Paleocurrents in the Jodhpur Formation around Bhopalgarh, Jodhpur District, Rajasthan

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Abstract

Dispersal pattern of sandstones of the Jodhpur Formation around Bhopalgarh (Rajasthan) was studied by measuring dip azimuths of cross-bedding foresets. Variance components of paleocurrents due to various sources were analysed. Low variance of paleocurrents, profusely cross-bedded character of sandstones and mainly arenaceous nature of the formation, suggested that the deposition of the major part of the Jodhpur Formation took place under braided fluvial conditions.

Introduction

Paleocurrents of the Jodhpur Formation have been studied in a general way near Jodhpur city by Chakrabarti and Singh (1968), Parkash and Srivastava (1975). The present investigation attempts a detailed statistical study of the dispersal pattern of sandstones of the Jodhpur Formation in this area using the azimuths of foreset dips of cross-bedded units and the analyses of variance of the paleocurrent data.

Geological setting

The Jodhpur Formation forms the lower part of the Trans-Aravalli Vindhyans. The term Trans-Aravalli Vindhyans refers to a group of unfossiliferous sediments which are exposed to the west of Aravalli ridge near Jodhpur and adjoining area. These rocks consist of orthoquartzites, subgreywackes, shales, and limestone-evaporite lithologic assemblages. These sediments are about 800 m thick and cover an area of about 50,000 sq km in and around Jodhpur district. The Trans-Aravalli Vindhyans overlie unconformably several older formations such as: the Malani rhyolites and their equivalents, the Jalor and Siwana granites, and the Aravallis.

The Trans-Aravalli Vindhyans are usually horizontal or show dips of 2° to 5°. However, in the eastern region, higher dips of up to 15° due North and East are also observed (Fig. 1).

Jodhpur Formation

The Jodhpur Formation can be divided into three sub-units. The lower unit with a maximum exposed thickness of 30 m consists of alternating fine-grained, poorly sorted, cross-laminated siltstones and sandstones and brick-red shales. At places it comprises of plane or cross-laminated, well sorted sandstones only. This unit is exposed only at a few places.

The middle unit with a thickness of about 50 m comprises red to maroon red, medium to fine grained, moderately to poorly sorted sandstones. The sandstones are profusely cross-bedded and the cross-bedded units are of medium thickness (25 cm). The upper part of this unit is marked by a few tens of centimetres thick cherty horizon and sandstones with inclusions of iron-oxide nodules. This horizon forms the top of many flat-topped hills.

The upper unit of the Jodhpur Formation consists of light grey, pale yellow to brown, medium grained, moderately sorted sandstones with large scale cross-bedding. This unit has a maximum exposed thickness of 20 m. At most of the places, the middle and upper units of the Jodhpur Formation are exposed and have been used for the paleocurrent analysis.

The Jodhpur Formation exhibits a host of sedimentary structures like tabular and trough types of cross-bedding, cross-laminations, plane-laminations, convolute bedding, rib-and-furrow structures, ripple marks and sun cracks. Petrographically, the sandstones of the Formation are mostly immature litharenites, feldspathic litharenites and sublitharenites following Folk's (1968) classification of sandstones.

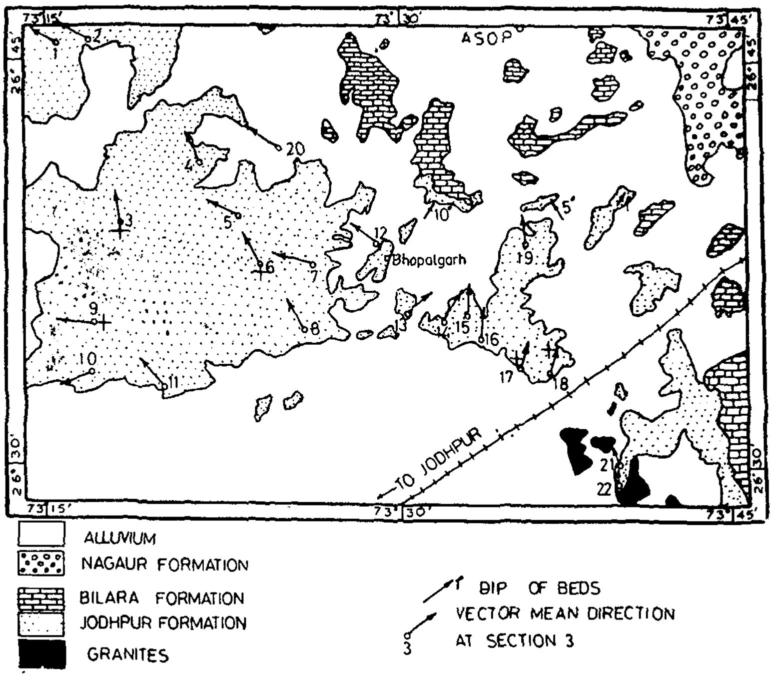

Figure 1. Map showing vector means of paleocurrents of the Jodhpur Formation at different field sections. Geological map presented by the authors.

Paleocurrents

The paleocurrents of the Jodhpur Formation were studied at twenty-two sections in the field (Fig. 1). Paleocurrents were determined by measuring the dip azimuths of foresets of all the well exposed tabular cross-beds at each of the sections. Some of the field data in the present analysis have been taken from Anbalagan (unpublished thesis 1976) and Tyagi (unpublished thesis 1976). Vector mean, vector magnitude per cent and variance of cross-bedding azimuths were calculated. Also, the significance of degree of preferred orientation was determined by calculating the Rayleigh Probability (Curray, 1956). The data are listed in Table I.

Mean Paleocurrent Directions: Vector mean directions for the different sections were plotted (Fig. 1). The Vector mean directions ranged from N46° to N244° indicating variations in the mean current directions from northeasterly to southwesterly directions.

The data were also analysed using moving average method. In this analysis, a square grid with squares having side of about 6.5 km length was placed on the map (Fig. 2). The vector means were then calculated at the corners of squares taking into account the observations in the immediately adjoining squares. Following

Potter and Pettijohn (1963, p. 274) an interpretive map (Fig. 3) was prepared using Figure 2 as a base. Figure 3 brings out clearly that the paleocurrents were northerly in the eastern part and there was a gradual change to westerly paleocurrents in the western part of the area under investigation,

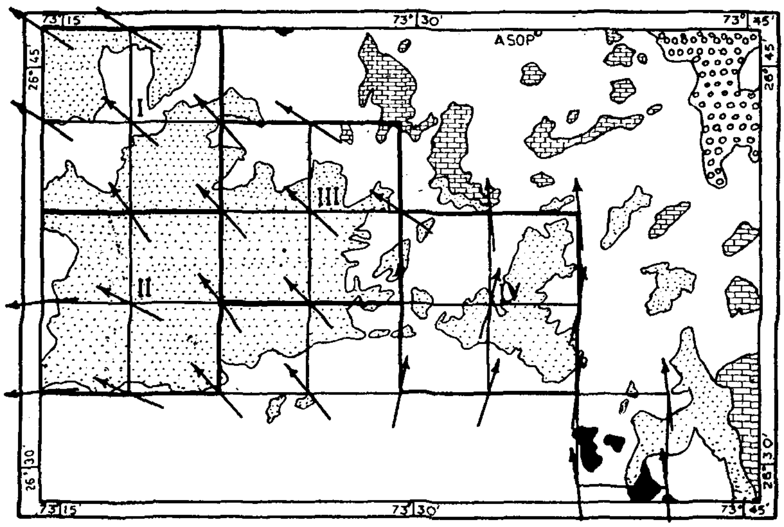

Figure 2. Moving average map for paleocurrents of the Jodhpur Formation. Symbols for the various formations as in figure 1.

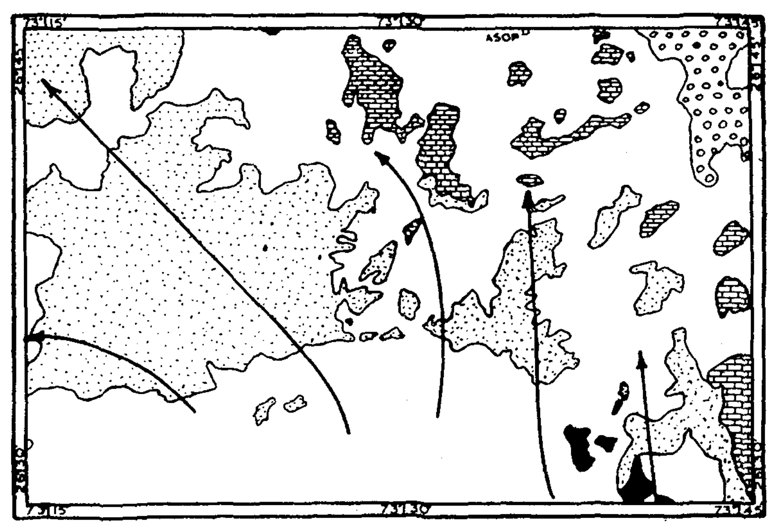

Figure 3. Interpretive map of paleocurrents of the Jodhpur Formation. Symbols for the various formations as in figure 1.

In contrast to the present results, Chakrabarti and Singh (1968) obtained westerly paleocurrents for the Jodhpur Formation near Jodhpur city. In the Jodhpur area, Parkash and Srivastava (1975) obtained two flow systems acting in NW-SE and WSW directions.

Variance of Paleocurrent Directions: The vector magnitude per cent for the various field sections ranges from 97.16 to 57.40 and the corresponding variance changes from 207.3 to 9981.0 though in most cases, it lies between 1000 to 6000 (Table I). Contributions of the various factors to the dispersion of paleocurrents were investigated by selecting four square sectors I to IV (Fig. 2). Two way Analysis of Variance Model with hierarchic design described by Middleton (unpublished notes 1966) was used to analyse the data. It was assumed that the individual observations at a section were random samples and also sections and sectors were selected

TABLE I

PALEOCURRENT STATISTICS FOR THE VARIOUS SECTIONS

Section Number	Number of Observation	Vector Mean	Vector Magnitude Per cent	Variance	Rayleigh Probability
1	13	296.7	58.7	3352.1	0.011*
2	12	299.8	81.8	1459.9	0.000*
3	5	348.4	31.1	8194.5	0.636NS
4	11	329.6	72.0	2417.0	0.003*
5	15	291.7	26.1	6475.2	0.359NS
6	18	330.0	66.2	2695.6	0.000*
7	11	284.8	46.6	5147.4	0.091*
8	14	316.9	57.4	9981.0	0.010*
9	8	273.9	58.5	3652.0	0.059*
10	4	243.5	64.7	3696.7	0.187NS
11	13	314.5	58.4	4257.5	0.012*
12	15	306.0	75.8	1857.0	0.000*
13	10	45.8	70.1	3077.8	0.007*
14	16	25.1	59.3	5735.7	0.004*
15	33	3.1	80.0	1639.7	0.000*
16	6	0.8	96.7	264.2	0.004*
17	11	12.3	92.7	546.8	0.000*
18	10	12.0	67.6	3008.1	0.010*
19	11	350.4	97.2	207.3	0.000*
20	16	297.2	68.4	3437.6	0.000*
21	13	331.0	66.1	2884.6	0.003*
22	20	358.0	69.3	3325.3	0.000*

* Significant at $\alpha = 0.10$
NS Not significant at $\alpha = 0.10$

randomly. Results of Analysis of Variance given in Table II brought out the fact that the variance at individual section level was 4127.4 and that the contributions of the variation among sections in the sectors and the variation among sectors were significant at 5% significance level as indicated by the variance ratio 'F'. This suggested that areal variability of paleocurrent was of a higher order than that at individual sections.

Further attempt was made to estimate the magnitude of variance contribution by each source. Table III shows the statistics estimated by mean squares calculated in Table II, which were further used to calculate the various variance components due to different sources by utilising the method given by Snedecor (1966, p. 271-275).

The variance component due to observations within sections (s^2) was 4127.4, whereas the variance component due to variation among sections in sectors (s^2_A) and among sectors (s^2_B) were 13744.9 and 1001.8 respectively. It is suggested that the high variance components due to variation within sections and among sections in the sectors probably reflect the characteristics of the depositional environment. It is demonstrated below that these sediments were deposited by fluvial streams. The

TABLE II

ANALYSIS OF VARIANCE OF PALEOCURRENT DATA

Sources of Variation	Degrees of freedom	Sum of squares	Mean Square	Variance ratio 'F'
Among sectors	003	218111.4	72703.8	17.615*
Among sections within sectors	15	2610775.5	174051.7	42.17*
Within sections	219	668632.9	4127.4	
Total	237	951519.8		

* Significant at $\alpha = 0.05$

TABLE III

COMPONENTS OF ANALYSIS OF VARIANCE

Sources of Variation	Estimated statistic	
Among sectors	$s^2 + (n_{oB}) s^2_A + (nb)_o s^2_B$	$s^2_B = 1001.8$
Among sections in sectors	$s^2 + (n_{oA}) s^2_A$	$s^2_A = 13744.9$
Within sections	s^2	$s^2 = 4127.4$

where s^2, s^2_A and s^2_B are variance components corresponding to observations within sections, among sections in sectors and among sectors respectively. n_{oA}, n_{oB} and $(nb)_o$ are constants which depend upon the sample sizes.

low variance components due to variation among sectors suggest uniformity of paleoslope and sediment calibre of the depositing streams (Morisawa, 1968, p. 145-150).

Environments of Deposition

As noted earlier, most of the variance values range between 1000 and 6000 and the mean variance within sections (Table II) also turns out to be 4127.4. These results suggest a fluviatile origin for these sediments (Potter and Pettijohn, 1963, Table 4.2). The presence of mud cracks indicating subaerial deposition and texturally immature nature of the sandstones also support the above conclusion. Mainly the arenaceous nature of the formation with minor shales suggests that the major part of the formation was deposited by braided fluvial streams.

Conclusions

Paleocurrents of the Jodhpur Formation were northerly in the eastern part and changed gradually to westerly direction in the western part of the area of investigation. Analysis of Variance of paleocurrent data suggests that the variance of observations within sections (s^2) was 4127.4 and among sections in sectors (s^2_A) and among sectors (s^2_B) were 13744.9 and 1001.8, respectively. Values of s^2 and s^2_A are thought to reflect intrinsic nature of depositional environment, and small value of s^2_B suggests uniformity of paleoslope and sediment calibre of streams. The low variance of paleocurrents within sections, presence of mud cracks, profusely cross-bedded nature of these immature sandstones and the virtual absence of shale in the major exposed parts of the Jodhpur Formation indicate that it was deposited by braided fluvial streams.

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