Notes on Determination of Position Near the Poles

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From the above it will appear that the extensive sledge-trips, and the collections which will, it is hoped, be the results of these sledge-trips, must necessarily pre-suppose a ship as the headquarters of the expedition. To manœuvre the boat we must, I think, have a captain, a mate, and three sailors.

Besides, the captain of the ship, together with the mate, must do the necessary cartographical work, which, especially in north-western Baffin's Land, will be very considerable; likewise, they must be able to make the meteorological observations.

Seeing that the route followed by the ship-expedition, also in other respects, will offer very interesting, hitherto unsolved scientific problems, the staff will further include a geologist and a physician who, together with the geologist, will be able to undertake the botanical and zoological studies if necessary, also to do the work of an anthropologist and archæologist. Chiefly as regards the study of glacial geology the districts round the projected winter harbours are of the greatest interest, and offer the possibility of making important comparison with the natural conditions found in Greenland. In northern Baffin's Land the glacial formations, the extension and nature of which are hitherto unknown, as well as the Quartiary formations in connection with the glacier, will offer an instructive transitionary stage between the totally ice-covered district of Greenland and the Barren Ground, now free from ice, but in former days covered with glaciers. In Baffin's Land and the Melville peninsula there is also the prospect of carrying on important palæontologic studies, while the Barren Grounds to the west of Hudson bay, which, geologically, are hitherto known through a few hasty visits from Canadian geologists, are furthermore of the special interest that the great American glacial period probably originated in these districts, for which reason researches carried on here offer the possibility for solving a series of problems as to the motion of the ice.

From a geographical point of view, the regions in question are, generally speaking, so unknown that every increase of our knowledge will be of the greatest value, and the expedition therefore ought to profit by the opportunity of making studies and collections in various directions, provided that this work does not throw obstacles in the way of the chief purpose of the expedition—the ethnographical researches.

NOTES ON DETERMINATION OF POSITION NEAR THE POLES.*

By ARTHUR R. HINKS, Royal Geographical Society Lecturer in Surveying and Cartography, Cambridge University.

THE writer is fully conscious of the fact that in the severe conditions of polar travel it is not a question of what observations might with advantage be made, but of what can actually be done. The only purpose of these notes can be to

* Research Department, November 18, 1910.

provide a few pegs upon which those who have experience of polar observation are invited to hang the results of their experience.

Published accounts of the details of polar observation are scanty. By far the most complete is Prof. Geelmuyden's discussion of the astronomical results of Nansen's expedition ('Scientific Results,' vol. 2). But these refer, in great part, to a special case—the winter drift of the *Fram*. Star navigation of winter quarters is altogether exceptional. We will confine ourselves for the present to the case of sledging equipment and sights to the Sun only.

The points for discussion may be grouped under three heads—

(1) The instrumental equipment and methods.

(2) The chronometers or watches.

(3) The reduction of the observations.

(1) The principal question is, Theodolite or Sextant? Recent experience seems all in favour of the small "mountain" theodolite, as used by Captain Scott and Sir Ernest Shackleton. Its obvious advantage is that by observing on both faces the errors of adjustment are self-eliminated. A recent traveller observed only on one face. But if, owing to severity of cold or want of time, the double observation is awkward, observations on alternate days should be made on alternate faces. The stand for the theodolite is of importance. Nansen used a brass plate bedded on snow, and lay down. But this must be uncomfortable, and it will be interesting to hear the experience of Antarctic observers. No account of the *Discovery's* theodolite has been published. What was it made of? Nansen found aluminium very unsatisfactory.

The sextant and artificial horizon together weigh little less than the theodolite. The sextant was found by Nansen to be unreliable in extreme cold; very probably it developed error of eccentricity, which is very difficult to determine. And observation of a low sun with an artificial horizon is always difficult. Mercury horizons are liable to freeze; glass horizons do not seem to give satisfactory results. Occasionally it is possible to use a pool of water on the ice; but this must be rare. Some observers have used the natural ice horizon; but this must be very rough and uncertain owing to the piling of the ice; and further, there is a difficulty about the "dip" and the raising of the apparent horizon by abnormal refraction. Geelmuyden gives some interesting results which show that in extreme cold the visible horizon is sometimes elevated by twice the amount that it should be depressed.

Considering all these difficulties, we may conclude that the theodolite is much better than the sextant for taking altitudes. And it is immensely superior in the observation of azimuth. The verdict must therefore be for the theodolite.

It must be important to cover the metal of the instruments as much as possible to protect the hands and face from contact. It would be interesting to learn the details of methods which have been found successful.

(2) On board the *Fram* the chronometer Hohwü 639 maintained an excellent rate, and the uncertainty of G.M.T. probably never exceeded $\pm$ 20^s, though G.M.T. in summer could be checked only by solar eclipses, of which two were observed during the drift. It would be interesting to have full information about the rates of the chronometers on the *Discovery* during her stay in the ice. Chronometers landed for use in observation huts undergo much severer conditions, and Drygalski found it impossible to keep his chronometer going in the pendulum hut.

The travelling rates of watches differ, of course, considerably from their stationary rates; on the *Fram* sledge expedition, the mean rate of two watches differed 12^s per day from the rate on board. The slight information given by Lieut. Mulock (National Antarctic Expedition, 1901–1904, Charts) suggests that the watches on the *Discovery* sledge journeys ran better, but details are wanting.

(3) The correction for refraction is important and difficult. Geelmuyden used Albrecht's tables, founded on Bessel's and extended to −50° C. by his formula. He gives observations of very low altitudes made expressly to determine refraction, but does not discuss them. Mulock used Bessel's tables, but gives no details of his extension of the tables for low temperatures.

Very little information is available as to the accuracy of the sights obtainable under Arctic conditions. The writer would urge that it is important that full details of all the observations made on recent expeditions should be published, in order to provide material for the discussion of their accuracy. Astronomers have an invariable rule, to publish their observations in such detail that it may be possible to assign limits of probable error to the results. The same rule might very well be observed in the publication of the results of polar expeditions. This remark need not be taken to imply an expectation of impossible refinement in observations made under rough conditions. But at present it is difficult to say whether the probable error of a "fix" with the mountain theodolite on a sledge expedition is one mile or two or five. And this might be remedied at once by full publication of the observations.

Near the poles the ordinary methods of determining position fail to some extent. Local time and longitude tend to become indeterminate, and this gives the impression that there are great uncertainties in the "fix." To a considerable extent this difficulty is artificial, and by a suitable modification of the methods of reduction employed may be avoided. The writer suggests that a modified Sumner method will give a rapid and easy graphical method of discussing polar observations. [A brief account of the method is appended. It is being developed, and a fuller account will be published later.] The method is suggested, in the first instance, as a convenient way of examining a long series of records. But it is possible that it may be of use on an actual expedition.

Incidentally the method shows very clearly that the accuracy of the "fix" depends entirely upon the accuracy of the "sight" and the accuracy of the G.M.T. carried by the watches. So long as pairs of observations can be secured on considerably different true bearings of the sun, it is comparatively unimportant at what time of day the observations are made; there is no real necessity to interrupt the journey at local noon; and the apparent difficulties connected with local time and longitude disappear.

Graphical Method of Reducing Polar Observations.

Take a polar chart, with parallels numbered in degrees of polar distance, and meridians numbered in hours from Greenwich.

Suppose two sights—

A at G.M.T.	$14^h\ 29^m$	alt. of sun	18° 20′	decl.	13° 46′
B „	$20^h\ 47^m$	„	14° 12′	„	13° 50′

Reduce to G.A.T. and lay off meridians in the corresponding azimuths.

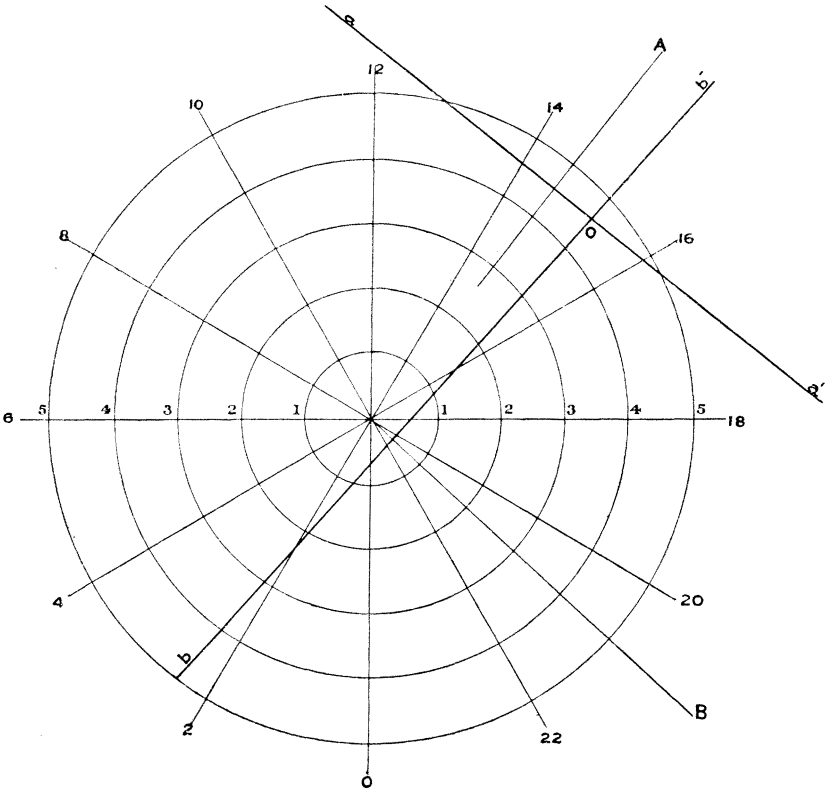
At first observation Sun is on meridian A. The circle of equal altitude 18° 20′ cuts this meridian at polar distance = altitude − declination = 4° 34′. The line aa' at right angles is an approximation to the circle of equal altitude, and the observer must be near it.

Similarly construct the perpendicular bb' to meridian B, cutting it at polar distance (14° 12′ − 13° 50′) = 0° 22′. The observer must also be near this line. Hence his position must be near the intersection O. The method is evidently a modification of Sumner's.

The circles of equal altitude are necessarily very large, as the Sun is always low. They lie on the Sun side of the approximate Sumner lines drawn. In the present case the circles would evidently intersect outside O, close to the line aa' and a little removed from bb' towards a'. Within 5° of the Pole the correction for curvature of the Sumner lines does not exceed about 3′. Hence the method gives a rapid way of checking a whole series of observations made on any bearings. Perhaps it is well known. The writer has not come across it.

Incidentally it shows that two sights on well separated bearings give as good a fix close to the Pole as anywhere else. The apparent trouble about the indefinite-

QUICK METHOD OF DETERMINING APPROXIMATE POSITIONS.



ness of local time and longitude is artificial, due to use of unsuitable co-ordinates. A little extra trouble will make the method sufficiently accurate for all purposes. Use a polar stereographic projection, which is practically the same as the polar equidistant close to the Pole. Then the circle of equal altitude becomes a circle on the projection. It is easy to calculate its radius on the projection, and hence its divergence from the tangent at any distance from the point of contact. It would then be easy to make the fix graphically within 1′.

Small tables to give the curvature correction are under construction.

The method has all the advantages of Sumner's or Johnson's. Sights may be made at convenient opportunities, not necessarily at local noon. The only table

required is that of the Sun's declination. Within 5° of the Pole the sights may be worked up graphically in a couple of minutes with all required precision. The method is suggested, in the first instance, as a convenient way of examining a long series of records. But it is possible that it may be of use on an actual expedition.

Dr. STRAHAN (before the paper): The paper for this afternoon is on the Methods of taking Observations in the Polar Regions, by Mr. Arthur Hinks. It is unnecessary for me, in view of recent events, to enlarge upon the importance of an observer being able to ascertain his position when he is approaching the Pole. The difficulties of doing it are sufficiently obvious to any one who has glanced at the summary of Mr. Hinks' paper.

Dr. STRAHAN (after the paper): We have among us several distinguished cartographers from different parts of the world. We should be very pleased to hear any remarks on the subject from them.

The following letter was read from Admiral Sir ALBERT H. MARKHAM: Speaking from my own experience while sledging northwards over what we called the Palæocrystic sea, I am inclined to say that when a high latitude has been reached by a traveller, whose object is the attainment of a still higher latitude, no matter in which hemisphere, there are only two observations to be taken that are of any real importance in order to enable him to determine his position. These are for latitude, and those for ascertaining the variation of the compass. The latter is of great importance, for it enables the traveller to steer a straight and direct course towards the Pole. Observations for longitude are therefore unimportant supposing, of course, that your departure has been made from a base, whose latitude and longitude have both been ascertained before leaving. When I was sledging north, I never bothered my head about taking any observations for determining my longitude, but I was very careful to check my course by constant observations for the variation of the compass, thus enabling me to shape my course along the same meridian of longitude.

The only other observations that I took were those for latitude, and these were obtained by observing daily the meridian altitude of the sun, either at noon or midnight, whichever was the most convenient, and, of course, when weather conditions permitted me to do so. The taking of these apparently simple observations was not quite so easy as might be imagined. Even at the latitude that I reached, which was just beyond the 83rd parallel, I found it an extremely difficult matter, with a mercurial artificial horizon (constructed specially for use in high latitudes), to obtain reliable observations when the altitude of the sun was very low—as it was at midnight—for it was not an easy matter to bring the two suns, the true sun and the reflected one, into the artificial horizon, so as to obtain a proper contact with the lower and upper limbs. Then it must not be forgotten that the difficulties which were experienced by me in the neighbourhood of the 83rd parallel, and during the months of May and June, would be very materially augmented in a higher latitude, and would be doubly intensified at an earlier period of the year, say in April!

I am of opinion that during that particular month, it would be almost impossible, in a high latitude, to obtain the meridian altitude of the sun with the ordinary mercurial artificial horizon, even if the mercury was in an unfrozen state, and I know of no other practicable horizon that could be used so as to obtain an accurate observation.

I have no faith in a glass horizon; the difficulty of adjusting it, so as to make it perfectly horizontal by means of spirit-levels and thumbscrews in a temperature 30° or 40° below zero, would be enormous, especially when placed on