TIDES

I. On the Nature of Tides.

§ 1. *Definition of Tide.*

WHEN, as occasionally happens, a ship in the open sea meets a short succession of waves of very unusual magnitude, we hear of tidal waves ; and the large wave caused by an earthquake is commonly so described. The use of the term “ tide ” in this connexion is certainly incor­rect, but it has perhaps been fostered by the fact that such waves impress their records on automatic tide-gauges, as, for example, when the wave due to the volcanic outbreak at Krakatoa was thus distinctly traceable in South Africa, and perhaps even faintly at Brest. We can only adequately define a tide by reference to the cause which produces it. A tide then is a rise and fall of the water of the sea pro­duced by the attraction of the sun and moon. A rise and fall of the sea produced by a regular alternation of day and night breezes, by regular rainfall and evaporation, or by any influence which the moon may have on the weather cannot strictly be called a tide. Such alternations may, it is true, be inextricably involved with the rise and fall of the true astronomical tide, but we shall here distinguish them as meteorological tides. These movements are the result of the action of the sun, as a radiating body, on the earth. Tides in the atmosphere would be shown by a regular rise and fall in the barometer, but such tides are undoubtedly very minute, and we shall not discuss them in this article, merely referring the reader to the *Mécanique Celeste* of Laplace, bks. i. and xiii. There are, however, very strongly marked diurnal and semi-diurnal inequalities of the barometer due to atmospheric meteorological tides. Sir William Thomson in an interesting speculation@@1 shows that the interaction of these quasi-tides with the sun is that of a thermodynamic engine, whereby there is caused a minute secular acceleration of the earth’s rotation. This matter is, however, beyond the scope of the present article. We shall here extend the term “ tide ” to denote an elastic or viscous periodic deformation of a solid or viscous globe under the action of tide-generating forces. In the techni­cal part of the article by the term “a simple tide” we shall denote a spherical harmonic deformation of the water on the surface of the globe, or of the solid globe itself, multiplied by a simple harmonic function of the time.

§ 2. *General Description of Tidal Phenomena.@@2*

If we live by the sea or on an estuary, we see that the water rises and falls nearly twice a day ; speaking more exactly, the average interval from high water to high water is about 12h 25m, so that the average retardation from day to day is about 50m. The times of high water are then found to bear an intimate relation with the moon’s position. Thus at Ipswich high water occurs when the moon is nearly south, at London Bridge when it is south­west, and at Bristol when it is east-south-east. For a very rough determination of the time of high water it is suffi­cient to add the solar time of high water on the days of new and full moon (called the “establishment of the port”) to the time of the moon’s passage over the meridian, either visibly above or invisibly below the horizon. The interval between the moon’s passage over the meridian and high water varies sensibly with the moon’s age. From new moon to first quarter, and from full moon to third quarter (or rather from and to a day later than each of these phases), the interval diminishes from its average to a mini­

mum, and then increases again to the average ; and in the other two quarters it increases from the average to a maxi­mum, and then diminishes again to the average.

The range of the rise and fall of water is also subject to great variability. On the days after new and full moon the range of tide is at its maximum, and on the day after the first and third quarter at its minimum. The maximum is called “ spring tide ” and the minimum “ neap tide,” and the range of spring tide is usually between two and three times as great as that of neap tide. At many ports, how­ever, especially non-European ones, two successive high waters are of unequal heights, and the law of variability of the difference is somewhat complex ; a statement of that law will be easier when we come to consider tidal theories. In considering any tide we find, especially in estuaries, that the interval from high to low water is longer than that from low to high water, and the difference between the intervals is greater at spring than at neap.

In a river the current continues to run up stream for some considerable time after high water is attained and to run down similarly after low water. Much confusion has been occasioned by the indiscriminate use of the term “ tide ” to denote a tidal current and a rise of water, and it has often been incorrectly inferred that high water must have been attained at the moment of cessation of the upward current. The distinction between “rising and falling” and “flowing and ebbing” must be carefully maintained in rivers, whilst it vanishes at the seaboard. If we examine the progress of the tide-wave up a river, we find that high water occurs at the sea earlier than higher up. If, for instance, on a certain day it is high water at Margate at noon, it is high water at Gravesend at a quarter past two, and at London Bridge a few minutes before three. The interval from low to high water diminishes also as we go up the river ; and at some distance up certain rivers—as, for example, the Severn—the rising water spreads over the flat sands in a roaring surf and travels up the river almost like a wall of water. This kind of sudden rise is called a “ bore.”@@3 In other cases where the differ­ence between the periods of rising and falling is consider­able, there are, in each high water, two or three rises and falls. A double high water exists at Southampton.

When an estuary contracts considerably, the range of tide becomes largely magnified as it narrows ; for example, at the entrance of the Bristol Channel the range of spring tides is about 18 feet, and at Chepstow about 50 feet. This augmentation of the height of the tide-wave is due to the concentration of the energy of motion of a large mass of water into a narrow space. At oceanic ports the tidal phenomena are much less marked, the range of tide being usually only 2 or 3 feet, and the interval from high to low water sensibly equal to that from low to high water. The changes from spring to neap tide and the relation of the time of high water to the moon’s transit remain, how­ever, the same as in the case of the river tides.

In long and narrow seas, such as the English Channel, the tide in mid-channel follows the same law as at a station near the mouth of a river, rising and falling in equal times; the current runs in the direction analogous to up stream for three hours before and after high water, and down stream for the same period before and after low water. But near the sides of channels and near the mouths of bays the changes of the currents are very complex ; and near the headlands separating two bays there is usually at certain times a very swift current, termed a “ race.”

@@@1 Société de Physique, September 1881, or Proc. Roy. Soc. of Edinburgh, 1881-82, p. 396.

@@@2 Founded on Airy’s “Tides and Waves,” in Ency. Μetrop.

@@@3 See a series of papers bearing on this kind of wave by Sir W. Thomson, in Phil. Μag., 1886-87.