nately, only eight months are available in 1898 and 1899. No satisfactory method for interpolation for the missing months, where no annual mean is on record, has suggested itself, but the figures actually observed are given for comparison in Table 1 which sets forth the results of the study. To determine the weight which should be accorded to the final result, its probable error has been computed by applying the noted mean correction to each of the sixty-seven months, and proceeding in the usual manner. The probable error is found to be 0.0023 inches. It would appear, therefore, that 29.906 inches may be adopted with confidence as the desired mean reading at the level of mean tide in the region in question.

TABLE 1.—*Barometric pressure in inches, reduced to mean sea level.*

Month.	Bridgetown, 2 years.	Willemstad, 2 years.	Mean, 4 years.	Port of Spain, 19 months.	Mean, 3 stations.	Monthly corrections.	Colon, 8 months.
January	29.943	29.906	29.924	29.893	29.916	−0.010	29.842
February	29.990	29.933	29.962	29.937	29.953	−0.047	29.865
March	29.966	29.914	29.940	29.917	29.933	−0.027	29.874
April	29.948	29.873	29.910	29.902	29.907	−0.001	29.851
May	29.960	29.885	29.923	29.916	29.921	−0.015	29.857
June	29.964	29.892	29.929	29.932	29.930	−0.024	....
July	29.938	29.888	29.913	29.903	29.910	−0.004	....
August	29.926	29.871	29.898	29.904	29.907	−0.001	....
September	29.923	29.860	29.892	29.903	29.895	+0.011	....
October	29.878	29.824	29.851	29.949	29.850	+0.056	29.836
November	29.879	29.829	29.854	29.853	29.854	+0.052	29.868
December	29.913	29.882	29.897	29.915	29.903	+0.003	29.932
Annual mean	29.936	29.880	29.908	29.902	29.906	....	29.866

NOTE.—The departure is subtracted from, or the correction is added to, the monthly reading in order to produce the annual mean.—ED.

It remains to determine the corresponding reading of the barograph belonging to the new Panama Canal company, which is given in Table 2 the missing reading for May, 1902, being interpolated from the curve of corrections in the manner indicated above.

TABLE 2.—*Barograph readings in millimeters at Alhajuela, reduced to mean sea level.*

Month.	1899.	1900.	1901.	1902.	Mean.	Monthly corrections.	
						Millimeters.	Inches.
January	....	764.38	764.59	763.15	764.04	−0.53	−0.021
February	....	764.46	763.96	763.95	764.11	−0.60	−0.024
March	....	764.06	763.57	762.98	763.54	−0.03	−0.001
April	....	763.64	762.83	762.48	762.98	+0.53	+0.021
May	....	763.63	763.20	*762.65*	763.16	+0.35	+0.014
June	....	764.06	763.16	762.09	763.10	+0.41	+0.016
July	763.63	764.53	763.15	762.74	763.51	0.00	0.000
August	763.07	764.29	763.28	762.51	763.29	+0.22	+0.009
September	763.64	764.70	763.58	762.88	763.70	−0.19	−0.007
October	764.28	764.17	762.88	763.64	763.74	−0.23	−0.009
November	763.27	764.21	763.94	763.60	763.83	−0.32	−0.013
December	763.73	764.12	762.25	763.35	763.16	+0.35	+0.014
Annual mean	763.60	764.21	763.37	763.00	763.51	....	....

NOTE.—The italic figures, May, 1902, indicate interpolation.—ED.

The mean reading deduced in the table is thus 763.51 millimeters. The mean of the three complete years is 763.53 millimeters, and the grand mean of all the months observed is 763.54 millimeters, all reduced to mean sea level. The desired correction to the barograph is, therefore, −3.90 millimeters.[1] Applying it to each of the forty-one months for which we have mean readings, corrected for monthly variation by the local curve of corrections, we have for the reading at mean sea level 759.61 ± 0.062, or 29.904 ± 0.002 inches. It would seem, therefore, that confidence may be accorded to this estimate of the desired correction. It may be added that as the reduction to the sea level only ranges from +3.74 to +3.78 millimeters, according to the observed readings and corresponding temperatures, the two corrections nearly balance each other, and the recorded reading of the barograph may be adopted as that at sea level with a trifling error, not exceeding 0.006 of an inch.

Incidentally, this study has thrown light on the question of mean monthly variation of barometric pressure. Table 3 recapitulates the above corrections for each month:

[1] See the note by Professor Bigelow on a subsequent page.—ED.

TABLE 3.—*Monthly variation in barometric pressure at sea level, in inches.*

Month.	The three stations long. 65°.	Alhajuela long. 80°.	Mean correction.
January	−0.010	−0.021	−0.015
February	−0.047	−0.024	−0.035
March	−0.027	−0.001	−0.014
April	−0.001	+0.021	+0.010
May	−0.015	+0.014	−0.001
June	−0.024	+0.016	−0.004
July	−0.004	0.000	−0.002
August	−0.001	+0.009	+0.004
September	+0.011	−0.007	+0.002
October	+0.056	−0.009	+0.024
November	+0.052	−0.013	+0.019
December	+0.003	+0.014	+0.008

These figures certainly indicate a remarkable uniformity of barometric pressure in this tropical region throughout the year, and tend to give confidence in the above conclusions.

NOTES ON A FEEBLE EARTHQUAKE RECORDED AT WASHINGTON, D. C.

By C. F. MARVIN, Professor of Meteorology.

A new seismograph was installed at the Weather Bureau in the latter portion of February and on the morning of March 15, 1903, the first slight earthquake was recorded. The seismograph will be fully described elsewhere in the MONTHLY WEATHER REVIEW.

The instrument is so installed that the record gives the horizontal component of motion in the north and south directions. The tracing index magnifies the movement of the earth ten times. The free period of oscillation (complete) of the steady mass was eighteen seconds at the time of the earthquake.

The record was perfectly inscribed and showed all the recognized characteristics of these phenomena. Section *C* of fig. 1 is a reproduction of a portion of the record showing the earthquake. The short, transverse strokes are minute marks made on the record electrically by a standard clock. At the time of the earthquake the clock was 8.5 seconds, viz: 0.14 minute, fast. Each line of the original sheet contains the record for sixty minutes, hence, the transverse strokes forming a somewhat irregular line across the sheet are corresponding minutes of successive hours. Thus, on the margin one mark is checked 3:38 p. m., March 14, 1903. The corresponding mark on the adjacent line is 4:38 p. m., and so on.

From the record the earthquake is seen to consist of three distinct portions, namely: First, the preliminary tremors from *a* to *b*; second, the main or principal portion, from *b* to *c*; and finally the terminal portion, beginning at *c* and extending some distance beyond the section of the record here reproduced. All earthquake records of this kind exhibit these marked characteristics, especially when the vibrations have traveled to a great distance from the origin of the disturbance. Near the origin the preliminary tremors are of short duration or may be absent altogether. The times of the different phases of the record are as follows:

March 15, 1903 (75th meridian time).

	H.	*m.*	*s.*
Preliminary tremors began	9	29	0
Duration of preliminary tremors		5	0
Principal portion began	9	34	0
Duration of principal portion		2	36
Beginning of terminal portion	9	36	36
End of tremors	10	3	0
Duration of terminal tremors		26	24
Total duration of disturbance		34	0
Strong vibrations at the maximum rate, comprising three full semivibrations, continued for a period of			19
Period of complete vibration at maximum			12.8

Maximum double amplitude of earth movement, 0.31 millimeter.

The beginning of the principal portion is marked by several long-period oscillations of thirteen and one-half seconds, followed by shorter oscillations having about ten seconds period.

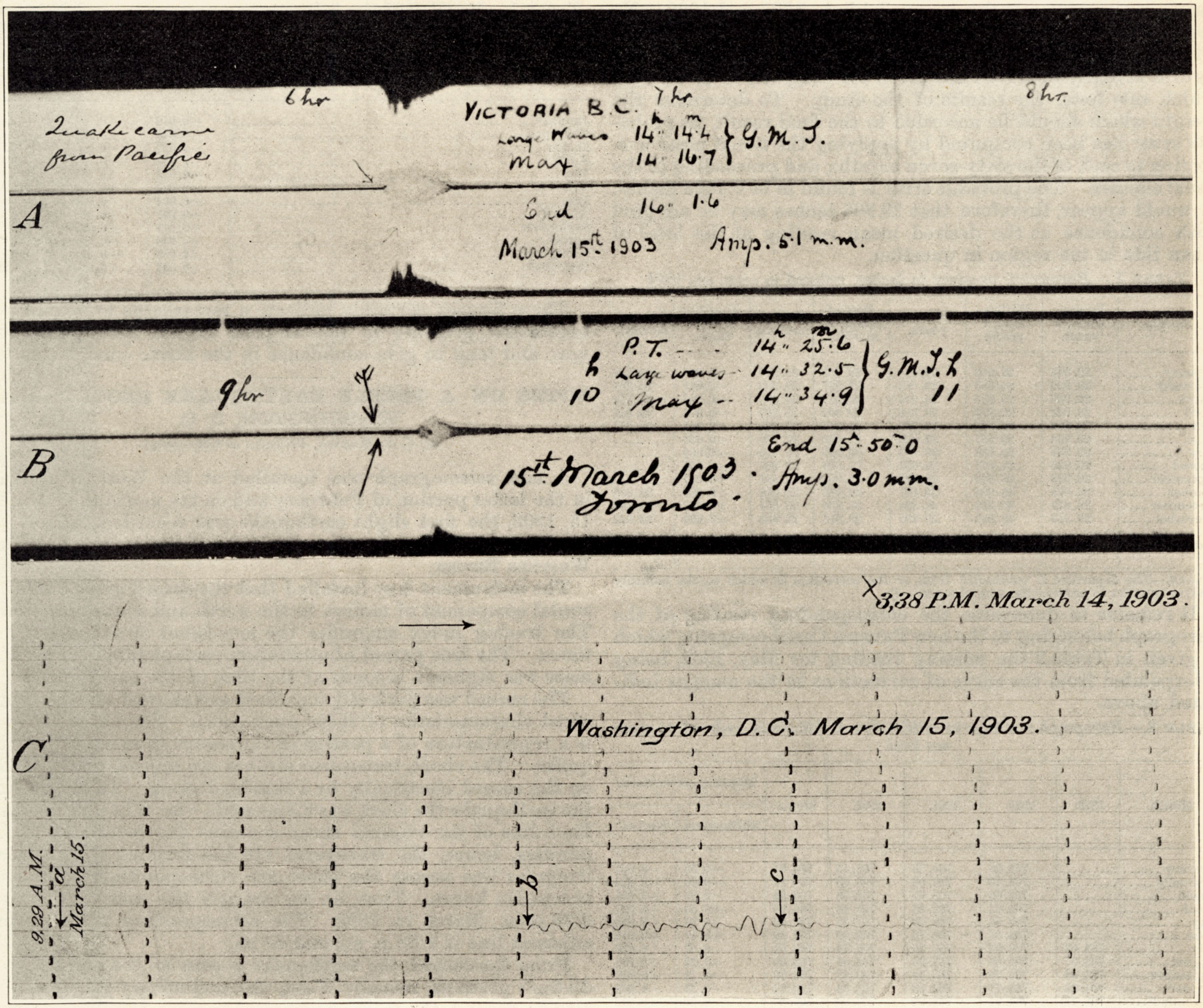

FIG. 1—Seismograph records for March 15, 1903.

It is impracticable to determine the periods of the preliminary tremors, which, while perfectly definite on the original trace, are of extremely small amplitude.

Origin.—Very little can be said concerning the origin of this disturbance, but we learn that it was recorded on seismographs of the Milne type at Baltimore, Md., Toronto, Can., and Victoria, B. C.

Prof. R. F. Stupart of the Canadian Meteorological Office has kindly furnished copies of the records at Victoria and Toronto, which are reproduced in fig. 1, *A* and *B*, respectively.

The following table gives the times, in Greenwich mean time, of the principal features of the earthquake at the several stations:

Stations.	Preliminary tremors began.	Principal portion began.	Maximum waves.	End of tremors.
	h. m.	*h. m.*	*h. m.*	*h. m.*
Victoria, B. C.	None.	14 14.4	14 16.7	16 1.6
Toronto, Can	14 25.6	14 32.5	14 34.9	15 50.0
Washington, D. C	14 29.0	14 34.0	14 36.6	15 3.0

For purposes of comparison the moments of beginning of the strong waves in the principal portion are comparatively definite points. From these we find the time of transmission from Victoria to Toronto was 18.1 minutes, and from Toronto to Washington 1.5 minutes. The maximum waves are also fairly definite points and give us corresponding times of transmission of 18.2 and 1.7 minutes, respectively, which agree quite as closely as could be expected.

Taking the distance from Victoria to Toronto as 3500 kilometers we get 3.2 kilometers per second, for the speed of propagation of the stronger waves, which is very close to recognized values.

From a study of a large number of earthquakes in Japan and elsewhere, and of which good records were obtained in Europe and at great distances, Omori[1] found an empirical relation between the duration of the preliminary tremors and the distance of the origin, thus:

$$d = 14.9t - 24.9,$$

where d is the distance in kilometers and t the duration of the

[1] Report of the Earthquake Investigation Committee of Japan in foreign languages. No. 5.

preliminary tremors in seconds. In the present case the calculated distance is 4445 kilometers (2762 miles), a result which, without corroborative data, must be regarded as very problematic.

The reasoning in this case is to this effect: Earthquakes in general are caused, it is believed, by more or less sudden breaks or slips or fractures in the crust of the earth. Yielding of a gradual sort may have been going on for a long time before, but when the final fracture comes the phenomenon we call an earthquake results, and elastic and quasi-elastic waves of both compression and distortion and of a highly complex character radiate from the origin in all directions. The purely elastic vibrations within the elastic limits of the strata, and hence of smaller amplitude, are undoubtedly transmitted at a higher linear velocity than the great surges which doubtless strain the earth materials far beyond the elastic limit and are soon dissipated. Hence, we should expect the earthquake record to begin with preliminary tremors and this is found to be the case, except in very rare instances. The absence of preliminary tremors in the case of the present earthquake as recorded at Victoria would indicate a nearby origin for the disturbance.

A study of the records of distant earthquakes shows a most marked difference in the velocity of propagation of different phases of the phenomena. From Omori's investigations, already referred to, the *preliminary* tremors are transmitted at an average velocity of 12.8 kilometers per second; whereas, the large waves of the principal portion of the earthquake travel at the slow rate of only 3.3 kilometers per second. The theory of the speed of propagation of vibrations would require that the elastic properties of the strata should exceed those of steel in order to give the observed high velocities of the preliminary tremors.

A satisfactory explanation of this apparent conflict with our knowledge of the elastic properties of bodies has not yet been offered. A theory has been advanced that the preliminary tremors make a short cut for the distant station by traveling through the earth rather than around it, but even in this case the transmitting medium must have a very high modulus of elasticity.

THE DISTRICTS OF THE DOMINION OF CANADA.

In answer to many inquiries the Editor submits the accompanying sketch map, kindly furnished by Prof. R. F. Stupart, showing the names and locations of recent subdivisions in the Northwest Provinces of Canada.

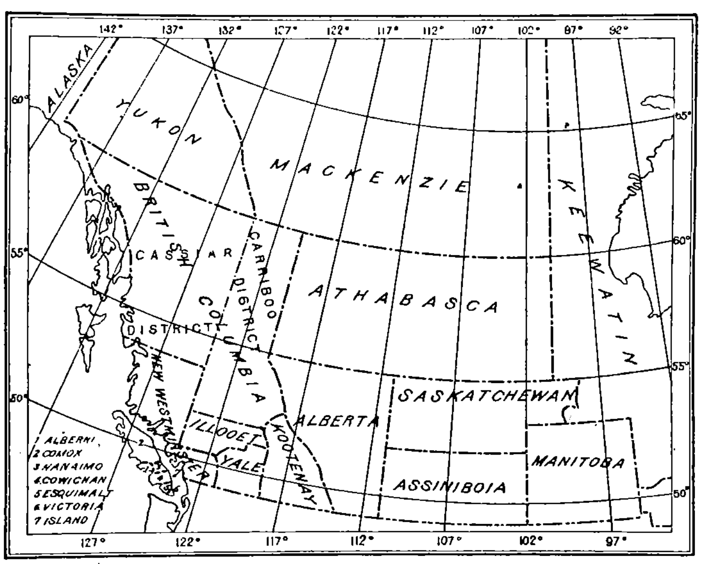

FIG. 1.—Districts of the Dominion of Canada.

THE SEMIDIURNAL TIDES IN THE NORTHERN PART OF THE INDIAN OCEAN.

By R. A. HARRIS, of the United States Coast and Geodetic Survey.

In this paper an attempt will be made to show by means of cotidal lines the average Greenwich lunar time of high water over the northern part of the Indian Ocean. Of course an unlimited number of sets of cotidal lines can be drawn which shall satisfy all reliable observations because the measurements of the tide have been confined to shores and islands. But unless one duly considers the causes and nature of the tide it is almost certain that such arbitrary lines will, when carried out far from land, represent an impossible state of affairs.

Before passing to the subject proper, it may be well here to call attention to the desirability of procuring more and better observations on many of the islands. Observations should also be made over shoals and, if possible, at places of greater depths.

It is the intention of the writer to cover the sea and all its principal arms with cotidal lines similar to those here shown in fig. 5. The maps showing such lines will probably also appear in an appendix to the United States Coast and Geodetic Survey Report for the year 1904. In view of this considerable delay, it is reasonable to suppose that the map accompanying this paper may by that time be modified somewhat in ways suggested by future observations and experience.

In fig. 5 Roman numerals denote the Greenwich lunar time of mean high water; when decreased by the east longitude of the place expressed in time they give its establishment in lunar hours. The Arabic numerals, generally scattered along the shores, denote the approximate mean range of tide in feet. Values given to tenths of a foot are based upon harmonic analyses; bracketed values indicate the range of the semidiurnal part of the tide where the latter is chiefly diurnal.

The northern part of the Indian Ocean is chosen for study at this time because the origin of the tide is there more easily accounted for than in most other regions, and because the results of extensive observations made by the survey of India, by the Dutch, and by the British Admiralty are available.[1]

In Appendix No. 7, United States Coast and Geodetic Survey Report for 1900, an attempt is made to partially explain the principal ocean tides. A preliminary sketch of parts of the theory involved in this appendix may be found in the MONTHLY WEATHER REVIEW for March, 1900, and this sketch should be consulted if the full paper is not available.

The Indian Ocean north of the thirtieth degree of south latitude is, with one exception, but little influenced by the tides of other waters. The exception is due to the fact that there is a good rise and fall around southern Africa, and in Mozambique Channel, where the tide depends upon two systems of oscillations which are determined by boundaries largely outside of the region to be considered in this paper. These systems, styled south Atlantic and south Indian, are described in Chapter VII of the Appendix No. 7 above referred to. It may be noted here that observations indicate about I.5 as the Greenwich lunar time of high water in Mozambique Channel, and that this is about the theoretical time of the tide, for it is a mean between XII or 0 and III; see fig. 1, which is taken from the chart of semidiurnal systems in the paper just referred to. Extending from Mozambique Channel to Baluchistan and India is a half-wave area whose time of tide, as will be noted later, is largely governed by the tide in the channel.

[1] Most of the data used in the construction of the accompanying map may be found in the British Admiralty Tide Tables; The United States Coast and Geodetic Survey Tide Tables; and Appendix No. 7, United States Coast and Geodetic Survey Report for 1900, sections 79–97 and figs. 25, 29.