Paleocurrent Analysis of Kolhan Basin: Implications to Paleogeographic Reconstructions

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Abstract

The paleocurrent investigation of a basin is one of the preliminary task for understanding paleogeographic reconstructions and fluvial paleo-channels. Correct paleo channel analysis helps in supporting paleotectonic conclusions from petrology and geochemistry. In this paper paleocurrent of Proterozoic Kolhan basin has been calculated from various methods. It reveals the pattern of transport towards the north-west or north-east in the central region of the area. In the southern region it shows prominent north or northeasterly paleocurrent patterns especially in its lower part. The presence of NNE and NW paleocurrents, in addition to an important current parallel to the NW has also been indicated. The vector means calculated from grain orientation and cross-bedding indicate at least two distinct flow systems, approximately north-westerly and northeasterly directions during the deposition of the siliciclastics. However the overall polymodal nature of the current rose diagrams suggests interaction of factors during the deposition. The mean directions are almost uniform although magnitude of the vector resultants exhibit frequent variation in the different facies.

Introduction

Paleocurrent refers to the current system, which has long vanished but has left imprints on rocks in the form of textural and structural attributes. In sedimentary rocks it is used extensively as aids in the analysis of sedimentary basins and the development of paleogeographic reconstructions. By analyzing the direction of flow in fluvial paleo-channels, deltaic systems and turbidites, the sedimentary facies whether upstream or downstream may be predicted. Reconstructions developed using paleocurrent data along with lithofacies are important in exploration for mineral deposits (e.g., gold and tin placer deposits) and in petroleum exploration (e.g., the trend of channel sandstone reservoirs). Such paleogeographic reconstructions are often simplistic and limited to general statements about the direction of flow and probable position of the source area [1-3].

Paleocurrent data are used frequently in large scale paleogeographic reconstructions as a means of predicting relative positions of facies belts and basin margin, but only in a semi quantitative way. Primary sedimentary structures and textures (grain size) of sediments are the major features that provide information about the medium and mode of transport and energy conditions at the time of deposition. In the present area of investigation, both small and large scale cross-bedding of directional structures are measured systematically in the field and in the laboratory apposition fabric analysis is completed. Based on certain standard figures and formulae paleohydraulic study for different lithofacies is carried out to establish the hydrodynamic conditions of the Kolhan basin. The sedimentary structures are used as clues for understanding the geometries and hydraulics of paleochannels [4-10].

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In the investigated area both small-scale and large-scale cross-bedding of directional sedimentary structures have been systematically measured in the field. Fabric analysis has been carried out in sedimentological laboratory. Based on standard methods a palaeohydraulic study of different lithofacies has been carried out to determine the hydrodynamic conditions of the Kolhan basin [11-13].

Paleocurrent pattern from cross bedding

Circular histograms (with vector azimuth) showing paleocurrents have been shown in Figure 1. The computed vector mean suggests northwesterly and northeasterly paleoflow. The sector level paleocurrents on the other hand show wide variation ranging from 357° to 14° (Table 1). Higher
value of vector strength, with unimodal distribution for most of the sectors suggests predominantly unidirectional sediment transport. A general northwesterly-northeasterly paleoflow was deduced in this study.

![Figure 1: The figure shows the calculated paleocurrent directions.](image)

### Table 1: Statistical analyses of paleocurrent data *(95% confidence limits of vector means are given in brackets).*

| Location | No. of data | Class intervals | Vector mean in Degrees | 95% confidence intervals in Degrees |
|----------|-------------|-----------------|------------------------|-------------------------------------|
| A        | 20          | 10              | 338                    | 7.2                                 |
| B        | 15          | 10              | 36.2                   | 4.1                                 |
| C        | 10          | 10              | 311                    | 10.2                                |
| D        | 8           | 10              | 23                     | 5.6                                 |
| E        | 50          | 10              | 339                    | 10.2                                |
| F        | 8           | 10              | 3                      | 29.9                                |
| G        | 14          | 10              | 19 & 199               | 4.3                                 |
| H        | 17          | 10              | 46 & 226               | 13.7                                |
| I        | 8           | 10              | 138.3                  | 36                                  |
| J        | 21          | 10              | 114.3                  | 38                                  |
| K        | 28          | 10              | 12.2                   | 12                                  |
| L        | 14          | 10              | 6.2                    | 6                                   |
| M        | 50          | 10              | 111.3                  | 19                                  |
| N        | 7           | 10              | 28.2                   | 33                                  |

**Paleocurrent pattern from preferred grain orientation**

The percentage frequency distribution of azimuths of detrital quartz in thin section cut parallel to bedding plane, in which the azimuth is grouped into twelve class intervals (Table 2). The statistical operation carried out on the above data includes Tukey chi-square test for preferred grain orientation data and circular arithmetic means. Table 3 & Table 4 summarize the computational procedure adopted in the present study. Table 5 tabulates the chi-square, preferred grain orientation direction, linear arithmetic mean and circular arithmetic mean for 30 samples studied.
Table 2: Paleocurrent data from preferred grain orientation.

| Sector name                  | No of observations (n) | Sector Mean 0 (V) | Vector Strength [R] % | Circular standard deviation(s) | Variance(s²) | Probability of randomness(p) | Nature of distribution |
|------------------------------|------------------------|-------------------|----------------------|--------------------------------|--------------|------------------------------|-----------------------|
| Bistampur                    | 28                     | 14°(±11)          | 87.36                | 28°                            | 830          | <10-9                        | Unimodal              |
| Gangabasa                    | 8                      | 316°(±23)         | 91.56                | 23°                            | 554          | <10-2                        | Unimodal              |
| Gumua Gara river section     | 14                     | 38°(±120)         | 17.96                | 73°                            | 5391         | <10-2                        | Unimodal              |
| Matgamburu                   | 50                     | 302°(±6)          | 80.26                | 36°                            | 1297         | <10-13                       | Bimodal               |
| Pungsiya                     | 40                     | 357°(±59)         | 59.71                | 51°                            | 2648         | <10-2                        | Bimodal               |
| Rajanbasa                    | 7                      | 3°(19)            | 90.75                | 24°                            | 607          | <10-2                        | Unimodal              |

Table 3: Results of Vector Resultant and Circular Arithmetic Mean of the Directional Structure.

| Location                      | Facies        | Azimuth of vector resultant (θV) in Degrees | Circular arithmetic mean(Z) in Degrees | Linear arithmetic mean (Y) | Circular standard deviation in Degrees (S) | Magnitude of vector resultant @ | Chi-square (χ²) | Level of significance |
|-------------------------------|---------------|-------------------------------------------|---------------------------------------|---------------------------|-------------------------------------------|-------------------------------|-----------------|---------------------|
| Behind ITI College(i)         | SSD,RSD&TLSD  | 337.2                                     | 282                                   | 334.5                     | 71.42                                     | 0.22                          | 25.69           | 99.5th              |
| Surjabasa                     | Shale         | 35.2                                      | 157.9                                 | 36.42                     | 70.32                                     | 0.25                          | 20.19           | 99.5th              |
| Bingtopang                    | SSD&TLSD      | 311.6                                     | 81.4                                  | 312                        | 72.01                                     | 0.32                          | 7.03            | 95th                |
| Gumuagara                     | GSD&SSD       | 22.9                                      | 153.9                                 | 22.5                       | 65.2                                      | 0.35                          | 17.8            | 99.5th              |
| Diliyamarcha                  | SSD           | 338.8                                     | 181.4                                 | 274.8                      | 75.11                                     | 0.14                          | 100.39          | 99.5th              |
| Behind ITI College(ii)        | SSD&TLSD      | 2.9                                       | 135.15                                | 78.75                      | 65.18                                     | 0.35                          | 13.8             | 99.5th              |
| Tunglai                       | SSD&PLSD      | 29.87                                     | 181.4                                 | 274.8                      | 69.39                                     | 0.27                          | 100.39          | 99.5th              |

Table 4: Paleohydraulic data from different lithofacies.

| Facies                        | Sedimentary structures | GLSD             | GSD              | SSD              | PLSD             | RSD              | TLSD              |
|-------------------------------|------------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Sedimentary structures        | Graded bedding (no movement) | Trough cross-bedding | Tabular cross-bedding and symmetrical wave ripples | Parallel lamination (plane bed) | Asymmetrical wave ripples (large scale ripples) | Small scale ripples |
| Mean size (mm)                | 0.25-0.5               | 0.3-0.5          | 0.18-0.5         | 0.21-0.5         | 0.18-0.5         | 0.06-0.5         |
| Median (mm)                   | 0.35-0.5               | 0.3-0.5          | 0.25-0.6         | 0.21-0.6         | 0.18-0.5         | 0.06-0.21        |
| Flow velocity (cm/sec)        | 82-91                  | 50-60            | 71-76            | 71-78            | 64-66            | 15-20            |
| Flow depth (cm)               | Dec-18                 | 53-77            | 151-160          | 150-203          | 113-123          | 121-180          |
| Mean sediment discharge (m3/sec) | 1.2-4.9               | 5.4-13.8         | 70.6-81.4        | 70.6-146.6       | 34.7-43.1        | 21.3-27.4        |
| Frroude number                | 0.19                   | 0.22             | 0.18             | 0.18             | 0.19             | 0.16             |

Table 5: Estimates of Paleohydrologic Parameters of the Study Area.

| Parameters                   | Mean Estimate |
|-------------------------------|---------------|
| Mean cross-bed set thickness  | 0.13 m        |
| Mean water depth (ds)         | 1.38 m        |
| Channel width (w)             | 61.59 m       |
| Width/depth ratio (F)         | 42.97         |
| Meander wavelength (Lm)       | 701.26 m      |
| Mean annual discharge (Qm)    | 94.34 m³/s    |
| Channel slope (Sc)            | 0.0084        |
| Flow velocity (v)             | 0.66 m/s      |
| Froude number (Fr)            | 0.2           |
Figure 1 plots the grain orientation direction in the localities grand preferred orientation direction is found to be S 16° mean and circular arithmetic mean for 33 samples studied. The square, preferred grain orientation direction, linear arithmetic data and circular arithmetic means. Table 1 summarizes chi-square test for preferred grain orientation analysis in thin sections of oriented sandstone samples collected which shows that the direction varies from NE to SW through E and SE. Such directions should roughly correspond to the paleocurrent directions in the present case, as the rocks are only slightly deformed and the palaeocurrent direction obtained from the scanty sedimentary structures like cross bedding appear to be in rough agreement.

**Paleohydraulics**

The channel width\(W\), meander wavelength\(\text{lm}\), channel depth\(d\), flow velocity\(v\), mean sediment discharge\(Q\) and Froude number\(F\) have been calculated following standard methods.

\[
d = \left(\frac{H}{0.086}\right)^{1/3.9}\text{in } m
\]

\[
W = 4.2(d)^{1.11}\text{in } m
\]

\[
\text{lm} = 10.9(W)^{1/3} \text{in } m
\]

\[
Q = \left(\frac{\text{lm}}{106.1}\right)^{1/4.46} \text{m}^3/\text{s}
\]

\[
v = \frac{Q}{A} \text{in m/s}
\]

\[
F = \frac{v}{\sqrt{gd}}
\]

Where, \(H\) is average cross-bed set thickness/average ripple height.

\(A\) is cross sectional area,

\(g\) is acceleration due to gravity.

**Discussion and Interpretation**

The ultimate aim of sedimentary petrological investigations is to discover the characteristics of the provenance, to discuss the probable mode of dispersal of the clastic constituents and finally to specify the various parameters of the environment of deposition. Reliance is given in such studies on the sedimentary characteristics of clastic particles deposited in known environments.

Keeping in view the limitation of the various methods of environmental analysis as set forth by students of sediments, an attempt is made in the following pages to reconstruct as far as practicable the source area.

The data collected from azimuth reading of cross-bedding and preferred grain orientation analysis are subjected to vector resultant method and circular arithmetic mean method to predict the paleo-flow directions. The statistical procedure carried out on the frequency percent of grain orientation and azimuths of cross-bedding in twelve do decant includes the Turkey's chi \(\chi^2\) square test modified after Harrison (1957), Rusnak (1957) and Middleton (1965b, 1967).

The regional distribution of current vectors is shown in Figure 2. It reveals the pattern of transport towards the north-west or north-east in the central region of the area. In the southern region it shows prominent north or northeasterly paleocurrent patterns especially in its lower part. The presence
of NNE and NNW paleocurrents, in addition to an important current parallel to the NW has also been indicated. The vector means calculated from grain orientation and cross-bedding indicate at least two distinct flow systems, approximately northwesterly and northeasterly directions during the deposition of the siliciclastics. However the overall polymodal nature of the current rose diagrams suggests interaction of factors during the deposition. The mean directions are almost uniform although magnitude of the vector resultants exhibit frequent variation in the different facies.

Figure 2: The regional paleocurrent direction in Kolhan basin.

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