part of the study area. It revealed the existence of several joints/fracture and drainage parallel to the lineament in the area. The low-density values were obtained in the south east part of area. The current study may be useful for groundwater research and mineral prospecting in this area.

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