Paleocurrent Reconstruction

Primary Structure

Structures produced during the process of sedimentation are old records on the basis of which the paleocurrent system of the area has been studied. Paleogeographic reconstructions are made with the help of these primary structures. The structures indicate the regional paleoen slope, extent and deeper part of the basin, direction of transport, provenance etc. Downslope direction is indicated specially by the azimuthal direction of cross-bedding at a regional scale which gives an idea about the downslopes of the basin in particular.

In Bhopal area the current beddings are not common. Asymmetrical, symmetrical and interference ripple marks are noted throughout the area except a few places. Primary current lineations are also common.

There are at a few places, there are local variations in the azimuth but the regional slope can be had by plotting mean direction of the current in the region. The plotting indicates the slopes are from areas which lie at the southwest of Bhopal.

To know the paleoslope, paleocurrent direction and its relation with facies boundaries, provenance the measurement of different structural features in the area was done.
Different methods and techniques are applied to note down the current patterns of geologic past. Sampling was done for collecting the paleocurrent data in Bhopal area. Most of the directional structures represent a preferred orientation.

Cross-Bedding

Cross-bedding is a structure confined to a single sedimentation unit consisting of internal bedding, called foreset bedding, inclined to the principal surface of accumulation.

The unit of cross-bedding in the Upper Bhandar Sandstones in Bhopal area varies from 8 to 30 cm cross-bedding with planer contacts are not seen in the area. Mostly the curved basal contacts are seen which are concave so the cross bedding and is referred as of festoon type.

Three dimensional view of cross-bedding can be had at various places where the beds are small. Two dimensional sections are seen near Birla Mandir road cutting and here it is very difficult to measure unit and scale of cross-beddings. The cross-beddings at this place are trough type. The foresets of trough type corss-beddings are concave to downdip or towards north-eastern direction. Dip, or angle between foreset bed and horizontal, was measured with the help of clinometer and it does not exceed more than 6. The measurement of one foreset in each bedded layer was not
possible as cross-bedding is rare there.

After taking the readings of a cross-bedding in a locality, average was calculated and upon that basis it is plotted on the map. Unit of cross bedding was also measured wherever the measurements of cross beddings were taken. In the given area no tectonic disturbance has occurred so the cross-beds are tangential downward, and are truncated upward representing the beds to be right side up.

A statistical analysis of both azimuth and indication frequencies of cross bedding in several localities of the showed this structure to have a regionally consistent pattern indicating south-west to north-east current system which might have been imposed by the ruling current of the past ages in Vindhyan times. The current movement is indicated away from south west, towards basin which probably lies in north easterly direction. A number of measurements were made because both the direction and the angle of inclination were somewhat variable in the same outcrop. The little variability in scale and orientation in cross beds are indicative parameters of stability in current system of past. There was a little change in current system at the time of deposition of Upper Bhandar Sandstones.

The older rocks from where the material has been derived lie in the south western direction. Ripple marks and cross beddings are commonly associated which is a characteristic of orthoquartzitic sandstone.
In this thesis primary structures and dimensional fabrics are used as parameters for paleocurrent reconstruction. Directional structures are helpful in reconstruction of the paleoslopes. Cross beds also help in giving idea about paleoclimatic condition and position of shore line. Arrows marked on the map represent the azimuth of cross beds, these arrows also represent the mean dip azimuth, which gives an idea of current direction. Ancient current patterns reveal the physical geography and its relation with current system as, is seen in many modern rivers, seas and estuaries. The current pattern has much influence on the physical geography and can be inferred to some extent.
Parallel long equidistant ridges are seen on the surface. These ridges are parallel or curved in nature. These are produced due to movement of the particles which produce rippling due to certain velocity of current. No megaripples are seen in Bhopal area. Symmetrical, asymmetrical and interference ripple marks are noted in the area. The occurrence of ripple marks together with the cross bedding represents Bhandar sandstones deposited under shallow water conditions. Symmetrical ripple marks are distinguished being more regular, with rounded trough and broad crest. The study of these ripple marks in Upper Bhandar Sandstones prove them to be right side up and it is also indicative of the area not being tectonically disturbed.

Shorter slope of each ridge is inclined to the south-west to north-east direction, that is, the current direction in Bhopal area. The ripple index is small proving it to be of shallow water origin. It has a greater width in proportion to their height. In symmetrical ripples mark, a gradation is seen in the particles where coarser particles are set in troughs and finer at the crest while in asymmetrical ripple marks the coarser material is noted in troughs on lee-side. This also proves the ripple marks to be of shallow water origin rather than to be eolian in which reverse phenomenon occurs. So the Upper Bhandar Sandstones are supposed to
have been deposited under the current action. The ripple marks in Bhopal area represent a small scale structure, the wavelength and amplitude being few cm to few mm respectively. Asymmetrical ripples which are products of current action, their orientation is a means of direction of ancient current flow which was from south-west to north-east at the Upper Vindhyan times. Symmetrical ripple marks represent the sense of a standing body of water where depth was not exceeding few tense of feet. Line drawn perpendicular to strike of crest indicates a line of transport.

Current direction is measured by the azimuth of the asymmetrical ripple marks where steeper side is indicative of direction of movement. No tectonic deformation has occurred in the area so ripples are well preserved. Preferred direction is shown by these ripples at many places - the regional mapping of these ripple mark readings may give an idea of paleoslope.

The mean reading of asymmetrical ripple marks of one locality points down the direction of current to the north-east whereas the symmetrical ripples tend to be parallel to the shore. These ripples are noted in fine grained sandstone to coarse gravels in the area. Average cross-bedding direction comes to be perpendicular to average strike of symmetrical ripple marks.
Cut arrow marked on the map represents the average direction of each set of asymmetrical ripple marks. Double arrows indicate the direction of symmetrical ripple marks.
FIG. ROSE DIAGRAMS OF DIMENSIONAL FABRIC DATA ON UPPER BHANDER SANDSTONE

S18

S12

S2

S22

S13
FIG. ROSE DIAGRAMS OF DIMENSIONAL FABRIC DATA ON UPPER BHANDER SANDSTONE

HE 1

BM 1

BM 2

S 5
Parting Lineation

This is a sedimentary structure which represents a line of movement. These lineations are helpful, in plotting the paleocurrent data, together with ripple marks and cross-beddings. These are plotted as the double arrowed points on the map.

Grain Orientation

Preferred orientation is shown by the quartz grains due to the forces which acted at the time of deposition of the rock. The fabric in Upper Bhandar Sandstone of Bhopal area shows an anisotropic pattern. This fabric is primary because it came into existence during the time of the deposition. The grains or pebbles etc. rest at a stable condition to resist the stress put by running current and this forms a linear body along the line of movement. Because the sandstones contain about 84% of quartz, so here the long axes of clastic quartz grains are considered and the preferred orientation was caused by ruling current of past times.

To know about the direction of current responsible for the deposition of sediments in the area study of directional fabric was done. The maximum orientation of grains was calculated which came about south-west to north-east direction.
Secondary structures are those which develop after the compaction of beds. Tectonic forces and other processes by which forces are neutralized or released the structures come into existence. Fold, fault and other structures are included in it. These structures are helpful in forming the history of past and its relation with present.

The given area in Bhopal was not tectonically much disturbed as it is proved by the rocks of horizontal extent. No folding is recorded throughout the area. A fault of local extent is only noted near Bhadbada pumping station.

Fault

The fault lies near Bhadbada village 8 km from Bhopal in the south-western part of the area. The Upper Bhander Sandstones are very highly jointed here the sandstones contain pebble at the base then they are bedded and are quartzitic in nature they also contain lenses of shale and Deccan Traps which have a clear faulted contact with Upper Bhander Sandstones. The joints are mostly vertical joints and dip at about 70° being steeper. A dark reddish very weathered sandstone crop out near the stream it retains a thickness of about 0.8 meter. The quartzites, are a little variable on both the flanks of the stream, which form low
hills varying from coarse gritty quartzitic through current bedded to massive even-grained sandstones.

The beds strike at N 10° E - S 10° W and dip at 6 to 8 eastward. The strike swings to N 55° W - S 55° E, dipping at 25° to N 55° E near fault. Where there is faulted contact the sandstones are highly weathered. There are dark greyish spots on the sandstone masses which might have been developed due to chilling effect of hot lava. The fault trends WNW - ESE dipping 25° southwards.

Deccan lavas have intruded into sandstone. The lavas rest unconformably over sandstones and also in bedding planes.

Jointing is very common at Bhadbada pumping station. Most of the joints are the vertical joints the joint directions are N 10° E - S 10° W, N 30° W - S 30° S, N 50° E - S 50° W. Some of the joints trend N 50° W - S 50° E dip at 70° to SW. There is a greater concentration of joints near the fault between sandstone and traps. Second set of joints are more open. Joints do not extend to a greater depth.

The sandstones represent slight folding where these are broken into block like fragments due to jointing.
Petrography

Texture

The mechanical composition of Upper Blander Sandstone is shown in the table I.

Table I

Mechanical composition of Upper Blander Sandstones
(Frequency Percentage)

<table>
<thead>
<tr>
<th>Grade Scale</th>
<th>HE₁</th>
<th>S₁</th>
<th>S₂</th>
<th>S₃</th>
<th>BM₁</th>
<th>BM₂</th>
<th>S₁₂</th>
<th>S₁₈</th>
<th>S₂₂</th>
<th>S₂₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-1 mm.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-0.5 φ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-1/2 mm.</td>
<td>6.5</td>
<td>2.5</td>
<td>2.0</td>
<td>0.5</td>
<td>3.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5-1 φ</td>
<td>73.0</td>
<td>35.5</td>
<td>7.0</td>
<td>40.0</td>
<td>3.0</td>
<td>1.0</td>
<td>14.5</td>
<td>3.0</td>
<td>4.5</td>
<td>21.5</td>
</tr>
<tr>
<td>1/2-1/8 mm.</td>
<td>19.5</td>
<td>31.5</td>
<td>57.5</td>
<td>37.0</td>
<td>24.0</td>
<td>41.0</td>
<td>38.0</td>
<td>31.0</td>
<td>53.0</td>
<td>47.0</td>
</tr>
<tr>
<td>1/8-1/16 mm.</td>
<td>1.0</td>
<td>23.0</td>
<td>35.0</td>
<td>17.0</td>
<td>44.5</td>
<td>47.0</td>
<td>26.5</td>
<td>51.0</td>
<td>30.5</td>
<td>20.5</td>
</tr>
<tr>
<td>20-2.5 φ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/16-1/32 mm.</td>
<td>7.0</td>
<td>0.5</td>
<td>4.0</td>
<td>28.5</td>
<td>10.5</td>
<td>20.5</td>
<td>15.0</td>
<td>12.0</td>
<td>7.0</td>
<td></td>
</tr>
</tbody>
</table>
FIG. HISTOGRAMS SHOWING SIZE FREQUENCY DISTRIBUTION OF UP. BHANDER SANDSTONE (UP. VINDHYANS) BHO PAL

THIN SECTION

PARTICLE SIZE IN x UNITS
FIG. HISTOGRAMS SHOWING SIZE FREQUENCY DISTRIBUTION OF
UP. BHANDER SANDSTONE (UP. VINDHYANS)
B H O P A L

THIN SECTION
PARTICLE SIZE IN UNITS

FREQUENCY IN NUMBER

FREQUENCY IN NUMBER
A good sorting is shown by some of the samples where 90 per cent or more of the material is concentrated over only two classes. This spreading of material in two classes with more than 90 per cent of material concentration proves the sample to be very well sorted. Some samples show variable character and they show a spreading over five classes but in these classes the concentration or spreading is over two or three classes where over 80 per cent of material is spread in these classes.

A visual estimation of the size characteristics can be made from the histogram shown in figure and from the frequency curve shown in the figure.

The cumulative curves are very steep and indicate that the sandstones are well sorted and homogeneous in character. The curves overlap each other which clearly indicates the homogeneous character of sandstones.

next page.............
Composition

The composition of Upper Bhander Sandstone is shown in the table II.

Table II
(Percent Modal Composition)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Sample No.</th>
<th>Felspar</th>
<th>Quartz</th>
<th>Rock Fragments</th>
<th>Chert</th>
<th>Accessory</th>
<th>Cemnt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>0.0</td>
<td>84.4</td>
<td>3.4</td>
<td>1.8</td>
<td>6.0</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>0.6</td>
<td>88.4</td>
<td>1.6</td>
<td>1.2</td>
<td>2.6</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>0.0</td>
<td>92.6</td>
<td>1.2</td>
<td>0.6</td>
<td>3.6</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>1.2</td>
<td>85.4</td>
<td>2.8</td>
<td>2.6</td>
<td>6.0</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>1.0</td>
<td>80.0</td>
<td>6.4</td>
<td>4.0</td>
<td>3.6</td>
<td>5.4</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>1.8</td>
<td>80.6</td>
<td>4.8</td>
<td>5.0</td>
<td>3.8</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>1.6</td>
<td>80.2</td>
<td>4.4</td>
<td>3.0</td>
<td>6.6</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>1.2</td>
<td>84.2</td>
<td>2.8</td>
<td>2.6</td>
<td>7.2</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>1.6</td>
<td>81.8</td>
<td>3.8</td>
<td>4.0</td>
<td>3.2</td>
<td>5.4</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>0.6</td>
<td>80.0</td>
<td>7.2</td>
<td>6.6</td>
<td>4.0</td>
<td>1.6</td>
<td></td>
</tr>
</tbody>
</table>

In the given area the specimens were collected from many places. The sandstone is mainly composed of quartz and
the variation in the composition ranges from 80 to about 92 percent of quartz by volume. This composition proves the sandstone to be of purest variety and, so, can be mentioned as orthoquartzite.

The framework is normal because there are normally 0.86 contacts per grain seen under microscope. The grains touch each other to form a stable mass. The voids in between are filled up by detrital matrix in the form of chert, rock fragments and precipitated secondary silica cement which shows optical continuity with detrital quartz grain. Quartz grains show anisotropic fabric which is clearly seen by the orientation of the quartz grains which are generally medium grained, rounded to well rounded and well sorted in character.

The size of the particles indicate that they have been transported for a long distance from the provenance. The fast flowing current might have also been helpful in carving to quartz grains to smaller size at the time of deposition. The idea of prolonged transportation is also supported by the roundness of quartz grains which are rounded to well rounded.

The quartz is of detrital nature and has authigenic overgrowths on the detrital grains. The grains
are variable in shape. They are sub-spherical to elongated. The ratio between long axes and the short axes is variable but it has an average ratio of 1.5 nun. The elongation is supposed to be in the direction of C-axes. This elongation phenomenon might have been produced due to the bottom current action and the orientation portion is supposed to be parallel to the direction of current flow.

Strain shadows are common in the sections under crossed nicols. The grains do not get extinct when the stage of Petrological Microscope is rotated, at once. The shadow of darkness passes slowly from one end to another end of the grain boundary slowly. The phenomenon of strain shadow happens due to the effects of the strain (pressure) exerted on the quartz grain. This proves the quartz to be of metamorphic origin. Thus the same holds good for the provenance. The pressure is not much stronger because these strain shadows are not so much pronounced.

Inclusions are not very common. There is no regular arrangement of inclusions in quartz grains. The nature of inclusions indicates the nature of provenance which is acicular type where the tourmaline, rutile, apatite etc. made the needle-like inclusions. Regular inclusions are there but are rare. Few gaseous bubbles
are noted. They indicate a granitic provenance.

Composite type of overgrowth is also seen in many quartz grains which proves the quartz to be the second cycle quartz which might have completed more than one cycle of erosion and deposition. The overgrowth forms a secondary rim over the detrital grain. The crystalline form cementing material. The nucleus is distinctly marked by the presence of iron oxide stain. Some time irregular boundaries are noted existing between the two growing nuclei but this case is rare.

Quartz is very stable mineral. The second cycle quartz which has been transported from the long distances forms 86 percent of rock by volume. Association of heavy minerals like tourmaline, rutile and zircon etc. along with quartz show a resistance against erosion. Felspars are very minor in quantity.

Rock fragments constitute 3.8 percent of the rock by volume. These rock fragments seem to be derived from igneous and metamorphic rocks by disintegration. Chert is detrital in nature.

Cement

Silica cement shows the optical continuity with the detrital quartz grains. The large number of quartz grains
are packed and cemented together as a crystalline aggregate. The toughness and compactness of sandstones in the given area is mainly related to the nature of the cement.

Iron-oxide forms a boundary line between the detrital quartz grains and separates the nucleus from the secondary rim. The detrital quartz grains were first deposited and later the iron oxide cement was introduced. The cement in the form of secondary quartz seems to have originated in the last stages.