up the back. To Bob's surprise, his mother smiled, and he, encouraged thereby, laughed.

"I say, little mammy, I never thought I could be so happy in these garments."

"You are not very much *in* them," sighed his mother.

"I 'll wear them hereafter with pleasure," laughed Bob.

VI. WELL, IS HE EVER COMING BACK?

FROM the deck of the *Empress of India* Bob at last saw a small gray figure arrive upon the pier. He thought it looked just a little woeful. He dashed down the gang-plank and almost over it.

"I knew you 'd come!" he cried.

She seemed frightened by his ardor.

"House is all fixed up again."

He saw by her face that she knew this.

"I say, it was good of you and Amaterasu to bring on that earthquake just at the right moment, and give me a chance."

"You *got* make speech then!"

Bob shouted joyously. He had about exhausted his small talk.

"Tha' 's mos' bes' nize speech of all."

"An' that the mos' bes' nize earthquake of all."

"Me? I also lig gents what kin *do* things."

"Me? I also lig girls what kin *say* things."

The ship was giving its last warning.

"Well," began Bashful Bob, with another such an uprising in his throat as on the night of his party, holding out his hands. But she was looking down, and did not see them.

"Sa-*ay*, you aever coming back at Japan 'nother time? Me? I think I git that lonely —if you don'," was what she was murmuring.

It was her most charming pose again.

"*Am* I ever coming back? Oh, say, look up here!"

She did it; and Bob, who had seen a man on his right snatch a kiss and run up the gang-plank, did the same—such is the bane of example.

And all down the bay Bob kept his handkerchief going, and Kohana-San kept answering it, till long after he was out of sight. Then she turned happily away.

"Tha' 's firs' time I aever been kiss," she mused, as she went. "Tha' 's—tha' 's mos' bes' nize—" she thought a moment, "tha' 's *mos'* bes' nize—" She came into collision with a jinriki-man a moment later. She looked up with the little dream still in her eyes, and murmured: "Tha' 's mos' *bes'* nize—" Kohana-San smiled. "*Gomen nasai*" ("I beg your pardon"), she said, still smiling, as she went on her way.

BORES.

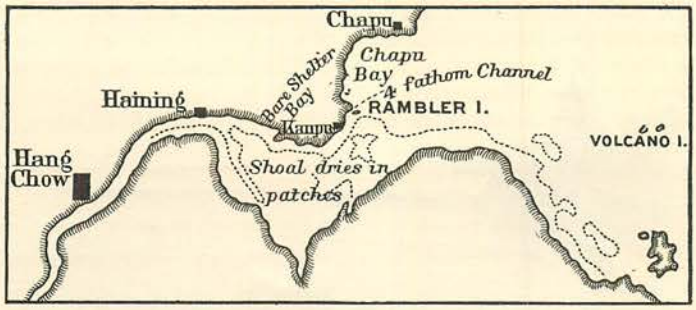
BY PROFESSOR GEORGE H. DARWIN.

THERE are in the estuaries of many rivers broad flats of mud or sand which are nearly dry at low water, and in such situations the tide not unfrequently rises with such great rapidity that the wave assumes the form of a wall of water. This sort of tide-wave is called a "bore," and in French *mascaret*. Notwithstanding the striking nature of the phenomenon, very little has been published on the subject, and I know of only one series of systematic observations of the bore. As the account to which I refer is contained in the official publications[1] of the English Admiralty it has probably come under the notice of only a small circle of readers. But the experiences of the men engaged in making these observations were so striking that an account of them should prove of interest to the general public. In writing this article I have, moreover, through the kindness of Admiral Sir William Wharton, the advantage of supplementing verbal description with some previously unpublished photographs.

After the description of the bore itself, I shall endeavor to give some explanation of the causes which lead to this remarkable sort of tide-wave.

The estuary on which the observations were made is that of the Tsien-Tang-Kiang, a considerable river which flows into the China Sea about sixty miles south of the great Yangtse-Kiang. At most places the bore occurs only intermittently, but in this case it travels up the river at every tide.

[1] "Report on the Bore on the Tsien-Tang-Kiang," by Commander Moore, R. N., 1888. "Further Report," etc., 1892. Potter, 31 Poultry, London.



THE ESTUARY OF THE TSIEN-TANG-KIANG.

The bore may be observed within seventy miles of Shanghai, and within an easy walk of the great city of Hangchow; and yet nothing more than a mere mention of it is to be found in any previous publication.

In 1888 Captain Moore, R. N., being in command of her Majesty's surveying-ship *Rambler*, thought that it was desirable to make a thorough survey of the river and estuary. He returned to the same station in 1892; and the account which I give of his survey is derived from reports drawn up after his two visits. The accompanying sketch-map shows the estuary of the Tsien-Tang, and the few places to which I shall have occasion to refer are marked thereon.

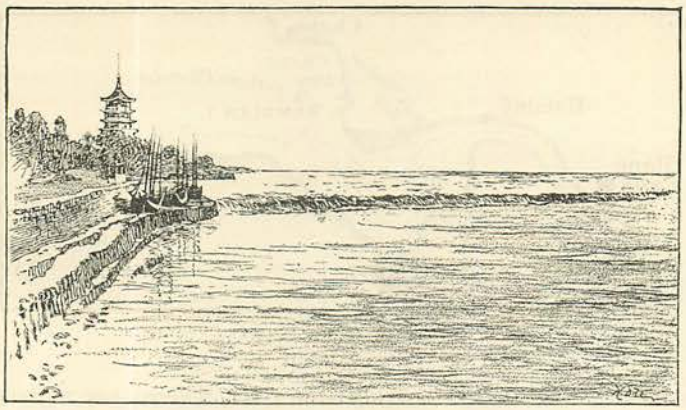
On the morning of September 19, 1888, the *Rambler* was moored near an island, named after the ship, to the southwest of Chapu Bay; and on the 20th the two steam-cutters *Pandora* and *Gulnare*, towing the sailing-cutter *Brunswick*, left the ship with instruments for observing and a week's provisions.

Captain Moore had no reason to suspect that the tidal currents would prove dangerous out in the estuary, and he proposed to go up the estuary about thirty miles to Haining, and then follow the next succeeding bore up-stream to Hangchow. Running up-stream with the flood, all went well until about 11:30, when they were about fifteen miles southwest by west of Kanpu. The leading boat, the *Pandora*, here grounded, and anchored quickly, but swung round violently as far as the keel would let her. The other boats, being unable to stop, came up rapidly; and the *Gulnare*, casting off the *Brunswick*, struck the *Pandora*, and then drove on to and over the bank, and anchored. The boats soon floated in the rising flood, and although the engines of the steam-cutters were kept going full speed, all three boats dragged their anchors in an eleven-knot stream. When the flood slackened, the three boats pursued their course to the mouth of the river, where they arrived about 4 P. M. The ebb was, however, so violent that they were unable to anchor near one another. Their positions were chosen by the advice of some junkmen, who told Captain Moore, very erroneously as it turned out, that they would be safe from the night bore.

The night was calm, and at 11:29 the murmur of the bore was heard to the eastward; it could be seen at 11:55, and passed with a roar at 12:20, well over toward the opposite bank, as predicted by the Chinese. The danger was now supposed to be past; but at 1 A. M. a current of extreme violence caught the *Pandora*, and she had much difficulty to avoid shipwreck. In the morning it was found that her rudder-post and propeller-guard were broken, and the other boats, the *Brunswick* and the *Gulnare*, were nowhere to be seen. They had, in fact, been in considerable danger, and had dragged their anchors three miles up the river. At 12:20 A. M. they had been struck by a violent rush of water in a succession of big ripples. In a few moments they were afloat in an eight-knot current; in ten minutes the water rose nine feet, and the boats began to drag their anchors, although the engines of the *Gulnare* were kept going full speed. After dragging for three miles, the rush subsided, and when the anchor was hove up, the pea of the anchor and the greater part of the chain were as bright as polished silver.

This account shows that all the boats were in imminent danger, and that great skill was needed to save them. After this experience and warning, the survey was continued almost entirely from the shore.

The junks which navigate the river are well aware of the dangers to which the English boats were exposed, and they have an ingenious method of avoiding them. At various places on the bank of the river there are shelter platforms, of which I show an illustration. Immediately after the pass-



BORE OF THE TSIEN-TANG-KIANG. PAGODA AND SHELTER PLATFORM.

ing of the bore the junks run up-stream with the after-rush, and make for one of these shelters, where they allow themselves to be left stranded on the raised platform shown in the picture. At the end of this platform there is a sort of round tower jutting out into the stream. The object of this is to deflect the main wave of the bore so as to protect the junks from danger. After the passage of the bore, the water rises on the platform very rapidly, but the junks are just able to float in safety. Captain Moore gives a graphic account of the spectacle afforded by the junks as they go up-stream, and describes how, on one occasion, he saw no less than thirty junks swept up in the after-rush, at a rate of ten knots, past the town of Haining toward Hangchow, with all sail set, but with their bows in every direction.

Measurements of the water-level were made in the course of the survey, and the results, in the form of a diagram, exhibit the nature of the bore with admirable clearness. The observations of water-level were taken simultaneously at three places, viz.: Volcano Island, in the estuary; Rambler Island, near the mouth of the river; and Haining, twenty-six miles up the river. In the figure, the distance between the lines marked "Rambler" and "Volcano" represents fifty-one miles, and that between "Rambler" and "Haining" twenty-six miles. The vertical scales show the height of water, measured in feet, above and below the mean level of the water at these three points. The lines joining the vertical scales, marked with the hours of the clock, show the height of the water simultaneously. The hour of 8:30 is indicated by the lowest line; it shows that the water was one foot below mean level at Volcano Island, twelve feet below at Rambler Island, and eight feet below at Haining. Thus the water sloped down from Haining to Rambler, and from Volcano to Rambler; the water was running up the estuary toward Rambler Island, and down the estuary to the same point. At 9 and at 9:30 there was no great change, but the water had risen two or three feet at Volcano Island and at Rambler Island. By ten o'clock the water was rising rapidly at Rambler Island, so that there was a nearly uniform slope up the river from Volcano Island to Haining. The rise at Rambler Island then continued to be very rapid, while the water at Haining remained almost stationary. This state of affairs went on until midnight, by which time the water had risen twenty-one feet at Rambler Island, and about six feet at Volcano Island, but had not yet risen at all at Haining. No doubt, through the whole of this time, the water was running down the river from Haining toward its mouth. It is clear that this was a state of strain which could not continue long, for there was over twenty feet of difference of level between Rambler Island, outside, and Haining, in the river. Almost exactly at midnight the strain broke down, and the bore started somewhere between Rambler Island and Kanpu, and rushed up the river in a wall of water twelve feet high. This result is indicated in the figure by the presence of two lines marked "midnight." After the bore had passed there was an after-rush that carried the water up eight feet more. It was on this that the junks were swept up the stream, as already described. At 1:30 the after-rush was over, but the water was still somewhat higher at Rambler Island than at Haining, and a gentle current continued to set up-stream. The water then began to fall at Rambler Island, while it continued to rise at Haining up to three o'clock. At this point the ebb of the tide sets in. I do not repro-

duce the figure which exhibits the fall of the water in the ebbing tide, for it may suffice to say that there is no bore down-stream, although there is at one time a very violent current.

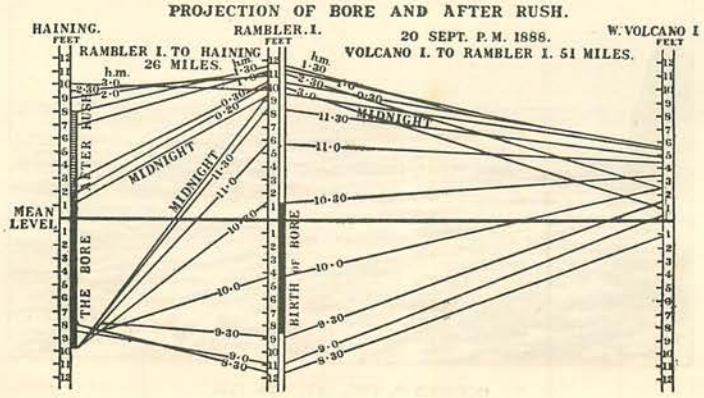
In 1892, Captain Moore succeeded, with considerable difficulty, in obtaining these photographs of the bore as it passed Haining. They tell more of the violence of the wave than could be conveyed by any amount of description. The photographs, however, do not show what is often the case, namely, that the broken water in the rear of the crest is often disturbed by a secondary roller, or miniature wave, which leaps up, from time to time, as if struck by some unseen force, and disappears in a cloud of spray. These breakers were sometimes twenty to thirty feet above the level of the river in front of the bore.

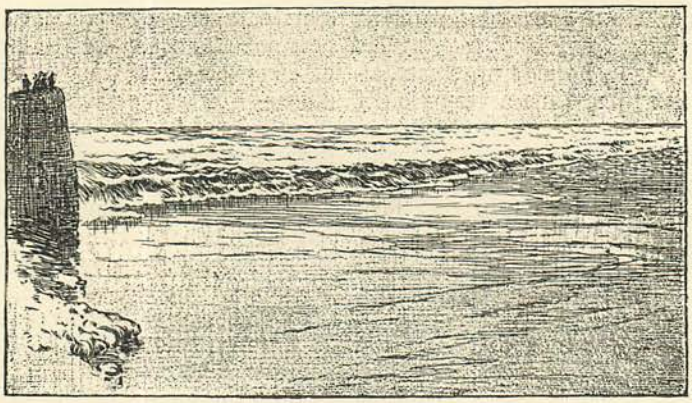
The Chinese regard the bore with superstitious reverence, and their explanation, which I quote from Captain Moore's report, is as follows: "Many hundred years ago there was a certain general who had obtained many victories over the enemies of the Emperor, and who, being constantly successful and deservedly popular among his countrymen, excited the jealousy of his sovereign, who had for some time observed with secret wrath his growing influence. The Emperor accordingly caused him to be assassinated and thrown into the Tsien-Tang-Kiang, where his spirit conceived the idea of revenging itself by bringing the tide in from the ocean in such force as to overwhelm the city of Hangchow, then the magnificent capital of the empire. As my interpreter, who has been for some years in America, put it, 'his sowl felt a sort of ugly-like arter the many battles he had got for the Emperor.' The spirit so far succeeded as to flood a large portion of the country, when the Emperor, becoming alarmed at the distress and loss of property occasioned, endeavored to enter into a sort of compact with it by burning paper and offering food upon the sea-wall. This, however, did not have the desired effect, as the high tide came in as before; and it was at last determined to erect a pagoda at the spot where the worst breach in the embankment had been made. Hence the origin of the Bhota Pagoda. A pagoda induces the good *fungshui*, or spirit. After it was built, the flood-tide, though it still continued to come in the shape of a bore, did not flood the country as before."

We "foreign devils" may take the liberty of suspecting that the repairs to the embankment had also some share in this beneficial result.

This story is remarkable in that it refers to the reign of an emperor whose historical existence is undoubted. It thus differs from many of the mythical stories which have been invented by primitive peoples to explain great natural phenomena. There is good reason to suppose, in fact, that this bore had no existence some centuries ago; for Marco Polo, in the thirteenth century, stayed about a year and a half at Hangchow, and gives so faithful and minute an account of that great town that it is almost impossible to believe that he would have omitted to notice a fact so striking. But the Emperor referred to in the Chinese legend reigned some centuries before the days of Marco Polo, so that we have reason to believe that the bore is intermittent. I have also learned from Captain Moore himself that at the time of the great Taiping rebellion, the suppression of which was principally due to "Chinese" Gordon, the intensity of the bore was far less than it is to-day. This shows that the bore is liable to great variability, according as the silting of the estuary changes.

PROJECTION OF BORE AND AFTER RUSH.





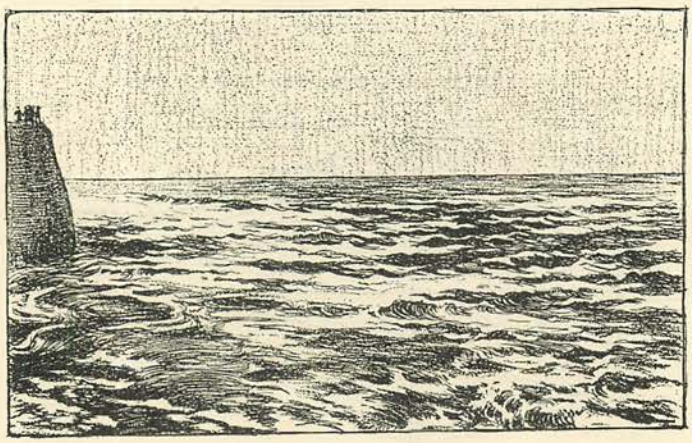
BORE OF THE TSIEN-TANG-KIANG. OCTOBER 9, 1892, AT 1:28 P. M.

The people at Haining still continue to pay religious reverence to the bore, and on one of the days when Captain Moore was making observations, some five or six thousand people assembled on the river-wall to propitiate the god of the waters by throwing in offerings. This was the occasion of one of the highest bores at spring tide, and the rebound of the bore from the sea-wall, and the sudden heaping up of the waters as the flood conformed to the narrow mouth of the river, here barely a mile in width at low water, was a magnificent spectacle. A series of breakers were formed on the back of the advancing flood, which for over five minutes were not less than twenty-five feet above the level of the river in front of the bore. On this occasion Captain Moore made a rough estimate that a million and three quarters of tons of water passed the point of observation in one minute.

The bore of which I have given an account is perhaps the largest known; but relatively small ones are to be observed on the Severn and Wye in England, on the Seine in France, on the Petitcodiac in Canada, on the Hugli in India, and doubtless in many other places. In general, however, it is only at spring tides, and with certain winds, that the phenomenon is at all striking. In September, 1897, I was on the banks of the Severn at spring tide; but there was no proper bore, and only a succession of waves up-stream, and a rapid rise of water-level.

The reader will naturally ask why the tide should rise in this tumultuous manner. In answer, I would say that, while a complete explanation cannot be given, yet some light may be thrown on the physical causes of the wave. It would not, indeed, be possible, from the mere inspection of an estuary, to say whether the tide would rise as a bore or not; we could only say that the situation looked promising or the reverse. In order to give such explanation as is possible, I must now consider the nature of the tide-wave.

The sea resembles a large pond, in which the water rises and falls with the oceanic tide, and a river is a canal which leads into it.

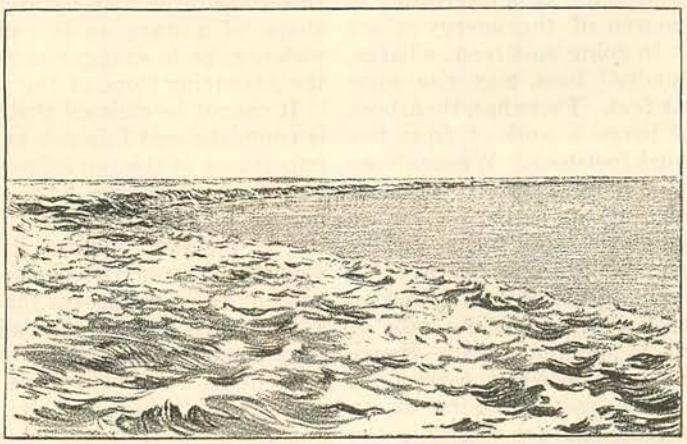


OCTOBER 9, 1892, AT 1:29 P. M.

The rhythmical rise and fall of the sea generates waves which would travel up the river, whatever were the cause of the oscillation of the sea. Accordingly, a tide-wave in a river owes its origin directly to the tide in the sea, which is itself produced by the tidal attractions of the sun and moon.

When the length of a wave is greater than the depth of the water, it progresses at a speed independent of wave-length, and dependent only on the depth of the water. Now a river is very shallow compared with the length of the tide-wave, and therefore the velocity of the wave depends only on the depth of the river. The speed of propagation in the river is very slow compared with that of the great oceanic tide-wave in the open sea.

rises as much above that level at high water as it falls below it at low water. The law of tidal current is, then, very simple. Whenever the water stands above the mean level the current is up-stream and progresses along with the tide-wave; and whenever it stands below mean level the current is down-stream and progresses in the direction contrary to the tide-wave. Since the current is up-stream when the water stands above mean level, and down-stream when it stands below mean level, it is obvious that when it stands exactly at mean level, the current is neither up nor down, and the water is slack or dead. Also, at the moment of high water the current is most rapid up-stream, and at low water it is most rapid down-stream. Hence the tidal current "flows" for a long time after high



OCTOBER 10, 1892, ELEVEN FEET HIGH.

The terms "ebb" and "flow" are applied to tidal currents. The current ebbs when the water is receding from the land seaward, and flows when it is approaching the shore. On the open sea-coast the water ebbs as the water-level falls, and it flows as the water-level rises. Thus at high and low tide the water is neither flowing landward nor ebbing seaward, and we say that the water is slack or dead. In this case ebb and flow are simultaneous with rise and fall, and it is not uncommon to hear the two terms used synonymously; but we shall see that this usage is incorrect.

I begin by considering the tidal currents in a river of uniform depth, so sluggish in its own proper current that it may be considered as a stagnant canal, and the only currents to be considered are tidal currents. At any point on the river-bank there is a certain mean height of water, such that the water has passed and when the water-level is falling, and "ebbs" for a long time after low water and when the water-level is rising.

The law of tidal currents in a uniform canal communicating with the sea is thus very different from that which holds on an open sea-coast, where slack water occurs at high and at low water instead of at mean water. But rivers gradually broaden and become deeper as they approach the coast, and therefore the tidal currents in actual estuaries must be intermediate between the two cases of the open sea-coast and the uniform canal.

A river has also to deliver a large quantity of water into the sea in the course of a single tidal oscillation, and its own proper current is superposed on the tidal currents. Hence in a river the resultant current continues to flow up-stream after high water is reached, with falling water-level, but ceases flowing

before mean water-level is reached; and the resultant current ebbs down-stream after low water, and continues to ebb with the rising tide until mean water is reached, and usually for some time afterward. The downward stream, in fact, lasts longer than the upward one. The moments at which the currents change will differ in each river, according to the depth, the rise and fall of the tide at the mouth, and the amount of water delivered by the river. An obvious consequence of this is that in rivers the tide rises quicker than it falls, so that a shorter time elapses between low water and high water than between high water and low water.

It may be here remarked, parenthetically, that the upward flow of water in a river with the flowing tide is used, almost all over the world, for enabling barges and boats to carry goods up-stream. It is interesting to consider the source of the energy which does the work. In going up-stream, a barge, say, of one hundred tons, may rise some twenty or thirty feet. There has, then, been done upon that barge a work of from two to three thousand foot-tons. Whence does this energy come? Now, I say that it comes from the rotation of the earth; for we are making the tide do the work for us, and by so doing we increase the friction to which tidal movement is subject. But tidal friction has the effect of diminishing the rate at which the earth is spinning round. Hence it is the earth's rotation which carries the barge up the river, and (of course to an infinitesimal degree) we are retarding the earth's rotation, and making the day longer by using the tide in this way. But this is not the place to go further into this matter, and I must return to the consideration of the behavior of waves in rivers.

I have not yet spoken of another important peculiarity of the tide in rivers. The complete theory of waves in shallow water being too technical for an article of this sort, I must ask the reader to accept as a fact that a wave cannot progress along a river without changing its shape. The change is such that the front slope of the wave gradually gets steeper, and the rear slope becomes more gradual. If the steepening of the advancing slope of a wave were carried to an extreme, the wave would present the form of a wall of water; but the mere advance of a wave into shallow water would by itself never suffice to produce so great a change of form without the concurrence of the natural stream of the river. The downward current in the river has, in fact, a very important influence in heading the sea-water back, and this coöperates with natural change in the shape of a wave as it runs into shallow water, so as to exaggerate the steepness of the advancing slope of the wave.

It cannot be claimed that the explanation is complete, and I do not know the relative importance of the two influences which combine to produce the bore. It only serves, indeed, to explain the fact of a very rapid rise in the tide, and not its absolute suddenness. The capriciousness of the appearance of the bore proves that it depends on a very nice balance between conflicting forces; and the irregularity in the depth and form of an estuary renders the exact calculation of the form of the rising tide an impossibility. It would be easy to imitate the bore experimentally on a small scale, but, as in many other physical problems, we must rest satisfied with a general comprehension of the causes which produce the observed result.

A CHORD.

BY MARY AINGE DE VERE.

I LOVE you, dear. When I have said the words
My lips grow dumb, speech has been beggared quite,
As if some mastering hand had swept the chords
Of all my life into one chord of might,
That rang—and snapt! . . . And I, the quivering lute,
Throbbing with music still, must evermore be mute!