ART. XXXIII.—*Imbricated Structure in River-gravels;*¹
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Gravel deposits formed in river beds and bars frequently show a characteristic mode of arrangement of the coarse gravel and shingle. The stones, for the most part dip upstream and overlap or imbricate. This mode of arrangement of the stones was figured and referred to by James Geikie as imbricated structure.² It is only rarely described in text books on geology or physiography but has probably been noted by many geologists in the field. Because it is a criterion which can be used occasionally to distinguish marine from non-marine deposits and because of the fewness of such criteria, attention is here directed to it. Furthermore there seems to be a misconception on the part of some geologists as to the character of the structure.

Imbricated structure was described and its mode of formation explained by G. F. Becker in 1892, who stated³: "If a flattened pebble is dropped into a running stream, the water will exert a pressure upon the stone until its inertia is overcome, and during this time the pebble will tend to swing across the current so as to present its greatest area to the pressure. As soon as the resistance due to its inertia is overcome, the pebble will sink through the water as if the fluid were at rest until its edge touches the bottom, and it will then tip downstream until it meets support. . . . Many pebbles thus deposited will, with few exceptions, be inclined downstream and will rest against one another, like overlapping tiles." This view as to the attitude of the stones agrees with Geikie's description and with the present writer's observations. The important points are that the stones tend to dip upstream or, as the placer miners sometimes put it, the up-ends of the stones are the downstream ends or point downstream, and the upstream stones tend to overlap on the downstream stones. In a recent text-book, however, it is stated⁴ that the pebbles in river beds may imbricate up-

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² James Geikie: *Structural and Field Geology*, 1905, p. 311.

³ *Finite Homogeneous Strain, Flow and Rupture of Rocks*, Bull. Geol. Soc. Amer., vol. 4, pp. 53-54, 1893.

⁴ Lahee, Frederick H., *Field Geology*, 1916, p. 88.

stream and dip downstream. This view is apparently incorrect. The stones finally assume a position in which they offer the least possible resistance to the current. If the stones dipped downstream they would present their edges to the current and therefore offer considerable resistance to the current. Moreover field observations show that the dip is upstream. It is well recognized that in hydraulic work it is necessary, in order to achieve maximum results, to direct the stream against the

FIG. 1.

FIG. 1.—Vertical section of river gravels at Campbellford, Ontario, Canada, showing imbricated structure. The direction of the current was from right to left.

“stratification” of the stones, that is in a direction opposite to that of the current which deposited the stones. Imbricated structure is frequently used by placer miners as a criterion to determine the direction in which the streams in abandoned channels flowed and thus to attempt to trace the old channels. The inclined attitude of the stones is chiefly relied upon for this purpose and the further fact that the longer axes of the stones usually lie in the direction of the current. Imbricated structure

is, therefore, of economic importance and its character should be clearly understood.

Becker also pointed out that “On beaches pebbles are sometimes imbricated for a few feet in one or another direction and sometimes lie nearly flat. The constant reversal of the currents due to breaking and retreating waves prevents any extensive methodical arrangement, and this fact is of assistance in discriminating marine

FIG. 2.

FIG. 2.—Vertical section of conglomerate, on Burrard inlet, near Vancouver, British Columbia, showing imbricated structure. The direction of the current was from left to right.

gravels from river deposits.”⁵ This criterion for distinguishing marine from non-marine deposits does not appear to have received much consideration by geologists, probably because of its limited application, but it may be occasionally used, as pointed out below, and is of importance because of the fewness of such criteria.

Imbricated structure is usually best shown in the very coarse gravel and shingle deposits of river beds, but is

⁵ Opus cit. p. 54.

also shown, in places, in comparatively fine gravel as in fig. 1. This figure shows a section of river gravels in the bed of Trent river, at Campbellford, Ontario. The largest pebbles in the section are about 8 inches in diameter. The direction of the current was from right to left. Imbrication of the pebbles is not well shown because of the fineness of much of the material, but the pebbles have a fairly uniform dip in an upstream direction and lie with their longer axes in the direction of the current. The face of the section is vertical except in the lower part which is talus.

Fig. 2 shows a vertical section of Tertiary conglomerate exposed on the south side of Burrard inlet near Vancouver, British Columbia. Imbricated structure is fairly well shown in the conglomerate and shows that it was formed from river gravels. It is therefore non-marine. The section is an east-west one, and the stream which deposited the gravel flowed west, that is, from left to right in the section. The conglomerate beds have a general dip of 10 to 15 degrees towards the south. As the depositional dip must have been in the direction of the current, the dip towards the south is structural. Imbricated structure may be occasionally used, therefore, both to distinguish marine from non-marine deposits and for structural purposes.