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STATISTICAL ANALYSIS OF LINEAMENTS OF GOA, INDIA

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ABSTRACT

A study of the lineaments of Goa identified from aerial photographs is presented here. The shapes of histograms representing direction vs total number and direction vs total length have close similarities. The trended data set was treated statistically to obtain the nonlinear pattern in the form of a cosine wave. Three distinct peaks were found at azimuths of 40–45°, 90–95° and 140–145°, which have peak values of 5.85, 6.50 and 5.80 respectively. These three peaks are correlated with three cycles of tectonic activities occurring in this region, the most prominent being in the E–W direction.

INTRODUCTION

LINEAMENTS are representations of linear physiographic features related to joints, faults, fractures or folds. A study of lineaments gives valuable information for groundwater and mineral exploration and in understanding the tectonic framework of any area. Though the term 'lineament' is used for apparently straight features, it is well known that no geological trend is absolutely straight. Stream diversions, minor faulting and jointing and other features may be present in any given area.

Previous studies of lineaments of Goa[1-4] indicated three major trends NW–SE, NE–SW and ENE–WSW. This study presents a mathematical relationship between the length and direction of lineaments and correlates them with the observed tectonic activities.

MATERIALS AND METHODS

The study area is between 14° 48′ N and 15° 48′ N, and 74° 20′ E and 75° 40′ E along the central west coast of India. It is bounded by the rivers Terekhol in the north and Kali in the south, and by the Sahyadris in the east and the Arabian Sea in the west (figure 1). The lineaments were traced from aerial photographs (scale 1:60,000 approx.) and satellite images. In this area 207 lineaments were traced, and their lengths were measured and represented as histograms (figure 2). Field work was carried out to confirm some of these lineaments.

The lineament data have been divided into 5° equidistant intervals in terms of direction. Over 34 intervals were averaged and the average lineaments were subjected to statistical treatment in terms of direction (table 1).

The division of the average lineament data into such equidistant intervals gives rise to the pattern shown in figure 3. It was desired to obtain this nonlinear pattern in the form of a cosine wave to evolve the periods of amplitude from wave movement[5].

$$\chi_{t^\circ} = \bar{X} + R\cos(\omega t + \phi) + \varepsilon t^\circ,$$

where $\bar{X}$ is the average of χ_{t° for $t = 1, 2, 3, \ldots, n$; R the amplitude of the wave; ω the frequency, and ϕ the phase angle.

The above equation can also be written as

$$\chi_{t^\circ} = X + A\cos\omega t^\circ + B\sin\omega t^\circ + \varepsilon t^\circ$$

where A and B are constants and $R = (A^2 + B^2)^{1/2}$ and $\phi = \tan^{-1}(B/A)$. The constants are obtained by the method of least squares.

Because analysis of periods in a data series demands removal of any trend the data were detrended. The lineaments were classified into different intervals and the data were averaged with fluctuations being minimized. The average lineament features were divided by moving average, which contained trend, in order to detrend the data (table 1). The data series was left only with period or cycles in the 'bloom' of lineaments with change in

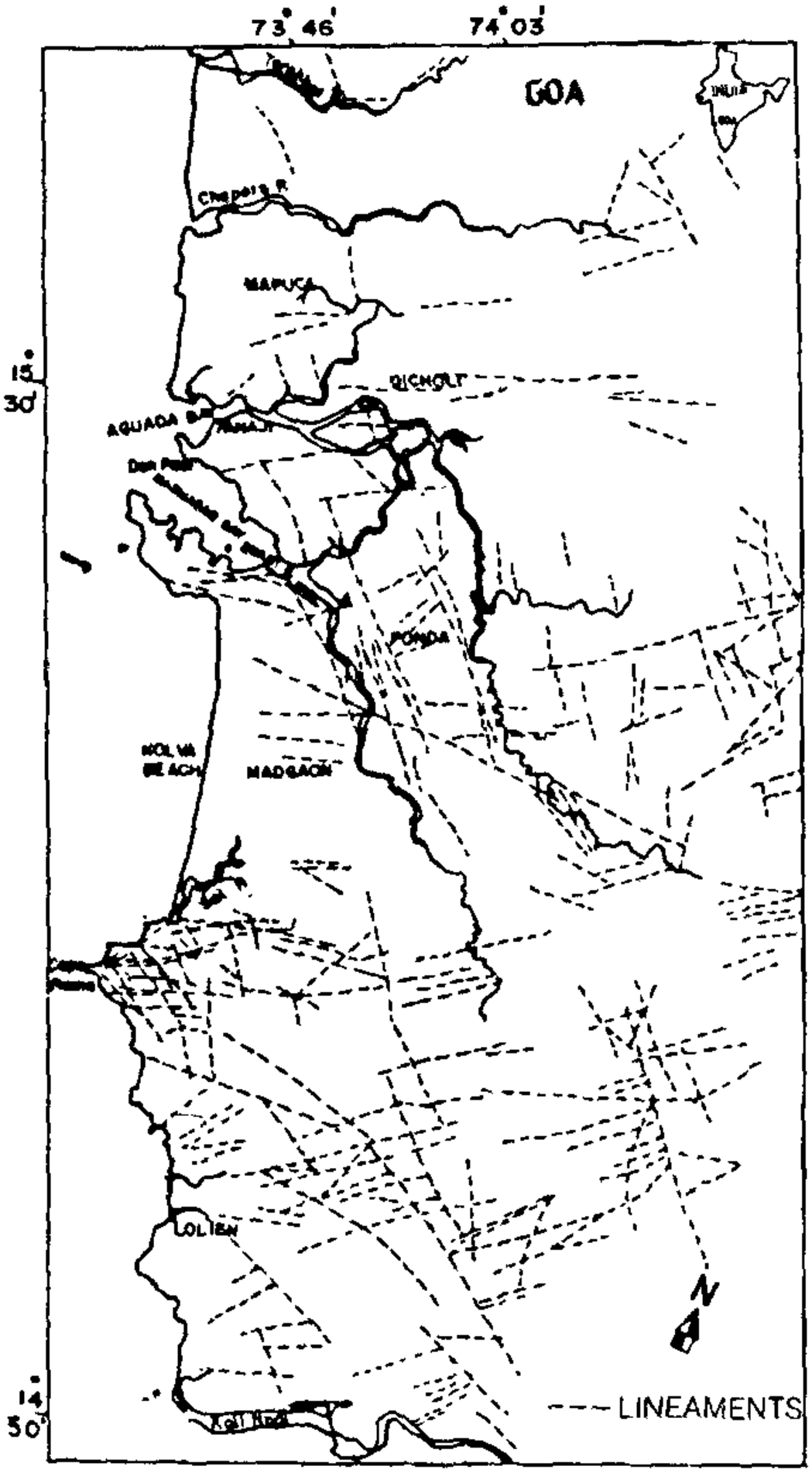

Figure 1. Lineament map of Goa.

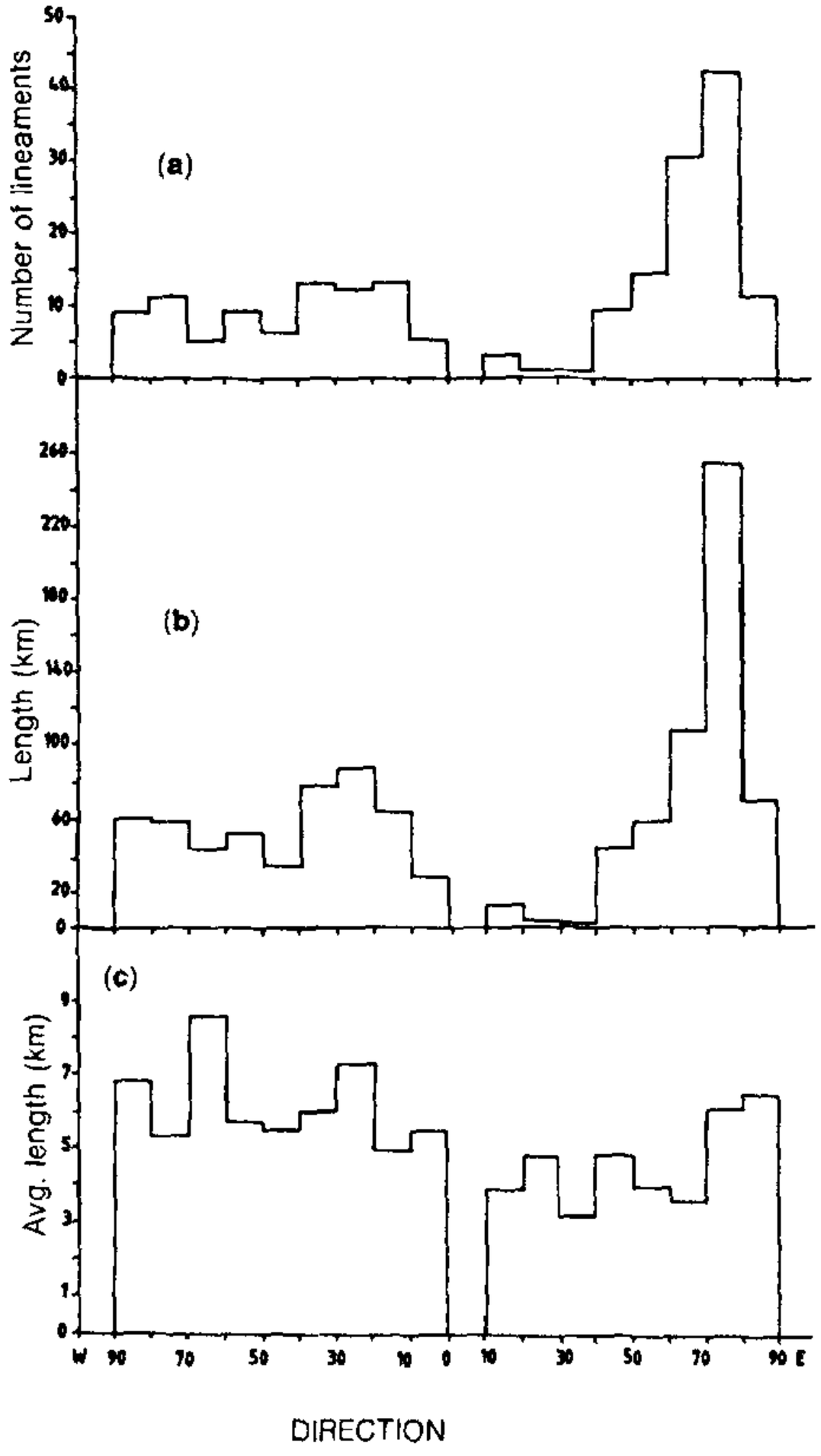

Figure 2. Histograms: (a) number of lineaments in 10° direction intervals, (b) total length of lineaments, and (c) average length of lineaments.

direction. The cosine curve which explains the period or cycles of the lineaments was of the form

$$\chi_{t^\circ} = 1.299 + 0.134 \cos(1.84\,t^\circ - 79.64\,t^\circ).$$

Also,

$$\chi_{t^\circ} = 1.299 + 0.024 \cos(1.84\,t) - 0.131 \sin(1.84\,t^\circ)$$

The frequency ω of the curve was found to be 1.8487; $\omega = 2\pi f/n$, where f is the number of peaks in the curve and n the number of observations. The value $\omega = 1.8487$ was found for $f = 10$.

RESULTS AND DISCUSSION

In the study area 207 lineaments were measured. The lineaments have a total length of 1095.96 km spread over an area of 4721.04 km^2, giving an average lineament density of 0.043/km^2.

Three kinds of histograms were drawn[6] (figure 2): (i) number of lineaments in each 10° against the segment bearing, (ii) total length of all lineaments in each 10° segment against the segment bearing, and (iii) the average length of lineaments in each 10° against the segment bearing compared with the average length of all lineaments in the area.

Figure 2 reveals the following. Generally, the histograms for total number of lineaments (figure 2a) and total length of lineaments (figure 2b) show fairly close similarities in shape. A slight fall in lineament

Table 1 *Statistical treatment on data for lineaments of Goa*

Direction interval (deg)	Average lineament	Moving average lineament	Detrended lineament
10–15	4.38	4.38	1.00
15–20	3.72	4.05	0.92
20–25	4.86	2.97	1.64
25–30	3.24	3.24	1.00
30–35	2.59	2.59	1.00
35–40	3.18	2.69	1.18
40–45	5.85	3.14	1.86
45–50	4.59	3.32	1.38
50–55	2.75	3.25	0.85
55–60	4.60	3.39	1.32
60–65	3.59	3.41	1.05
65–70	3.86	3.44	1.12
70–75	6.04	3.65	1.66
75–80	5.45	3.78	1.44
80–85	5.60	3.89	1.44
85–90	3.15	3.85	0.82
90–95	6.50	4.00	1.48
95–100	1.62	3.87	0.42
100–105	4.24	3.89	1.09
105–110	5.62	3.98	1.41
110–115	7.39	4.14	1.79
115–120	5.40	4.12	1.31
120–125	4.84	4.23	1.14
125–130	5.33	4.27	1.25
130–135	4.59	4.28	1.07
135–140	7.41	4.41	1.68
140–145	5.80	4.46	1.30
145–150	6.85	4.54	1.41
150–155	7.29	4.64	1.57
155–160	13.86	4.94	1.40
160–165	6.48	4.97	1.30
165–170	5.66	5.07	1.13
170–175	5.98	5.02	1.19
175–180	5.46	5.02	1.08

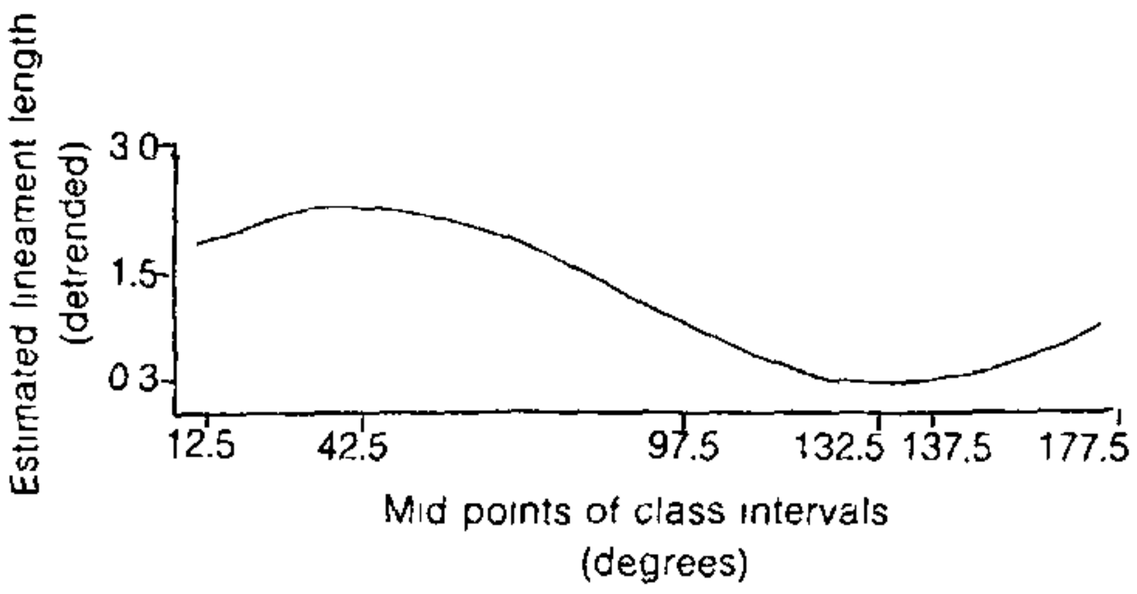

Figure 3. Cosine wave curve obtained from data for lineaments of Goa.

number is seen between 20 and 30° W for which a corresponding peak occurs in the length histogram. This may be explained as being caused by greater lengths of a smaller number of lineaments. The number of lineaments in this zone (20–30° W) is 12, with a total length of 88 km. The 'average length' histogram (figure 2c) and the 'total number' histogram show that in the direction internal 70–80° E there is an increase in average length of lineament and a greater concentration of lineaments. Hence the 'total lineament length' histogram shows a distinct and sharp peak in this region. But the 'average length of lineament' histogram does not closely conform to the shape of the 'total number of lineament' histogram in the other direction intervals. To some extent the 'average length' histogram has an apparent increase whereas the 'total number' histogram shows an apparent decrease in concentration of lineaments. Hence the 'total lineament length' histogram tends to have some change in the pattern outside the 70–80° E interval compared to the pattern in the 'total number of lineaments' histogram.

The cycle in the data was observed to be 10, i.e. after every ten direction intervals a peak in the average lineament feature occurs. In cos $(\omega t + \phi)$, because of negative ϕ the $t = \phi/\omega$ value corresponds to about 43.07°, at which the cosine curve vanishes. This value of 43.07° lies in the 40–45° direction interval in which the first peak with average lineament length of 5.85 is observed. The next peak, of 6.5, occurs in the 90–95° interval, followed finally by a peak of 5.80 in the 140–145° interval. The fit therefore seems to be in reasonable agreement with the observed data.

The present results indicate that the moving average of lineaments shows an increasing trend with direction. The highest peak value of 6.5 (90–95°) corresponds to the E–W trending round hinged folds. The other two peak values, 5.85 and 5.80, correspond to the NW–SE and the NW-plunging folds respectively.

CONCLUSION

In conclusion it may be stated that tectonic activities were maximum in the E–W direction, and less in the NW–SE and the NE directions. These results corroborate earlier studies[7] which revealed that the major parts of Goa witnessed three cycles of folding of varying intensities during the Archaean.

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ANNOUNCEMENTS

Success and Creativity in Pharmaceutical Research and Development

Place: Royal College of Physicians, London
Date: 30 April to 1 May 1990
Contact: Dr Renata Duke
IBC Technical Services Ltd.
Bath House (3rd Floor)
56 Holborn Viaduct,
London EC1A 2EX, UK

Bisphosphonates — Current Status and Future Prospects

Place: Royal College of Physicians, London
Date: 21/22 May 1990
Contact: Dr Renata Duke
IBC Technical Services Ltd.
Bath House (3rd Floor)
56 Holborn Viaduct
London EC1A 2EX, UK

Autoimmunity — New Targets and Therapeutic Approaches

Place: Royal College of Physicians
Date: 5/6 June 1989
Contact: Dr Renata Duke
IBC Technical Services Ltd.
Bath House (3rd Floor)
56 Holborn Viaduct
London EC1A 2EX, UK

Twentyfifth Course on Management of R and D Systems

Place: Hyderabad
Date: 12–17 March 1990
Contact: The Programmes Officer
Administrative Staff College of India
Bella Vista, Hyderabad 500 049

National Congress on Biotechnology

Place: Hyderabad
Date: 16–18 March 1990
Theme: Biotechnology for Human Welfare
Contact: Prof. P. P. Reddy
Director
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