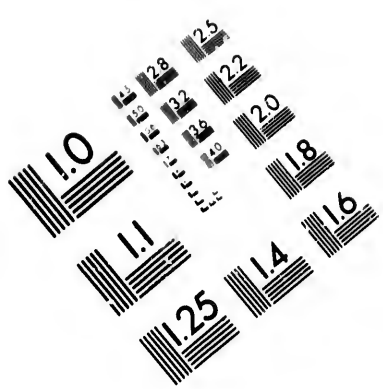

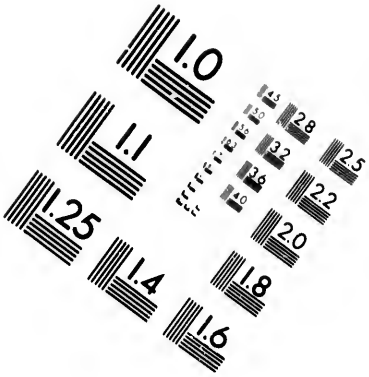

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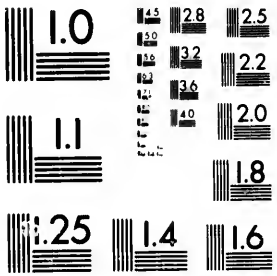

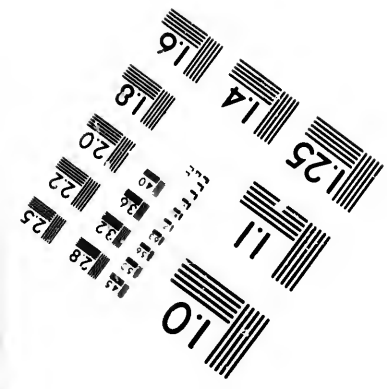

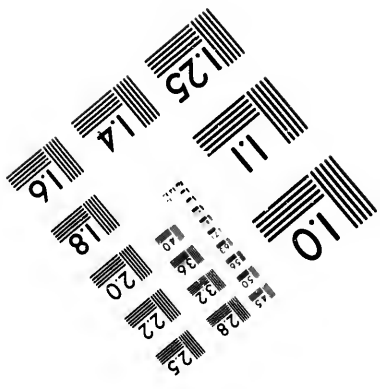

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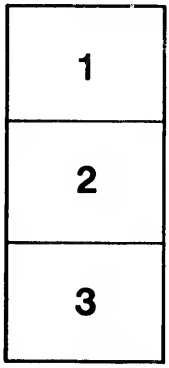

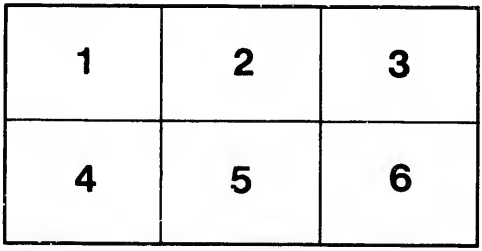

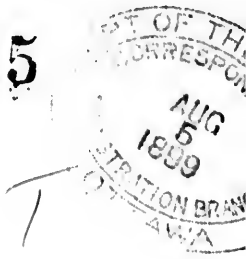

REPORT OF COMMITTEE

...ON...

Topographical Surveying.

Otto J. Klotz, Chairman.

(*Extract from the proceedings of the Asssociation of Ontario Land Surveyors for* 1899.)

Report of Committee on TOPOGRAPHICAL SURVEYING.

OTTO J. KLOTZ, Chairman.

(Extract from the Proceedings of the Association of Ontario Land Surveyors for 1899.)

MR. PRESIDENT,—Your Committee on Topographical Surveying beg to report as follows:

Although since the last report the inauguration of active work cannot be reported, yet matters of importance have taken place, and undoubtedly a beginning for triangulation or geodetic operations has been brought forward in a specific manner. The Committee refers to the paper by H. S. Pritchett, Superintendent of the U. S. Coast and Geodetic Survey, on "A Plan for International Measurement of an Arc of the 98th Meridian," read before the Royal Society of Canada, May 27th, 1898, a copy of which, with his accompanying charts, is herewith submitted, to be incorporated with this report.

Your Chairman was present at the reading of the paper, and took part in the discussion: he also presented a copy of the Memorandum prepared by the Committee of the Dominion Land Surveyors' Association in 1888, on the general scheme of a "Trigonometrical Survey of the Dominion," and read extracts of letters to him from Dr. Gill, Astronomer Royal at the Cape, earnestly advocating the latter.

The reading and discussion of Dr. Pritchett's paper was followed by a memorial from the Royal Society to the Federal Government supporting the scheme, to which the Mexican Government has already given its support.

You will notice that the 98th meridian has been chosen on account of its great length on land, and, therefore, available for measurement.

In our country it passes a little west of Winnipeg, through Lake Winnipeg and on towards King William's Land, in the Arctic, together about 750 miles.

From the geographical position of this meridian, it will be seen that its utilization for our practical purposes is rather circumscribed,

and a prolongation of the oblique arc along the Atlantic, extending to our borders, through New Brunswick, Nova Scotia, and Cape Breton, would serve more useful purposes for land surveys and accurate delineation of topographical features there than that offered by the 98th meridian. However, the latter as an international work, and one of the highest importance from a scientific point of view, deserves our hearty support, and we should take pride in taking part for the first time in an undertaking of such import, toward which every civilized and progressive nation of the world has bent her energies in some way.

It must be impressed that the inauguration of this work is a serious undertaking, for the work, in order to be valuable, must be done as well as can be done anywhere, otherwise its value will be comparatively useless for the object in view. Experienced men for such work we have not many, and we would necessarily have "to feel our way."

However, if the measurement along the 98th meridian is inaugurated, the scheme for a general triangulation of the Dominion would necessarily and undoubtedly follow.

For this reason, too, we think that the support of the Association should be extended for the international measurement of this meridian, and formally presented to the Dominion Government.

All of which is respectfully submitted.

OTTO J. KLOTZ, Chairman.

February 27, 1899.

The necessity for a careful and accurate triangulation of any country, as the basis of a systematic survey, is so well established, and the expense involved in such work so well justified on utilitarian grounds, that no defence for such expenditure on the part of any civilized country is now needed.

The large systems of triangulation, which have been constructed by different countries, have usually been designed as the bases of systematic surveys. Their employment in the determination of an arc, either of a meridian or of a parallel of latitude, has been ordinarily a secondary consideration, but the value of the data furnished by such triangulation schemes, for the final solution of the problem of the earth's spheroid, are of such high interest, that most nations have been glad to shape their plans for triangulation in such a way as to accomplish the latter end as well as the former. The necessity for an accurate triangulation across Canada, as the basis of a systematic map of the country, needs no argument from me, but I gladly avail myself of this opportunity to call to the attention of the Royal Society a plan by which, not only the utilitarian object of a primary triangulation may be secured, but also, a plan by

which, through the co-operation of the three Governments in North America, an international geodetic work, of the highest value to this continent and to the world, may be carried out.

The size and shape of the earth may be found, either from two meridional arcs or two longitudinal arcs, or from a single oblique arc. The first method was exclusively employed during the last century, because it was possible to determine latitudes with far greater precision than longitudes; but, in recent times, the electric telegraph has so simplified the determination of longitudes, that the last two methods may now be applied with entire success.

All three are comparatively simple in their theory, although the problem, considered in detail, becomes an intricate and difficult one.

The process in each case is as follows:—For the first case, we have only to measure the length of two lines running north and south, and observe the latitudes of the extremities. From this data, the flattening is first found, and afterwards the absolute length of the axis. This method was that used up to the present time, and our knowledge of the figure of the earth, and of the constants of the spheroid, depends wholly on measurements of such arcs of the meridian.

The second case, that of determining the earth's figure by means of longitudinal arcs, is rapidly coming into use, on account of the application of electricity to the determination of longitudes. The fundamental idea, like the preceding one, is simple. We measure the distance between two points lying nearly, or exactly, east and west, determine their longitudes, and, also, their reciprocal directions. The latitudes need not be accurate when the observations are near the equator, and when the line is nearly east and west the azimuths do not need to be accurately known. A second arc gives similar relations, and by means of both we can determine the earth's compression and its absolute size.

A third way of getting at the constants of the spheroid is by an oblique arc, such as has just been completed in the United States, between the northern part of Maine and the southern part of Alabama. Here we have a case, where the directions between the extreme points are of much greater importance than in the last method. As usual, the latitude of the extreme points must be found, and with this data, and the reciprocal azimuths, the flattening of the earth may be deduced. The simple addition of the length of the line joining the two points, enables us also to find the size of the earth, and thus completely determine the figure. It is evident that the method is not applicable, when the line is nearly north and south, or east and west, or when the work lies near the equator. The most favorable conditions are when the arc is quite oblique to the meridian, and above middle latitudes.

Two discussions of the form and size of the earth are in use in geodesy, and both depend entirely on the results obtained of

measures and arcs of the meridian. The first of these is that obtained by Bessel, in 1841, from ten small arcs, whose aggregate length amounted to 50.6 degrees. This discussion gave an equatorial value of the radius of 6,377,397 meters, and a polar semi-axis of 6,356,079 meters, and a value of the compression of 1-299.15. The arcs employed in the discussion are all short, and are now considered of little importance. The result, however, was by far the most correct up to this time, and was accepted universally among scientific men until the discussion of Colonel Clarke in 1866. From a combination of five arcs, having an aggregate length of 76.5 degrees, he deduced an equatorial radius of 6,378,206 meters, and a polar semi-axis of 6,356,584 meters, giving a compression of 1-294.98. The arcs included in this result were the English, the Indian, the Russian, the Cape, and the Peruvian arcs. In 1880, Colonel Clarke published another discussion of the problem of the earth's figure from a discussion of six arcs, whose aggregate length was 81.7 degrees, from which he deduced values slightly different from those just given. From the homolographic projection which accompanies this paper, the meagreness of the data is at once evident. See fig. 1.

I beg now to call your attention to two arcs which have been completed in the United States by the Coast and Geodetic Survey, and which, with the exception of the Peruvian arc, and a few small arcs measured years ago in the United States and of but little value, constitute the first important contributions to the determination of the figure of the earth made in the western hemisphere. The first of these is an oblique arc, extending from Calais, Me., to Mobile, Ala., a distance of 22.1 degrees, or 1,525 statute miles. The number of principal triangulation stations is 172, and the number of base lines 6; 61 latitudes, 48 azimuths and 14 longitudes, all telegraphic, constitute the astronomical data for the discussion. The ease with which this arc could be extended from the Canadian border to Cape Breton is evident at once, from an inspection of the map of the region. This extension would increase the length of the arc about 5 deg., and would, at the same time, form an admirable foundation for a trigonometric survey of the Maritime Provinces.

The second arc is that which is just nearing completion, an arc of the parallel in latitude 39 deg. The character of the triangulation throughout the extent of this arc varies greatly, on account of the difference in the character of the country. The terminal points of the arc are Cape May, N.J., and Point Arena, Cal. The length of the arc measured on the parallel is 48 deg. 46 min., equal to 2620 statute miles. The number of base lines is 10, the length of the shortest being 2.4 statute miles, and of the longest 7.9 statute miles, or an average of 5.3 miles. The average number of conditional

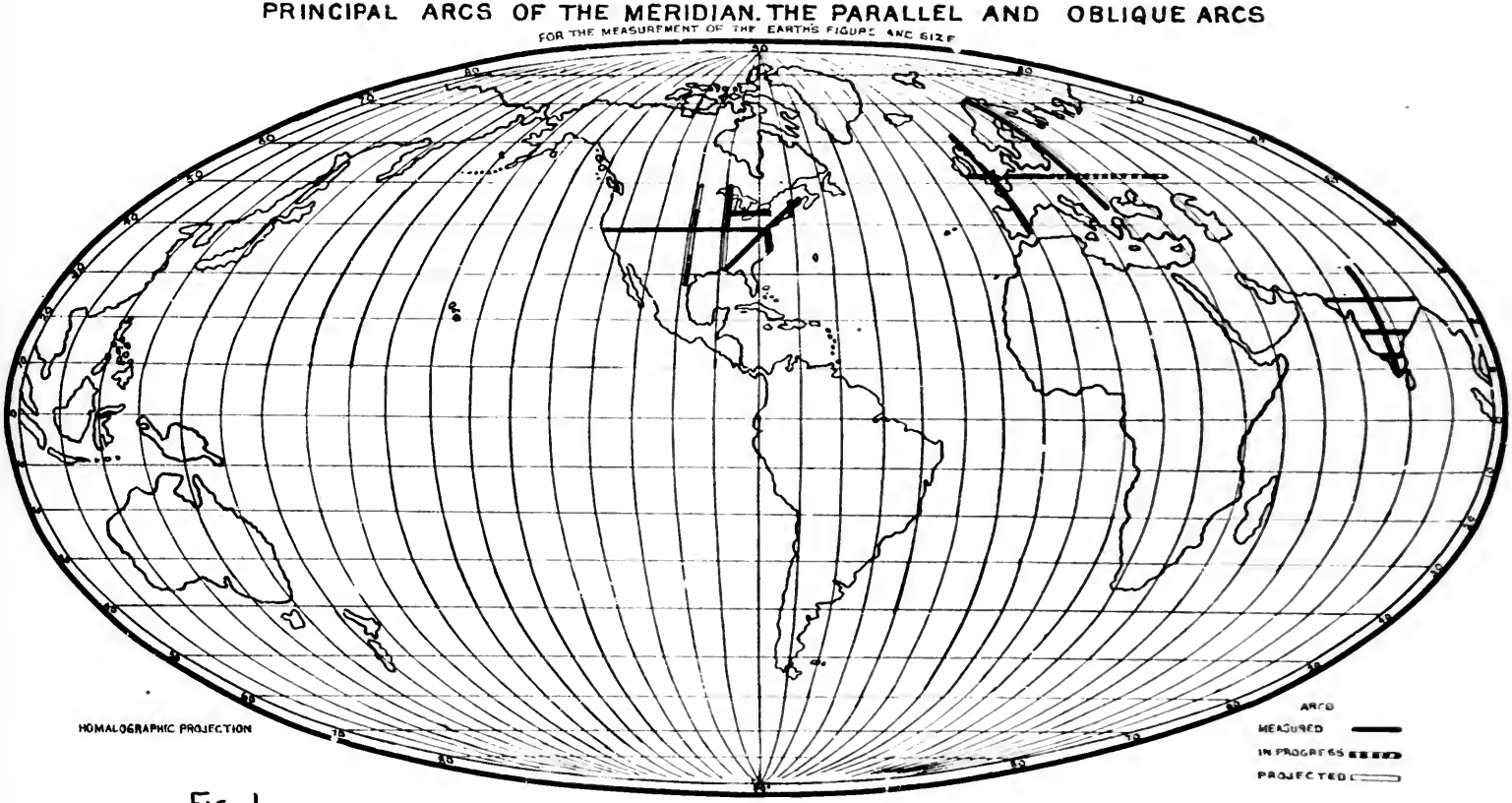
PRINCIPAL ARCS OF THE MERIDIAN. THE PARALLEL AND OBLIQUE ARCS
FOR THE MEASUREMENT OF THE EARTH'S FIGURE AND SIZE
HOMALOGRAPHIC PROJECTION
ARCS
MEASURED
IN PROGRESS
PROJECTED

FIG. 1.

equations, subsisting in the triangles of the base net, is between 20 and 21. A number of different kinds of apparatus were employed in the base measures. They all depend on the committee meter as the unit of length. This iron meter is one of the original standards introduced by the French committee in 1879, compared at different times and by different means.

The distance between adjacent base lines varies from 108 miles to 531 miles. This long chain of triangles is characteristic, as compared with similar undertakings, by its strength of composition. The chain consists of quadrilaterals, central figures, or other strong combinations of triangles. The size of the triangles, where they cross the central valley is of necessity of ordinary character; but in crossing the Rocky Mountains their utmost development has been reached. The longest side of a triangle, from Mount Ellen to Uncompaghre, was 182.1 statute miles. The highest trigonometric station was 14,396 feet, and the spherical excess of the adjusted triangle was 73.8 seconds, the triangle having an area of 5,600 square miles. The observation of this gigantic arc was begun 27 years ago, and the last observations which remain to complete the work are now in progress. They will be finished during the present summer, and as the discussion of this vast amount of material is already well advanced, it seems possible that we shall have the results of the completed work ready for publication within the next eighteen months. A preliminary discussion of these results points to certain interesting conclusions relative to the form of the ellipsoid which will best represent this portion of the globe.

The results of the discussion point in the same direction with the preliminary discussion of the arc of the 52nd parallel in Europe, namely, that the curvature is greater than would be required in an oblate spheroid of the dimensions of our earth.

Without, however, attempting to give in detail these preliminary results, I beg to call your attention to the inauguration of the measurement of an arc of the 98th meridian, which has already been begun in the United States, and which, if it could be extended along its whole length throughout Canada and Mexico, would make by far the longest arc of the meridian which has ever been measured, and would, taken in connection with the arc of the parallel, and the arc which I have just mentioned, give data for a most excellent definitive discussion of the spheroid which would best fit the continent of North America. This arc, as is seen from the attached sketch, extends throughout the United States, north and south, and from the southern limit of Canada to the Frozen ocean, and from the southern limit of the United States to the Pacific at Acapulco. The southern end of the arc is in latitude 17 deg., and the northern limit of the arc may very well be extended to 67 deg.,

making a total length of 50 deg. The longest arcs of the meridian heretofore measured are the following:

The Anglo-French arc	22 deg.	10 min.
The Russian arc	25 "	20 "
The Indian arc	23 "	49 "

It will thus be seen that the arc here proposed is double the longest arc of the meridian which has up to this time been measured. The value of this arc, as compared to the part lying in the United States, alone would be enormous. Dr. Gill has called attention, in the report on the Geodetic Survey of South Africa, 1883-1892, pp. 157-159, to the great advantages to geodesy, which accrue from the measurement of long arcs.

The length of the arc in the three countries is as follows: In Canada, to latitude 67 deg., 760 miles; in the United States, 1,590 miles; and in Mexico, 690 miles; in all, 3,040 miles. The character of the country through which the triangulation would need to be carried is such that it would be comparatively inexpensive, unless in Canada the forests should add to the expense. A very close estimate of the cost of this work can be gained from the cost of similar work in the measurement of the 39th parallel, since more than a thousand miles of this arc passed through a region which was entirely similar to that contained in the arc of the 98th meridian. I find, after a careful investigation, that the entire cost of this work, including salaries, expenses of travel, instruments, and erection of signals, subsistence of parties, and all expenses connected with the work, was at the rate of $120 a mile. At the present time it could doubtless be done for less; probably at the rate of $100 a mile. The sides of the triangles would be from ten to thirty miles, and the work would be in every way analogus to that which has already been carried on along the 39th parallel, through the States of Indiana, Illinois, Missouri, Kansas, and portions of Colorado. Part of this line, at the time when the observations were made, was heavily wooded; and required the cutting out of long and expensive lines, the removal of obstructions, and the building of signals, which made that work quite as expensive, if not more so, than the work of the 98th meridian would be. At this estimate, the cost to the three countries would be as follows: To Canada, $76,000; to the United States, $159,000; and to Mexico, $69,000. The rapidity with which this work could be carried out, would depend on the number of parties that can be put in the field. It is expected that the part of the triangulation lying in the United States will be finished in from six to eight years.

Without going into any longer discussion of this matter, one may say, briefly, that the completion of this measurement of the

98th meridian would, combined with the measurement of the 39th parallel already completed, make an epoch in our knowledge of the earth's figure and size, and would furnish data which could probably never be improved upon, so far as the North American continent is concerned. See fig. 2.

In suggesting this co-operation in a great international work, it seems fitting to call attention to the history of the International Geodetic Association for the measurement of the earth. The first plan for co-operation in geodetic measurements on a large scale seems to have come from General Bayer. In 1861 he wrote to the Prussian Minister of War recommending that the nations of middle Europe should combine forces, and devote themselves to the solution of this problem; and calling attention to the fact that France had undertaken the work on a large scale in the eighteenth century, England and Russia in the nineteenth, and that the eastern and western parts of the continent were much farther advanced in this work than his own country. At this time only three arcs of the meridian had been measured in Europe, and the anomalies in the deflection of the plumb line had not been explained. The first and most natural proposition was that these anomalies were due to the attraction of the mountains, but when deflections of the plumb line were found on extended plains, and when, as they then supposed, the great Himilayas exercised no appreciable effect, they were led to suppose great changes of density in the earth's surface. Perhaps this phase of the question stimulated, as much as anything else, the co-operation of the different Governments; and in October, 1864, there was effected an organization for the measurement of arcs in middle Europe. Nineteen States gave support to the project. This general plan remained unchanged until 1887, when the middle European association was merged into an international one, and nations from all parts of the world became parties to the convention. The organization was continued for a period of ten years. In 1896 new powers were assumed by the organization, and a new convention to last for ten years, or until 1906, was drawn up. The following countries have joined this convention:

Germany,	Spain,	Japan,	Roumania,
Austria-Hungary,	United States,	Mexico,	Russia,
Belgium,	France,	Norway,	Servia.
Chile,	Greece,	Holland,	Sweden,
Denmark,	Italy,	Portugal,	Switzerland,

It is with very great pleasure that I am able to add that, within the last month, Great Britain has also given her adherence to this convention, and has named as delegate and representative on the permanent committee Professor George Darwin.

This is, in brief, the origin and growth of the present inter-

PRINCIPAL ARCS MEASURED AND IN PROGRESS ON THE CONTINENT OF NORTH AMERICA

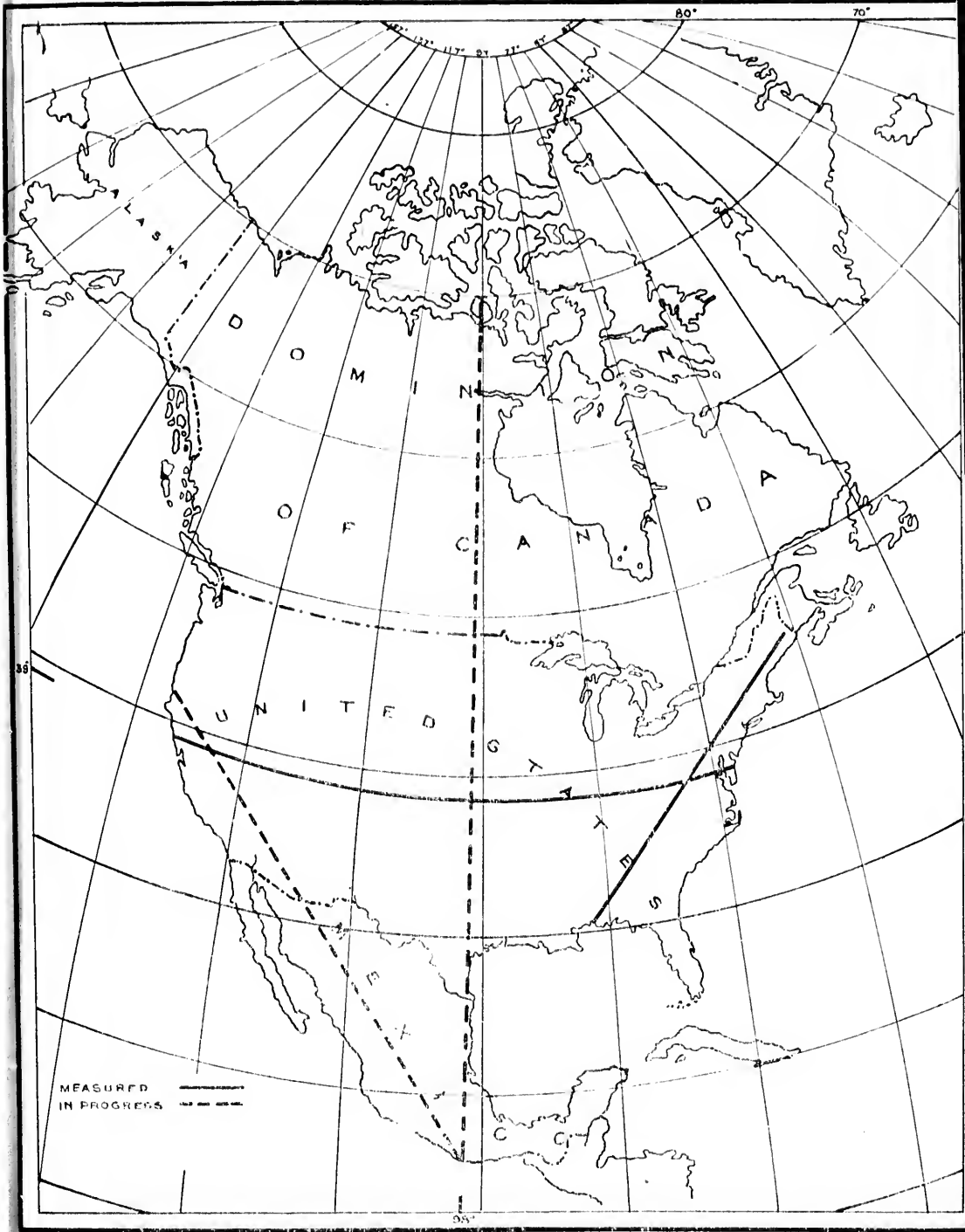

FIG. II.

national organization. An outline of the methods of the work, and the results attained, will show what is being done by concerted national action to determine the size and the figure of the earth. From the beginning of the work up to 1887, the results were largely of local importance. Each State Government reported on the operations within its borders, and which were intended primarily to serve as bases of maps for the various countries. The triangulation, measure of base lines, astronomical observations, precise levels, and tidal observations, found their greatest use locally, but in the last ten years questions have been taken up which are of the greatest interest to each individual country, and to the world as a whole.

As illustrating the methods which are now being pursued, I may mention that the last undertaking on the part of the International Geodetic Association contemplates a final and definite solution of the variation of latitude. The association proposes to establish four stations, as nearly as possible at equal distances around the earth, and all within half a mile of the same parallel of latitude. The character of latitude variation from season to season is now comparatively well known, and the fact that we are sixty feet nearer the equator at one season of the year than at another no longer appears startling, but the results so far have been to a certain extent vitiated by the fact that the star places are uncertain; and although by an ingenious method of combining the observations this defect to a large extent disappeared, nevertheless the observations do not yield the desired precision. The method proposed by the International Association, and now in progress of being put into practice, will be free of any errors in the accepted position or proper motions of the stars. This can be accomplished by locating the points on the same parallel of latitude, and as nearly as possible equally distant. Four stations have been chosen, all on the parallel of 39 deg. 8 min. Two stations are taken in the United States, one on the Atlantic coast, and one on the Pacific coast; one station in Japan, and one in Italy. At the present time, a most careful examination of the topography of the various regions in which stations are to be established is being made, in order that all the conditions may be comparable and well determined. It is proposed to carry on latitude observations with precision at these four stations, for a period of seven, possibly ten, years; at the end of which time sufficient data will be at hand to predict the position of the pole with all the precision necessary for the most refined astronomical calculations for at least a century to come.

The result of this international effort at co-operation seems so striking, and the ends to be accomplished are so well worthy the efforts of the best thought and the best energy of any nation, that

it seems a fitting example to encourage an effort of similar co-operation among the nations of the North American continent.

NOTE.—Since this paper was read, the Government of Mexico has announced, through the Secretary of the Interior, its readiness to undertake its part of the work here proposed.

[COPY.]

To His Excellency the Governor in Council, etc.:

The Royal Society of Canada has the honor to bring to the notice of Your Excellency a proposal by Dr. Pritchett, Superintendent of the United States Coast and Geodetic Survey, to measure an arc along the 98th meridian from Acapulco, Mexico, to the shore of the Arctic Sea in Canada. Dr. Pritchett's views are explained in a paper read by him at the last meeting of the Society. A copy of this paper, with explanatory maps, is appended.

The measurement of the 98th meridian has been in progress for some time as part of the general survey of the United States. The object of Dr. Pritchett in urging its extension through Canada and Mexico is to provide data for the determination of the figure and dimensions of the earth and while from this point of view the work would be purely scientific, the Canadian portion of it would also be of great practical utility in forming the basis of a thorough geographical survey for this Dominion.

While it is true that the promotion of science is mainly due to a few of the most advanced and wealthy nations and that these nations have frequently sent expeditions, or established stations abroad when information had to be obtained in semi-civilized or wild and uninhabited countries, it is also a fact that the least favored of the civilized nations have not unfrequently assumed the task of assisting science to the extent of collecting data obtainable within their own borders.

In the present instance the survey is in progress within the limits of the United States and quite recently the Government of Mexico has announced its readiness to undertake its part of the work. The successful execution of the project as a whole, therefore, now entirely depends on the co-operation of Canada. It is respectfully suggested, therefore, that a limited grant for this purpose would be regarded as a contribution to aid in the general researches of the nations of the world, while at the same time it would serve to inaugurate a very much needed work and one of great practical importance to the future of the Dominion.

Extensive triangulations have seldom been undertaken upon

scientific grounds alone; their primary object has been utilitarian and to provide a basis for systematic surveys. Without such a basis there is no finality in results; the same ground is being surveyed over and over again, as is the case in the Dominion, by the land surveyor, the geologist, the railway and canal engineer, the hydrographer. For every new project a new survey has to be made. The labour and expenditure on these surveys would be considerably reduced and often entirely unnecessary if we had a systematic triangulation carried out as in other countries. This fact has long been recognized in Europe, where every country has been accurately mapped. Outside of Europe may be cited the United States, whose triangulation is well advanced; India, which offers a striking instance of extensive and well conducted surveys; the Cape of Good Hope and Natal, which have executed a joint triangulation of South Africa; New Zealand, where triangulation has preceded all other surveys. It must not be supposed that there were no objections raised in these countries to the inception of the work; on the contrary, it was frequently opposed by those who did not understand its practical value, but their opinions changed after they had been in a position to appreciate its usefulness. Of the survey of South Africa, Mr. David Gill, Her Majesty's Astronomer at the Cape, says:

"The influence of the geodetic survey has made itself felt by raising the whole tone of survey operations in South Africa. Strongly as it was at first opposed and grudgingly as it was maintained, its advantages are now fully acknowledged, and by none more warmly than the Surveyor-Generals of the Cape Colony and Bechuanaland."

The triangulation of the 98th meridian would be for Canada the first step in the right direction, to be followed by others, as the resources of the country would allow. It is believed that an appropriation of say $10,000 for a few years would be sufficient to carry to completion the measurement of the 98th meridian. The Royal Society of Canada strongly recommends such a grant, and believes that the work will be of great benefit to Canada, not only by its immediate practical results, but also in placing the country in a more favorable light before the scientific world.

And your memorialists humbly pray that Your Excellency will take the foregoing facts into your favorable consideration.