30. Patel, M. P., Proc. Sem. Quat. Landscape of India Sub-continent (eds. Desai, N., Ganapathi, S. and Patel, P. K.), M. S. U., Baroda, 1991, pp. 119–129.
31. Baskaran, M., Rajagopalan, G. and Somayajulu, B. L. K., *Chem. Geol.*, 1989, **79**, 65–82.
32. Chakrabarty, A. and Baskaran, M., *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 1989, **73**, 311–315.
33. Merh, S. S., The miliolite problem, Presidential address, 67th Indian Sci. Cong., Geol. Geog. Section, 1980, pp. 17–42.
34. Merh, S. S., Workshop on N–Q stratigraphy including the study of fluvial and glacial systems, Dept. of Geology, Delhi University, Delhi, 1991, pp. 5–25.
35. Pandya, K. and Bastani, B., Proc. Natl. Workshop on Quaternary Carbonate, P. R. L., Ahmedabad, 1986, pp. 12–14.
36. Peryt, T. M. *Coated grains* (ed. Peryt, T. M.), Springer Verlag, 1983, pp. 437–449.
37. Flugel, E., *Microfacies Analysis of Limestones*, Springer Verlag, 1982.
38. Baskaran, M., Marathe, R. A., Rajaguru, S. N. and Somayajulu, B. L. K., *J. Arch. Sci.*, 1986, **13**, 505–514.
39. Baskaran, M., Rajagopalan, G. and Somayajulu, B. L. K., *Chem. Geol.*, 1991, **86**, 83–84.
40. Bruckner, H., Dusseldorf, Augusto, M., Hiedelberg, Lucien, M., Steclotilde, France, D. O. M. and Konrad, R., Krefeld, *Berl. Geogr. Studies*, 1987, **25**, 343–361.
41. Sharma, V., Unpublished Ph D Thesis, Univ. of Delhi, 1991.
42. Wynne, A. B., *Mem. Geol. Surv. India*, 1872, **9**, 163–213.
43. Patel, M. P., Patel, S. G. and Merh, S. S., Proc. Sem. Quat. Episodes in India (eds. Merh, S. S. and Vashi, N. M.), Dept. of Geology, M. S. U., Baroda, 1985, pp. 49–54.
44. Fakhri, A. H. and Vashi, N. M., Proc. Sem. Quat. Stud. in India (eds. Patel, M. P. and Desai, N.), Dept. of Geology, M. S. U. Baroda, 1988, pp. 367–376.
45. Biswas, S. K., *A. A. P. G. Bull.*, 1982, **66**, 1497–1513.
46. Chappel, J. and Shackleton, N. V., *Nature*, 1986, **324**, 137–140.
47. Nair, R. R., *Proc. Indian Acad. Sci.*, 1974, **79**, 197–203.
48. Nair, R. R. and Hashmi, N. H., *Proc. Indian Acad. Sci. Earth Planet Sci.*, 1980, **89**, 299–315.
49. Pant, R. K. and Chamyal, L. S., *Proc. Indian Natl. Sci. Acad.*, 1990, **56**, 501–511.

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Slope-deviatory alignment, stream network and lineament orientation of the Sabarmati River system—Neotectonic activity in the Mid- to Late Quaternary

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The Gujarat alluvial plain located in the semi-arid zone is bounded by the arid Thar region in the north and the coastal/estuarine zone fringing the Arabian Sea in the south. It has been built by the rivers originating in the Aravalli Hills in the northeast. The drainages, with an average length of about 300 km, generally follow the NE-SW regional slope. However, the Sabarmati River shows a flow deviating from the regional slope and follows a N-S to NNE-SSW trend in the alluvial area.

The slope-deviatory trend of the Sabarmati has been investigated with regard to Late Quaternary neotectonics, fluvial-aeolian interaction and sea-level change. Lineament analysis indicates an E-W to WNW-ESE trajectory of maximum principal stress, and that drainage is primarily controlled by geodynamic processes. This is obvious from the correspondence in stress trajectories obtained from the lineament and drainage orientations, respectively.

Sub-surface data indicate pre-Neogene faulting in the basin. It is inferred that these faults have been reactivated in the Mid- to Late Quaternary times. The slope-deviatory drainage of the Sabarmati River is, to a large extent, the result of fluvial adjustment to neotectonic reactivation in the region.

Introduction

THE state of Gujarat in western India consists of four physiographic micro-regions, namely the Rann, the Kachchh peninsula, the peninsular Gujarat, and the Gujarat alluvial plain. The alluvial plain has a network of drainages, emerging from the N-S to NW-SE trending Aravalli hills. Of these, the Sabarmati (Figure 1) and Mahi are the most important drainages. The Sabarmati River originating in the southern Aravalli follows, for 185 km, a nearly north-south trend up to Navapura (22° 40′ 54″; 72° 30′ 12″). The contour map of

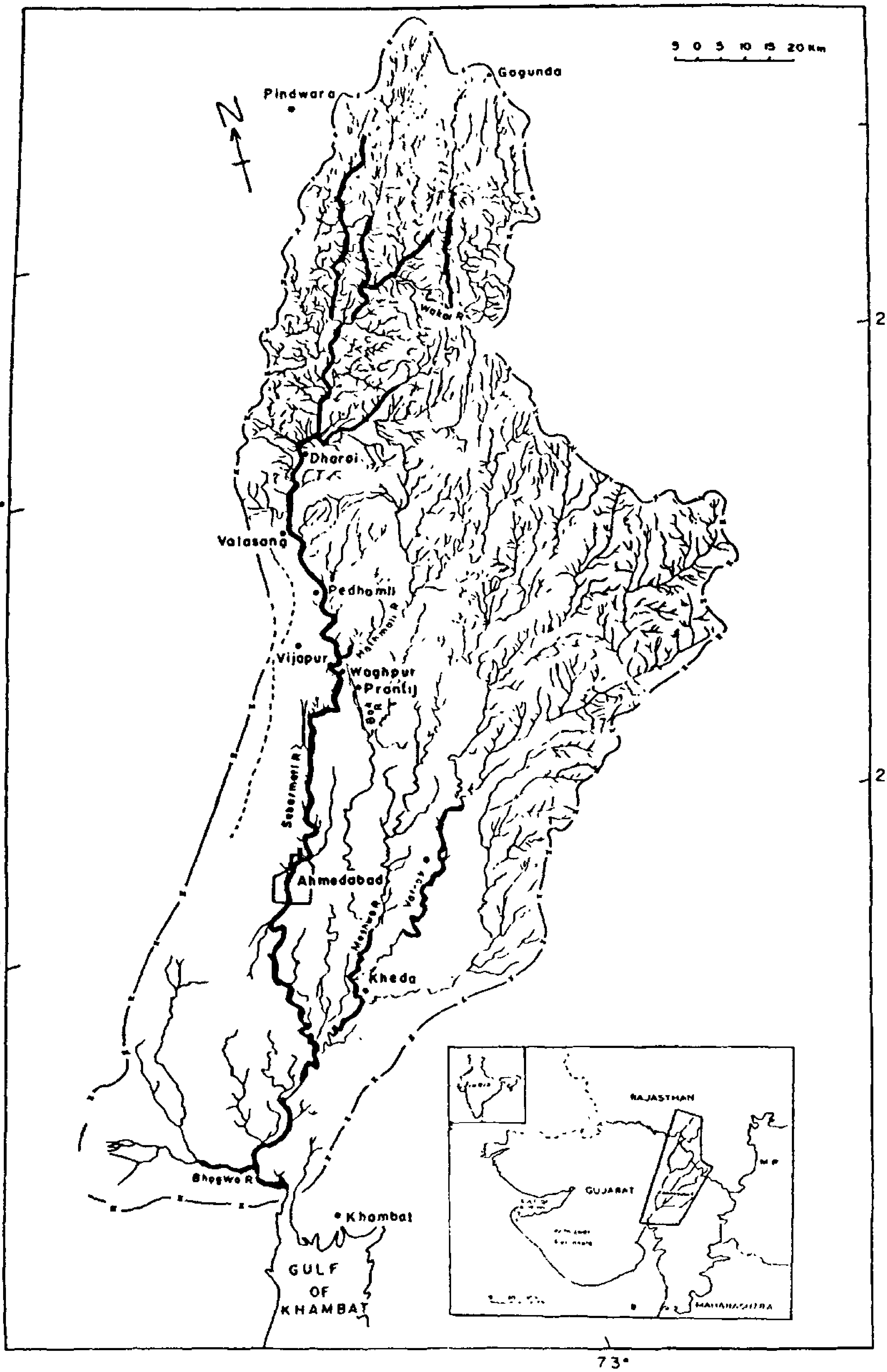


Figure 1. The Sabarmati drainage basin.

the alluvial plains in the alluvial sector between Dharoi and Vijapur shows that there is a maximum deviation of 40° in the flow vector of the Sabarmati from the NE-SW regional slope (Figure 2). The Banas, Saraswati and Rupen rivers to the west of Sabarmati follow the NE-SW regional slope of this alluvial terrain (Figure 3). North Gujarat has been affected by neotectonic activities[1–5] (also see ref. 10, 11) while the West Coast has had a complex history of sea-level changes. There are three high-level strands corresponding to 6,000; 30,000 and 1,20,000 years B.P.[6] Evidence for the 30,000 yr high strand is lacking[7]. Recent work on miliolites has provided dates for three episodes of high sea-level strand and these correspond to 50–70; 75–115 and

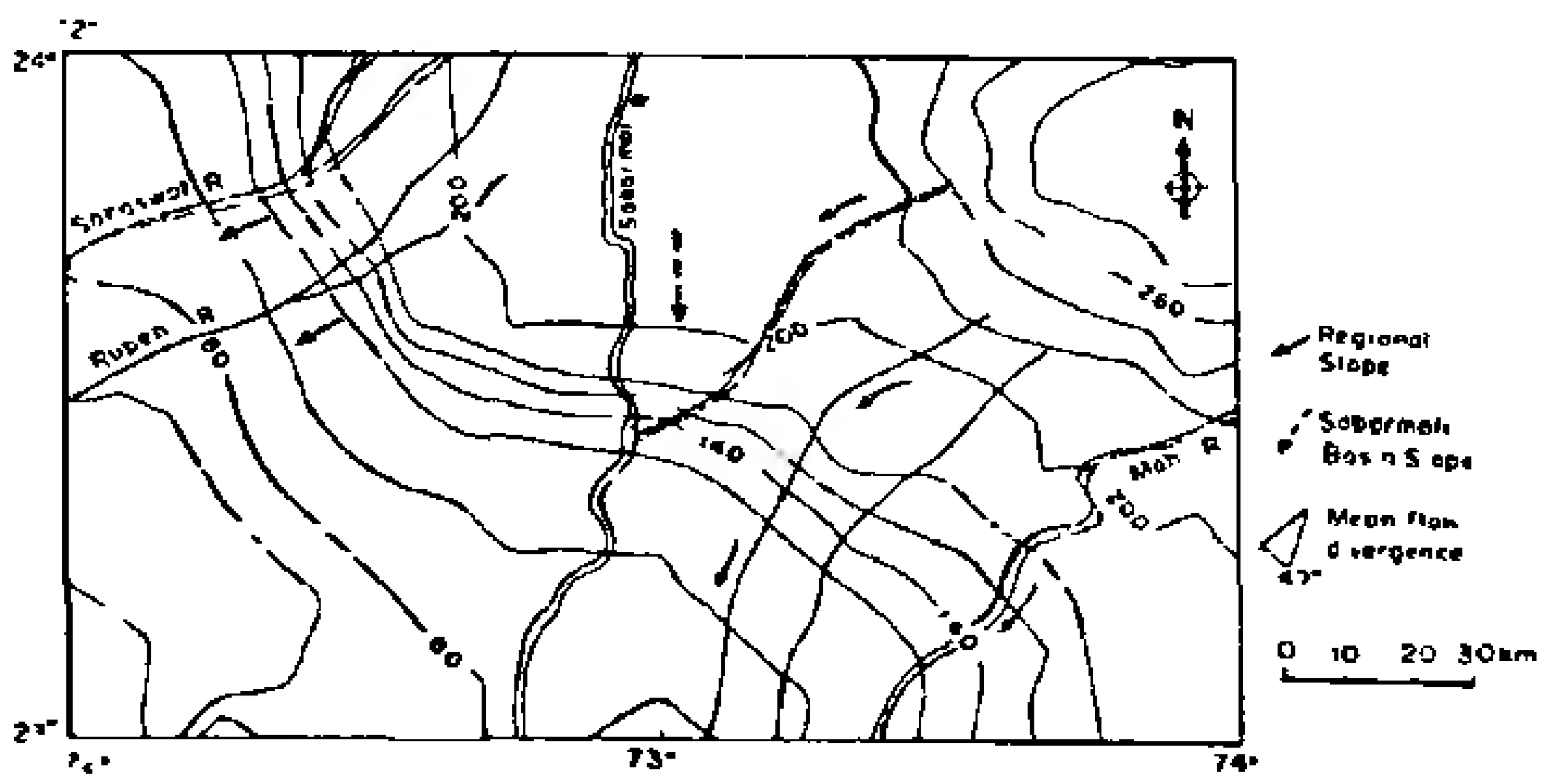


Figure 2. Generalized contour map prepared by a computer using the contour and spot elevation data of 1:2,50,000 scale degree sheets Note the divergence of flow of the Sabarmati River with respect to other slope parallel rivers of the region

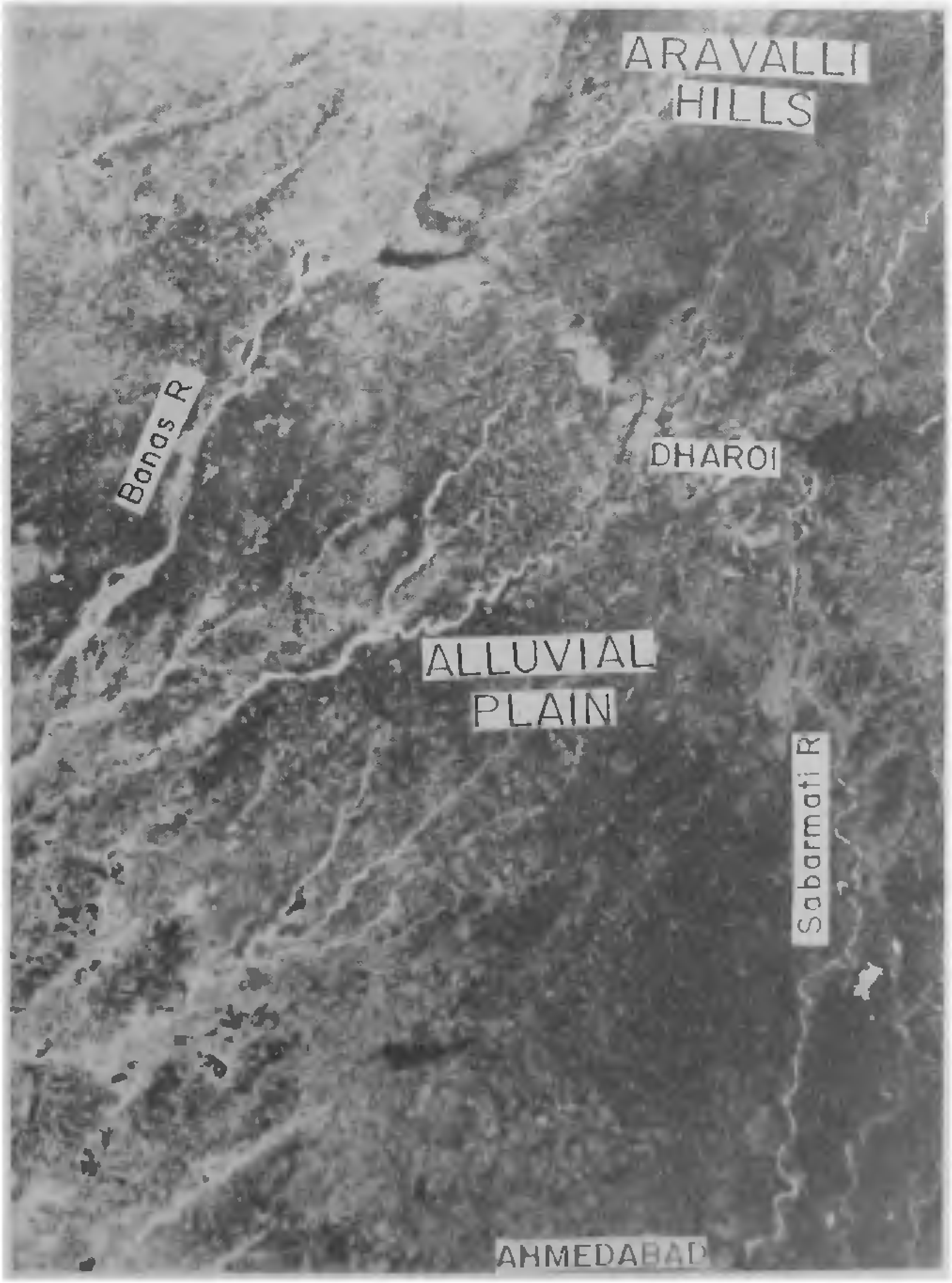


Figure 3. Satellite imagery covering the Sabarmati River and other important rivers in the region

140–210 thousand years[8]. A factor of importance is the increase of aridity in north Gujarat. The SE-NW trending dune fields are developed on both sides of the Sabarmati basin and within the interfluves of the tributaries of the river basin. The dune complexes on the western side of the Sabarmati river are stabilized and are dated to 20,000 to 5,000 yr[9].

The primary objective of this study is to examine the development of the Sabarmati drainage system in relation to neotectonic activity. The anomalous flow of the main Sabarmati channel reflected by a deviation of 40° from the regional slope and lack of development of flow lines on the eastern flank of the river is also investigated for recognition of possible causal factors. Studies carried out on various aspects of neotectonic activity in the surrounding areas of Thar desert[10], Southern Aravalli[5], Cambay[11] and Saurashtra[1] indicate reactivation of pre-Quaternary faults in the region. Several earthquakes have also been recorded in recent years[12,13]. However, information about the alluvial terrain comprising the Gujarat plains is meagre[4].

Sabarmati basin

The Sabarmati basin is a narrow oblong basin which has a wide eastern flank and a narrow western flank (Figure 1). The basin has three broad sub-divisions: (1) the upper reaches, where left and right bank tributaries flow on greater slopes and act as erosive channels debouching on to the alluvial plains; (2) the middle reaches, where all the tributaries join the main channel from the wider eastern side of the basin; and (3) the lower reaches, where all the tributaries of the Sabarmati converge into one main channel. This area is also influenced by estuarine tidal processes from the Gulf where the river meets the sea.

The basin margin on the eastern side is marked by a sharp break in slope-forming escarpments whereas the western basin margin marks a piedmont zone. Southwards, from lat. 24° 15′ N to 24° N, the river basin margin tends to become wider as the characteristic linear trend of ridges spreads into low, diffused masses of hills and dissected granitic country with occasional granite tors. Further southwards, from lat. 24° N to lat 23° N, the river basin becomes widest (115 km) as the river cuts through a flat alluvial plain. The main channel flows nearly N-S and closer to sharp, and linear western margin of the basin. The wider eastern margin is gradational. All the tributaries from the eastern side of the River flow in the NE-SW direction. No river tributaries join from the west.

From lat. 23° 30′ N to 23° N, southwards the River maintains a N-S to NNE-SSW trend. The basin width is reduced to about 90 km and the main channel closely follows the western margin. From lat. 23° N to lat. 22° 30′ N southwards the River enters the estuarine zone and the main channel occupies the centre of the basin, which is only 60 km wide. South of lat. 22° 30′ to

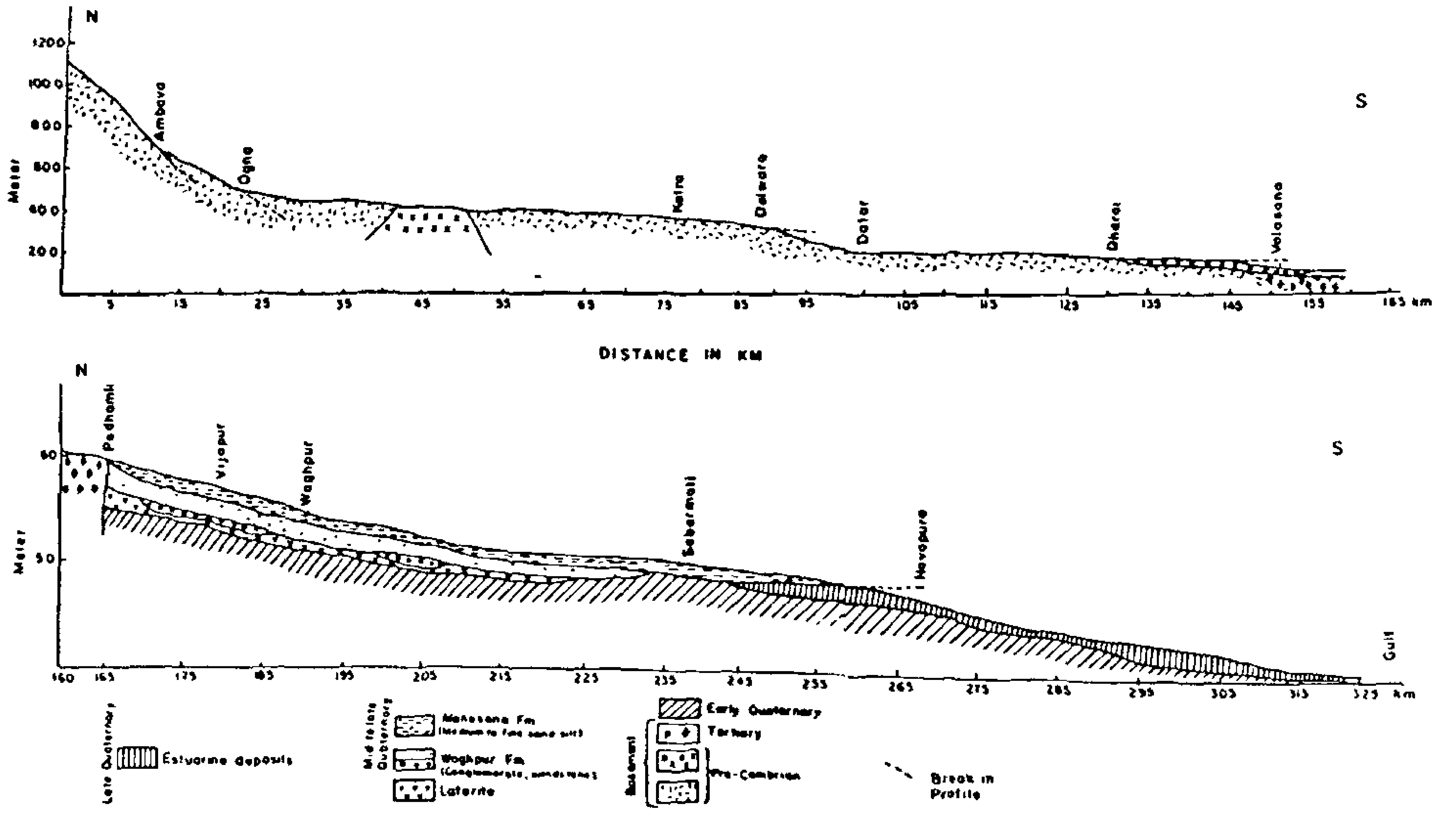


Figure 4. Longitudinal profile of the Sabarmati River in the Aravalli and alluvial areas.

lat. 22° 15′ the river flows along the eastern basin margin. A tributary joins the river from Saurashtra uplands from the western side and in contrast the eastern basin margin becomes narrow (Figure 4). In general, the Sabarmati valley profile (Figure 4, Table 1) is smooth with only a few visible breaks. There are six breaks in the river profile of which three are observed in the higher reaches in the hilly terrain, two in the middle reaches of the river in alluvial area and one break in the alluvial/estuarine interaction zone.

Lineament studies and analysis of stress fields

Lineament studies in and around Sabarmati basin were carried out on LANDSAT false colour composite (FCC) covering bands 2, 3 and 4 of 1:250,000 scale. The multispectral scanner (MSS); thematic mapper (TM) and Indian Remote Sensing Satellite (IRS-IA) data were analysed (Figure 5).

Assuming that all the lineaments are traces of shear lines or vertical fracture surfaces of a tectonic stress field, maximum and minimum stress directions have been determined[14,15].

Alluvial area

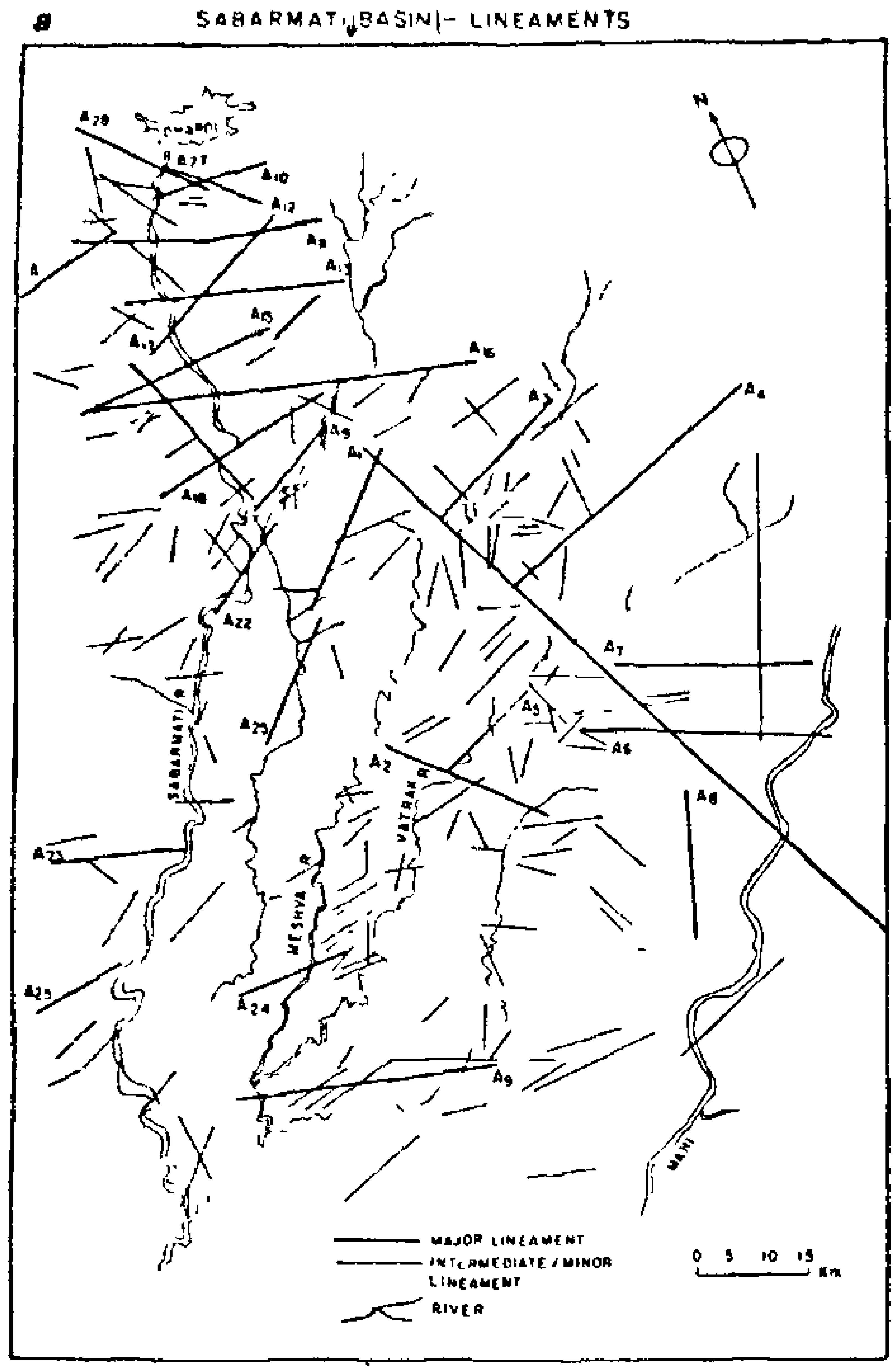
The 185 lineaments demarcated in the alluvial area (Figure 5*a*) fall into two groups of preferred orientations, one trending ENE-WSW to E-W and the other trending NW-SE. The two maxima are calculated to be 68° and 138° with an acute intermediate angle of 70°, giving maximum (P) direction as 103° and minimum (T) direction as 13° (Figure 6, Table 2).

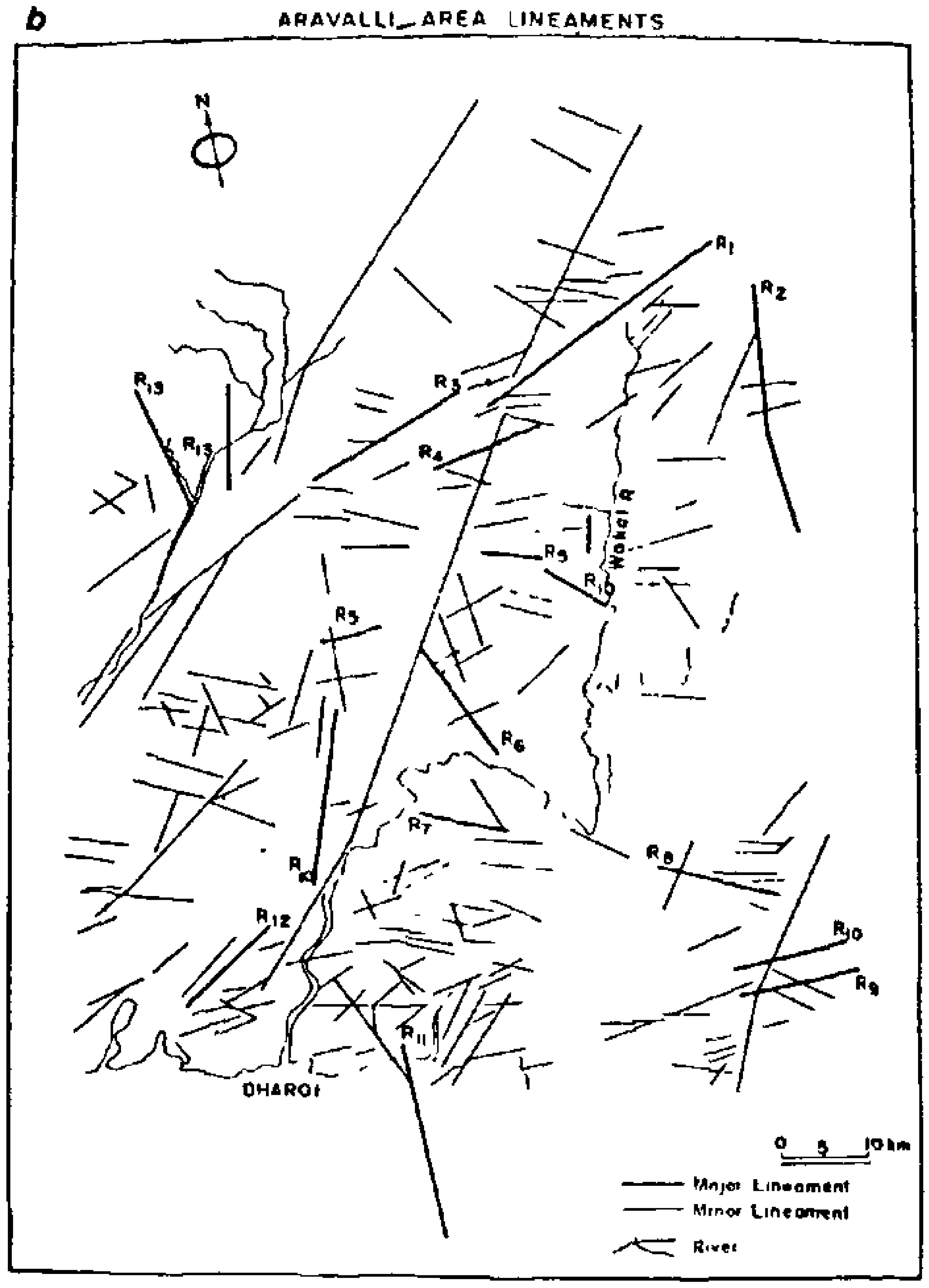
Using enhanced seismic techniques, several NW-SE to NNW-SSE trending subsurface faults have been recorded in the Mahesana-Ahmedabad sector, east of Sabarmati River[16]. This information is corroborated by data from a number of exploratory wells. Obviously, the lineament orientations are related to the subsurface faults and folds and thus suggestive of reactivation of the pre-Quaternary faults.

Table 1. Channel characteristics: Sabarmati River

S.No.	Segment From	Segment To	Length (km)	Altitude (m) From	Altitude (m) To	Fall	Confluence/ tributary Rt/Lt Bank	Distance from source
1	Khakhdi	Ambava	14.55(12.5)	1123	700	423)		
2	Ambava	Ogna	22 63(18.5)	700	500	200)		
3	Ogna	Nayagaon	20 87(17.5)	500	416	84)	Wakal	
4	Nayagaon	Manpur	13.93(12.5)	416	390	29)	River	
5	Manpur	Kotra	21.04(16.75)	390	350	40)		
6	Kotra	Delwada	7.98(7)	350	325	25	Sabarmati (Rt. Bank)	
7	Pipla	Merpur	7.25(5.25)	698	600	98		7.25
8	Merpur	D. mata	25.78(23.0)	600	400	200		33.03
9	D. mata	Delwada	15.11(12.5)	400	325	75	Wakal (Lt. Bank)	48.14
10	Delwada	Datar	16 95(11.75)	325	300	24	Sei river (Rt. bank)	65 09
11	Datar	Champa	4.87(4.25)	300	250	50		69.96
12	Champa	Bhanpur	6 18(5.5)	200	200	50		76.14
13	Bhanpur	Thalvara	5 61(5)	200	190	10		81.75
14	Thalwara	Vijlasan	17.77(15)	190	180	10	Marnar (Lt. Bank)	99.52
15	Vijlasan	Dharoi	7.24(5)	180	168	12		106.76
16	Dharoi	Valasana	25.82(20)	168	155	13		132.58
17	Valasana	Pedhamli	19.25(17.5)	155	110	45		
18	Pedhamli	Vijapur	14.5(11.25)	110	90	20		166.33
19	Vijapur	Waghpur	17.52(11 75)	90	78	12	Hathmati (Lt. bank)	183.85
20	Waghpur	Varsoda	13.86(10)	78	70	8		197.71
21	Varsoda	Sadra	11.77(8.75)	70	63	7		209 48
22	Sadra	Pethapur	8 92(8 0)	63	55	8		218 40
23	Pethpur	Sabarmati	29.33(22)	55	48	7		247.73
24	Sabarmati	Navapura	36 55(28 75)	48	40	8		284 28
25	Navapura	Virpur	30 06(21 25)	40	20	20	Vatrak (Lt. bank)	317.34
26	Virpur	Rinjha	20.23(16 25)	20	12	8		337 57
27	Rinjha	MotiBoru	17 52(13.25)	12	52	7	Bhogwa (Rt bank)	355 09
28	Moti Boru	Gulf	13 36(10 5)	5	0	5		368 45
29	High water line	Low water line	13 14					381 59

* Figures in parentheses indicate direct length.





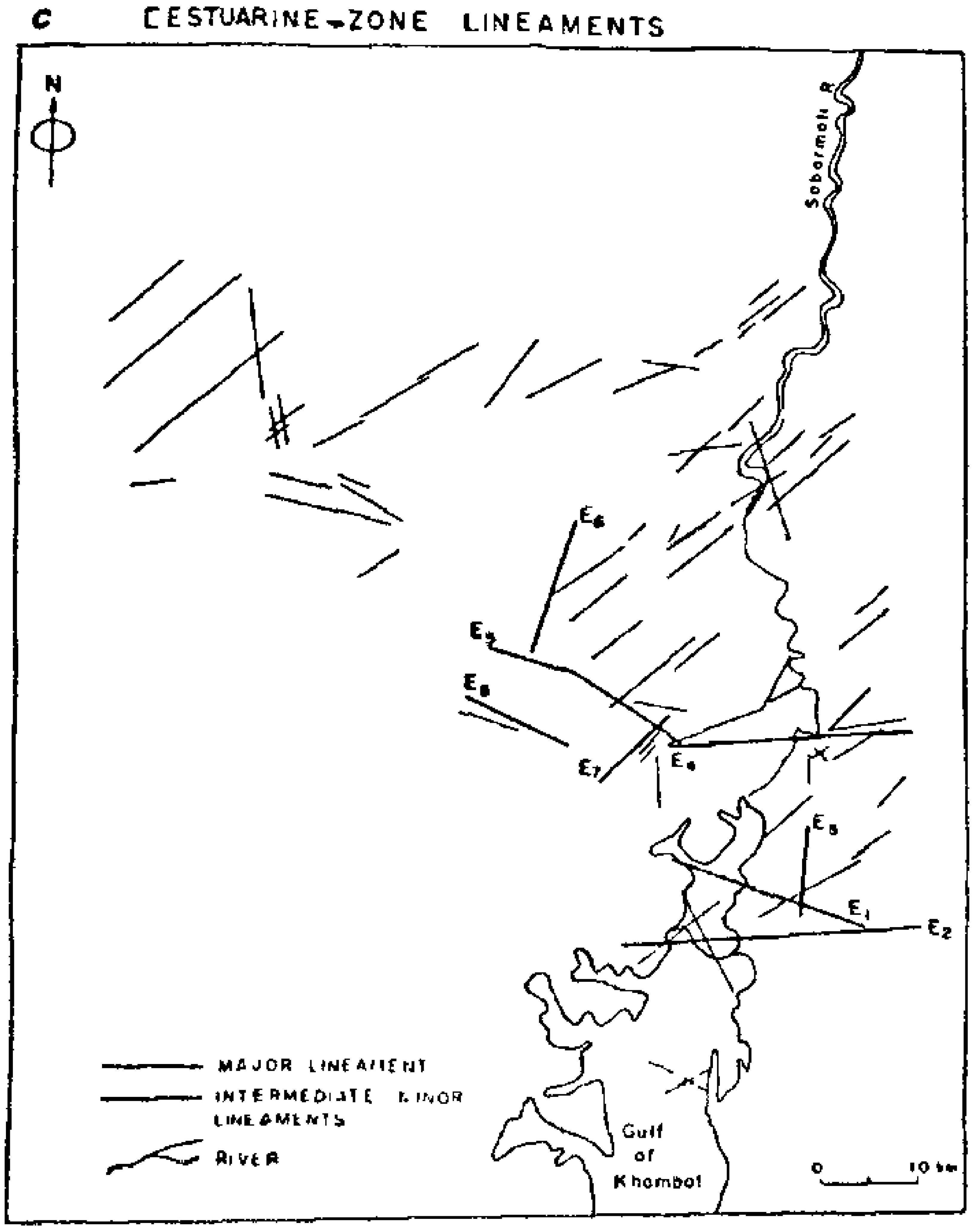


Figure 5. Lineament maps of the Sabarmati Basin (based on Satellite FCC data): (*a*) Alluvial area, (*b*) Aravalli area, (*c*) Estuarine area.

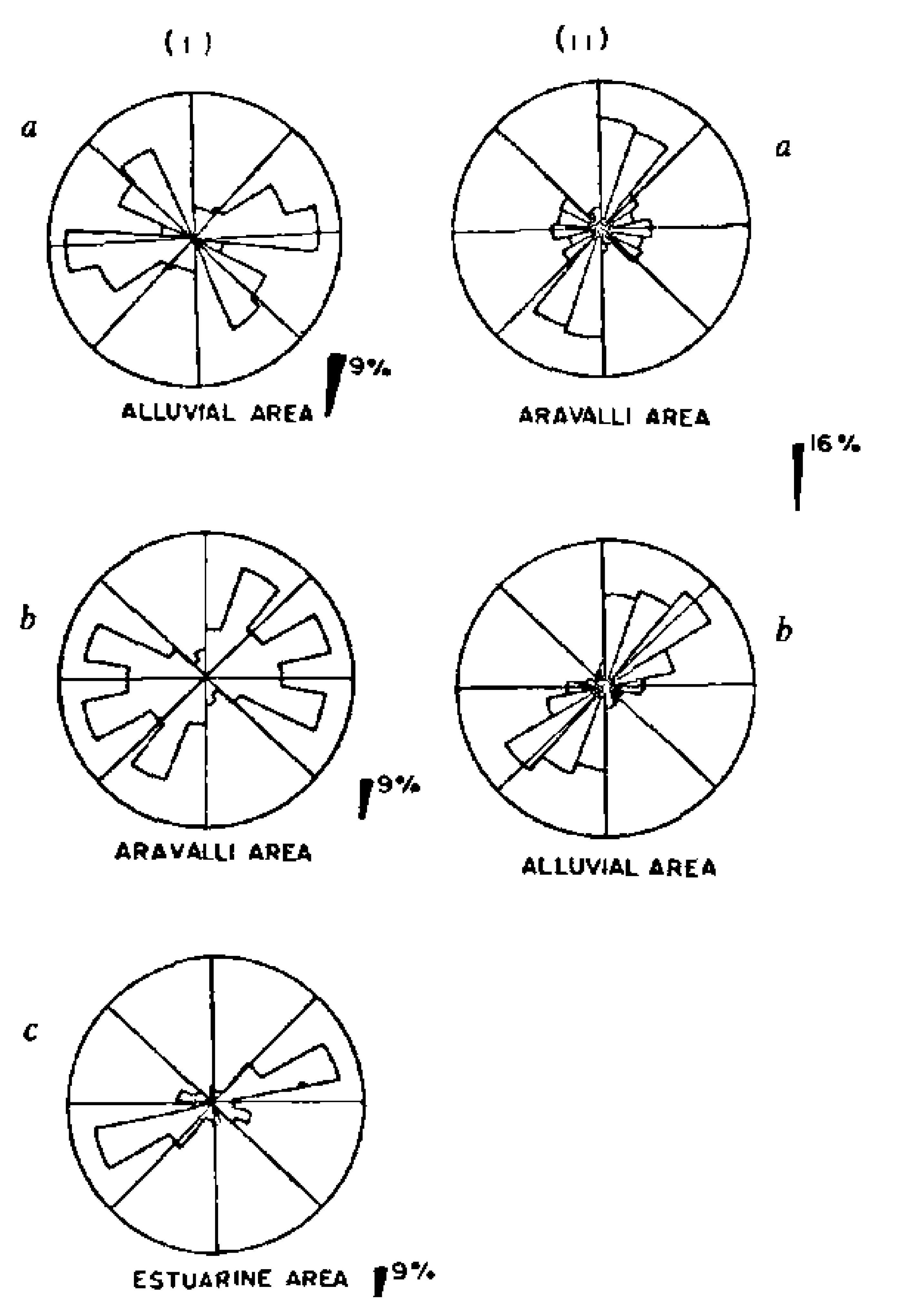


Figure 6. (i) Circular histograms of weighted average lineament azimuths: (a) Alluvial area; (b) Aravalli area; (c) Estuarine area. (ii) Circular histogram showing weighted average rectified link length azimuths in Sabarmati basin. (a) Aravalli area; (b) Alluvial area.

Aravalli area

The southern Aravalli ranges bounding the Sabarmati basin (Figure 6) show strong WNW-ESE; NE-SW and ENE-WSW trends. Geomorphological studies showed that the Aravalli region has been tectonically reactivated along the Precambrian regional faults[5]. Multispectral LANDSAT images of the Precambrian shield of Rajasthan also indicate later rejuvenation of Precambrian lineaments[4]. However, the involvement of NE-SW trending Aravalli lineaments[17] during Quaternary reactivation is doubtful for this trend is not reflected in the analysis of the Quaternary alluvial area. The WNW- ESE and ENE-WSW trends represent possible reactivation of earlier tectonic trends as indicated by geomorphic studies[5]. These two conjugate sets have been considered for calculation of stress direction. This conjugate pair has an angle of 71° and 119° with maximum principal stress (P) directed towards 95° and minimum principal stress (T) towards 5° (Figure 6). Stress analysis for entire Aravalli reveals a maximum principal stress (P) of N 110° and minimum principal stress of N 25°[18].

Estuarine zone

In the estuarine zone, recognition of the lineament features is difficult owing to extensive sediment cover. There are two strong trends—the ENE-WSW trend and a minor NW-SE trend. The two maxima calculated by taking weighted averages are 61° and 118° with an intermediate angle of 57°. The direction of maximum principal stress (P) is calculated to be 90° and the minimum stress (T) to be 360° (Figure 7).

Analysis of valley trends

Orientation of river valley trends of Sabarmati River has also been carried out by applying the techniques of Scheidegger[14,19–21]. There are two prominent preferred trends—the NNE-SSW trend and NE-SW trend. The regularity of the trends is assumed to be a result of neotectonic phenomenon with little lithological influence[22].

The rectified drainage map (Figure 8) of Sabarmati basin, characterized by linear drainages is studied in conjunction with analysis of circular histograms (Figure 6) of lengths and azimuths of drainage lines and the statistical distribution of link orientation. Applying the Scheidegger technique[21,23], the following deductions have been made.

Aravalli area

There are two trends—the strong but scattered NS to NE-SW trend and the weaker EW to ENE-WSW trend

Table 2. Maximum and minimum stress directions

Area	No. of observations	Max. 1	Max. 2	Max. 3	Angle (2.3)	P	T
(1) Lineament trends							
Aravalli Hills	214	38	71	119	48	95	5
Alluvial Plain	29	–	68	138	70	103	13
Estuarine Zone	68	–	61	118	57	90	360
(2) Rectified drainage (Valley trends)							
Aravalli Hills	116		28	120	92	74 (P)	344 (T)
Alluvial Plain	192		36	128	92	81	351

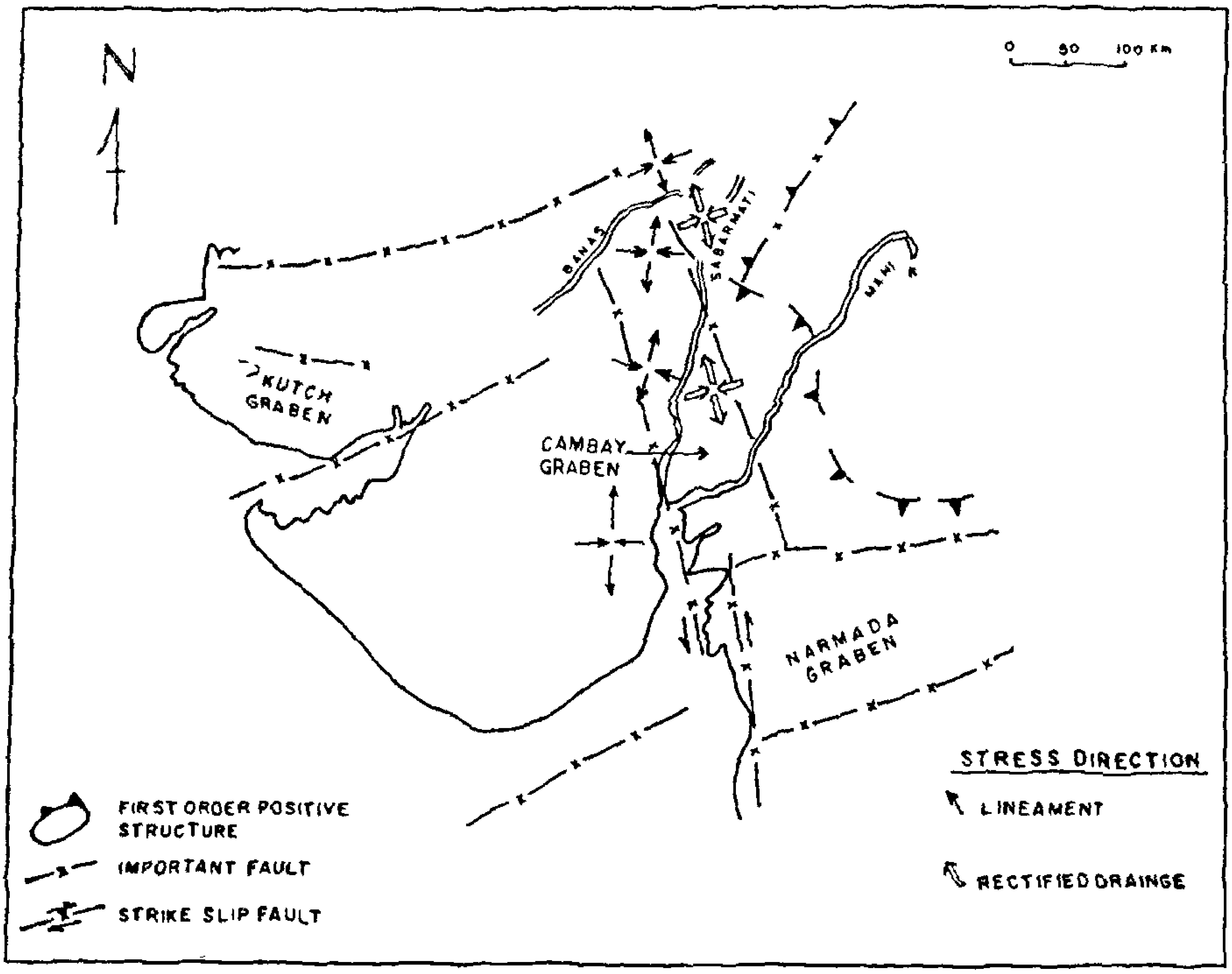


Figure 7. Stress direction in various sectors of the Sabarmati valley as revealed by lineament and valley trends. Corresponding regional faults are also shown.

(Figure 6). Two maxima are obtained by dividing these two sub-populations and calculating their mean orientations. Max. 1 and Max. 2 are obtained as 28° and 120° respectively. It may be noted that the angle between the two conjugate pairs is close to 90°. The two principal stress directions obtained are 74° and 344° (Figure 7). However, identification as to which of the two stresses represent maximas (P and T) is uncertain as the conjugate pairs are formed at nearly 90° angle.

Alluvial area

There are preferred valley trends—the prominent but scattered N-S to NE-SW trend and the weak E-W to NW-SE trend (Figure 6*b*). The mean of these two distributions is calculated to be 36° and 128° respectively. The control in this case is due to NE-SW regional slope for smaller drainages. The N-S to NNE-SSW oriented main Sabarmati drainage may be influenced by the fault structures of the Cambay graben. However, as only two maximas are present in the case of rectified drainages, these are assumed to be a conjugate pair developed by a single tectonic episode, the stress directions of which are calculated to be 81° and 351° (Figure 6). As in the case of Aravalli area, determination of maximum (P) and minimum (T) is not possible as both the conjugate pairs are developed at nearly 90°.

The origin of the lineament patterns of the Aravalli and alluvial areas is different—the former represents reactivation along Pre-Cambrian faults[5] and the latter along Tertiary faults[2]. Significantly, the parametric statistical analysis does not reveal any significant difference in valley orientation trends and stress trajectories developed in the Aravalli and the alluvial areas. They correspond more or less with each other. In the analysis of valley orientations, it has not been possible to ascertain P and T due to the development of

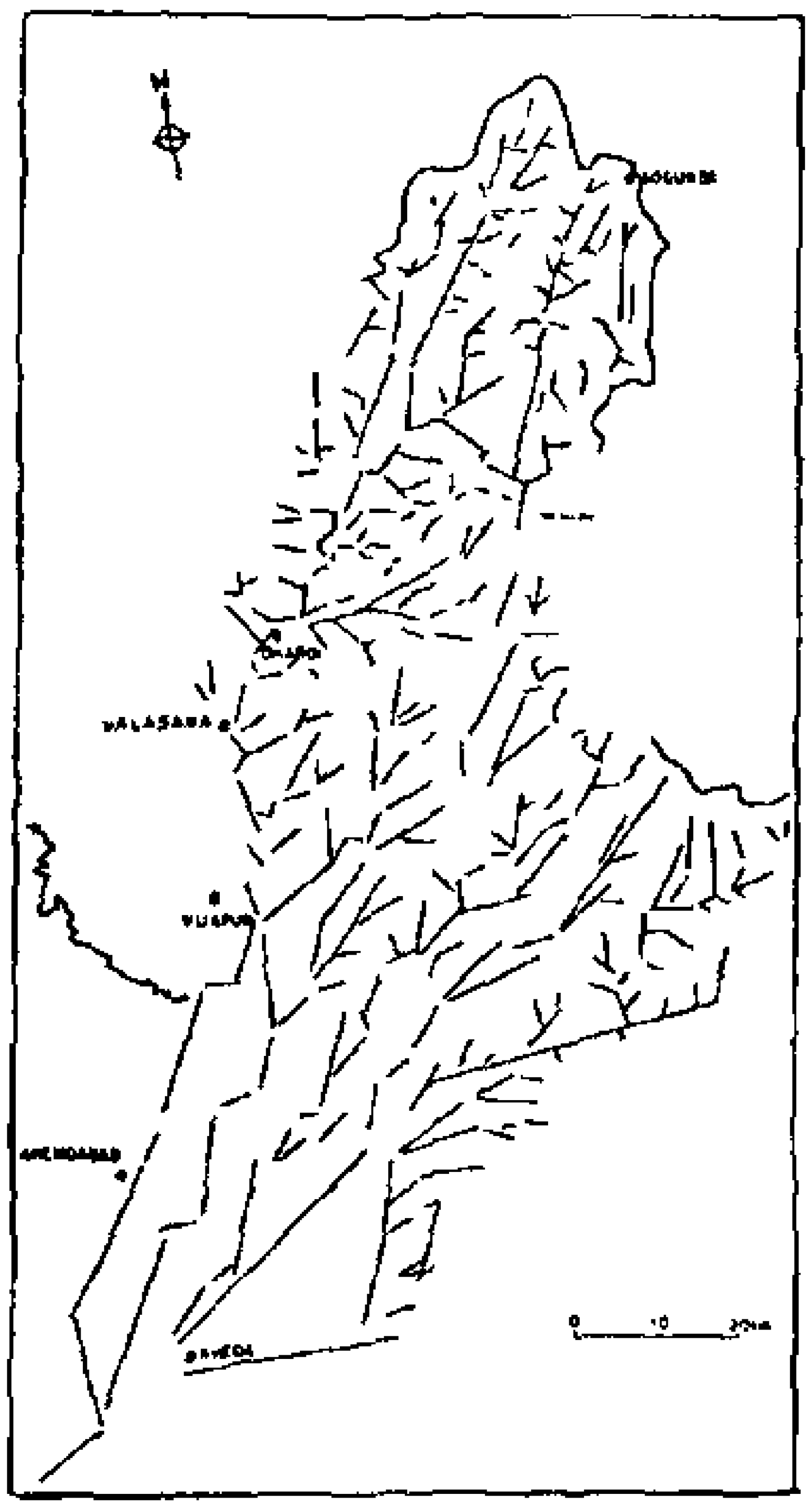


Figure 8. Rectified map of the Sabarmati and its tributaries. Only higher order drainages have been rectified.

the *normal* conjugate pair. However, a comparison with lineament azimuth of the two areas suggests that the maximum principal stress (P) developed nearly E-W and minimum principal stress (T) nearly N-S direction.

Discussion and conclusion

In the stretch from Gogunda to Dharoi (Aravalli area), the river alignment follows, mainly, two prominent trends—the main lines of drainages follow the NE-SW Aravalli-Delhi structural trend which incidentally is also the regional slope trend and the network drainages follow a joint-controlled E-W trend. The Sabarmati main drainage shows a marked change to N-S direction in the alluvial area in the Dharoi-Vijapur sector and to the NNE-SSW direction in the Vijapur-Ahmedabad sector. The network drainages in the alluvial area show a greater NE-SW slope controlled pattern with a subordinate E-W to WNW-ESE lineament controlled pattern.

From a comparison of the neotectonic stress fields obtained from lineament analysis and the valley orientations, the stress trajectory angles show a difference of 22° in the Quaternary alluvial areas of the Sabarmati basin. The control of the main Sabarmati channel by the Aravalli structural trend becomes obscure in this stretch. The computed compressional stress (P, max., σ_1) is confined to a regional E-W trend and extensional stress (T, min., σ_3) to N-S trend, respectively (Figure 9). It is also interesting to record that in the alluvial area, the River flows in the Cambay

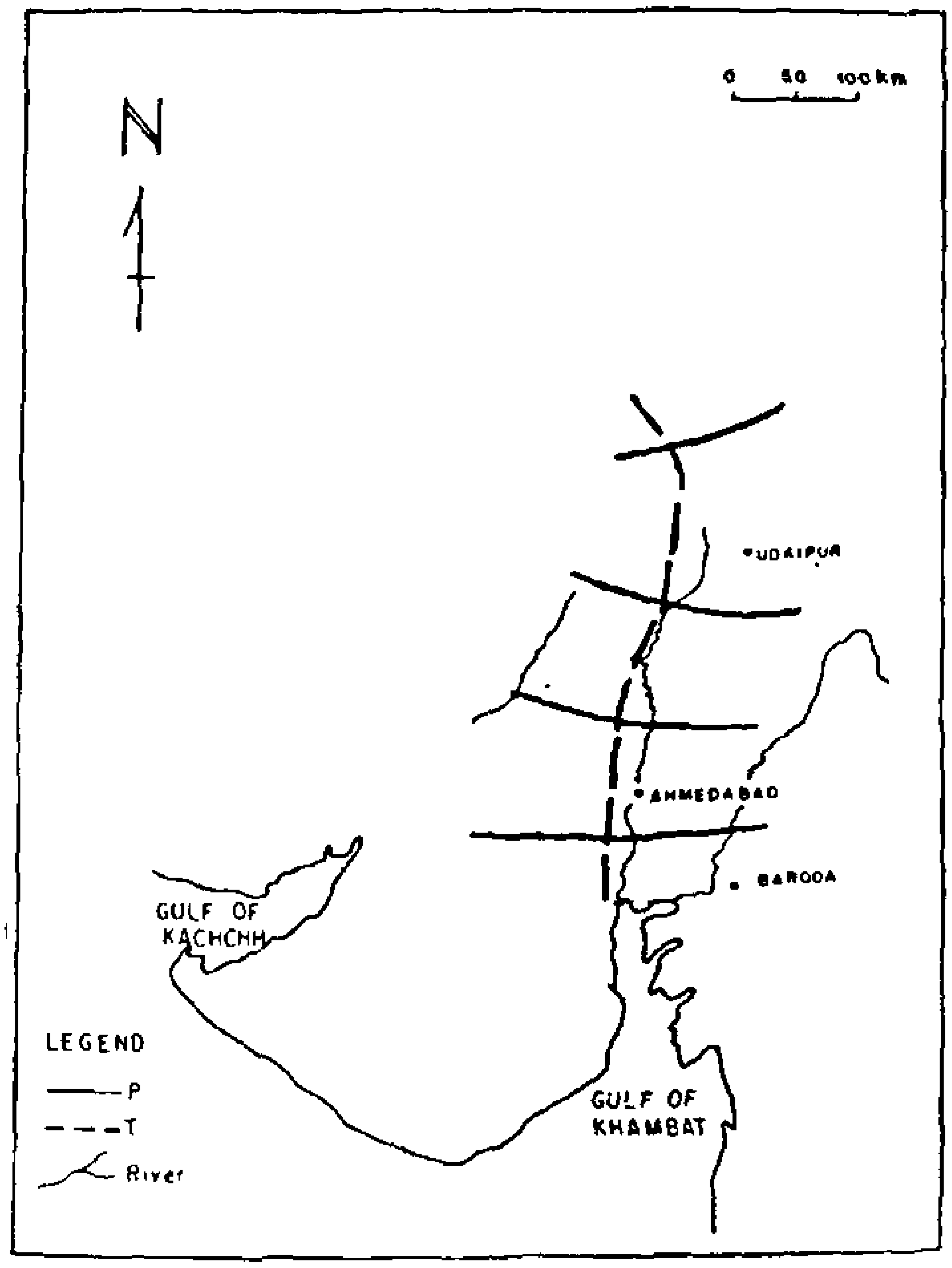


Figure 9. Horizontal stress trajectories (σ_1 and σ_3) causing development of lineaments.

graben. Figure 10 shows the position of the Cambay graben which occurs in the form of a long and narrow depression trending N-S in southern Cambay and NNW-SSE in the northern part. The southern part of the Cambay graben is downthrown by a N30E-S30W trending fault[24]. The Sabarmati River follows this trend

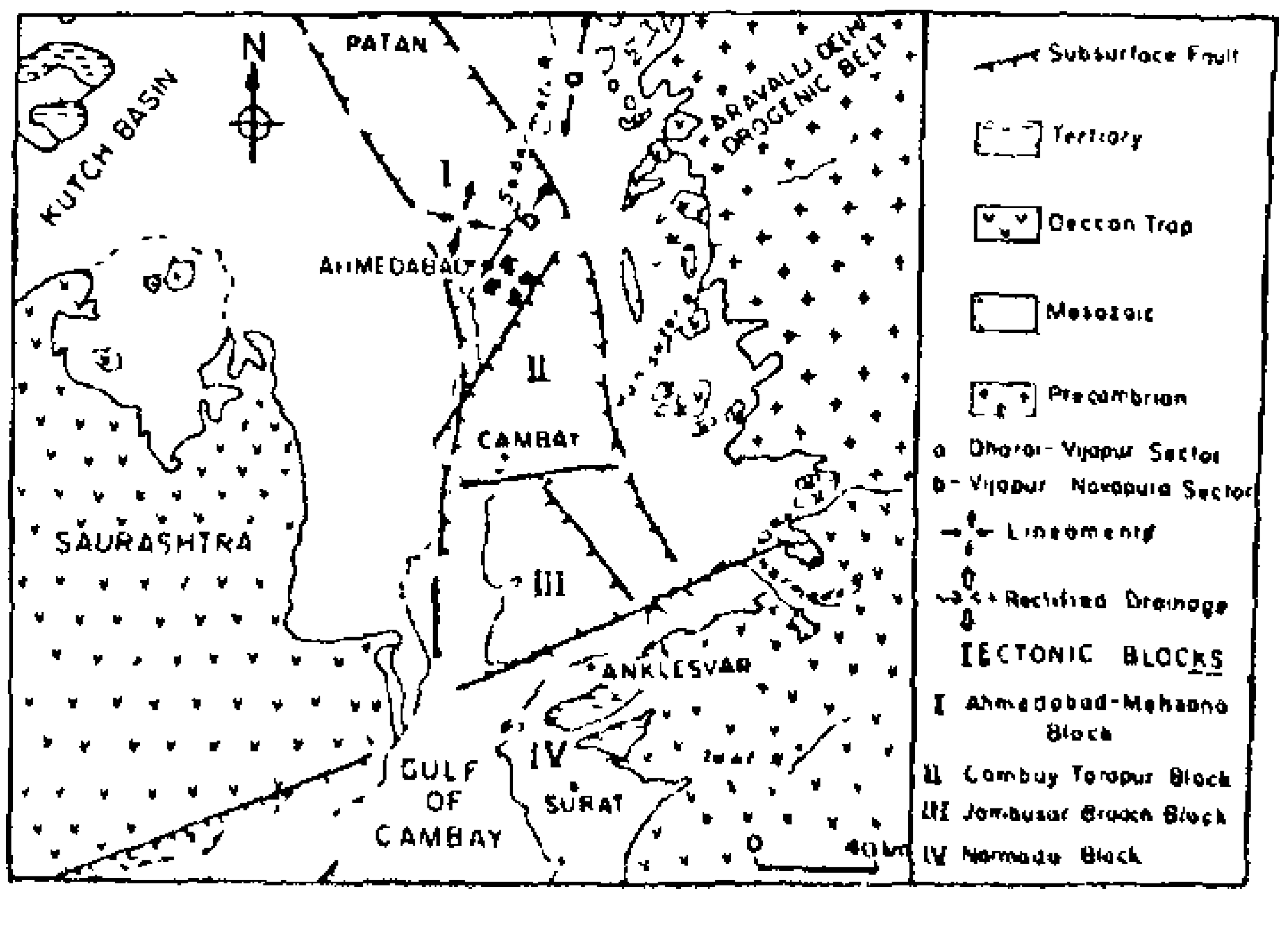


Figure 10. Pre-Neogene position of the Cambay graben and associated structures (modified after Biswas[3])

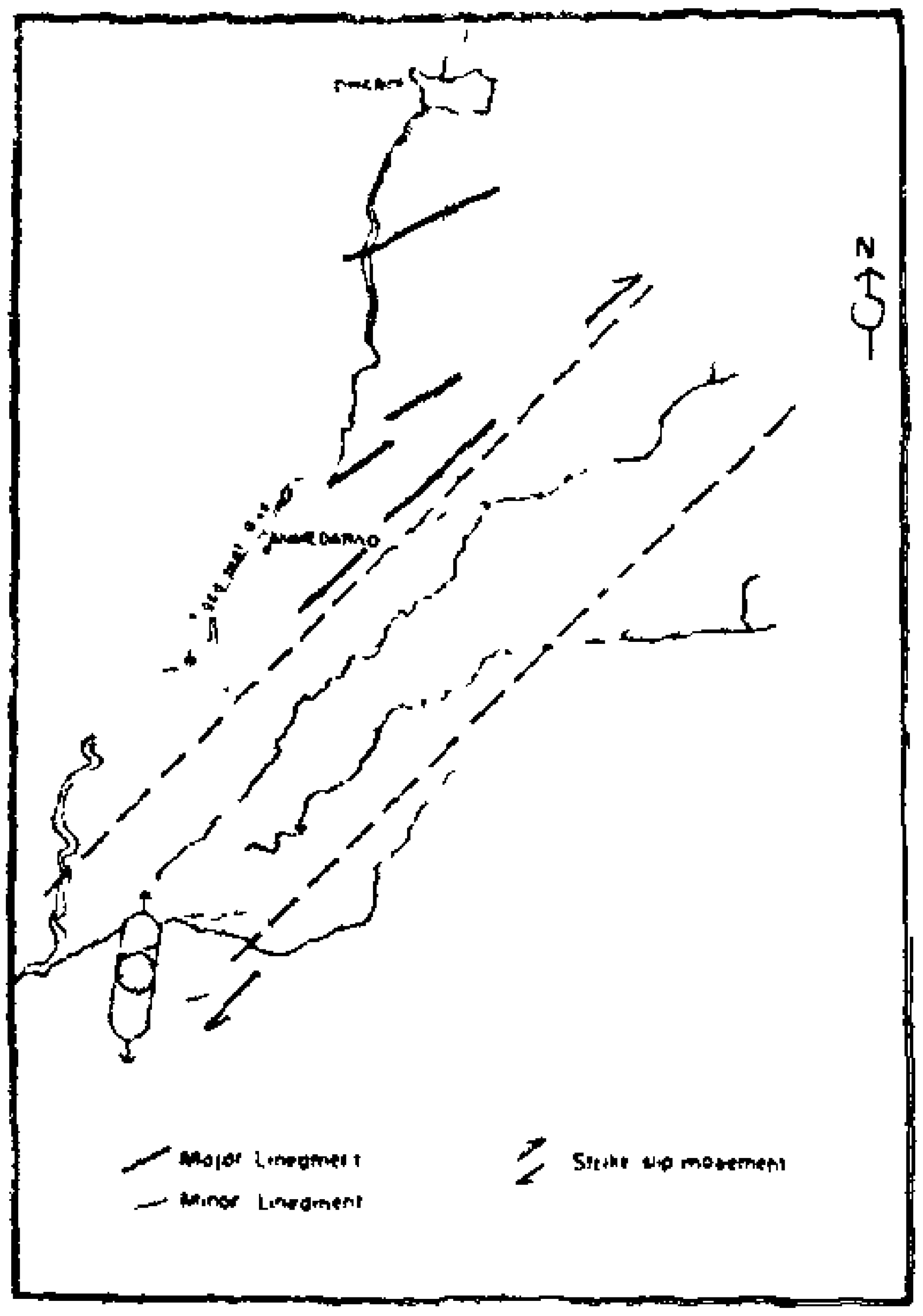


Figure 11. Zone of development of en-echelon lineaments and resultant strain ellipsoid.

in the Vijapur-Navagam area. In the estuarine zone, the river follows the N-S trend along the Cambay fault. Clearly, the E-W lineaments recorded in the alluvial area have not exercised a major control on the development of the Sabarmati main drainage as a minimal tendency of shifting of the river along the E-W axis is observed. The area east of the Sabarmati main channel (shown by dashed lines, Figure 11) is a zone of development of en-echelon lineaments corresponding to a zone of shear. and a dextral strike slip movement along NNE-SSW direction. The western margin of the Sabarmati main channel is, therefore, a morpho-structural feature and is a positive area forming N-S uplift axis along the western margin. The N-S to NNE-SSW trend of the Sabarmati river in the alluvial area appears to have developed in response to the complex neotectonic stress field originating through reactivation of the pre-Quaternary faults.

Development of river bends, knick points, river deviations and linear fractures are some of the indirect evidence of faulting involving loose sediments. Several such features are observed in the Sabarmati basin.

The Sabarmati drainage basin anomaly is to a large extent the result of fluvial adjustment to neotectonic activity. The lowermost Waghpur Formation (preliminary TL age ~300 k.y.) is dissected by the N-S flowing Sabarmati channel[25]. The palaeoflow directions in the Waghpur Formation indicate the presence of palaeodrainages flowing along the NE-SW regional palaeoslope. Hence, this neotectonic activity causing the N-S alignment of the Sabarmati is younger than ~300 k.y. and can be dated Mid- to Late Quaternary.

The study of the mutual relationship of the drainage orientation structure, lineament patterns and trends, supported by the study of alluvial deposits in the basin has allowed for the interpretation that the regional slope deviatory trend of the Sabarmati basin represents a fluvial adjustment to neotectonics in the Late Quaternary.

1. Sood, R. K., 1983, PhD Thesis, I.I.T., Powai, Bombay.
2. Biswas, S. K., *Tectonophysics*, 1987, **135**, 307–327.
3. Biswas, S. K., Proc. Third Indian Geol. Congr., Pune, 1980, pp. 255–272.
4. Gupta, R. P. and Bharkatya, D. K., *Tectonophysics*, 1982, **85**, T9–T19.
5. Sen, S. and Sen, D., *Tectonophysics*, 1983, **93**, 75–98.
6. Gupta, S. K., *Ecology and Archaeology of Western India* (eds. Agrawal and Pande), Concept Publ. Co., New Delhi, 1977.
7. Somayajulu, B. L. K., Broecker, W. S. and Goddard, *Quat. Res.*, 1985, **24**, 235–239.
8. Baskaran, M., Rajagopalan, G. and Somayajulu, B. L. K., *Chem. Geol.*, 1989, **79**, 65–82.
9. Wasson, R. J., *et al.*, *Z. Geomorph N. F.*, 1983, **45**, 117–151.
10. Kar, A., *Geomorphology and Environment* (eds. Singh and Tiwari), Allahabad Geographical Soc., Allahabad, 1988.
11. Bedi, N., in *Morphology and Evolution of Landforms* (eds. Verma *et al.*), Deptt. of Geology, Delhi University, 1978, pp. 26–40.
12. Guha, S. K. and Powar K. B., Abstr. Sem. on Indian lithosphere: structure and evolution, Poona Univ., 1982, p. 29.
13. Ramakotaiah, G., *Bull. ONGC*, 1970, **7**, 48–51.
14. Kohlbeck, F. and Scheidegger, A. E., *Rock Mech.*, 1977, **9**, 9–25.
15. Scheidegger, A. E. and Ai, N. S., *Tectonophysics*, 1986, **126**, 285–310.
16. Ray, S., De, S. K., Samanta, S. C., Gupta, D. C. and Prasad, S., *Bull. ONGC*, 1982, **19**.
17. Bakliwal, P. C. and Ramasamy, S. M., *Rec. Geol. Surv. India*, 1987, 54–64.
18. Bharkatya, D. K. and Gupta, R. P., in *Recent Researches in Geology-10* (ed. Sinharoy, S.), Hindustan Publ. Co. Delhi, 1983, pp. 186–197.
19. Scheidegger, A. E., *Arch. Met. Geoph. Biokl.*, 1979, **A28**, 89–106.
20. Scheidegger, A. E., *Z. Geomorph. N. F.*, 1980, **24**, 19–30.
21. Ai, N. S. and Scheidegger, A. E., *Z. Geomorph. N. F.*, 1980, **25**, 203–212.
22. Tandon, S. K., *Z. Geomorph. N. F.*, 1974, **18**, 460–471.
23. Tandon, S. K. and Joshi, D. D., *Z. Geomorph. N. F.*, 1991, **35**, 269–282.
24. Berger, P., *et al.* Well Evaluation Conf., 1983, ONGC, Dehradun.
25. Sareen, B. K. *et al.*, Abst. Int. Symp. Evol. of Deserts, P. R. L., Ahmedabad, 1992, pp. 177–179.

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