UNCONFORMITIES IN THE FLUVIAL COLUMBIA SEDIMENTS REVEALED BY THIN PEBBLE BEDS

BY

NENAD SPOLJARIC

STATE OF DELAWARE
NEWARK, DELAWARE
MAY, 1982
UNCONFORMITIES IN THE FLUVIAL COLUMBIA
SEDIMENTS REVEALED BY THIN PEBBLE BEDS

By

NENAD SPOLJARIC

May 1982
UNCONFORMITIES IN THE FLUVIAL COLUMBIA SEDIMENTS REVEALED BY THIN PEBBLE BEDS

ABSTRACT

An explanation is suggested for the origin of thin, laterally persistent pebble beds commonly found in the Columbia Formation of Delaware.

The pebbles in the thin beds are usually less than 16 mm in diameter, well rounded, spherical, and composed mainly of resistant material: chert, vein quartz, and quartzite.

The process thought to be responsible for the origin of these beds is a combination of erosion and transport of sand and pebbles in suspension by highly turbulent streams resulting in selective deposition of pebbles in thin, laterally persistent layers.

An attempt is made to estimate quantitatively the amount of sand that has to be eroded to produce thin pebble beds. The results suggest that such pebble beds mark significant erosional unconformities within the fluvial Columbia sequence.

INTRODUCTION

Thin, laterally persistent pebble beds are common in the Columbia Formation in Delaware. Mostly these beds are less than 0.8 inches (2 cm) thick and composed of pebbles less than 16 mm in diameter. The pebbles are well rounded and spherical, and are composed mainly of resistant materials: chert, quartzite, and vein quartz. The sand matrix is similar in texture and composition to the overlying sands.
The purpose of the study is to investigate the origin of these thin pebble beds and determine their geologic significance. The study was carried out in a small area between Odessa and Middletown in northern Delaware (Fig. 1).

Figure 1. Locations of gravel pits indicated by numbers.

Geology of the Columbia Formation

The sediments of the Columbia Formation cover the older sediments in almost all of the Coastal Plain in Delaware. They are composed of gravels, sands, silts, and some clays. Boulders are also found scattered throughout the State (Jordan, 1964).

In the area of the present study the Columbia deposits were laid down in a braided stream system (Spoljaric, 1974). Sands make up about 60 percent of the total of the Columbia
sediments, gravels about 30 percent, and clayey silts the remaining 10 percent. The sands are unconsolidated with a matrix of, usually, less than 10 percent silt and clay. The most common sedimentary structures are cross-bedding, which is present in about 80 percent of the sand beds, and horizontal bedding in coarse sand beds in most of the remaining 20 percent. Ripple marks in fine sands are subordinate. Cross-bedding is well developed; it is both of tangential (predominant) and non-tangential type. All cross-bedded layers investigated lack topsets. Thus, the original thickness of the layers is unknown; the measured thicknesses rarely exceed 3 feet (1 meter). Individual beds of horizontally bedded, coarse sand are difficult to differentiate due to the coarseness of this sediment. Scattered small pebbles are quite common in such sands. Layers containing pebbles have less silt and clay matrix than those which lack pebbles. Individual beds of horizontally bedded sand containing pebbles are usually less than 1.5 inches thick (4 cm).

As separate rock units, silt and clay are extremely rare: about one percent of the total volume of the Columbia sediments. However, combined in the form of clayey silt they comprise about 10 percent of the material investigated, not counting the amount of fine material incorporated as matrix in sands and gravels.

METHOD AND RESULTS

Pebble Beds and Distribution of Pebbles in Sands

Pebbles similar to those composing thin pebble beds (Fig. 2) are found scattered throughout the Columbia sand beds. The amount of these pebbles in the sand beds is between 0.2 and 8 (weight) percent. The abundance of pebbles does not seem to be related to mean grain size, sorting, kurtosis, skewness, measured bed thickness, thickness of individual foreset and bottomset laminae of cross-bedded sands, or inclination of foresets. Thus, the abundance and distribution of pebbles in the sands appears to be random.
Figure 2. Well developed thin pebble beds (arrows): (a) gravel pit no. 2; (b) gravel pit no. 3.
Origin of Thin Pebble Beds

The relative abundance of coarse, horizontally bedded sands and cross-bedded gravels in the Columbia Formation suggests that for a large portion of their existence the streams that deposited these sediments were flowing in upper flow regime (Spoljaric, 1970).

Additional evidence revealed by the present study shows that these streams were not only highly competent, but also extremely turbulent. Figures 3 and 4 demonstrate this.

Figure 3. Evidence of erosion and transport of sand and pebbles in suspension; partial destruction of horizontally bedded sand layers and disarray of pebbles in sand are indicative of turbulent, high velocity streams of great competency. Flow direction is from left to right. Gravel pit no. 2.
Figure 4. Erosional process more advanced than that shown in Figure 3. Note a small segment of cross-bedded sand (arrow) which was preserved due to a wake caused by the boulder on the left. The length of the sand bed (about 3 feet; 1.0 m) is evidence for turbulent, high velocity stream of great competency. The flow direction is from left to right. Gravel pit no. 2.

Thoroughly mixed sand-size and small pebble-size materials must have been transported in, and deposited from, suspension loads. Such suspension loads are only possible in highly turbulent streams where the shear stresses several times exceed critical values (Blatt et al., 1972).

Highly turbulent streams also caused extensive erosion of previously deposited sediments including sand beds containing small pebbles. The intensity of this erosion is indicated in Figures 3 and 4 where only remnants of hori-
zontally bedded sand beds are preserved. The more than three-foot (1 meter) long tongue of a sand bed preserved in the wake behind the boulder, shown in Figure 4, attests to both high velocity and intensive erosion of the Columbia stream.

Sudden drops in velocities and turbulence in the Columbia streams, such as those caused by shifts of stream channels, resulted in almost instantaneous "dumping" of suspended loads (mixtures of pebbles, sands, and finer materials). This is evidenced by a lack of grain-size gradations and absence of any distinct primary sedimentary structures in such deposits (Figs. 3 and 4).

On the other hand, gradual decrease of velocities and turbulence in the Columbia streams resulted in gradation of suspended loads according to grain-sizes, with the coarse materials becoming concentrated at the bottom of the streams. When the competency of the stream fell below the critical velocity, the stream became unable to continue to transport pebbles and a pebble bed was formed as an openwork gravel (Fig. 2).

The absence of gradational contacts between the pebble beds and the directly overlying sands suggests that there was a time lag between the deposition of pebbles and the formation of overlying sands. Therefore, the matrix found in the pebble beds is secondary, deposited after the pebbles were laid down. How much time elapsed before the matrix was introduced into the pebble beds is unknown.

Geologic Significance of Pebble Beds

Because the proposed process of formation of the thin pebble beds requires erosion of sands and finer sediments, such beds mark erosional unconformities. An attempt was made to determine the amount of sand which would have to be eroded to produce a thin pebble bed. The computations are based on weight percentages. Although the great majority of pebbles are less than 16 mm in diameter, there are also those which are larger. In the following discussion only the average weight percentages of pebbles found in the collected samples were considered. Table 1 shows the data used in the computations.

Table 1 shows that the horizontally bedded coarse sand contains far more pebbles than the cross-bedded sand. This is not surprising as horizontal bedding in coarse sands is indicative of great competency and high velocity streams capable of transporting pebbles (Jopling, 1960).
Table 1 illustrates pebble contribution to thin pebble beds by equal volumes of cross-bedded sand and horizontally bedded coarse sand.

Table 2 illustrates pebble contribution to thin pebble beds by equal volumes of cross-bedded sand and horizontally bedded coarse sand.

Taking into consideration the relative abundance of cross-bedded sand (80 percent) and horizontally bedded coarse sand (20 percent) in the Columbia Formation in the study area, the data in Table 2 were used to determine the actual contributions of each of the two sand types (Table 3).

To determine the amount of sand that would have to be eroded to produce a thin pebble bed, it is necessary to make the following assumptions:

1. Pebbles are spheres. Pettijohn (1957) points out that the sphericity of pebbles is usually 0.80 or higher.
2. Specific gravity of pebbles is 2.65. Most of the pebbles are quartzose rock types.

3. Estimated porosity of thin pebble beds is 35 percent.

4. Estimated porosity of sands is 25 percent.

5. Specific gravity of sands is 2.65. Jordan (1964) has shown that more than 80 percent of the sand fraction of the Columbia Formation is quartz.

<table>
<thead>
<tr>
<th>TABLE 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual contributions of pebbles by the two sand types</td>
</tr>
<tr>
<td>(in weight percent)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>2-4 mm</th>
<th>4-8 mm</th>
<th>8-16 mm</th>
<th>&gt;16 mm</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-bedded sand</td>
<td>30.3</td>
<td>1.7</td>
<td>-</td>
<td>-</td>
<td>32.0</td>
</tr>
<tr>
<td>Horizontally bedded sand</td>
<td>49.5</td>
<td>15.7</td>
<td>2.5</td>
<td>0.3</td>
<td>68.0</td>
</tr>
</tbody>
</table>

The pebble bed occupying an area of one square meter (10.76 sq. ft.) and 20 mm (0.78 inches) thick is considered. Such a layer would take up a space of 20 dm³ (1,220 cu. in.); the pebbles alone would occupy 13 dm³ (793 cu. in.) and the remaining 7 dm³ (427 cu. in.) would be voids. The total weight of the pebbles would be about 34.5 kg (75.9 lb.). To produce such a pebble bed it would be necessary to erode the following amounts of sands:

Cross-bedded sand...ca. 1,025 kg (2,255 lb.) or ca. 516 dm³ (18 cu. ft.)

Horizontally bedded sand...ca. 2,103 kg (4,627 lb.) or ca. 1,058 dm³ (37 cu. ft.).

This is equivalent to a sand unit occupying an area of one square meter (10.76 sq. ft.) and about 1.6 m (5.2 ft.) high.

*1 dm = 10 cm.
It seems, therefore, that the erosion indicated by thin pebble beds is considerable indeed, and that the unconformities marked by such beds are quite real and significant.

CONCLUSIONS

Thin pebble beds, although quite inconspicuous in outcrops, bear the evidence of significant erosional episodes brought about by competent streams of high velocity. Simple mathematical computations have shown that it is possible to estimate quantitatively the amount of erosion necessary for the formation of a thin pebble bed. Although several assumptions were made, the results of these computations are considered significant enough to warrant careful future study of similar beds in the investigation of other fluvial deposits.
REFERENCES CITED


