TIDAL RESEARCH IN THE RED SEA AND THE GULF OF SUEZ (1)

by Mme EDMÉE CHANDON

This research was suggested to the author by the strange results reached by the Astronomer A. BLONDEL in his thesis "On the theory of Tides in channels with special reference to the Red Sea".

Using the harmonic constants observed at Périm, BLONDEL applied the RITZ method and obtained a much higher value than that observed for the amplitude of the principal semi-diurnal tide at the Northern end of the Sea (Shermsheik), *viz.* 5 metres instead of 0.25 metres. He considered that this divergence might be attributed to friction and proposed to re-examine the tides in this Sea after ascertaining the numerical value of the coefficients which the friction hypothesis introduces into the equations. But, in 1916, the services of this young astronomer were lost to Science for he died in the service of his country, and Mme CHANDON took up the research where he dropped it.

This research is of all the higher interest in that the hydrographic expedition carried out in 1923 and 1924 by the Italian Navy have given accurate harmonic constants for the principal constituents in eight parts of the Red Sea.

In the first chapter all the observational data which are necessary for the study of the variations of the tide in the Red Sea and in the Gulf of Suez, are collected.

In the second chapter Mme CHANDON has checked the lengthy calculations necessary in the RITZ method and directs attention to two numerical errors at the end of BLONDEL's thesis. Having made the necessary corrections she completed the examination of the tides in the Red Sea and the results obtained agree fairly well with observed results. Yet the remainder "Observations minus Calculations" with reference to amplitudes are negative throughout, which seems to suggest that the effect of friction is not entirely negligeable.

It must be noted, however, that the type of tide varies very rapidly in the close neighbourhood of the Island of Perim and that the observational data in this area are somewhat scanty, and thus it was considered better to re-examine the tides, adopting Shermsheik, the Northern closed extremity of the Red Sea, as the point of departure.

The method employed in chapters III and IV, which is shorter than that used by RITZ, is but summarized in the standard works. It consists in replacing any channel which is closed at one extremity by a series of similar channels which are such that each has a constant depth and has a width which is either constant or an exponential function of the distance x from the closed extremity, the distance being measured along the axis of the channel.

The sub-division of the channel may be carried out so that the generating potential $\frac{W_i}{g}$ of any given wave will have the form $A_i+B_i x+C_i x^2$, where A_i, B_i, C_i are harmonic functions of the time in each similar channel (2). In this way a differential equation is obtained for each similar channel which may be integrated, and it is easy to turn up formulae of recurrence which will allow channel $i+1$ to be examined when channel i has been examined.

As no detailed calculations have yet been made for this method, the author thought it might be interesting to apply it to two channels of very different dimensions, namely the Red Sea, which is 1,975 km. long (from Shermsheik to Perim) and the depth of which is over 1,000 metres in the central part, and the Gulf of Suez which is 300 km. long and has an average depth of 45 metres.

Soundings taken recently have made it possible to obtain an approximate determination of the mean depth at 18 profiles at right angles to the axis of the Red Sea, and thus this sea can be divided into 4 channels whose length is 1,076, 467, 260, and 172 km. respectively, the depths of these being 692, 359, 146, and 43 metres respectively.

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(1) *Thesis for the degree of Doctor of Mathematical Science to the Faculté des Sciences of Paris in* 1930, 8vo, 100 *pages, Gauthier-Villars & Cie, Paris,* 1930.

(2) POINCARÉ, *Théorie des Marées,* § 132.

Between Suez and Assab, *i. e.* for a distance of about 2,200 km. where the amplitudes of the various tides reach 30 cm., in certain areas the differences (observation minus calculation) found are on an average 2 c/m, and as these differences do not appear to be regular Mme CHANDON rightly concludes, first that the method used is quite satisfactory, and second that friction and tidal movements in the earth's crust do not have any appreciable effect on the tides of the Red Sea or even on those of a shallow gulf, such as the Gulf of Suez.

At Périm the calculated amplitude of the semi-diurnal tide concurs with the observed amplitude, but the calculated amplitude of the diurnal tide does not exceed 1 c/m whereas the observed amplitude of the principal component K_1 reaches 35 centimetres. If HARRIS's theory be accepted these results may be explained as follows: there is considerable resonance of the Red Sea and the Indian Ocean with the semi-diurnal period, but for the diurnal period the Indian Ocean only gives suitable resonance, whereas the Red Sea does not.

Hence the rapid variation in the amplitude of the diurnal tide in the straits which connect these two basins, which variation the method of division into channels of constant depth, which is applicable to a narrow sea only, is unable to disclose.

The following information may also be drawn from the research made in these seas. In the Gulf of Suez the variation in width has no appreciable influence on the tide, and the fact that the calculated amplitudes at points on the axis of the gulf agree satisfactorily with the observed amplitudes in the neighbourhood of the coast shows that the tide is practically the same right across the section perpendicular to the axis; this statement is applicable to the Red Sea also.

While examining the tides of the Red Sea by the method of division into channels of constant depth it was found that there was no advantage in dividing the sea into a large number of parts; the general run of the variation in mean depth will always be sufficient guide in selecting the smaller channels.

It was noted also that no systematic error was introduced by including a generating potential, and the suppression of this simplifies the calculation very much.

Finally the formulae which represents the variation of the tide in these areas where the mean depth is greater than about 140 metres (which is the case in channels 1, 2, and 3), were drawn up on the basis of the depth found by sounding. By using a depth which is somewhat different the results, so far as amplitudes and cotidal hours are concerned, are scarcely modified. For instance in areas where the mean depth is about 800 metres, it makes no difference if an error of 100 metres in depth is made.

However, to represent the tide in channel 4 and in the Gulf of Suez correctly, in which areas the mean depth is less than 80 metres, the method of successive approximations had to be used. An error of 2 metres only in depths of 44 metres produces at certain places a variation in the amplitude which may exceed 2 centimetres in the tide of a semi-diurnal wave. As soundings are more numerous in the shallow parts, it is possible to find the depth, after several trials around about the figure calculated from the soundings, which agrees best with the whole of the observations.

Mme CHANDON intends to apply the method of division into channels of constant depth to closed seas which are larger than the Red Sea in which the existence of amphidromic points has not been observed. A comparison of the results of calculation and of observation will give the extent of the error introduced by neglecting the compound centrifugal force. The same method applied to gulfs which are larger than the Gulf of Suez will determine the depth at which friction begins to have effect.