



Notes on Determination of Position Near the Poles: Discussion

Dr. Strahan; Lewis Beaumont; Captain Scott; David Gill; Admiral Field; Arthur R. Hinks; S. C. N. Grant; Mr. Reeves; T. H. Holdich; H. H. P. Deasy; Mr. Bernacchi

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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

snow or ice. Oil or water horizons would be useless in low temperatures. I know nothing more aggravating than taking the meridian altitude of the sun in a high latitude; for its actual passage of the meridian is practically inappreciable, and it is most difficult to determine when the sun has actually ceased to rise and has commenced to dip! It is almost impossible for an observer to decide for at least thirty or forty minutes when the sun has passed the meridian!

I have had no practical experience of the use of a theodolite, but I am inclined to think it would be a better and more useful instrument than a sextant. No observations taken with an "ice horizon" would, in my opinion, be of any value.

Until recently I have never heard of chronometers forming part of a sledge equipment. In the first place, they would never stand the extreme cold to which they would be exposed, nor would they be improved by the rough usage which they would be subjected to on a sledge. I certainly would put no trust to their rate after being on a sledge for a few hours! In the expedition of Captain Nares, each officer in charge of a sledge was supplied with a chronometer watch, which he wore in a little pocket on the vest next to his skin, but nearly all these watches stopped, in consequence of the slight amount of oil, by which the works were lubricated, freezing. Finally, I should say that the more simple and the fewer observations, compatible with determining your position, the better. I have no reliance in positions determined by dead reckoning alone. I know on occasions when I was unable, from thick weather or snowstorms, to obtain observations of the sun for perhaps four or five consecutive days, I had to estimate the distance I travelled by various methods, and I always endeavoured to underestimate the distance, so that I should not be greatly disappointed when I was enabled to fix my position. I may say I was *always* disappointed, for I invariably found I had overestimated the distance travelled.

Sir LEWIS BEAUMONT: I have no doubt we shall hear later the practical experience of officers who have taken part in recent expeditions. I can only speak of the one which has been described by Admiral Markham, but there are one or two points in connection with it which I think it is worth while remembering. The expedition of 1875 was the last offspring of the great Franklin Search. It was fitted out by the officers, who themselves had taken part in that search, in the way which they looked upon as the very best. As you may remember, it was based on man-hauled sledges only, which has never been done since. That shows that it is hardly worth while going back to the expedition of 1875 for the purposes of making comparisons with later ones, but several points have been mentioned by the lecturer upon which I can give a little information. For instance, our expedition only used sextants, and the reason was that in the outfit everything was cut down to the very narrowest margin of weight, so that a heavier instrument, such as a theodolite, was rejected for the sextant. All exposed parts of the metal were covered with chamois leather, so that the inconvenience of touching them with your bare hand or face was removed. It must be remembered that in the expedition I am speaking of, it was not considered possible to travel in the winter, consequently the sun was higher during the long sledge journeys, and there was not the same difficulty in obtaining sights which winter travelling involves. There was no difficulty about the mercurial horizon either as to extreme cold or low altitudes.

We may look upon it that expeditions to the North Pole are practically finished. Commander Peary has been there, as the American Geographical Society has certified, and it is not likely that anybody else will ever again attempt it; there is Amundsen's expedition, it is true, but that is not for the purpose of reaching any definite point, and they will have no difficulty in fixing their position. There remains the South Pole; it will be very interesting to hear what the experience in the Antarctic is.

If the object is to reach the Pole, we believe now, from Sir Ernest Shackleton's discoveries, that it will be by a continuation of land travelling, and not over moving ice. The travelling, therefore, will be in spring or summer, and so free from some of the difficulties due to low altitudes.

Captain SCOTT: I wish to say that I heartily agree with the lecturer in considering that such a discussion as this may serve a useful purpose in defining the nature of the evidence which a scientific society such as the R.G.S. considers necessary that a polar explorer should produce to substantiate his discoveries. I regret that I had not sufficient notice of it to communicate with Lieut. Mulock, who had charge of our *Discovery* records; but I should have required a long notice to do so, as Lieut. Mulock is now in China. Speaking generally of the *Discovery* observations, it is to be recalled that observations for position were usually accompanied by bearings of conspicuous landmarks, and in a long series these would naturally form a check on one another. Any considerable error in position would be shown up by the impossibility of fitting in the land bearings taken at the same spot.

In regard to instruments, I am confident that the 3-inch theodolite, such as we used, is in every way more serviceable for polar work than the sextant. The natural horizon both in the north and south is hopelessly erratic from a variety of causes, and the artificial horizon is a clumsy and unstable instrument quite inadequate for the observation of low altitudes. A duplicate of the 3-inch travelling theodolite which we used can no doubt be seen at any time in Carey's shop, in Pall Mall. It is a very handy little instrument, but has certain drawbacks, to which I may briefly refer. I found the tripod unsatisfactory on the Barrier surface, as the legs had to be driven 8 or 9 inches into the snow before any degree of rigidity could be achieved; in some places even this did not suffice, and to get observations I was obliged to wait some hours to allow the tripod to freeze in and thus fix itself. I think this difficulty can be surmounted, and I propose to have flat plates attached to the base of the tripod legs in my future instruments.

Another difficulty arose on account of the contraction of the spirit in the levels; the bubbles became so enlarged in consequence that their limits could not easily be brought within view together. I think it advisable in the future to start with the smallest possible bubble or some device for compensating the contraction of the spirit. Our small theodolite could only be levelled roughly by the base-levels. To obtain accurate levelling it was necessary to adjust by the telescope level, by turning it over two screws or the third in the usual manner. With such small instruments, liable to occasional shocks, it is most important to take observations on "both faces." I will not say I always did so, but if I omitted to do so one day, I was most careful to take the fuller observations the next. A round of angles after chronometer sights was often a tedious and cold business, and I must confess that I often missed the final check which is customary after such a round, that of taking a second bearing of the sun.

With regard to refraction, we were, of course, greatly puzzled as to what tables to use. I am inclined to think the refraction small on the Great Barrier. I may mention that I frequently took meridian altitudes within a few miles, at noon and at midnight, and the difference in position given was never more than 3 or 4 miles. This gave the difference in refraction between a very low sun, 10° or so, and one at a considerable altitude, about 30° . I think it is arguable that if the difference in refraction at these altitudes is so small, the total refraction for either altitude cannot be very great. It is interesting to consider that in very high latitudes a sight at midnight and noon would practically eliminate refraction, and you have thus means of escaping all criticism of observations in this respect. At the pole refraction would not count at all if observations were taken on several bearings.

The lecturer has said that the watches supplied to the *Discovery* Expedition appeared to have been satisfactory. I regret that I cannot endorse that view; the only really good watch we had was that which I am now wearing—the rest were anything but reliable. But it must be remembered that it is asking a great deal of a watch, to expect it to keep an accurate rate under the circumstances under discussion. It is bound to receive occasional shocks; it is in continuous and irregular motion, and subject to considerable differences of temperature. It is remarkable that watches can be made to retain any degree of accuracy under such conditions. It is for this reason that I should deprecate placing too much reliance on any form of Sumner method such as that suggested by the lecturer. I remain a firm believer in the meridian sight, for latitude is, after all, the most important point for the polar explorer to determine. As a purely practical consideration, I might add, also, that the difficulties of handling a chart and fixing positions by drawing lines upon it are greater than those presented by notebook calculations. One can do a lot of calculation in a polar tent with notebook, tables, and pencil, when to spread out a chart and use rulers on it might be most difficult.

I do not think I have anything more to add, except perhaps to point out the ease with which the discoverer of the South Pole should be able to fix his position. Unharassed by the consideration of breaking sea-ice, he would aim at reaching his goal in the middle of the southern summer, when the sun has achieved its maximum altitude. The ideal day would be December 23. The change of declination would then be negligible in twenty-four hours—that is, the sun would revolve about the observer at a constant altitude. One can imagine, as a rough check, tracing the shadow of a vertical stick and finding a complete circle. May I add that I think the lecturer's suggestion that records of positions should be treated like other scientific data and published is a good one.

Sir DAVID GILL: I do not know, from the rather slighting way in which the polar traveller seems to speak of astronomical observations and their importance, that the astronomer very well comes in. I think that the suggestion of Mr. Hinks about the employment of the Sumner method is instructive. The Sumner method is really *the* practical method, for, at the instant of observation, it shows that the traveller must be somewhere on a particular circle on the Earth, and that is all that any single altitude can tell. A similar observation at another instant of time gives another circle on which the observer must be, and the intersection of these circles is the traveller's position. Lord Kelvin some years ago gave a simple means for working out Sumner observations. I do not see that the whole of the observations need be completely worked out at the time. The astronomer, when he goes on an expedition, is only careful to collect the observations, and when he gets home he reduces them in the best way he can, and I think that what Mr. Hinks says is right, viz. that if we had access afterwards to those observations, they could be thoroughly discussed so as to give us some idea of the experience of the observers, and what accuracy is obtainable in such circumstances; and, at all events, it would put an end to all questions as to whether a man was or was not there. If we had these observations made in that way, simply a record that we had an altitude at such and such a chronometer time, you have perfect control, and I defy anybody to cook a series of such altitudes as the traveller went along.

Admiral FIELD: I am under the disadvantage of having had no practical experience of observations in the polar regions, but I can, nevertheless, realize the difficulties under which the observations are made. Perhaps it does not do to be too critical of the results which may be obtained from them. It would

be very desirable, no doubt, to have the original observations and to investigate them. I dare say the difficulties of fitting things in would rather surprise some of us. One knows quite well that it is not easy, even under most favourable conditions, to get three bearings to cut into a point when taken from three astronomical observation spots. I have never yet been able to do it satisfactorily, and that it must be still more difficult up in the Arctic regions I can fully realize. I think the lecturer referred to the necessity of taking observations on both faces of the theodolite. With a theodolite of ordinary pattern it is perhaps putting rather a heavy and unnecessary burden on the observer. His principal source of error lies, of course, in his level and collimation. These he can determine by separate methods, with less chance of disturbing the instrument. Frequently in our hydrographical work we do not observe on both faces, and I do not see, if it is good enough for hydrographical work, why it should not be good enough for polar work, provided the proper precautions are taken. I think there is an exaggerated idea of the accuracy of the observations that can be made in these regions. As regards the sextant *versus* the theodolite, under ordinary circumstances I am a strong upholder of the sextant, but in polar regions I think there can be no doubt about it that, considering the difficulty of observing with an artificial horizon at low altitudes, the theodolite must be preferable, and apparently that coincides with the experience of other officers. As regards the chronometers, the more recent chronometers of the Admiralty are keyless with quick train, so that they are very much better than the old pattern beating 5 to 2 seconds, which I think were supplied to the '75 polar expedition, and possibly to the *Discovery* expedition. Our recent pocket chronometers, if treated properly, are just as good as a box chronometer; they keep excellent time, and, by being fitted with quick train, beating 9 to 2 seconds, they stand very much rougher treatment without altering their rates. There is one other remark as regards the method which the lecturer proposes. It seems to me to depend upon the assumption that circles of equal altitude cut circles of declination at right angles. Now, in the figure which appears in the paper, when you are at the pole, of course your circle of declination is a meridian, but that is not so if you are not at the pole, and therefore it seems to me that this method can only be true absolutely when at the pole. I see the lecturer proposes using it within five degrees of the pole, but it would have an error, it seems to me, varying with the latitude and the hour-angle of the heavenly body. I may be wrong, and I should like to know if that has been considered by the lecturer?

Mr. HINKS: I think that there can be no doubt that the circle of equal altitude approximates very nearly to a straight line.

Admiral FIELD: I am not referring to the fact that the circle of equal altitude approximates to a straight line, but whether it cuts the circle of declination at right angles. I cannot see that it does.

Mr. HINKS: It is not on your own meridian; it is the meridian on which the sun is.

Admiral FIELD: I may be wrong, but that is as it strikes me.

Colonel S. C. N. GRANT: I should like to speak on one small point, and that is to explain an incident I have come across practically, about observing face right and left with a theodolite. I was once working in Africa with some foreign officers, and I found we were always differing by a fixed quantity in the results of the observations. One night I said I would like to see how they observed, and I found that one of the officers observed his north star face right, and the south star face left; east star face right, and west star face left. That is an error which perhaps people who do not thoroughly understand the subject might get

into. Trying to get right, this officer went more wrong than if he had observed on one face only. Can any gentleman tell us at what temperature the spirit used on spirit-levels will freeze, and at what temperature watch-oil will freeze?

Captain SCOTT: Watch-oil will freeze directly it is out.

Mr. REEVES: The spirit with which spirit-levels are usually filled freezes at -200.2° .

Colonel Sir T. H. HOLDICH: Nearly everything I proposed to ask the lecturer has been anticipated, but there is just one point to remark as regards the theodolite. I have not had an opportunity of observing under such Arctic conditions as Captain Scott, but I have taken a great many observations with the temperature below zero and in pretty deep snow. I do not see why Arctic or Antarctic explorers should limit themselves to so small an instrument as the 3-inch theodolite, although I admit that the main point is the vertical circle. I have myself always used a 6-inch theodolite with both horizontal and vertical circles, and with this I could observe a latitude to one second of arc; and I found great value in the additional size of the instrument when I had to watch what the levels were doing. I did not find that if the stand was fitted with shoes it sank appreciably; but I did find it an absolute necessity to observe on both faces. No observation would have been accepted as valuable that was not taken on both faces, because the double observation not only eliminates the zero error, but also the level error, which is more important. I also wish to know, at what temperatures do levels cease to act? I imagine that there is a point of low temperature when you cannot trust your levels. Under any circumstances, I am in favour of an equipment of one 6-inch and one 3-inch theodolite.

Captain H. H. P. DEASY: I should like to ask Sir David Gill if he considers it would be possible to observe planets in the daytime, with a 3-inch theodolite?

Sir DAVID GILL: You can easily get Venus; I question very much whether you would see the other planets so well, but Venus is of course always easy to see, if you know where to point at.

Mr. BERNACCHI: I have had a little experience in the Antarctic with instruments, and do not agree with the lecturer that the conditions are so arduous. Most of these observations are taken in the middle of summer; in the winter of course the difficulties are greater. I think the theodolite is perhaps the best instrument for polar work, provided you have an expert observer thoroughly competent to make all the necessary adjustments. At the same time a great deal of good work can be done with an ordinary sextant if properly adjusted. The glass horizon is utterly useless in the polar regions. I have great belief in the mercurial horizon. The sextant is seldom used at temperatures below -40° , and if you have a mercury horizon and use it in a round dish say 6 inches in diameter, I think you could do very good work indeed. With regard to the refraction tables, we very seldom had to employ them at low temperatures: in the few cases, I simply had to take ordinary refraction tables, and subsequently work out the formula on my return home. The lecturer referred to the chronometers and the important data that might be derived from the *Discovery's* chronometers. I do not think you would get very much information from those chronometers, as they were kept in the ward-room of the ship, where the temperature was practically uniform; but I had one chronometer employed for pendulum observations on shore. I think you will find, in the results of our physical observations, some interesting information with regard to the behaviour of that chronometer at low temperatures.

Mr. REEVES: For years past it has fallen to my lot to investigate and compute observations taken by travellers in all parts of the world, including the polar regions, and I suppose I have thus naturally become a sort of repository of the experience

of travellers generally as regards these matters. It is for this reason that I venture to make a few remarks on the subject before us. In the first place, it seems to me that, whether we attempt to plot the results of observations by the adaptation of Sumner's method as shown by Mr. Hinks, or by any other such arrangement, or whether we follow the more exact method of computation, the final result must depend upon the altitude; therefore the method of obtaining the most accurate altitude in the exceptional conditions of high latitudes becomes a question of the greatest importance. Since an explorer in these regions must travel by daylight, star observations are practically out of the question, and he is restricted to the sun. First, as regards latitude, the observation for which is doubtless the most important of any on polar expeditions, instead of a single-meridian altitude, it would be better to take the altitude of the sun both at its upper and lower culmination. By this means refraction will be very nearly eliminated, or, at any rate, it will only be a differential quantity for the two altitudes, and as the difference between the altitudes can only be a few degrees near the pole, this method of observation should certainly give a more accurate result than an altitude measured only one side of the zenith. It would further tend to eliminate instrumental or personal constant errors in the measurement of the altitude. With reference to instruments, there can be no question that, provided a firm foundation can be obtained for the stand, a theodolite is preferable to the sextant; but when this instrument is used, the altitude should be measured on both faces instead of one face only, and the level-readings should also be noted, as if this is disregarded, considerable error may at times be introduced. For this purpose the level should be on the vernier arm, and not on the telescope. However, the value of face-left or face-right readings only depends upon whether the instrument is in proper adjustment. When this is the case, and the readings have been found beforehand to be the same on both faces, an altitude taken on one face only should give a satisfactory result. Of course, a theodolite cannot be used except on land or firm ice; on moving ice there is nothing to be done but take altitudes with a sextant, with the best available horizon, either artificial or natural. But the latter is never likely to be very satisfactory. The best form of artificial horizon is doubtless the mercurial, when it can be used; but as mercury freezes at -40° , this may frequently be out of the question, unless it is warmed by some means or other, as I have known to have been done on more than one occasion. The silvered plate-glass artificial horizon is never so satisfactory as the mercurial, specially at low altitudes, but has the advantage of being light and portable. The best form of plate-glass artificial horizon is one in which the glass is blackened throughout, for if it is silvered or blackened only on the back, there may be a double reflection, which considerably distorts the image of the sun. The plate-glass artificial horizon has necessarily to be levelled by a spirit-level, and this must be most accurately performed. The levels should not be attached to the artificial horizon, but separate, so that in the process of levelling their ends can be reversed. Owing to vibration due to traffic, it is impossible to use the mercurial artificial horizon in the Society's observatory, so I have had considerable experience with the plate-glass pattern, and find that with care, when the altitude is not too low—say, 30° or over—it is possible to obtain the latitude from the meridian altitude of the sun to a greater degree of accuracy than is generally supposed. However, altitudes such as 6° and 11° , of which we have heard lately as having been observed for obtaining latitude in the north polar regions, cannot possibly give reliable results. Several attempts have been made to combine some form of artificial horizon with the sextant instead of having separate instruments, and the most recent of this kind is a pendulum arrangement designed by myself, and noticed in the *Geographical Journal* for December, 1908. By reversing the

reflecting mirror errors are to a great extent eliminated, and I see no reason why this arrangement should not answer well on polar expeditions, specially as it is suitable for taking low altitudes. Reference has been made by Mr. Hinks to altitudes of the sun, taken during a recent Antarctic expedition, on one face of the theodolite only. As before stated, the value of such observations depends entirely upon whether the instrument was in adjustment, and in the case of the observations taken by the Shackleton expedition on the southern journey, I find, after careful inquiry, that every care was taken to see that the adjustments were perfect. The observations for latitude during this journey were made with a 3-inch transit theodolite, reading to single minutes, similar in pattern to that taken by Captain Scott on his expedition, and the readings were checked by several members of the party before being written down. I have seen the original notebook containing the record of the observations, and, after re-computing all the latitudes, it is satisfactory to find that in no case did the results of my computations differ from those made by Dr. Marshall and verified by the other officers of the expedition by more than 1', although I used the best refraction tables and applied all possible corrections. In the case of the furthest south latitude obtained, $87^{\circ} 22''$, the result of my computation agreed with that previously obtained within $10''$ of arc. In order to test what could be really done with a small 3-inch theodolite, I recently took a single-meridian altitude of the sun for latitude with a similar instrument, on one face only, without paying particular attention to adjustments, and obtained a result within 3' of the correct latitude of the R.G.S. observatory. Taking all the circumstances into consideration, I feel sure that the observations for latitude observed on Shackleton's furthest south journey can be relied on to within about 2', plus or minus, of the result given on his charts. I can only speak for the Southern journey map, but the mapping of the magnetic pole expedition I have every reason to believe has been most carefully done by Mr. Douglas Mawson, who is, I understand, a trained Australian Government surveyor of considerable experience.

As regards Mr. Hinks's chart, it is of course, as he admits, only a modification of Sumner's lines. Very similar methods have been used for years past, but I consider the manner in which he has plotted the lines to be original and ingenious. With reference to what Mr. Hinks states about the difficulties of time and longitude observations in polar regions being artificial, although I fully understand what he means by this, I think it must be admitted that in another sense the difficulty is often very real indeed. His own charts depend for their plotting upon Greenwich Mean Time. It is almost impossible to carry chronometers showing Greenwich Mean Time with anything like accuracy over the rough sledge journeys of polar explorers. Chronometers are all well enough on board ship, but when it comes to overland journeys through rough country, it is practically impossible to carry time, whether you have box chronometers or half-chronometer watches, unless careful and constant observations are taken to rate them. In very high latitudes the altitude observations for time necessary to rate the chronometers must be extremely uncertain, so that it becomes practically impossible to rate chronometers by the ordinary method, and to attempt to do so by any other method is usually quite out of the question. In lat. 88° an error in altitude of 8' of arc will make an error of about a quarter of an hour in the time with an hour-angle of about five hours. Apart from the question of longitude, this uncertainty in Greenwich Mean Time has a direct bearing on the latitude observations, since it affects the corrections for the declination of the sun, which of course is given in the Nautical Almanac for Greenwich time.

Dr. STRAHAN: I have seldom heard a more interesting discussion than we have

had on this paper. It only remains for me to ask Mr. Hinks to reply, at a not too great length, to the large number of questions that have been raised.

Mr. HINKS, in the course of a reply on the whole discussion, said that the greater number of questions asked had been answered already for him far better than he could do himself. He was glad to recognize that the consensus of opinion was in favour of the theodolite as against the sextant, and that it was generally agreed that it was not unreasonable to insist upon observations being made on both faces, even if pressure of time demanded that the alternation should be only from day to day. The very interesting statement of Captain Scott increased his desire that the observations should be published in detail. Captain Scott had remarked that if you observe the lower as well as the upper culmination of the sun during the perpetual daylight, you nearly eliminate the refraction and get your latitude accurately. It is equally true that a discussion of these observations would throw much light upon the amount of the refraction.

Mr. Reeves had suggested, in opposition to his view, that the difficulties concerning time and longitude were by no means artificial, but very real indeed; and had argued that a graphical method depending upon knowledge of G.M.T. neglected the fact that G.M.T. is difficult to carry, and almost impossible to determine during the Arctic day. In reply to this the speaker desired to point out that the graphical method was in this respect on all fours with other methods; you must know your G.M.T. approximately or you are altogether lost, until you get to the actual pole. The disadvantage of the ordinary methods was that they exaggerated the uncertainties due to the vagueness of local time and longitude. The graphical method avoided any direct consideration of these necessarily vague quantities, and at the same time exhibited in the most plain manner the uncertainties which were due to the uncertainty of G.M.T.

Admiral A. A. CHASE PARR, a member of the Nares Expedition, 1875-76, sends the following:—

“Perhaps some of the experience gained in working the transit and alt-azimuth instruments during the winter of 1875-76 at the winter quarters of H.M.S. *Alert* may have a bearing on this subject. Also remarks on the behaviour of the pocket-chronometers and sextant during the sledge journeys.

“Two of the principal difficulties in using the transit and alt-azimuth were—(a) The formation of rime on the glasses of the telescopes; and (b) the levels being rendered sluggish by the cold.

“With regard to (a) the difficulty occurred mostly in the winter, and was greater with the transit, which was in a house, than with the alt-azimuth, which was in a snow hut without a roof. On more than one occasion observing had to be given up on this account. The observation of an eclipse of the sun which was being made from the top of a hill near the ship was interfered with from this cause, the temperature at the time being -37° Fahr.

“As to (b), our levels were specially filled with the purest spirit and very small bubbles. This answered perfectly as far as the bubbles were concerned, for even in the coldest weather they were always a suitable size. Below -40° Fahr., however, the spirit became so sluggish that the readings were not reliable. Good observations were obtained with a temperature of -39° Fahr., and others are recorded at -43° Fahr., but there is some doubt as to the value of these.

“Before -70° Fahr. was reached the spirit was of such a consistency that it was necessary to alter the level considerably before the bubble would move at all. Also the liquid had turned a brownish colour, which may possibly have been due to some impurity.

“No difficulty need be anticipated from handling instruments in cold weather.

As has been seen, they are useless from other causes when the temperature falls below -40° Fahr., and experience shows that, in calm weather, it is quite possible to work an alt-azimuth for over an hour at that temperature with bare hands, uncovered as well as covered parts of metal being manipulated. At lower temperatures mitts would be worn, which would be sufficient protection in themselves. It might perhaps be advisable to put leather on the eye-piece, but elsewhere it cannot be considered absolutely necessary.

"The only instruments we took with us sledging were a sextant and prismatic compass. The latter worked well, with a variation of about 102° , while as to the former we had no reason to complain. We had no experience of a theodolite when sledging, but neither theodolite nor sextant would be of much value at temperatures below -40° Fahr. However, in the Arctic there is not much chance of the thermometer falling so low when the sun is high enough for observation, though in the Antarctic it may be different.

"With regard to errors induced in instruments by extreme cold, there was some difficulty in adjusting our alt-azimuth, partly owing to the cold and partly owing to the fact that the case it was in had suffered somewhat on the passage out. The result for the determination of latitude by observation of thirteen stars passing south and a similar number passing north was a difference between the two of $8''.5$, which was quite good enough for our purposes.

"It is true that all the pocket-chronometers carried by sledging officers of the *Alert* stopped at some time or other, mostly for a short interval, and then went on again. To give a definite example of how two of them behaved. We left the ship on April 3, when one chronometer had a rate of 4.65 seconds daily losing, the other 7.75 seconds gaining. Soon after leaving a temperature of -42° Fahr. was experienced. On May 6 the difference between the longitudes obtained by two observers using the same sextant, but different chronometers, was 51 seconds; on May 11 one of the chronometers stopped for about ten minutes without any apparent cause, and then went on again. On the same day the difference in the longitudes obtained by the two observers using the chronometer which had not stopped was 6 seconds, the altitude of the sun being about 17° and the latitude $83^{\circ} 19' N$.

"The deck-watch was used for all observations with the transit and alt-azimuth, and on those occasions was fully exposed to the cold for perhaps two hours or more without its being much affected.

"During the summer, provided it is not required to observe altitudes less than 15° , and provided the distance from the magnetic pole is sufficient to admit of the compass working satisfactorily, a theodolite does not seem to be necessary.

"As in all probability the accuracy of the longitudes ascertained when sledging would depend upon the accuracy with which the longitude of the winter quarters had been determined, a word with regard to that may not be out of place. Owing to the causes which have been mentioned, and others which have not, it was not easy for a single observer to obtain good results from moon culminations, the greatest difference amongst eleven accepted observations being 54 seconds. With occultations, however, none of these difficulties existed, the only thing necessary being a clear sky. One observation was made at a temperature of -71° Fahr., and another during a gale of wind through a small slit in the housing, both with good results. The greatest difference among six accepted results was 11 seconds."
