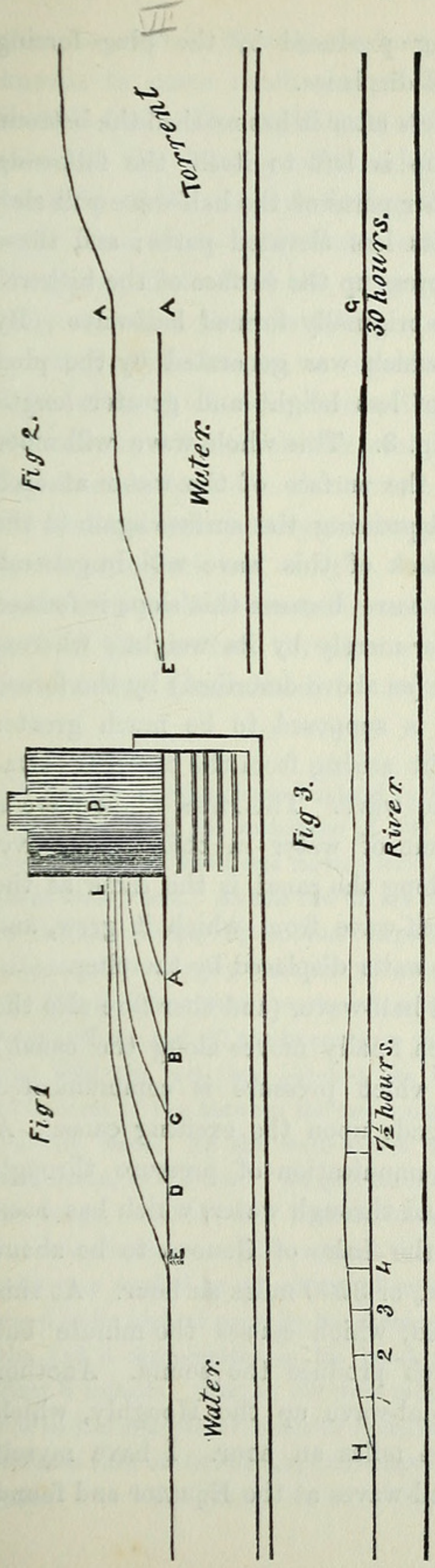
from the preceding theory, regarding the late flood—much local knowledge would be requisite to obtain any result which would be even generally satisfactory. Moreover, the disturbing effects of friction, through varying depths and breadths, and the influence of tributaries; would perhaps always prevent a close approximation between observed facts and theoretical deductions. Still, however, as correct methods of investigation are only second in importance to accurate observations of phenomena; I trust that the foregoing exposition of what I believe to be the true principles of tidology will not be wholly valueless—which, it will not be, if it only induce those who are better able to deal with the difficulties of the subject, to examine and refute the errors into which I may have fallen.

On the physical difference between a rush of water like a torrent down a channel and the transmission of a Wave down a river—with reference to the Inundation of the Indus, as observed at Attock, in August, 1858.—*By* Archdeacon J. H. Pratt.

The following paper is the substance of some remarks I made at the monthly meeting of the Asiatic Society early in September, after the reading of Mr. Obbard's paper published above. That interesting communication was shown to me and to one or two other members when it was first forwarded to the Society, and a discussion which ensued persuaded me that some further explanation of the manner in which a wave may have been generated on the Indus, as supposed by Mr. Obbard, by the bursting of a bund and the precipitation of the pent-up waters, would not be unacceptable.

I do not stand forth precisely as the advocate of the view, that the rise and fall of the water at Attock was produced by the transmission of a wave, rather than by the ordinary rush of water in a swollen river; because there are several facts, which it is necessary to determine before coming to a decision. We ought to know whether there are any great bends and shallows in the river; and the phenomena to be explained ought to be more fully before us. My object is to show the possibility of such an explanation as Mr. Obbard has advanced; and to give my reasons for on the whole inclining to the view that the disturbance at Attock was produced by the passage of a wave. J. H. P.



1. In fig. 1 suppose that A E is a surface of still-water, in a canal closed at one end and extending indefinitely to the left. P is a gigantic plug, supposed to be thrust down vertically into the water. As the plug descends, pressure will be continually communicated through the water so as to lift up the surface of the water in the canal. As the plug descends successively to a, b, c, d, e (omitted by the engraver) the surface will be raised up into the curves at A, B, C, D, E. The greatest rise at any instant will be close to the plug, where the pressure has been acting longest; and the elevation of the surface in each curve will be less and less in passing down the canal, because the pressure has been acting for a shorter and shorter time. At the instant the plug reaches the bottom, the surface will have been elevated into half a convex wave L E, its length depending upon the rapidity with which the pressure has been communicated. The amount of water in this elevated half-wave will be equal to the volume of water displaced by the plug. It is evident, that during the formation of this half-wave the several particles of water beneath its surface have received a slight upward and forward mo-

tion of transfer; this effect being produced by the plug forcing onwards into the canal the water it displaces.

2. If the plug remains motionless after it has reached the bottom, and the half-wave it has forced up is left to itself, the following process will take place. The higher parts of the half-wave will sink by their own weight and press up its less elevated parts; and these in their turn will by their weight press up the surface of the hitherto still water of the canal beyond the originally formed half-wave. By this process the half-wave L E which was generated by the plug will form itself into a whole-wave of less height and greater length than the half-wave, like G K in fig. 3. This whole-wave will move freely along the canal, elevating the surface of the water at each place as it passes it, and then depressing the surface again to the original level. The slope of the back of this wave will, in general, be longer than the forepart of the wave, because this slope is formed by the sinking of the elevated water merely by its weight; whereas the forepart of the wave is formed (as above described) by the forced action of the plug, and this force is supposed to be much greater than the mere difference of weight arising from the different elevations of the different parts of the wave. This free whole-wave is represented in fig. 3. The volume of water in this whole-wave, which moves solitarily and freely along the canal, is the same as the volume of water in the forced half-wave from which it grew, and therefore is equal to the volume of water displaced by the plug.

3. The length of the generated half-wave, (and therefore also the length of the free whole-wave which finally moves along the canal,) depends upon the rapidity with which pressure is communicated through water. This rapidity depends upon the exciting cause. A very extreme example of the communication of pressure through water is seen in the velocity of sound through water, which has been found by careful experiments in the Lake of Geneva to be about eight-ninths of a mile in one second, or 3200 miles an hour. At this rate is the pressure communicated, which causes the minute but rapid vibrations of the water which produce the sound. Another example is the velocity of the tidal-wave up the Hooghly, which moves (as Mr. Obbard states) at 24 miles an hour. I have myself made experiments on the great swell-waves at the Equator and found

them to move at 27 miles an hour.* Waves may be made, as is well known, to move much slower than this, if the pressure producing them is less. The rapidity of the communication of pressure, and therefore the velocity of translation of the wave, depends upon the intensity of the cause producing the pressure.

4. In order to apply these results to the phenomenon in question, I suppose, instead of the plug pressing down the surface, a large body of water to have fallen upon the surface of the Indus by the bursting of the barrier, as represented in fig. 2. According to the force with which this descending mass struck the river, would be the velocity with which the front of the generated half-wave would begin to move down the river. As the cataract poured down from the broken barrier, its successive portions, after causing the pressure by their impact and weight and so aiding in the generation of the half-wave, would become themselves in turn part of the river, and so part of the medium through which the pressure of the next falling portion was transmitted, to continue the generation of the wave.

* During a voyage from England by the Cape in 1838 I made the following experiment with the assistance of the first and second officers. A day was chosen when the swell was moving from ahead aft, and the ship was making only about three knots. At one end of the log line a large bung was fastened, and 40 fathoms further up another large bung was tied on, the intermediate forty fathoms of line having a number of smaller corks attached to it to make it float. The line thus furnished was thrown into the water astern, and more line allowed to run off the reel till the bungs were well clear of the ship. The second officer, who held the reel, then checked the line from running out further: and the 40 fathoms of line between the two bungs were drawn out straight by the way the ship made. As the wave which was to be observed approached the vessel from ahead, at the word "let go" the line was allowed to run off the reel, and the bungs, with the line between them stretched straight, instantly remained stationary in the sea. The moment the wave lifted the first bung to its highest point was marked by my giving a "now," and the moment the second bung was raised to its highest point by the same wave a second "now." The first officer, who had a chronometer in his hand, marked the interval; it was found to be about 6 seconds. That is, the wave moved over 40 fathoms in 6 seconds, or 1 mile in 132 seconds, or about 27 miles in one hour. Each of us took the several places in turn of reel-holder, time-keeper, and observer; and the results were the same.

The half-wave would be in the process of generation until the pent-up waters were exhausted.

Major Cunningham states in his work on Ladak, that the mass of water which accumulated in 1841 and caused the inundation of the Indus in that year, was estimated at 20,000,000,000 cubic feet. This equals a volume 100 feet deep, 380 feet wide, and 100 miles long! If the flood of 1858 was only half of this or even much less, the reservoir was large enough to generate a half-wave of enormous length, and to produce a final free whole-wave much longer still.

As the Indus varies in width and depth, this wave would undergo various modifications as it passed down, especially as we must combine with it the natural downward current of the river—probably as much as from 7 to 10 miles or more at the season when the flood occurred. Thus at Attock where the river is confined at its usual level to a width of less than 800 feet by rocks there is no difficulty in assuming, that the elevation of the water would be greater than in other parts where the stream was wider.

5. The state of the Indus at Attock in ordinary years is this. The water is lowest in March. By the melting of the snow in May, and by the rains after that, the surface at Attock has risen by August through 50 feet above the lowest or winter level in March. The facts of the phenomenon of 1858, as observed by the late Captain Henderson at Attock (and recorded in the Journal for 1859, p. 199) were these. In August the river was unusually low for that season of the year, being only about 25 feet (instead of the usual 50 feet) above the winter level. On the 10th August at 6 A. M. the water began to rise, and in the first, second, third, and fourth hours rose through 26,12,7,4 feet, and in the next three hours and a half through 6 feet, so as at $1\frac{1}{2}$ P. M. to stand at 80 feet above the winter level. After this, it began very slowly to subside and returned to its usual level in about (say) $22\frac{1}{2}$ hours, making 30 hours for the whole rise and fall of the water at Attock. The rise occupied one-fourth of this time, and the fall three-fourths. This accords with the form of the wave, the slope of which on the back is much longer than the rise on the front, as explained in para. 2, and represented in fig. 3.

6. The difficulties in the way of receiving this explanation arise from the possible shallows and rapids and sudden bends in the river,

and the consequent checks and friction which might materially interfere with the motion and maintenance of the wave. It may be said, however, on the other hand, that the catastrophe occurred at the season of the year when the river is fullest of water; and although in 1858, even in August, the river was as low as to be only 25 feet (instead of 50 feet) above winter level, nevertheless there must have been a considerable amount of water in the river before the flood came, sufficient very likely for the generation and propagation of the wave. Here, however, is a ground of uncertainty. But even if it were admitted that some impediment of the kind existed between the broken barrier and Attock, yet the influx of waters would at length rise over the impediment like an ordinary rush of water on a much swollen river, and commence to generate a wave in the river below the impediment, as the influx of the tidal water at the sandheads produces a tidal wave.

7. We may understand how the water which the wave had raised just above the impediment would get over the impediment into the part of the river below it, ready to produce another wave by its pressure, by observing the breakers of the Bore in the Hooghly. The Bore is simply the flood-tide-wave moving along the river at the springs at which season the influx at the sandheads is greatest. The onward movement of this wave or form at the rate of 24 miles an hour is accompanied (as stated in para. 1) by an upward and onward movement of the parts of the water itself in the front of the wave, though at a much smaller rate than that of the form or wave itself. Conceive this wave coming suddenly from deep water into shallow. What will take place at the boundary line between deep and shallow water? The pressure lifts up the water on the deep side of the boundary line and so forms the front of the great tidal-wave at that spot, and at the same instant gives the water thus lifted up a slight onward motion, which carries it on to the shallow side of the boundary line between the deep and shallow parts. The pressure-action by which the wave should be propagated onwards over the flat is now destroyed; for the upheaved water thus lifted up over the shallow has nothing but the hard bottom to press down upon, and this unyielding bottom will not communicate the pressure onwards (as it would if it had been itself water) to keep up the formation of a wave

ahead. Hence the water, lifted upon the shallow bottom by the action of the wave moving up to the boundary line, will move on over the shallow with its own proper onward motion already acquired, increased by the action of gravity upon the unsupported front of the mass which has found its way, as described, upon the shallow. The water thus heaved up by the wave from the deep side is, so to speak, poured out upon the shallow, and it rushes along over the flat in a running torrent of breakers, till it covers it over with water to the level of the rest of that part of the river now swollen by the flood which is come in.

The violence of this process will depend very much upon the form of the bottom of the river, and the degree of abruptness of the transition from deep water to shallow. If this transition is gradual, the advancing wave will be reduced gradually by the increasing friction of the bottom; and the resisting pressure caused by the bottom (as it inclines up and so faces the wave) will reduce the action, and when the wave does break, if it break at all, it will do so feebly, like ordinary waves on the sea-shore. If, however, the transition be abrupt from deep water into shallow, the action will be as described above in explaining the Bore. This description will show why the phenomenon is so much more sensible when the Hooghly is full of water, in the freshes, than in the dry season. In the dry season the river lies down in the deep channel, and when the accession of water at the spring tides lifts it up, the highest part only of the tidal-wave rises above the flats or shallows, and runs on them, therefore, without violence. But when the river is full, the general level is raised higher than in the dry season and the flood-wave at the springs is bodily raised up above the level of the flats and falls upon them, and rushes over them with a correspondingly greater violence.

This digression about the Bore will serve to illustrate the action of the wave in the Indus when it reaches an impediment stretching across its breadth, such as a fordable shallow, or a rapid caused by broken rocks on a descent. The wave will break, and rush over the impediment (aided in this case by the downward current of the stream) in a torrent of breakers, and the mass of waters, on arriving at the deeper water below the impediment, will again form a wave by the pressure-action, though not so large as the previous one, because some force will have been destroyed by impact and friction.

8. If the barrier, causing the accumulation of waters, occurred on the main-stream, it might be objected, that, owing to the long stoppage of the supply, there could not have been water enough below the barrier for the descending mass to impinge upon and produce the wave. In this case the mass would rush down the dry or almost dry channel, and as soon as it came to a part of the river where (from its tributaries) the depth of water was sufficient, the sudden influx of the flood would by its weight press downwards and cause the wave to spring up ahead and run down the stream as already described, exactly as the tidal-wave is formed.

9. The reasons which favour the hypothesis of the wave-explanation are these :

(1.) Captain Henderson, who appears to have been the only European who observed the disturbance of the river, inclines to a velocity which accords more with the notion of a wave of water than with that of the water itself rushing down at such a speed : see Journal, 1859, p. 207.

(2.) In his account he says (p. 208) " at first it [the water] came welling up quietly, but very rapidly." This looks much more like the uplifting of the surface by a pressure from below, than the rush of water down the river.

(3.) He tells us in his account (p. 208) that four hours after the rise began, and three hours and a half before the maximum rise was attained, he crossed the river in a boat. This he hardly could have done had the waters of the swollen river been moving down bodily at the wave's velocity.

10. Mr. Obbard in his paper attributes the low state of the river at Attock before the flood came, to the hollow which precedes a wave, like the tidal-wave in the Hooghly, and he takes the existence of this depression to be an argument in favour of his explanation. But this would rather appear to have arisen from the stoppage of the full supply of water in consequence of the dam being formed : and it is evident that there was no *cause* producing a hollow in the process explained above by which the wave was generated.

For example, in the illustration I have given above, if the plug began to rise again after it had reached the bottom of the river, a hollow wave *would* be formed by the rushing back of the water to supply the vacuum caused under the plug. The hollow wave thus produced is analogous to the convex wave, and would run along the canal after the convex wave. If the plug were thrust down again and then raised again, another pair of convex and concave waves would be formed. If the rise and fall of the plug occupied six hours each, the action would be like the influx and withdrawal of the tidal mass of water at the Sandheads from the Bay of Bengal, and the convex and concave waves would represent the high and low tides. In this mode of action a concave or hollow always precedes, as well as follows, a convex wave.

But in the case of the Indus there was only the *addition* of a mass of water to the river as it was before the catastrophe took place and the wave was formed, and no subtraction of water. A wave of *elevation only* was, therefore, formed, which ran down the river and passed off into the sea, spending much of its strength no doubt on the way, and in part perhaps restoring the lost level which had arisen from the stoppage of the supply.

On the Flat-horned Taurine Cattle of S. E. Asia; with a Note on the Races of Rein Deer, and a Note on Domestic Animals in general.—By Ed. Blyth.

The species of Bovine animals (so far as known), whether recent or fossil, resolve into three primary groups : viz.

I. *Bisontine.* II. *Taurine.* III. *Bubaline.* Two of these groups being again divisable as follow.

I. *Bisontine* (adapted for a frigid climate). Subdivided into—1. Ovibos (the 'Musk Ox' of the Arctic 'Barren grounds' of America; but which, formerly, during the glacial epoch, was far more extensively diffused, remains of this animal having been met with in