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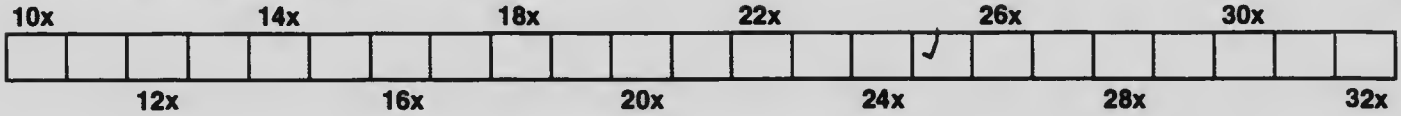

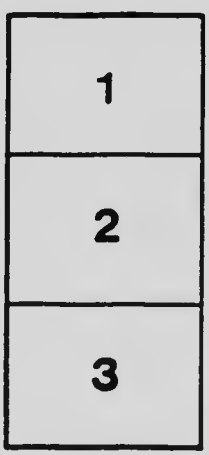

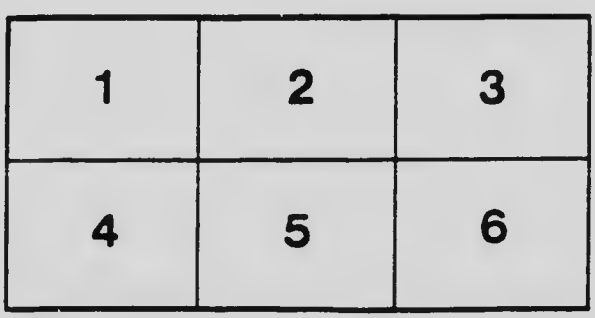

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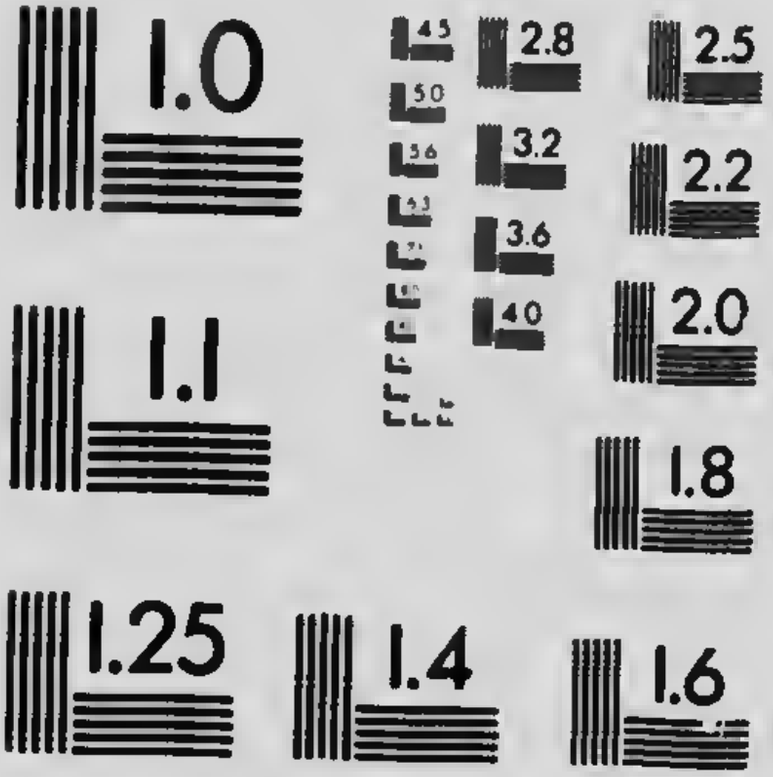

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REPORT

OF THE

CANADIAN ARCTIC EXPEDITION 1913-18

VOLUME X: PLANKTON, HYDROGRAPHY, TIDES, ETC.

PART C: TIDAL INVESTIGATIONS AND RESULTS

By W. BELL DAWSON

OTTAWA
THOMAS MULVEY
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1920

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Canadian Arctic Expedition, 1913-1918.

TIDAL INVESTIGATIONS.

Results Deducible from the Tidal Observations

By W. Bell Dawson, D.Sc., M.Inst.C.E., F.R.S.C.,
Superintendent of the Survey of Tides and Currents, Ottawa, Canada.

During the course of this expedition, under the leadership of Mr. Vilhjalmur Stefánsson, observations of the tide were obtained in the years 1911 and 1915 at seven points; situated along the open coast of the continent, eastward from Alaska to the head of Amundsen gulf, and north of this gulf on Banks island and in Prince of Wales strait. These may be classed together as being in the region of Beaufort sea. In the year 1916, tidal observations were obtained further north, at three points which were on the open shore of the Arctic ocean or in straits, in the vicinity of Ellef Ringnes land. These localities are shown on the accompanying map.

The expedition was supplied with an outfit of instruments by the Tidal and Current Survey, comprising a current meter with a set of accessories, a large registering tide gauge with two interchangeable clock cylinders, and another registering gauge of a more portable type. These gauges were furnished with spare fittings and all the accessories necessary for their operation.

The difficulty in using these gauges arose chiefly from the clock-work being stopped because of the hardening of the clock oil with the cold. This type of gauge is successfully used throughout the winter in the regular work of the Tidal Survey, under the severest weather conditions, with outside temperatures as low as 40 degrees below zero. But they require to be properly installed, with a view to maintain a temperature above the freezing point. On this Arctic expedition, the gauges were sheltered in snow houses; and it appears to be possible to keep such houses at a temperature of 40° to 50° Fahrenheit by lamp heat, without thawing the interior. The tide well, cut through the ice within the house, could thus also be kept from freezing up.

Another difficulty arose from the very small range of the tide in these regions. The range on the open shores of Beaufort sea was usually less than one foot, and seldom as much as one and one-half feet; and the greatest range met with, at the head of Amundsen gulf, and in the extreme north, occasionally exceeded two feet. With so small a range, the tide curves on the recording gauge, or when plotted from scale readings, were very flat; and when the height was read directly from a scale, the readings required to be at very frequent intervals, to be of service.

TIDAL DATA DEDUCIBLE.

On an expedition of this character, it might not be practicable to establish permanent headquarters where a tidal station could be maintained in continuous operation for purposes of comparison. But if some inhabited locality such as Herschel island, had been equipped as a reference station, all the tidal observations in the region could have been referred to it; and a much more satisfactory reduction of the observations would result. This plan of having a reference station for each region, is the uniform practice in the investigations of the Tidal

Survey. In default of this method, the only other way when the observations are not simultaneous, is to refer the time of the tide to the moon's position; so that the various localities may be compared, and the progress of the tide ascertained. The tide is referred to the moon by the luni-tidal interval; which is the interval of time between the moon's transit across the meridian and the next following high water. This interval at the Spring tides, when the moon is new or full, is termed the "Establishment". In dealing with complete tidal observations, this interval can be strictly defined; and in the region under consideration, where the range of the tide is often less than one foot, the time of high water is more definite at the Spring tides because the best range is then obtained; and the Establishment is thus the best time-factor to deal with.

The other element in the tide is its height or range. This can be determined independently at each locality; and it should properly be referred to a low-water datum, but this was not attempted in these regions. It is best, therefore, to deal with the range of the tide, from high water to low water, which can be directly observed; rather than the rise above a fixed datum level.

When desirable, the readings on tide scales were plotted, to obtain the corresponding tide curves. This plotting, and the general reduction of the observations, was carried out by Mr. H. W. Jones, of the Tidal Survey staff.

TIDAL OBSERVATIONS OBTAINED IN 1914 AND 1915.

Collinson point. On the north coast of Alaska. Longitude 9 h. 39 m. 19 s. West. Observations were obtained here in 1914 from January 16 to May 6, by Dr. J. J. O'Neill and Mr. J. R. Cox. As this was headquarters for the winter, the large recording tide gauge was used. There are some interruptions in the above period; but the observations afford the range at six Spring tides and five Neap tides. This range is only 7 inches at the Springs and 3 inches at the Neaps. With so flat a tide curve, the time of high water can only be obtained at all definitely at the Springs; and a value for the Establishment has been deduced, which shows a fair degree of constancy in the circumstances. The results are given in abstract in the table for Collinson point appended.

The time on the tide gauge record is assumed to be correct throughout. Collinson point local time was used; and although no time errors are noted, it is taken to be correctly kept on the average.

Martin point. On the north coast of Alaska, 50 miles east of Collinson Point. The observations were for three days only, on March 19 to 21, 1914. They were taken by Messrs. F. Johansen and G. H. Wilkins, as readings on a tide scale; the readings being to the hundredth of a foot, or to the nearest quarter of a tenth. A watch was used to carry the time from Collinson point; but as its error and rate are not stated, the time remains uncertain. As the observations were at the Neap tides, they would not serve in any case for a determination of the Establishment. The only value obtainable, therefore, is the Neap range; which is taken as the mean of four consecutive differences of level, between high and low water, to eliminate inequalities. This method of obtaining the range is used in all cases in dealing with these Arctic tides; and it is justified because of the small range. The Neap range here at this date was 3½ inches.

Demarcation point. Close to the Alaska boundary. Longitude 9 h. 21 m. 49 s. West. The time was carried by a watch which was correct when Collinson point was left on April 25, and was 46 minutes fast of Collinson point time on the return from the trip, on May 26. By assuming the gaining rate to be constant, and allowing for the difference of 14½ minutes in longitude, it is therefore possible to reduce the observations definitely to local time at Demarcation point.

The observations are at the Spring tides, from May 9 to 12, 1914; taken by Messrs. F. Johansen and W. S. Brooks. They are readings on a tide scale to the hundredth of a foot, taken every fifteen minutes day and night continuously. The Establishment obtained from the four best luni-tidal intervals, nearest to full moon, is 12 h. 14 m. Relatively to the nearest transit of the moon, high water occurs sixteen minutes previously; the transits being 12 h. 30 m. apart at the date of these observations. The difference in the time of high water with Collinson point, brought to absolute time by allowing for longitude, is thus found to be 49 minutes earlier at Demarcation point.

The Spring range, from the mean of four differences between high and low water, as shown in the table appended, is nearly 9 inches. The determination of the Establishment is also shown in the table.

Cape Kellett.—On the west side of Banks island, Beaufort sea. Approximate longitude of tidal station, in bay on south side of the cape, 8 h. 19 m. West. Observations were taken here in December, 1914, and January, 1915, by Messrs. G. H. Wilkins and C. Thompson; and simultaneously for a few days in January, by Messrs. W. J. Baur and S. Storkerson, at a point 20 miles north on Banks island, which is also on the open shore of Beaufort sea. There are also observations of wind and barometer, every four hours, throughout the period.

These observations were taken on a tide scale read from the top downwards to the water surface; the readings being in feet and inches to the nearest quarter of an inch. From December 26 to January 14 and again from January 17 to 21 and 27 to 30, the readings are at intervals of four hours, day and night. It is unfortunate that it is not possible to deduce any result from this series of observations when they represent so much labour; because the range is so slight and there are only six readings of height in the twenty-four hours. For two days at the Spring tides, on January 15 and 16, the observations are continuous every fifteen minutes, day and night; and they become so again for four complete days at the Neaps, on January 22 to 26. These continuous observations were plotted on a large scale, to obtain the true tide curves.

The observations at 20 miles north of Cape Kellett, are continuous every fifteen minutes, day and night, during four days from January 22 to 26. These are at the Neap tides. The best results that can be deduced for the range of the tide are as follows:

At Cape Kellett, Spring range	0·43 foot.
At Cape Kellett, Neap range	0·10 "
At 20 miles north, Neap range	0·11 "

In attempting to arrive at an Establishment, the difficulties are serious, because of the wide uncertainty in the time used in the observations, the small number of high waters at the Spring tides, and the great irregularity in the luni-tidal intervals due to the very small range of the tide. For, the time of high water is derived in some cases from a tide having less than two inches of range. The only note as to time error, refers apparently to the first period beginning December 26. It is as follows: "Time approximately one-half hour fast on local. By comparison, two hours fast on watch, January 20." In the other two periods, at Cape Kellett and at 20 miles north, there is no indication as to the time; and it can only be assumed that it is correct on the average, although the above note is not reassuring.

On working out the luni-tidal intervals on the basis above indicated, they are found to vary from 6 to 12 hours. The variation with successive transits is either from 6 to 10 hours, or from 8 to 12 hours; which must be actual, as the time used would be the same in the course of any one day. This

shows the large error that may result in the determination of the Establishment in these regions, if care is not taken to balance the values for both the tides in the twenty-four hours, which occur at the opposite transits of the moon. Possibly some of the apparent discrepancies in Arctic values may thus be accounted for, if they are based on unbalanced observations.

Because of these variations and uncertainties, the luni-tidal intervals at both Spring and Neap tides are included; since the change during the course of the month is not likely to be as much as these known amounts between successive transits. The primary values taken as a basis for averages, are in all cases the mean of two successive luni-tidal intervals, at the opposite transits of the moon; to eliminate the inequality. For the two localities taken together, as they are both near Cape Kellett, the result is as follows:—

At Springs—Mean of two luni-tidal intervals; Jan. 15-16..	10 h. 15 m.
At Neaps—Average of two mean values; Jan. 24-26.....	8 h. 05 m.
At Neaps—Average of three mean values; Jan. 23-25.....	11 h. 05 m.
Resulting approximate Establishment.....	9 h. 50 m.

Bernard harbour. On the south side of Dolphin and Union strait. Longitude 7 h. 39 m. 22 s. West.—The tidal observations here, were obtained in June and December of 1915. The first series, from June 6 to 23, were taken with a registering tide gauge; but the record is very broken and imperfect owing to the instrument not working properly; and there are no comparisons to show that the time is correct. The second series, from December 4 to 12, are readings on a tide scale, taken to the hundredth of a foot; and the watch time error runs from 0 to 18 m. fast on chronometer, not on local, during the seven days of observation. The readings were taken by Mr. G. H. Wilkins in June, 1915; and by Messrs. K. G. Chipman, J. R. Cox, F. Johansen, W. V. Bruce and Drs. J. J. O'Neill and R. M. Anderson, working in turn throughout the twenty-four hours during the December period.

The best result that can be obtained from the first series, is the Spring range about the date of the new moon on June 12; as the observations did not cover the following Neap tides. The result, averaged with the later observations of December, shows the Spring range to be nearly 1½ feet, which is the greatest range measured at any of these tidal stations in the region of Beaufort sea.

A good determination of the Establishment was obtained from the December series; as the chronometer error was ultimately ascertained, and the greater range of the tide makes the time of high water more definite than elsewhere. The result, together with the best value for the Spring range, is given in the table appended. It will be noticed that at times the luni-tidal intervals have an alternation of a full hour in their values; which again shows that results should be based on successive transits taken in pairs.

Prince of Wales strait.—This was made winter quarters for the *Polar Bear*, which was laid up in the strait near Armstrong point on Victoria island. Tidal observations were obtained here for a month, from October 8 to November 8, 1915. The height was read on a scale to the nearest quarter inch, at short intervals day and night; and these readings when plotted, gave a continuous tide curve for the period. The time was kept by a watch, and its error was obtained by comparison with a chronometer. (See Supplementary Note.) The resulting Establishment as given in the table opposite, is based on the luni-tidal intervals at three Spring tides. There are also complete meteorological observations covering this period of a month.

A good result can be obtained from these observations for the range of the tide, as shown in the tabulated statement for this locality. The range at Spring tides is again found to be not over one foot. The extreme difference of level during the period is 2.40 feet; but this appears to be due, in part at least, to a general raising or lowering of the water by the influence of the wind; and it is thus much greater than the true amplitude of the tidal undulation.

SUMMARY OF RESULTS.

Locality.	Spring range.	Neap range.	Establishment (Local time.)
Collinson point	0·60 foot.	0·26 foot.	0 h. 18 m.
Martin point	. . . "	0·29 "	. . . . .
Demarcation point	0·72 "	. . "	12 h. 14 m.
Cape Kellett	0·43 "	0·40 "	9 h. 50 m.*
Bernard harbour	1·46 "	. . . . "	6 h. 46 m.
Prince of Wales strait	0·95 "	0·20 "	1 h. 15 m.

*This value is only roughly approximate.

TIDAL OBSERVATIONS OBTAINED IN 1916.

These were taken at three localities in the region still further north; but they were limited to little over a day at each place. The dates selected in each instance for the observations were just after the new or full moon, in the endeavour to obtain data for the Spring tides. The time was taken with watches; but their face readings differed by two to four hours, and their actual errors have never been deduced from the astronomical observations taken for the purpose. It is doubtful, however, when the series of observations is so short, whether they would be adequate for the determination of an Establishment, even if the time errors could be correctly allowed for. The position of the localities is shown on the map.

Cape Isachsen.—Tidal observations were obtained at this cape, at the extreme northwest end of Ellef Ringnes land, during a full day on June 2 to 3, 1916. Readings were taken on a scale to the nearest half inch, every fifteen minutes continuously, for twenty-five hours.

The astronomical conditions were as follows, the hours being in Standard time for the 120th Meridian West: New moon, May 31 at 11 h. Moon maximum North, June 1 at 10 h. Moon in Apogee, June 3 at 13 h. The tides were thus at tl. apogee Springs, with the maximum of diurnal inequality.

The range of the tide was from 0·27 to 0·92 of a foot; the mean of the four consecutive ranges being 0·57 foot. This may be taken as the Spring range with the moon in apogee.

Hassel sound.—The tidal observations were obtained at the south end of this sound, at the cape on the west side of the entrance. They comprised twenty hours on July 18 and 19, 1916. Readings were taken on a scale to the nearest quarter of an inch, at intervals of five to fifteen minutes during this period.

The astronomical conditions were as follows: Full moon and Perigee on July 14. Moon on equator, July 18. The observations were thus two or three days after the Spring tides, but near perigee; and the diurnal inequality was inappreciable.

Only three consecutive ranges were obtained, but the fourth could readily be interpolated owing to the absence of diurnal inequality. The ranges observed were from 1·13 to 1·67 feet; the mean of the four being 1·38 feet. The middle of the period of the observations was just four days after the full moon, when the height should be beginning to decrease after the Spring tides. But this range probably represents the average Spring tides; as the date was not far from perigee, which must have some effect in increasing the height.

Third island.—This is a newly discovered island to the west of Findlay island. The tide was observed at the shore camp, at the southwest end of the island, which was thus near the open coast of the Arctic ocean. The observations comprised thirty hours on August 14 and 15, 1916. Readings were taken on a scale to the nearest quarter of an inch at intervals of ten minutes to one hour, during this period.

The astronomical conditions were as follows, the hours being in Standard time for the 120th Meridian West: Moon in perigee, August 12 at 1 h. Full moon, August 13 at 4 h. Moon on equator, August 15 at 5 h. The tides were thus the perigee Springs, without much diurnal inequality.

The observations afforded four consecutive ranges which varied from 1·39 to 2·25 feet; the mean of the four being 1·88 feet. This is the Spring range with the moon in perigee; which may account in part for its being so much larger than at the other localities.

Summary.- The results of the observations of 1916, in the more northern regions, are summarized below. It is to be noted that the diurnal inequality is eliminated from the values given; as they are derived in each case from the average of four consecutive ranges, as already explained.

Cape Isachsen—Range at Apogee Springs.....	0·57 foot.
Hassel sound—Range after Springs near Perigee..	1·38 feet.
Third island—Range at Perigee Springs.....	1·88 feet.

These various ranges cannot well be brought to a common standard for comparison, when there was no reference station in continuous operation in the region. The influence of the moon's distance may be inferred, however, from the proportionate ranges at perigee and apogee Springs, as determined from five months observation at Winter harbour, Melville island, during the Bernier expedition. The range of the tide there is $3\frac{1}{4}$ to $4\frac{1}{2}$ feet. Good comparative values show that the range at perigee Springs is 12 per cent greater, and at apogee Springs 12 per cent less, than the mean Spring range.

Tidal Streams.—These were observed at Cape Isachsen and in Hassel sound during the one day at each place that tidal observations were obtained. At Cape Isachsen, the current was NE. or NNE. during the rise of the tide, and SSW. during the fall; and the turn in direction occurred about two hours after high and low water. As this was at the Springs, when the currents would be strongest, the relation thus indicated between the tide and the current would appear to be trustworthy, although based on so short a period of observation. In Hassel sound, there was less current and it was less regular in turning; but the indications, so far as they go, are that the direction is southward during the rise of the tide and northward during the fall. This would correspond with the general progress of the tide from the open Arctic ocean, towards the straits and sounds extending southeastward from Ellef Ringnes land which adjoins this sound. The direction of the current was not observed at Third island.

CONCLUSIONS AND RECOMMENDATIONS.

Progress of the tide.—The direction in which the tide progresses in Beaufort sea is indicated by a comparison of the Establishments. The earliest on the open shores of the sea, is Cape Kellett; and Demarcation point is earlier than

Collinson point. It would appear, therefore, that the tide comes into this sea from the north, and proceeds southward and westward along its shores. This would accord with the view that the main tide of the Arctic ocean enters from its opposite side, from the North Atlantic, through the wide opening between Greenland and Norway.

The Establishments obtained from these observations are not definite enough to enable actual differences of time to be deduced from them, relatively to some one of these tidal stations. The general value of XII hours for the Establishment on these shores of Beaufort sea, is in good accord with XI h. 38 m. for Point Barrow, as formerly given in the Tide Tables of the British Admiralty; but it throws doubt on the value of VI h. 03 m. which is given for Herschel island.

At Bernard harbour, the Establishment VI h. 46 m. must be considered as later than the open sea by practically the whole of this amount with the deduction of the difference of longitude, which is 1 h. 46 m. relatively to Demarcation point. This leaves a difference of five hours for the run of the tide from the open, which seems large, when the distance from the mouth of Amundsen gulf is only 360 miles.

There is no uncertainty in the time however, as both watch and chronometer errors have been ascertained and allowed for. (See Supplementary Note.) As a term of comparison, the rate of travel of high water in the St. Lawrence estuary, in the wide part unaffected by river influence, is 1 h. 31 m. per 100 miles; which corresponds fairly well with this difference, if the depths are similar.

Range of the tide.—In regard to the range of the tide, it is too slight to have any direct effect upon navigation. It may be sufficient, however, to cause heavy ice that is grounded to move on, under certain conditions; and any rise of tide also tends to break up grounded ice.

Procedure recommended.—With regard to general procedure in any future tidal observations in the Arctic regions, it is to be strongly recommended that some permanent tidal station be established for reference in the region; and that it be maintained during the whole time that the explorations are in progress. The observations at the various points reached by the expedition, are liable to be for short periods or subject to interruption; but their value would be enhanced three or four fold if they could be compared with simultaneous observations at a reference station in the region.

Without such a reference station, the time of the tide at each local point where a short series of observations is obtained, has to be brought into direct relation with the time of the moon's transit. At the best, it may be quite uncertain whether the result represents a true average value, by which one locality can be compared with another, to determine the progress of the tidal undulation, or for other comparative purposes. But when the observations are simultaneous with those at the reference station, differences in absolute time can be determined which must be close to the true average even when the series of local observations is short. The results at different localities can then be compared without uncertainty, and the progress of the tide ascertained. At the reference station, the Establishment can be determined correctly from the long series of observations there; and the difference of time as found for any local point, when applied to this well-determined Establishment, should give a more trustworthy value than could be obtained independently.

In regard to the range of the tide, there are similar advantages in comparing local observations with the reference station. It can be readily seen, for example, whether the local range of the tide can be taken as the true Spring range or not, at the date of the observations. The comparison is valuable also as an indication of any abnormal tides due to wind or to ice obstruction; as such tides will be

out of accord with their normal relation to the reference station. It is thus evident that more reliable results for the range of the tide can be arrived at, than local observations for a short time would afford without the means for simultaneous comparisons.

The only assumption in this procedure is, that the tide is sufficiently similar in type throughout the region that is under exploration to enable comparisons for time and height to be made satisfactorily. Otherwise, the time-differences and the ratios in height become variable during the course of the month.

The Appendix.—The tables appended give a digest of the observations of 1914 and 1915, with the resulting ranges of the tide and the time values as far as these are deducible.

In the northern observations of 1916, the range of the tide as found from readings on a scale during one day at each locality, has already been stated and discussed.

To complete the tidal information obtained by Canadian Arctic expeditions, a synopsis of the tidal observations at the winter quarters of the Bernier expedition is included. This reduction of the observations as made by the Tidal Survey, appeared originally in the "Cruise of the Arctic," published by the Marine and Fisheries department in 1910.

OTTAWA, CANADA
February 28, 1920.

SUPPLEMENTARY NOTE.

Since the above was in type, the time reductions for Armstrong point, in Prince of Wales strait, were supplied by Mr. S. T. Storkerson of the Northern party, which was two years later in returning. The errors are as follows: Chronometer error in October and November, 1915, averages 3 h. 40 m. fast. Watch used in tidal observations, 3 to 3½ hours fast on chronometer. Total watch error, deduced from accurate rates and comparisons, 6 h. 31 m. to 7 h. 26 m. with resetting of one hour.

The errors, though so large, appear to be quite definite. The resulting values of the Establishment at three Spring tides, obtained by plotting the luni-tidal intervals, are as follows: 1 h. 18 m., 1 h. 15 m. approximately, and 1 h. 13 m. Mean adopted, 1 h. 15 m. This value is much earlier relatively, than at Bernard harbour, when the distance from the open sea is nearly the same.

Regarding the observations in Bernard harbour, it has now been ascertained that there was a chronometer error of 11 minutes as well as the watch error indicated in the original notes. This has enabled the value for the Establishment as given in the tables to be finally corrected. Also, during the June observations obtained with the registering gauge, the chronometer error on local time was less than one minute; and if it is assumed that the registering gauge was set with the chronometer, and further that the tide curves are inverted, so that apparent low water represents high water, a result can be obtained for the Establishment. This supposition is probable although there is no explanation regarding it; because the tide gauge was set on floating ice, and operated by a line anchored to the bottom. The value of the Establishment thus obtained is 7 h. 11 m., which is reasonably close in the absence of any time comparisons. It affords a valuable check on the result, as otherwise a comparison of time which was carried over from Armstrong point, might leave it an open question whether the same large chronometer error of 3½ hours should not be applied to the value at Bernard harbour.

W. B. D.

APPENDIX.

DIGEST OF OBSERVATIONS OF 1914 AND 1915, AND SYNOPSIS OF RESULTS DEDUCED FROM THEM.

COLLINSON POINT. North coast of Alaska.—The ranges given are the mean of the four consecutive differences between high and low water, which give the greatest or least averages at Springs and Neaps respectively. The time was local; and though the time errors were not noted, it was approximately correct throughout. Values in brackets are from incomplete observations.

Date. 1914.	Tide.	Range.		Date. 1914.	Moon.	Moon's Transit.	Luni-tidal interval.
		Springs	Neaps.				
		Feet.	Feet.				H. M.
Jan. 18	Neaps	...	0·37	Jan. 24	New	Lower	0 : 46
" 27	Springs	0·62		" 25	"	Upper	0 : 31
Feb. 5	Neaps		0·21	" 26	"	Lower	0 : 12
" 10	Springs	0·60		" 26	"	Upper	−12
" 17	...	...	...	Feb. 9	Full	Lower	0 : 24
" 26	Springs	0·62		" 10	"	Upper	0 : 04
Mar. 6	Neaps	...	0·19	" 10	"	Lower	0 : 02
" 13	Springs	0·65		Feb. 24	New	Upper	...
" 21	...	...	...	" 26	"	Lower	0 : 11
" 30	Springs	0·58		Mar. 10	Full	Upper	0 : 47
April 4	Neaps	...	0·35	" 11	"	Lower	0 : 26
" 10	Springs	(0·55)		" 12	"	Upper	0 : 21
May 3	Neaps		0·19	" 12	"	Lower	0 : 06
Mean		0·60	0·26	Establishment			0 : 18

MARTIN POINT. North coast of Alaska.—Observations for three days only, at Neap tides, March 19 to 21. Time not reliable, being carried from Collinson point and not checked on return. Observations being at Neaps, do not give the Establishment.

Neap range March 20, determined as before.....0·29 foot.

DEMARCATION POINT. At Alaska boundary.—Observations for four days, at Spring tides, May 9 to 12. The range given is the mean of the four consecutive differences between high and low water, which give the greatest average at the Springs. The time was carried from Collinson point, and checked on return, after a month. It is thus quite reliable, and is reduced to Local time by allowing difference of longitude.

Date. 1914.	Rise or Fall.	Difference of Level.	Mean Spring Range.	Date. 1914.	Moon.	Moon's Transit.	Luni-tidal interval.
		Feet.	Feet.				H. M.
May 9	Fall	0·54		May 9	Full	Upper	...
" 10	Rise	1·03		" 9	"	Lower	11 : 59
" 10	Fall	0·93		" 10	"	Upper	12 : 14
" 10	Rise	0·38		" 10	"	Lower	12 : 35
			0·72	" 11	"	Upper	12 : 10
				Establishment			12 : 14

BERNARD HARBOUR. North coast of Canadian mainland. In Dolphin and Union Strait.—In June, the time is uncertain as the time errors are not noted. In December, the time error is indicated; and the time is reliable as finally corrected. The range is determined in the manner already explained.

Date. 1915.	Tide.	Range. Spring.	Range. Neaps.
		Feet.	
June 12	Springs	1·19	
" 15	"	1·19	
Dec. 7	"	1·73	
Mean of two Springs		1·46	

Date. 1915.	Moon.	Moon's Transit.	Luni-tidal interval.
			H. M.
Dec. 4		Upper	7 : 53
" 5		Lower	6 : 58
" 5		Upper	7 : 56
" 6		Lower	6 : 25
" 6	N w	Upper	7 : 33
" 7		Lower	6 : 23
" 7		Upper	7 : 03
" 8		Lower	6 : 04
" 8		Upper	6 : 50
" 9		Lower	6 : 12
" 9		Upper	6 : 36
" 10		Lower	6 : 11
" 10		Upper	6 : 52
" 11		Lower	6 : 15
		Average	6 : 48

These values are corrected for watch comparisons, but not for chronometer error. See final result opposite.

ESTABLISHMENT.

Value for transit between 11 h. and 13 h.—	
At Upper transits	7 h. 30 m.
At Lower transits	6 h. 24 m.
Mean	6 h. 57 m.
Less chronometer error	0 h. 11 m.
Resulting Establishment	6 h. 46 m.

The marked alternation in the time values in the early part of December will be noted. The moon was at maximum declination South on December 6.

PRINCE OF WALES STRAIT. Near Armstrong point.—Observations for one month, from October 8 to November 8, 1915. The ranges for the Spring and Neap tides are based on the four consecutive differences between high and low water, which give the greatest average after the new and full moon, and the least average after the moon's quarters.

Date 1915.	Rise or Fall.	Difference of Level.	Mean Spring Range.	Date. 1915.	Rise or Fall.	Difference of Level.	Mean Neap Range.
		Feet.	Feet.			Feet.	Feet.
Oct. 10	Fall	0·66		Oct. 17	Fall	0·17	
" 10	Rise	1·46		" 17	Rise	0·17	
" 11	Fall	1·17		" 17	Fall	0·08	
" 11	Rise	0·71	1·00	" 17	Rise	0·33	0·19
Oct. 23	Fall	0·84		Nov. 1	Rise	0·20	
" 23	Rise	1·09		" 1	Fall	0·37	
" 24	Fall	0·80		" 1	Rise	0·11	
" 24	Rise	0·88	0·90	" 1	Fall	0·12	0·21
		Mean	0·95			Mean	0·20

SYNOPSIS of Tidal Observations at Winter Harbour, Melville Island, taken by Capt. J. E. Bernier, C.G.S. *Arctic*, assisted by W. E. W. Jackson, M.A., J. C. McMillan, B.A.Sc., and Geo. Braithwaite, first mate.

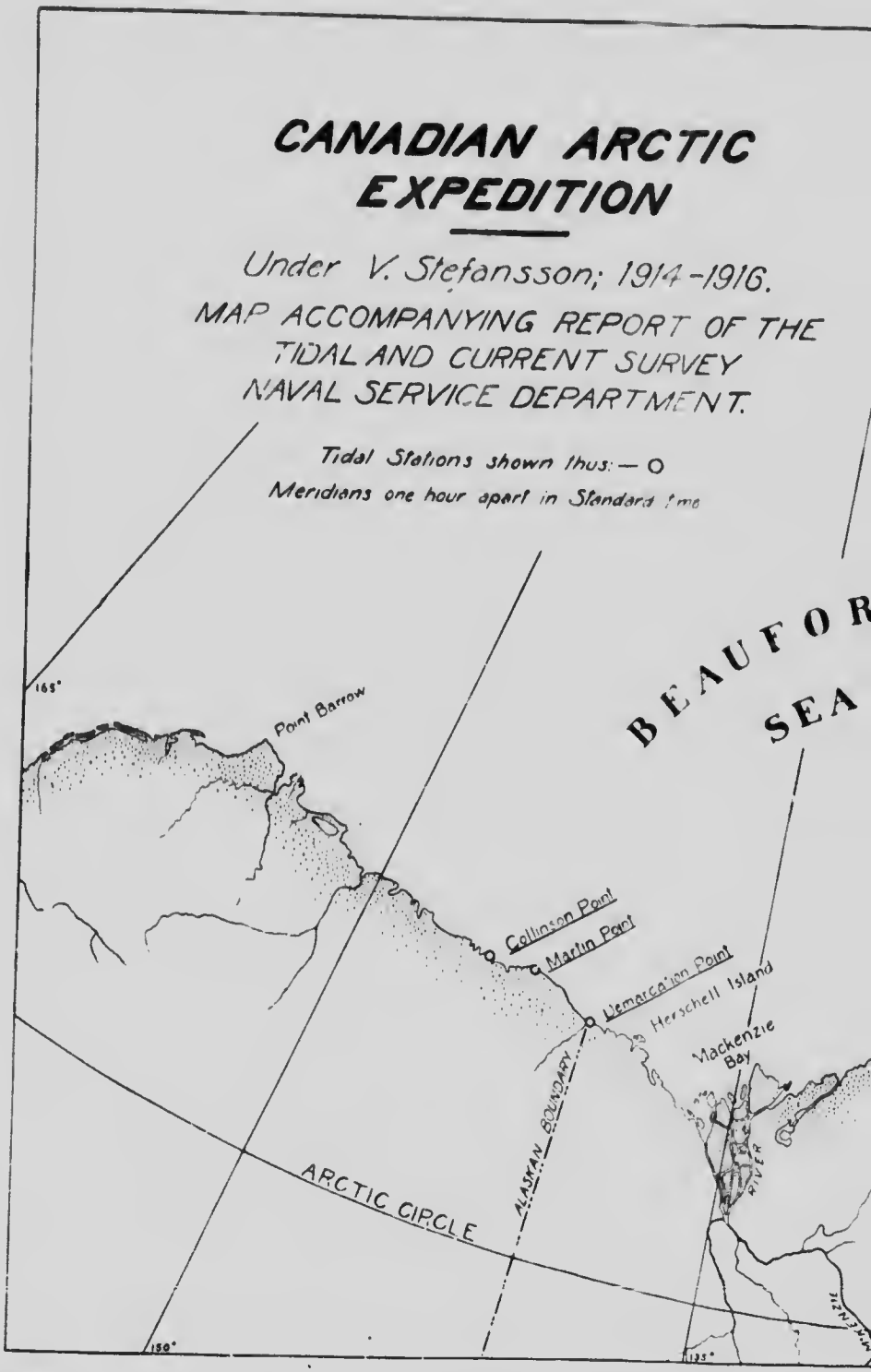
Spring Tides.					Neap Tides.				
Year.	Date.	Ranges.	Mean	Moon's distance.	Year.	Date.	Ranges	Mean.	Moon's distance
1908	Nov. 25	3·57			1908	Dec. 1	1·17		
		3·73	3·37				1·36	1·69	P
		3·25					2·19		
		2·93					2·05		
	Dec. 8	2·95				Dec. 17	0·93		
		3·24	3·24				0·78	1·19	A
		3·58					1·11		
		3·21					1·63		
	Dec. 25	2·80			1909	Jan 1	2·12		
		3·15	3·23				1·67	1·76	P
		3·70					1·36		
		3·29					1·89		
1909	Jan 8	2·58				Jan 16	1·27		
		2·73	3·12				0·88	1·29	
		3·65					1·10		
		3·50					1·61		
	Jan 23	3·40				Jan 31	1·67		
		4·42	3·73				1·91	1·55	
		3·62					1·30		
		3·47					1·33		
	Feb. 6	3·09				Feb. 15	0·64		
		3·78	3·28	A			0·79	0·97	
		3·20				Feb 16	1·04		
		3·05					1·41		
	Feb. 23	3·63				Mar 1	0·96		
		3·94	4·15	P			0·89	1·08	
		4·58				Mar. 2	1·29		
		4·16					1·19		
	Mar. 9	3·46				Mar. 16	0·93		
		3·78	3·58	A			0·81	0·94	
		3·77					0·84		
		3·32					1·20		
	Mar. 23	4·76							
		4·19	4·51	P					
	Mar. 24	4·35							
		4·90							

The figures in the column headed "Ranges" show the rise and fall of the tide on the days of greatest and least range in the month. The resulting means are thus the best values for the Spring range and the Neap range.

It will be noticed that there are times, when the moon's declination is high, that there is a marked diurnal inequality. This inequality is eliminated by the above method.

In the column headed "Moon's distance," P is for Perigee and A for Apogee, when these occur at the Spring or Neap tides respectively, as indicated.

ESTABLISHMENT.—At Winter harbour. Time errors are noted and accepted as reliable. Value deduced from luni-tidal intervals in five lunar months, taken in sets of four at each new and full moon to eliminate diurnal inequality, and averaged in pairs at full and change to eliminate semi-monthly inequality. Final mean, 12 h. 01 m.


CANADIAN ARCTIC EXPEDITION
Under V. Stefansson; 1914-1916.
MAP ACCOMPANYING REPORT OF THE TIDAL AND CURRENT SURVEY NAVAL SERVICE DEPARTMENT.
Tidal Stations shown thus: — O
Meridians one hour apart in Standard time
BEAUFOR
SEA
165°
Point Barrow
Collinson Point
Martin Point
Demarcation Point
Herschell Island
Mackenzie Bay
ARCTIC CIRCLE
ALASKAN BOUNDARY
150°
125°

70804


80°
Cape Isachsen
ELLEF RINGNES ISLAND
THIRD ISLAND
PRINCE PATRICK ISLAND
MELVILLE ISLAND
McCLURE STRAIT
MELVILLE SOUND
BANKS ISLAND
WALES STR
Armstrong Point
PRINCE
McCLINTOCK CHANNEL
Cape Kellett
VICTORIA ISLAND
AMUNDSEN GULF
DOLPHIN and UNION STRAIT
Bernard Harbour
120°
105°

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