marks of fire. There can be no doubt that this stratum marks the place where the dwellers in the cave, during Roman or immediately post-Roman times in Britain, kindled their fires and cooked their food. Underneath is a talus of limestone fragments detached from the cliff by atmospheric action, like the superficial accumulation. It is from six to seven feet in thickness. In some places the fragments were cemented together with a soft decomposing stalagmite. It rested on a layer of grey clay, of a thickness which at present has not been ascertained. At the bottom of the talus, and close to the entrance that is now being made into the chamber, there were found two rude flint flakes, a remarkably large lower jaw of bear, the broken bones of the Celtic shorthorn (*Bos longifrons*), and of the red-deer. On the 4th April a most remarkable bone harpoon was dug out from the same horizon. It is between four and five inches in length, and is furnished with two barbs on each side, arranged opposite each other, composing the head of the implement. The base presents a form of attachment to the handle which, so far as my knowedge extends, is new to Britain. Instead of having a mere projection to catch the ligatures, there is a well-cut barb on either side that points in a contrary direction to those on the head. Were the bases of a barbed arrowhead and of a harpoon joined together, the resultant form would be analogous to the one in question. There can be no doubt from the position of these remains, that man occupied the spot before the accumulation of the overlying *débris*. Ample use for his harpoon he would find in the mere, now drained and turned into green fields, which are almost overlooked by the cave. So far as the work has proceeded there is no trace of metal at this horizon in the section.

The value of the evidence hitherto obtained lies in the fact that the Roman stratum is separated from the lower level, in which the flints, harpoon, and bear were found by the talus of angular stones. And this in a rough way enables a computation to be made of the date of the lapse of time between them, if we allow that for a considerable time past, immediately outside the historical epoch, the disintegration of the cliff has been equal, in equal times. For since, in twelve hundred years, to put it at the lowest, only a thickness of twenty-four inches has been accumulated above the Roman remains, it would take three thousand six hundred years for a deposit of six feet to be formed, and thus the harpoon and flint stratum would be about four thousand years old. The accuracy of this calculation is indeed injured by the possibility that the winter cold was more intense, and the splitting action of the frost greater in Pre-, than in Post-Roman times. Nevertheless, the change from the Arctic severity of the post-glacial winter, to the climate which we now enjoy in Britain, has been so gradual, and has been spread over so long a period, that it may be assumed to have been very small in so short a time as four or five thousand years.

This account is merely an outline of the results obtained up to April the 4th. The cave promises to be a rich one, and will probably add very much to our knowledge of the Pre-historic dwellers in Yorkshire.

W. BOYD DAWKINS

THE ABRADING AND TRANSPORTING POWER OF WATER

I.—MECHANICAL PROPERTIES OF WATER

IT is not my intention to lay down definite rules or formulæ regarding the flow of water, but rather, by drawing attention to generally-acknowledged facts, to throw out suggestions which may serve to lead to the discovery of some general laws of practical use to the hydraulic engineer.

In 1857 a paper was read by me before the Royal Society of Edinburgh, "On the Delta of the Irrawaddy," in which I expressed an opinion that depth somehow affected the abrading and transporting power of water.

My experience of Indian rivers and canals during the succeeding ten years went to confirm this opinion, and before the Institution of Civil Engineers, as well as on two occasions before the British Association in 1868 and 1869, I ventured to give expression to my views of this law, as affecting artificial rivers for irrigation, and the bridging of rivers which flow through the alluvial plains of Northern India.

In the *Artizan* there have appeared during the last six months several short articles bearing on the same subject, showing how all questions relating to flowing water are affected by this supposed law, which may be stated as follows: "*the abrading and transporting power of water increases in some proportion as the velocity increases, but decreases as the depth increases.*"

The first question that arises in this inquiry is—What is water in a mechanical point of view?

This may be briefly answered by saying that it is a fluid, the particles of which, though easily separated, do again unite, and exert a certain affinity towards each other, and also to other bodies, so that a certain amount of power is necessary to effect a separation. The attraction of the particles of water to other bodies varies with different substances; for instance, in all bodies of a fatty nature the facility for wetting is very slight; and different temperatures also affect this property of water. This attraction or force is technically known as "skin friction," and deserves the most careful investigation; for it is owing chiefly, if not altogether, to the fact that water has the power of abrasion, and it is this property which introduces the most difficult problems that a naval architect has to solve.

The affinity of one set of particles of water to another set, may possibly be measured by noting the size of a drop of water which falls from a wetted surface of a given area. By thus determining accurately the weight of water a given area can support, some approximate results of an instructive character may be arrived at; but what adds to the complication of the question is, that the cohesion of the particles probably differs according to the temperature and the purity of the water experimented on. Thus, when water reaches the boiling point the affinity, it is believed, becomes very much lessened; and, again, it is thought that with pure or distilled water the particles probably have less affinity to each other than with water less pure. This impurity may arise from various causes; sewage, for example, would probably give much heavier drops from the same wetted area than rain water, in the same manner that drops of treacle are much larger than those of water; that is to say, the affinity, attraction, or cohesion of the particles is as a general rule increased by the introduction of foreign matter held in solution. With solid matter held in suspension a similar result is obtained, not by increasing the cohesion of the particles of water, but by increasing the surface area wetted; for each grain of foreign matter, be its shape what it may, must have all its surface in contact with the water. This probably explains how a drop of mud should be so much larger than one of water, and, at the same time, it may possibly explain why thick muddy water, or more properly speaking, liquid mud, with the same section and slope, cannot travel so fast as water.

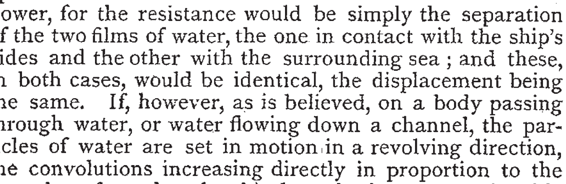
From this it may reasonably be supposed, that when muddy water runs down an inclined plane, the solid particles cannot by their own gravity sink so rapidly towards the bottom as to overcome the power dragging them in a different direction. As a consequence, the flow of water is retarded by having solid matter held in suspension in some proportion according to the load. On large rivers where this proportion may be only $\frac{1}{1000}$ or $\frac{1}{2000}$ part of the weight of water in motion, the retarding force may not be appreciable by the most careful experiments; so when calculating, the discharge may be left out altogether; but with torrents transporting 5 per cent. and more of solid matter, and with the discharge of sewage, it is believed that the retarding power is quite appreciable. The whole question is no doubt a very complicated one; yet by a set of careful experiments, conducted with a view to discover this adhesive power of water, it appears highly probable that an important step would be gained, towards the solution of some other difficult but important problems.

The next point to consider is—How does water travel? This also is a very abstruse question; but I believe that the true answer is given in the brief statement that water *rolls* rather than *slides*.

Were it not so, a ship with a foul bottom could not be so much retarded when passing through the water as experience shows she is. For example, supposing there are two ships in every respect the same, only that the first is covered with a coating of clean pitch a quarter of an inch thick all over her bottom to above her water line; and that the second, in place of the pitch, has got all her bottom covered with marine animals and weeds, so that when this second ship is passing rapidly through the water, none of the sea-weeds or marine animals extend more than this $\frac{1}{4}$ inch beyond the ship's sides, which is the thickness of the coating of pitch on the first ship: in such a case the displacement and the lines are exactly the same, but it is hardly necessary to ask any sailor which of the two ships, with the same wind and sails, would pass most rapidly through the water, and, in the case of two steamers, the extra resistance caused by the foul bottom could be easily measured in extra horse power required to force the foul vessel through the water at a speed equal to the other.*

If the motion of the water was a *sliding* one only, the speed in both cases would be the same with the same power, for the resistance would be simply the separation of the two films of water, the one in contact with the ship's sides and the other with the surrounding sea; and these, in both cases, would be identical, the displacement being the same. If, however, as is believed, on a body passing through water, or water flowing down a channel, the particles of water are set in motion in a revolving direction, the convolutions increasing directly in proportion to the wetted surface, then by this hypothesis some assignable reason for this retarding of the foul-bottomed ship can be given.

If the particles slid over each other rather than rolled, they would, so to speak, pass each other in parallel straight lines; but any one in a gale of wind, going behind a high square block of building, would very soon discover that, in air, such is not the case: for if he went a few yards away in the direction the wind was blowing, he would soon discover that the building no longer afforded any protection from the blast, but that there was some certain point to leeward where the currents again converged, while beyond this the storm raged with the same violence as at any other point. (Every boatman knows what it is to get under the lee of a very high island; the sea may be smoother, but the sudden gusts of wind are often more dangerous than when exposed to the full force of the gale.) Immediately in rear of the wall itself he would find eddies of air whirling about in all directions. Within the space



A B C D E there would be a partial protection from the storm, and instead of the wind being in the direction shown by the arrow, there would be whirling eddies within this space, which could not exist were the air to pass off in straight lines as represented by the dotted lines B B′, C C′, D D′, E E′; neither could the several currents of air converge at the point A, which it is well known is always the case.

In the same manner any obstruction placed in a stream of water, causes eddies in rear of it; that is to say, the water does not pass on in straight lines, but within this space it goes revolving about in all directions, the distance of A probably depending on the velocity: showing that there is neither a sliding motion nor a parallelism in the direction of the lines of current.*

T. LOGIN

* Possibly by the introduction of an elastic medium, such as air, between the ship's bottom and the water, the skin friction may be reduced, as it may, in a measure, reduce this rotatory action.

* By an experimental study of this subject, it may be discovered how far these eddies extend with different velocities, which may throw light on the proper length of the after portion of ships intended for different speeds.

THE CLIMATE OF IRELAND

IN the science of nature there is no chapter more interesting than that which treats of Physical Geography, which, properly understood, means the account of physical phenomena as they are modified by geographical position; and at the present moment the physical geography of Green Erin, or it speculiarities of soil and climate, presents a theme of no slight importance. It has been stated in the House of Commons as a proof of the retrograde condition of Ireland, that its production of cereals has of late years diminished, while its pasture lands have increased. To this it ought to have been answered that the decreased cultivation of cereals, and of wheat in particular, was a proof of improved knowledge. Years ago, at the meeting of the British Association in Cork, a communication was read, pointing out that agriculturists in general are governed wholly by example, their scanty science not allowing them to quit the beaten path. Hence Irish farmers, when they aim at improvement, endeavour to imitate the farming of Norfolk or the Lothians, and in so doing fail miserably, owing to the wide difference between the climates of the western isle and of the eastern side of Great Britain. It is commonly stated that Ireland has a very wet climate. It has undoubtedly a humid atmosphere, owing, perhaps, in some measure, to a great extent of undrained surface. But the total quantity of rain that falls in Ireland, little, if at all, exceeds the rainfall of England. In its distribution through the year, however, it differs much from the latter. The vicinity of the Atlantic gives Ireland in the highest degree an oceanic and, to some extent, an equatorial climate. Winter in the Green Isle is extremely mild. The southern and western coasts, though seldom free from wind and drizzling rain, never experience severe cold. Vegetation remains in mid-winter brilliantly green and undepressed. As spring advances, everything seems to flourish; crops of all kinds promise abundance, and already, in May, harvest seems to be close at hand. But now the scene changes. There is little or no dry summer. When the sun is highest in the meridian, there is a constantly clouded sky and no sunshine. Rain begins to fall in June. The rainfall of July is the heaviest in the year. In August the rain begins to abate; but clear skies and bright sunshine cannot be reckoned on till September, when the shortened days and the sun's declination have much reduced the solar heat. The crops in the meantime, arrested in their progress, are not the better for two months' slumbering under the clouds They have summer rain in excess, and too little sunshine. From this it will be seen that the character of the Irish climate is, that under it everything grows well, but that the process of ripening is painfully slow and uncertain. Now, to cultivators of the cereals the success of this process is of the utmost importance. The corn harvest in Ireland falls late in the year, in September and October, when the days are short and nocturnal frosts not unfre-