Length 5, wing 2 $\frac{6}{10}$ tail 2. Bill $\frac{9}{20}$, *deep blackish brown* with pale tomia. Tarsus $\frac{8}{10}$. Legs and claws *deep blackish-brown* with yellow soles and tips to claws. The olive-green above is much the same as in *sylvicultrix*, but the eye-streak and under-parts are *much yellower*.

On the Translation of Waves of Water with relation to the great flood of the Indus in 1858.—*By* J. Obbard, *Esq.*

"At 5 A. M. on the 10th August, 1858, the Indus at Attock was very low. At 7 A. M. it had risen ten feet. By 0.30 P. M. it had risen fifty feet, and it continued to rise until it stood ninety feet higher than it did in the morning. The Cabul river continued to flow upwards for ten hours. The fall was at first slow; but the river was about eight feet below its maximum by sunset; and continuing gradually to fall, it had during the 12th returned very much to the position it occupied before the flood came down."—*Extracts from Journal of Asiatic Society*, 1858, 1859.

1. Several papers have been recently forwarded to the Society upon the great flood of the Indus in August, 1858, and, as it is a subject in which I take great interest, I trust that I may be excused in submitting my views regarding it.

2. I propose, therefore, in the following paper, to consider the mode in which this vast body of water passed Attock, and with this view, I shall first treat cursorily of the nature of waves of water generally, more especially, however, dwelling upon waves of the class which from their formation and size, seem to be analogous to that which is under consideration, stating in general terms, their mode and rate of transit; and the limit within which wave translation is possible; and I shall then endeavour to shew the application of these laws to the specialities of the Indus wave, touching briefly upon some erroneous speculations which seem to have been made upon insufficient data.

3. A wave is an inequality of surface or variation of level in a stream of water, which may be of any size according to the force of its original cause. It is unnecessary to enquire into the origin of a wave for the purpose of elucidating its specialities, as all waves when

once formed and the original cause withdrawn, or as they may be termed *free*, obey the same laws, and are subject to the same peculiarities.

4. The undulation upon a smooth sheet of water from a school boy's pebble; the ocean wave thrown up by the wind; the gush of water from a destroyed dam or suddenly-withdrawn barrier; the swell from a steamer's paddle; and the great free tide-wave which, twice in the twenty-four hours is poured into all estuaries and rivers through the inequality of the attraction of the heavenly bodies:—all these waves so different in origin, size, and formation, are subject to the same series of laws, which have been, to a certain extent, investigated.

5. It should first be remarked that the progress of a wave is not the progress of the particles of which it is composed. A traveller, upon visiting the sea-shore for the first time, might be led to suppose that each wave was bringing with it the mass of water of which it was originally composed, and depositing it upon the shore. A little closer observation would, however, soon convince him of his mistake, as he would perceive that a piece of drift wood or of foam, would maintain the same mean distance from the beach, although several successive waves lifted it upon their crests, and deposited it in their succeeding hollows.

6. The same law may be shewn to hold with the tidal wave. In the accompanying tide table (with a copy of which, if thought useful, I shall be happy to furnish the Society annually)—the time of high water at Calcutta, or of the passage of the crest of the tidal wave at that place, is predicted for every day throughout the year. In the lower part of the sheet, the distances of places from Calcutta along the river are given in geographical miles, and against each, under the column of "correction for high water," is the interval of time which the crest of the wave occupies in travelling that distance. With these data it will be seen that the tidal wave of the Hooghly has a mean speed between Saugor and Calcutta of about 20½ geographical or 24 British miles per hour—while the speed of the water perhaps never exceeds eight, and is frequently as low as 2 miles per hour—without any corresponding variation in the rate of translation of the wave. The position, moreover, of the junction of the salt water of the ocean, with the fresh water of the river stream, is

not permanently affected by the passage of the wave, but oscillates between two fixed points upon flood and ebb, according to wave laws which will presently be indicated.

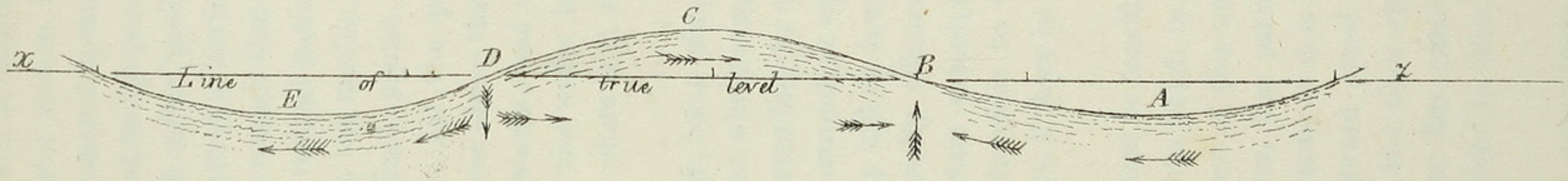
7. The progress of a wave then may be described as the translation of a shape or form, in which the particles are continuously changing—but these particles although they are successively cast off, have a certain motion communicated to them by the wave, though it is not that of the wave itself.

8. The sea side observer would with attentive watching perceive, that the piece of drift wood or foam is actually carried forward by the crest of the wave to a certain extent, though not in anything like the ratio of progression of the wave itself, and that when the wave has passed, it is carried backward in the succeeding hollow, so that it always occupies the same mean position; and in like manner, a boat or a ship, and the termination of the salt water, are carried a certain distance up a river by the flood or crest of a tidal wave, and down again by the ebb or hollow, so that if uninfluenced by other causes they will recover their original position.

9. It has been mathematically demonstrated, and direct experiment has established, that the particles of water of which a wave is composed, actually move in a circle; or an ellipse; the formation of which varies in proportion to the mass of the wave, and the depth of the water.

10. When the wave is small, and the water deep, the particles move nearly, if not quite, in a perfect circle,—in other words the vertical and horizontal displacements are about equal; but when the wave is very large, as the tidal wave, and the water shallow, the vertical displacement is wholly insignificant to the horizontal, and the motion of the particle, measured from any fixed point, is an extremely flat ellipse, of which the horizontal is the major axis.

11. In the accompanying sketch, a wave is supposed to be travelling along a level sheet of water from X. to Z.—A. is the centre of the preceding hollow:—B. the middle of the anterior slope:—C. the crest of the wave:—D. the middle of the posterior slope:—and E. the centre of the succeeding hollow. A particle of water which is at A. will be carried backward or towards the wave:—At B. its horizontal motion will be neutralized and it will be found



Sketch of the Motion of Wave Particles.

to move directly upwards. At C. it will be carried forwards with the wave:—At D. it will have no horizontal motion, but will be carried downwards to the same extent it was moved upwards at B. and at E., it will be again carried backwards:—at which point the whole wave having passed, it will hold the same actual position which it did at A., the vertical and horizontal displacements having exactly balanced each other. It is scarcely needful to remark that there is no sudden alteration from the horizontal to the vertical motions, and vice versâ, but that at each intermediate position the motion is a compound one, forming a gradual curve:—these fixed points having been only selected for convenient illustration. All the particles below the surface pursue the same course as those above them; i. e.—all those below the crest of the wave move forwards; and all those below the hollow move backwards, but where the water is deep the motion low down becomes imperceptible, and where it is shallow it is practically the same as at the surface.

12. The motion of a wave therefore, being simply the translation of a shape, is unaffected by any current which may be running in the stream on which it is generated. According to the direction of its original impetus it may travel with a current, at right angles to it, or even directly against it; and either up hill or down hill; without its speed or rate of transit being materially affected thereby. I say materially, for a current does, to a certain extent, modify the conditions of a wave, and I have reason therefore to think that it may also affect its speed, but that this effect, if there be any, is very slight, may be easily demonstrated.

The Hooghly, like all other rivers, must be considered as a stream of fresh water running towards the sea, into which is poured, once every twelve hours, a large wave. As the crest of this wave is approaching or passing a given spot within the river, the particles of which it is temporarily composed are flowing upwards, or it is technically termed flood tide. It is evident that the upward speed of the particles is checked by the constant resistance of the river stream, and that in like manner when the crest of the wave has passed, and the particles receding in the hollow, they are aided in their backward course, by the velocity of the river stream.

13. The river stream is therefore a constant—plus to the ebb, and minus to the flood.

14. But the speed or force of the river stream varies considerably at different times of the year. In the month of March, or the dry season, its rate off Calcutta does not exceed half a mile per hour; whereas in the month of August, or the height of the freshets it may amount to three miles per hour. Now, if the river stream does sensibly retard the passage of the wave itself, it is evident that its effect is far more potent when it is large, and we have thus a direct experiment of variation afforded us to discover if this be the case.

15. When the time of the lunar transit is 0h. 0m. or when the sun and moon are in conjunction; the crest of the tidal wave passes the floating light vessel, which is 119 miles below Calcutta, at 9h. 0m. throughout the year. This is not critically correct but sufficiently so for the purpose. In the month of March the same wave reaches Calcutta, at 2h. 35m.; and in the month of August at 2h. 10m. by which it would appear that it actually takes less time by twenty-five minutes to travel to Calcutta during the height of the freshets, than it does in the dry season, and this, although the upward current of the particles of which the wave is composed, is entirely neutralised by the increased rush of the river stream.

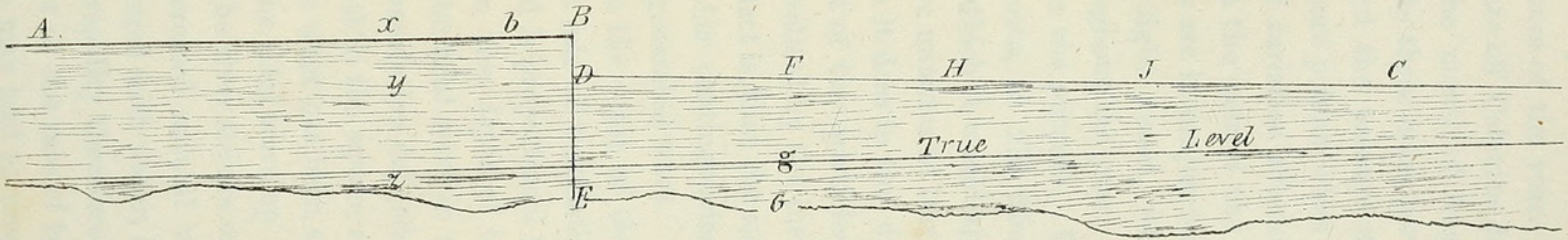
16. The fact is, that the speed of the wave depends almost entirely upon two other contingencies, viz. the depth of the water, and the mass of the generated wave.

17. When the depth of the water is greater than the length of the wave, the rate of translation depends entirely upon the mass of the wave, and is proportional to the square root of its length.

18. When the depth of the water is small and the wave very great, as in the tidal wave in rivers and those analogous to it, the velocity of translation depends solely upon depth of the stream, and is proportional to the square root of the depth.

19. From what has been above stated, the cause of the superior velocity of the tidal wave up the Hooghly in August is apparent; and that, if the river stream exerts any sensible retarding effect whatever, the increased natural velocity of the wave, through the river being surcharged with water, is sufficient to neutralise it altogether.

20. The rapidity therefore of a river stream or current is no criterion whatever of the rate of translation of a wave upon it; and such a supposition may lead to very erroneous conclusions, as the speed of



Portion of river with a barrier