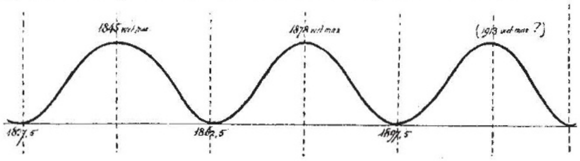
"At the same time the rain fell after sixty-six days' drought, no such instance of dry weather in the West Indies was remembered). The next minima (of wet) would correspond to 1862·5 (great earthquake in Greece, 26 Dec./61, and eruptions of Vesuvius accompanied by earthquakes), and the last, to 1897·5, which fairly corresponds to the great earthquake of Assam, so fully noticed in your journal, as one of the most intense of modern times. Moreover, these figures may be presented otherwise. Taking the great earthquake of Lisbon as of date 1755, roughly we have the annexed succession of years showing at the two extremes the dates (approx.) of two of the greatest earthquakes of modern times, and to some extent showing that thirty-five years represents a period of maximum earthquake action, and agreeing roughly with the intervals of extreme drought and with periods of great volcanic activity.



1755
+ 35
1790
+ 35
1825
+ 35
1860
+ 35
1895

As regards the year 1825, it is interesting to note that Mallet's Catalogue gives for July 26 and 27 of that year, "One of the most tremendous hurricanes on record occurred in the West Indies."

Of course a great deal has to be said as to the locality of the earthquakes, and as to the volcanoes to be considered. I certainly look on those of the Andes Cordillera as of prime importance by their influence on the upper currents.

Royal College of Science, Dublin, J. P. O'REILLY.
May 21.

Ebbing and Flowing Wells.

A CASE somewhat resembling those previously described (NATURE, May 12, p. 45, and May 19, p. 52), occurs on the dormant volcano of Barren Island in the Andaman Sea. The only (comparatively) fresh water to be found on the island reaches the surface in the form of hot springs, which gush out close to the shore at the breach through the ancient cone. The springs are due to the percolation of the drainage water beneath the most recent lava streams, which have not yet fully cooled down. The level of the springs rises and falls with the tide, and the lower part of a well, which I caused to be dug in the ash about twenty yards from the shore, filled with hot water at the flow of the tide, and ran dry at the ebb. The bottom of the well was between tide levels. The water is brackish, but rather less so at high than at low tide, the reason of which appears to be as follows. The porous volcanic materials of the island below sea level are saturated by the water of the sea, the surface of this inland subterranean water rising and falling in connection with the rise and fall of the sea tide. The drainage of the amphitheatre, then, soaks downwards until it reaches the inland salt water, over which, on account of the difference in specific gravity, it flows onward to the sea. At high tide, therefore, the drainage reaches the sea through materials which have been comparatively little wetted by salt water, while at low tide it percolates through, and washes, ejecta from which the salt water has just retired. The phenomenon is, of course, complicated by the difference in time between the inland tide and that at sea.

The springs are described in some detail in *Memoirs Geol. Surv. Ind.*, vol. xxi. p. 274 (also *Records G.S.I.*, vol. xxviii. pp. 31, 34). F. R. MALLET.
May 25.

NAVIGATION.

NAVIGATION, in its widest sense, is generally defined as the art of conducting a ship from port to port, and may conveniently be divided into coasting and guiding the path of a vessel across the trackless ocean.

Coasting is principally pilotage, assisted by a few rules based on geometry and plane trigonometry, combined with a knowledge of that oldest and most valuable of seamen's friends, the mariner's compass. A knowledge of the compass in Europe is much older than is generally supposed. It was certainly used as far back as the beginning of the thirteenth century.

The compass plays a still more important part in deep sea navigation (with which this paper is more particularly concerned), which is so closely allied to nautical astronomy that in one sense of the word it includes it, whilst in another it distinguishes the terrestrial methods of finding the position of a ship at sea, from the more accurate methods of locating her whereabouts, that the researches and labours of the astronomer have placed at the disposal of the navigator.

The earliest efforts of the seaman, when he ventured out of sight of land, were directed by the compass, which of late years has been immeasurably improved, and by a log for measuring the rate of sailing, which has become almost as obsolete as the plane sailing and the plane chart by which he estimated his position. This method, proceeding on the assumption that the earth's surface is a plane, was fairly accurate for moderate distances near the equator, or even in higher latitudes if the vessel sailed on, or near a meridian, but was quite incapable of measuring differences of longitude, and if used, for instance, on a westerly course from Cape Clear, would produce an enormous error, if the departure or westing was taken as the difference of longitude. Owing to the uncertainty and variability of the wind, sailing vessels altered their course so often that, to save the labour of working out the difference of latitude and departure for each course and distance by trigonometry, the traverse table was introduced. It is simply the tabulated values of the sides of a number of right-angled triangles, where the hypothenuse is the distance, the perpendicular the departure, the base the difference of latitude, and the course the given angle. By means of this table it was easy to get the difference of latitude made good, by taking the difference between the sum of the northings and southings, and the departure made good, by subtracting the eastings from the westings, or *vice versâ*. This was called resolving a traverse. The inability of plane sailing to afford the difference of longitude led to the introduction of parallel sailing, middle latitude sailing, and Mercator's sailing, and the inestimable chart that bears the name of the latter. It is easily demonstrated by solid geometry, that the arc of a parallel of latitude between any two meridians is equal to the corresponding arc of the equator multiplied by the cosine of the latitude; so that if a ship sails on a parallel, it is a simple operation to convert her meridian distance or departure into difference of longitude. But a ship does not always keep to a parallel; in sailing, however, from point to point, she must leave one parallel and arrive at another. Now let the portion of the rhumb line between these two parallels be conceived to be divided into infinitely small parts, which will be sensibly straight lines on each of which is a triangle representing the corresponding difference of latitude and meridian distance. Then the departure will be the sum of all these meridian distances, and must be equal to the arc of a parallel somewhere between the two extreme ones. In middle latitude sailing it is assumed to be equal to the arc of the parallel that lies midway between the one left and that arrived at, and the difference of longitude is obtained as in parallel sailing, substituting the middle latitude for the parallel.

Though the above assumption is not strictly accurate (the real parallel always lying on the polar side of the middle latitude), the results deduced from it in favourable cases are such very close approximations as to be preferable to those obtained by Mercator's sailing, which is theoretically irreproachable.

About the middle of the sixteenth century, Gerard Mercator introduced the chart which has since borne his name, in which the meridians are all parallel and the degrees of latitude increased towards the poles, and on which the rhumb line (or loxodromic curve which on the sphere is a spiral approaching nearer to one of the poles at every convolution) cuts every meridian that it crosses at the same angle. Mercator does not seem to have understood the principles on which his charts should be constructed, for he left no description of them, nor were they even accurate, and it was left to an Englishman, Wright, to demonstrate that, as in making the meridians parallel the meridian distances were being increased in proportion to the secant of the latitude the lengths of the degrees of latitude must be increased in the same ratio. This is obvious from the fundamental formula of parallel sailing. On this principle Wright proceeded to construct a table of meridional parts, by means of which we get a meridional difference of latitude which bears the same proportion to the difference of longitude as the true difference of latitude bears to the departure. We have then two similar triangles with the course as a common angle, either of which can be resolved by the rules of plain trigonometry. Now, whilst this method is in all cases theoretically accurate, in finding the difference of longitude in a low latitude corresponding to the distance run and the difference of latitude, if the course be near east or west, its tangent being large will rapidly multiply any error in the meridional difference of latitude (due to neglecting decimals, for the parts are generally given to the nearest whole number), and thus produce a large error in the difference of longitude, whereas the departure multiplied by the secant of the middle latitude would not be open to the same objection; besides, the course would approximate to a parallel, and so small would be the error from treating the middle latitude as such, that the result would be practically if not scientifically accurate For reasons of a similar nature the course and distance run from day to day, if sailing near a parallel, are better found by middle latitude sailing, especially in low latitudes, unless the ship crosses the equator, when the portions on each side of it ought to be obtained separately if this method be used. In all cases where the foregoing conditions do not obtain, recourse should be had to Mercator's sailing. In a doubtful case the course and distance might be calculated by both methods, and the results compared. For the purposes of steering, the course is only required to the nearest degree and, as a general rule, for computing the distance to the nearest minute. If, however, the course be near east or west, its secant, being large and changing rapidly, is required to the nearest second to obtain the distance accurately. As the seconds are of no use, except to get the secant exactly, they may be done without by observing that the required secant will exceed its tangent, which is in the computation already by the same amount as the nearest tangent in the tables is exceeded by its secant.

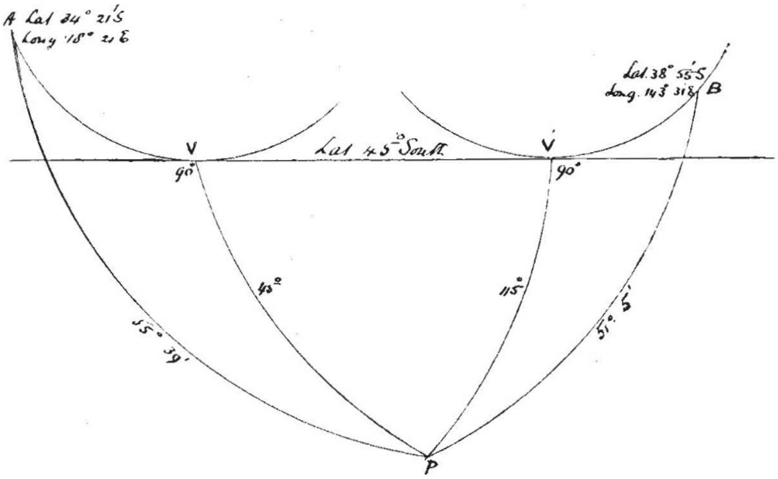


FIG. 1.—Showing the composite track from the Cape of Good Hope to Cape Otway, with 45° as maximum latitude. The composite track is from A to V, V to V′, and thence to B.
Cos AV = sin lat. A, cosec lat. V.
Cos BV′ = sin lat. B, cosec lat. V′.
Cos APV = tan lat. A cot lat. V.
Cos BPV′ = tan lat. B cot lat. V′
APB − (APV + BPV′) = VPV′ which × cos 45° = VV′.
Sin A = sec lat. A, cos lat. V and sin B = sec lat. B, cos lat. V′.

Except the ship is being navigated along the equator or a meridian, none of the foregoing methods give the shortest distance between two points on the globe, nor the courses to steer to attain it. This can only be accomplished by great circle sailing. A knowledge of great circle sailing is much older than is generally supposed, though it is only of late years that it, or a modification of it, has been at all generally practised, and even now it is not as much used as it ought to be. The earliest record that I have been able to find of the application to navigational purposes of a principle that must have been long known to mathematicians and astronomers, is in a work on navigation by Captain Samuell Sturmey, published in the middle of the seventeenth century, in which the gnomic chart is described. The gnomic chart is to great circle sailing what Mercator's chart is to the sailing of that name, and this old navigator gives rules how to convert a log slate into a chart on this projection so that the great circle courses can be read off with a protractor. Whilst great circle sailing can never have been forgotten, even if little practised, the gnomic chart seems to have dropped out of men's memories, for two centuries later it was rediscovered simultaneously by Mr. Godfray, of Cambridge, and Captain Bergen. Within the next few years Knorr, Hillarett, Jensen and Herrle all brought out gnomic charts more or less like Godfray's, of which Herrle's seems the best and most convenient for finding the distance as well as the course. Before, however, the gnomic charts were reinvented, Towson introduced a diagram and set of tables for facilitating great circle sailing. By means of the diagram the vertex of the required great circle is found, and then taking the successive courses and distances out of the tables is a mere matter of inspection. A few years later Deichman endeavoured to improve on Towson's diagram, and Brevoort brought out a somewhat similar diagram to accomplish the same object. Lecky has pointed out that great circle courses, within certain limits, may be taken out by inspection from Burdwood's (and other) azimuth tables, and almost without limit from his own A, B, and C tables. Lecky, too, gives short rules for computing the first course and distance. With all these methods open to the navigator, great circle sailing ought to come to the front. One of the drawbacks to it is that in the parts of the world where it would save most distance, it leads through inclement regions and amongst ice, and not the least of Towson's merits was showing how to combine it with parallel sailing so that, without going to a higher latitude than was desired, the shortest track could be followed. He finds either by calculation or his tables the two great circles passing through the points of departure and destination whose vertices just touch the limiting parallel. The vessel is navigated along the first arc till the parallel is reached, along which she is kept till the vertex of the second circle is attained when she takes the great circle arc to her destination. This is demonstrably the shortest distance between the two places under the given conditions.

The labour of utilising great circle sailing by the rigorous method has been much magnified. It is not necessary to find the distance accurately (or even at all) every day, and the first and last courses are easily and quickly worked with the two co-latitudes and difference of longitudes (two sides and the contained angle to find the angles at the base); and for this purpose it is near enough in practice to take out the logs to three or four figures. This is the same formula as for time azimuths, which explains why great circle courses can be obtained from azimuth tables. Towson gets a right angle at the vertex, and so obtains brevity of solution. Now I will introduce a short method of my own, which I always use when the conditions are suitable. It is a very general practice to settle on the point to cross the equator according to the season of the year. Proceeding from Cape Leeuwin to Cape Guardafui, for instance, to be well to windward in the south-west monsoon, it is advisable to cross the line in about 60° E. long. Now, by working towards this point, the first course and distance may be obtained by quadrantal spherics quicker than by Mercator's sailing, because, though there are the same number of figures, the logs can be taken out in pairs, or triplets if the last course is required, to see if the ship is keeping on the same great circle. Unfortunately, it can only be used approaching the equator or in calculating a track thence to the next point of destination; but I have already shown how the courses alone can be quickly obtained in other cases, independent of the innumerable ways of getting them by inspection, and the graphic methods of Airy and Fisher, besides which there are various protractors and mechanical devices for those that favour such methods.

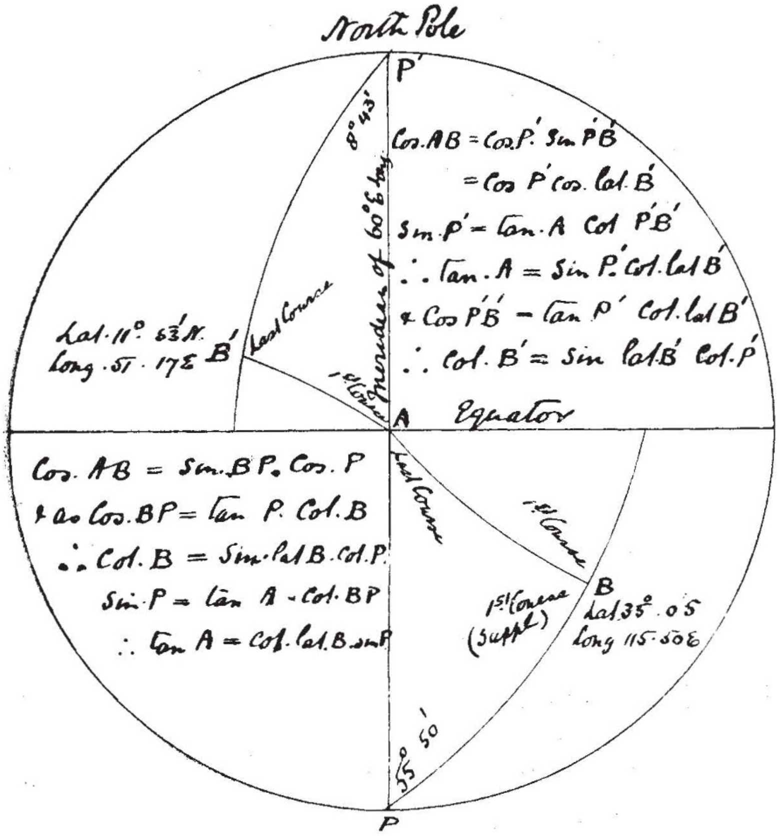


FIG. 2.

Example:

Lat. B 35° 0′	Sin 9·75859	Cos 9·91336	Cot 10·15477
D. long. 55° 50′	Cot 9·83171	Cos 9·74943	Sin 9·91772
	Cot 9·59030	Cos 9·66279	Tan 10·07249

1st course N. 68° 44′ W. AB 62° 37′ Last course N. 49° 46′ W.
60

Great circle dist. B to equator 3757 miles.

Now, whilst the foregoing methods are all sufficient to enable the navigator to obtain the bearing and distance of his port or destination, they are far from being irreproachable as a means of finding the daily position of a ship at sea, though they are always used for this purpose in case no better position is obtainable, or if it is, to compare with it. The cause of the deficiency is the uncertainty of the elements used in the calculation. When a ship on any given day leaves a well-ascertained point of departure, her position next day is obtained by the course steered and distance run. But neither can be absolutely relied on. In the finest vessels afloat with the most perfect navigating appliances, the course steered, even in fine weather, will be uncertain to 1°, which is equivalent to a deflection of 1¾ miles in every 100. This may easily be trebled or quadrupled in bad weather if compass errors cannot be checked, which, with every possible care, are liable to sudden and unlooked-for changes. In bad steering vessels, or with badly-placed compasses, or where the errors are not frequently checked, or from a combination of these causes, the error in the course may amount to 10°, which is equivalent to a deflection of 17½ miles in every 100. The distance run, under the most favourable circumstances, is liable to an error of 3 per cent., which head winds or other causes may easily double or, in exceptional circumstances, magnify still further. Then, again, the currents of the sea are the most uncertain element with which the navigator has to deal. Half a knot to a knot per hour is quite common, whilst five knots, or over, is not unknown. Except in a few localities, the direction is almost as uncertain as the strength. Even where currents run pretty regularly, these ocean rivers are not confined and held in position by fixed limits like those of the land, but are as flexible as snakes, which is perhaps the origin of the symbol denoting them on current charts, which at best only give a general idea what to expect: they are frequently deflected, or even reversed, by distant winds, or other causes quite beyond the ken of the navigator whose ship is being affected by them. With all these elements of uncertainty in the data used, it cannot be wondered at if the position by dead reckoning be of doubtful accuracy; and it would probably be more uncertain still, but that the numerous sources of error generally tend to compensate one another. It is, none the less, of the highest importance to the navigator to keep his log account with the greatest care, in case he has nothing better to depend on. Luckily, however, there are more accurate methods generally available, by which the navigator can find the position of his vessel—methods approximating to those of the astronomer in his observatory, whose more refined instruments and abstruse calculations supply the seaman with the data necessary to combine with his own observations, and fix the position of his ship with all needful accuracy. In a subsequent paper I will explain how this is done.[1]

J. F. RUTHVEN.

ANNIVERSARY MEETING OF THE LINNEAN SOCIETY.

THE anniversary meeting of the Linnean Society of London, held at Burlington House on May 24, was the occasion of presentation, by its Fellows, to Sir Joseph Dalton Hooker, G.C.S.I., C.B., F.R.S., of a commemoration gold medal, in addition to that of the Society's annual gold medal, which was awarded to Surgeon-Major G. C. Wallich, M.D., the veteran naturalist of the cruise of H.M.S. *Bulldog*. In presenting the medal to Sir Joseph Hooker, the President, Dr. A. Günther, F.R.S., made the following remarks.

The completion of a monumental work in botany, the "Flora of British India," has been chosen by our Council as a fit occasion for the Linnean Society to pay its tribute to the recognition of the eminent services which have been rendered to biological science by Joseph Dalton Hooker. A gold medal, specially struck for the occasion, of which copies could be distributed among his numerous friends and admirers, was considered to be the most appropriate and the most enduring form to serve as a memorial of this desire of the Society.

If I attempted, or were competent, to pass in review the work by which J. D. Hooker has advanced botanical science and enriched its literature, the few words I intend to address to you would swell into a biography; for of the sixty years which have elapsed since he entered the service of science, there are but few in which he has not left his mark upon its history.

The four years which he passed with the Antarctic expedition, and the three years during which he wandered among the ranges of the Himalayas, were the period in which he saw nature in her most diversified, grandest and purest aspects, and was brought face to face with the mysteries of the distribution of life over the globe. Then and for many years afterwards he made these phenomena and their causes the object of his special study. His writings on the subject have had the most powerful influence on, and were the guide in all subsequent inquiries. His travels were of the highest importance, and that not with regard to our biological knowledge alone; his intimate acquaintance with geology, meteorology, his proficiency as a surveyor have rendered his accounts of the countries visited by him equally valuable to the geographer.

When biology entered upon that eventful period of its history, in which the doctrine of continuous evolution by natural selection was striving to replace that of distinct creations, Hooker was one of the foremost champions of the former. Many systematic workers in zoology and botany were apprehensive at the time of dangers arising to their methods from the new doctrine. Hooker dispelled such fears by his own example; he continued his systematic work, but he showed at the same time that it was not the end, but only the means to the end, of biological research.

The part which he took, during the lifetime of his father, and during the twenty years of his directorship, in raising the Royal Gardens at Kew to their importance and eminence, is known to all of you. But I cannot pass this short allusion to his official work without referring to the position which Kew has taken as the centre of advice and help for the kindred institutions in India and the Colonies. This bond had been already established by the father; but it was strengthened by the son's personal acquaintance with their capabilities, and his sympathy with their needs.

His official duties, sufficiently arduous by themselves, did not prevent him from obeying other demands of science, when he was called upon to perform the functions of President of the British Association in 1868, and of the Royal Society from 1873-1878. And since his retirement from the public service in 1885, at an age when most men seek for rest from their labours, we have seen him still prosecuting his work with that single-minded devotion to science which has been characteristic of the whole of his life.

The prosperity of the Linnean Society, of which he has been a Fellow since 1842, has always been to him an object of special interest. Some of his most remarkable memoirs appeared in our *Transactions*: Bentham, who devoted years of care to the welfare of the Society, was connected with him by ties of closest friendship. And last, but not least, we remember that in honouring the son we are doing homage to the memories of the father and grandfather, both of whom were illustrious Fellows of the Society.

Sir Joseph Hooker, in acknowledging the presentation, said:

Mr. President, I cannot express my sense of the great, the exceptionally great honour which your Council has conferred upon me in the founding and awarding of this beautiful medal. In receiving it, let me assure you that I value it as much for the evidence it bears of the friendly regard of my associates as for their all too high estimate of my endeavours towards the promotion of science. Furthermore, let me say that from no scientific body could it be received by me with more cordial welcome than from the Linnean Society, which was the first to which I have the honour of belonging to enrol me amongst its Fellows, and which especially cultivates those branches of knowledge to which I have devoted the best years of my life. To these considerations must be added what you yourself have alluded to, namely, my hereditary interest in a Society of which my father and grandfather were very early Fellows, and both of them contributors to its *Transactions*. To this latter circumstance it may perhaps be due that I was elected at a very early age, being, I believe, the youngest member of our body with no further scientific claims on the support of my electors than that I was serving as a naturalist in the Antarctic expedition under Captain Ross, where I happened to be the youngest, as I am now the only surviving officer of those then under the command of that intrepid navigator. I may mention that Captain Ross was himself a Fellow, and had a copy of our *Transactions* in his cabin, which was a godsend to me. I was in the Falkland Isles when my election took place, and nearly a year and a half elapsed before my captain and I knew that we were fellow Linneans.

In 1842 the Lord Bishop of Norwich was President. He was the first of ten under whom I have been privileged to sit. Had the Society adopted the rule of biennial presidents I should have sat under thirty at least, which, in my estimation, would have detracted greatly from the dignity which I attach to the chair, and I venture to think from its utility also. In the year 1842 there were 610 members of the Society (including fellows, foreign members and associates) with fully one-fourth of whom I soon became personally acquainted. Twenty-eight years afterwards, that is about midway between the former date and the present time, the number of my personal friends in the Society had risen to one-half of the whole body. Our numbers are now 820, but the proportion of my personal friends among them has inevitably shrunk from my having outlived so many associates of my middle age. And this leads me to ask your indulgence for one more egotistical detail. It is that I am perhaps the only Fellow who personally knew four of the 169 naturalists who, 110 years ago, formed the nucleus of our Society. Of these four I knew two during my later teens · they were the Rev. W. Kirby, the author, with Spence, of the "Immortal Introduction to Entomology"; and Dr. Heysham, of Carlisle, an excellent entomologist and ornithologist. The others were Aylmer Bourke Lambert, a former President, and the last, as I have been informed, who wore in the chair the presidential three-cornered hat; and Archibald Menzies, who as naturalist accompanied Vancouver in his voyage in the Pacific, and who introduced the *Araucaria imbricata* into England. These all died very near the year of my election.

Referring now to the progress of the Society in status and efficiency during the years that have elapsed since 1842, the record cannot but be gratifying to its Fellows. Of this the best proofs are the increment in extent and value of its publications,

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[1] Throughout this paper the earth has been treated as a sphere. Of course it is really a spheroid with a compression of 1/300 in the polar axis. This hardly affects general principles, though it introduces slight modifications and corrections in detail. For these, and the rules of computation *in extenso*, the reader is referred to such standard and practical works as Riddle, Raper, Merrifield, Lecky, and others.