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THE FORTY-NINTH PARALLEL

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By Otto Klotz

WE shall begin by quoting two paragraphs from the Romanes Lecture on "Frontiers," delivered by Lord Curzon at Oxford on November 2, 1907.

"I wonder, indeed, if my hearers at all appreciate the part that Frontiers are playing in the everyday history and policy of the British Empire. Time was when England had no Frontier but the ocean. We have now by far the greatest extent of territorial Frontier of any dominion in the globe. In North America we have a Land Frontier of more than 3,000 miles with the United States. In India we have Frontiers nearly 6,000 miles long with Persia, Russia, Afghanistan, Tibet, China, Siam and France. In Africa we have Frontiers considerably over 12,000 miles in length with France, Germany, Italy, Portugal and the Congo State, not to mention our Frontiers with native states and tribes. These Frontiers have to be settled, demarcated, and then maintained. We commonly speak of Great Britain as the greatest sea-power, forgetting that she is also the greatest land-power in the Universe."

In discussing the various classes of frontiers, (1) the natural frontiers—the sea, deserts, mountains and rivers, and (2) the artificial frontiers, Lord Curzon says of the commoner forms of the latter:

"These are three in number: (1) what may be described as the pure astronomical Frontier, following a parallel of latitude or a meridian of longitude; (2) a mathematical line connecting two points, the astronomical co-ordinates of which are specified; and (3) a Frontier defined by reference to some existing, and, as a rule, artificial feature or condition. Their common characteristic is that they are, as a rule, adopted for purposes of political convenience, that they are indifferent to physical or ethnological features, and that they are applied in new countries where the rights of communities or tribes have not been stereotyped, and where it is possible to deal in a rough and ready manner with unexplored and often uninhabited tracts. They are rarely found in Europe, or even in Asia, where either long settlement or conflict has, as a rule, resulted in boundaries of another type.

"(1) The best known illustration of the astronomical line is the Frontier between Canada and the United States, which from the Lake of the Woods follows the 49th parallel of latitude to the Pacific coast, a distance of 1,800 miles [1,270,—

O. K.] This line well illustrates both the strength and the weakness of the system. As a conventional line through unknown territories it has answered its purpose. But its demarcation on the spot was so laborious and protracted that, fifty years after the conclusion of the Treaty which created it, the joint surveyors were still at work, clearing a strip 100 yards wide through the primeval forest, and ornamenting it with iron pillars and cairns, at a cost to both countries which was enormous. Similar lines have been employed to define the boundaries of Canada and Alaska, to separate many of the Australian Colonies from each other, to determine European Spheres of Influence or Protectorates in Africa, and, quite recently, to define the Russian and Japanese shares of the island of Saghalin. Such lines are very tempting to diplomatists, who in the happy irresponsibility of their office-chairs think nothing of intersecting rivers, lakes and mountains, or of severing communities and tribes. But even in the most favorable circumstances they require an arduous triangulation on the spot, and until surveyed, located, and marked out, have no local or topographical value."

The above-quoted two paragraphs contain very interesting statements, and the second one is particularly pertinent to the subject of this paper.

By Article II. of the Convention of October 20, 1818, "It is agreed that a line drawn from the most northwesterly point of the Lake of the Woods, along the forty-ninth parallel of north latitude, or, if the said point shall not be in the forty-ninth parallel of north latitude, then that a line drawn from the said point due north or south as the case may be, until the said line shall intersect the said parallel of north latitude, and from the point of such intersection due west along and with the said parallel shall be the line of demarcation between the territories of the United States, and those of His Britannic Majesty, and that the said line shall form the northern boundary of the said territories of the United States, and the southern boundary of the territories of His Britannic Majesty, from the Lake of the Woods to the Stony Mountains" (Rocky Mountains).

This line is 860 miles long.

In passing it may be remarked that in the above description is contained the explanation why Minnesota projects into Canada at the North West Angle,—because the North West Angle happened to lie north of the 49th parallel; a connection had to be made between a physical feature and a fixed astronomic line.

The remaining part of the international boundary along the 49th parallel is described in Article I. of the Treaty concluded at Washington on June 15, 1846, as follows: From the point on the "forty-ninth parallel of north latitude, where the boundary laid down in existing

treaties and conventions between the United States and Great Britain terminates, the line of boundary between the territories of the United States and those of Her Britannic Majesty shall be continued westward, along the said forty-ninth parallel of north latitude, to the middle of the channel which separates the continent from Vancouver's Island, and thence southerly through the middle of the said channel, and of Fuca's Straits, to the Pacific Ocean."

This line is 410 miles long, making a total in round numbers of 1,270 miles along the 49th parallel.

The part from the Lake of the Woods to the Rocky Mountains was surveyed and marked by monuments by an international commission during the years 1872–3–4, while on the remaining part to the Pacific, an international commission determined individual points on the 49th parallel and erected some monuments during 1857 to 1861, but the boundary line was not then wholly surveyed owing to the mountainous character of the country; this, however, has recently been effected by another international commission, of which Dr. W. F. King, C.M.G., was the British representative, and Dr. O. H. Tittmann the representative for the United States.

Let us dwell for a moment on the meaning of the word latitude and on the method of determining it. Latitude may be defined as the elevation of the Pole, or its height in degrees above the horizon, and the method is to measure with a suitable instrument from the horizon the angle to the Pole. Next let us inquire what is the horizon from which we measure, and the answer is, —the plane at right angles to the vertical; and, finally, we ask what is the direction of the vertical? the answer is,—it is the integrated result of the attraction of the individual particles composing the mass of the earth, and hence the position is affected by the relative distribution of them. We may therefore say that the unsymmetrical distribution of the particles, whether on the surface as mountains or valleys, or in the thin crust, is the cause of the "deflection of the plumb line" or vertical from its theoretical position, and latitude observations will be affected by just this amount of deflection. In some instances we are quite prepared to find local deflections of the plumb line, for example, when observations are taken on the plains at a point near

a more or less isolated upheaval, as the Three Buttes or Sweet Grass Hills in Montana, just south of the International Boundary. These hills, as we shall see later, pulled the 49th parallel out of its theoretical position about 800 feet. On the other hand, large deflections show themselves without any visible reason or cause as evolves from numerous observations and their geodetic connection. From such it must be concluded that there exists beneath the surface of the earth matter of abnormal density.

All observations for the determination of positions upon the earth depend upon the direction of the vertical. Latitude and longitude observations, the surveyor's and engineer's operations, all have their zero of reckoning in the center of the level bubble, and any displacement of the latter, which is equivalent to the displacement of the plumb-line, affects the results, and will show discordances when widely separated observations are geodetically connected.

It may be stated that a delicate level used for latitude work, reading to a second of arc, has usually a radius of about 1,700 feet, or nearly a third of a mile, for the curve ground on its inner upper surface.

When a boundary is defined by a parallel of latitude, the question invariably arises, in the demarcation of it, whether the astronomic or mean parallel is to be adopted. The astronomic parallel is that line on the surface of the earth on which direct observations for latitude give the same elevation of the Pole; geometrically, for the spheroid or ellipsoid of revolution, it is the angle made by the normal to the surface of the earth with the major axis, or it is the angle made by the tangent cone with the minor axis produced. Principally owing to the local deflection of the plumb line, points astronomically determined in latitude will not "close," that is, the line projected or determined as a parallel from one station will not meet the next point or astronomic station.

That line with reference to which the sum of the discrepancies north is equal to the sum of those south is the mean parallel.

However, as the latter can only be determined *after* the location and connection of the astronomic points, entailing revision of the whole work, and besides the difficulty of re-establishing points on the mean parallel in case of loss or disappearance of monuments and marks, it has generally been decided to adhere to the simpler and more readily established astronomic parallel. All such parallels traced upon the earth are irregular curves.

On the line from the Lake of the Woods to the Rocky Mountains, 860 miles, 40 astronomic stations were established, and 388 monuments erected.

After due consideration, the commissioners for this part of the parallel agreed upon the astronomic parallel. The recommendation for this, by the chief astronomers of the commission, was based on the following grounds:—1st: That the portion of the parallel of 49° included within the operations of the commission, being only about one-twentieth of the entire circle of latitude, was not sufficient to fix, with any mathematical accuracy, the true position of the mean line of 49°, and that, therefore, if such a parallel were described, depending on the mean of the astronomic stations, no known point of the boundary would be in latitude 49°; 2nd: That as the amplitude of the arcs, included between the mean and the astronomical parallels, would in many cases be very considerable, grave errors and complications might arise in the subsequent re-survey of any lost portion of the boundary; 3rd: That the definition of a mean line would involve a re-adjustment of the whole boundary, after the first careful survey should have been completed, and consequently a very considerable increase of expense, without any practical benefit accruing; 4th: That for every purpose, except that of geodetic computation, a parallel of points determined astronomically (instrumental errors aside), is a true parallel of latitude, and, therefore, fulfils the stipulations of the treaty under which the joint commission was organized.

Accordingly, astronomic positions were determined at approximate intervals of twenty miles. These stations were connected by tracing upon the ground tangents or the prime

vertical circles at each successive point. From these tangents, checked and corrected for errors of azimuth, the calculated offsets to the small circle of latitude were measured at convenient intervals, varying from one to three miles. From the last mentioned offset the relative station error (deflection of plumb line) was found and distributed between the two stations in the ratio of the distances where offsets were taken. From this method it results that the boundary line, as actually traced, is an irregular curve, affected at each astronomical point by instrumental errors and by the local deflection of the plumb line, making the closest probable approximation, at every point, to a true astronomical parallel.

Of the forty astronomical stations on the 49th parallel, four were observed jointly, seventeen by the United States astronomer and nineteen by the British. The mean of the probable errors of the British stations was $\pm$″·088 and of the United States +″·05.9 The average of the probable error is then a little over seven feet.

The greatest difference of station errors is 13″·89 or 1,407 feet, being in a distance of 97 $^{7}/_{10}$ miles, between the Cypress Hills to the north of the boundary, and the Three Buttes or Sweet Grass Hills near, and to the south of the 49th parallel. The station error of the former is + 5″·94, of the latter −7″·95, that is, the Three Buttes pulled the 49th parallel 805 feet south, and the Cypress Hills 602 feet north of the mean parallel. The greatest discrepancy between adjacent stations, about twenty miles apart, is 7″·28 or 738 feet, near the Three Buttes.

Looking at the accompanying diagram, in which the upper figure is a representation (much exaggerated) of the relative position of the astronomic and mean parallels, while the lower figure shows the main features of the topography for a distance of about thirty-five miles on each side of the boundary line, the large deflections appear obvious from the topography. From the Lake of the Woods, westward, into the valley of the Red River, the station errors increase, and for a reason which, from our lack of knowledge of the underlying strata, must be conjectural. The escarpment of the Pembina Mountains (elevation would be

a more appropriate term, height 1,695 feet) naturally draws the vertical southward, continuing to do so until the Turtle Mountains (of moderate elevation, 2,550 feet) are reached, which, too, deflect to the south. After entering the Côteau of the Missouri we pass along the southern base of the high ridge, separating the waters flowing into the Gulf of Mexico, from those flowing into Hudson Bay, and find, naturally, a deflection to the north, increasing to a maximum south of the Cypress Hills (3,800 feet). Here the extrusive masses of the Three Buttes produce a violent disturbing effect. When we actually enter the tumultuous Rocky Mountains, with all their varied conditions of composition, of faults and dykes, and our lack of hypsometric maps, we are unable to even make a plausible estimate in which direction the local deflection is to be expected.

It is evident that observations at two places, which are also geodetically connected, can only give the relative deflection of the plumb line.

For the boundary between the Lake of the Woods to the summit of the Rocky Mountains, the Commissioners agreed that the line joining any two adjacent monuments shall be an arc of the parallel. This was to apply, too, in the case of restoring any monument whose position was lost. This agreement differs from that of the boundary commissioners, who had charge, some 17 years previously, of defining the boundary from the Gulf of Georgia to the summit of the Rocky Mountains. They agreed that the connecting line between monuments shall be a straight or direct line, *i.e.*, an arc of a great circle.

Between the extreme east and west points, upon the watershed of the Rocky Mountains, and the eastern shore of the channel which separates the continent of North America from Vancouver Island in west longitude 114° 3′ 34″ and 123° 3′ 53″ respectively, the exact length of the boundary line upon the 49th parallel of north latitude is 409 $^4/_{10}$ miles. The position of the parallel was determined by 28 astronomical stations, 11 of which were established by the British Commission, 14 by the American Commission, and 3 were observed by both. Another station was

fixed by the British Commission at Schweltza Lake, but it was at the time rejected on account of the apparently large deflection of the plumb line, though the after experience of the most accurate instrumental observations in that mountainous country, led to the conclusion that the result at Schweltza was quite as trustworthy as any of the others. It is, however, not included in the final determinations.

At the first meeting of the Commissioners at Semiahmoo, August 13, 1858, it was concluded, after discussing plans for determining and marking the line as far as the Cascade Mountains, to be inexpedient at that time, in consequence of the great expense, consumption of time, and the impracticable nature of the country, to mark the whole boundary by cutting a track through the dense forest. It was therefore agreed to ascertain points on the line by the determination of astronomical points at convenient intervals on or near the boundary ; and to mark such astronomical stations or points fixed on the parallel forming the boundary, by cutting a track of not less than 20 feet in width on each side for the distance of half a mile or more, according to circumstance. Further, that the boundary be determined and similarly marked where it crosses streams of any size, permanent trails, or any striking natural features of the country. In the vicinity of settlements, the line was to be cut a greater distance. Bessel's value of the figure of the earth was adopted.

From the two points on the parallel, dependent, respectively, on the Sumass and Schweltza astronomical stations, cuttings were made to connect the points. When the cuttings met, there was found to be a discrepancy of 8″, say about 810 feet ; they were, however, connected, though the line thus defined is obviously not strictly *the* boundary of the treaty. The distance is about 9¼ miles. This relative deflection of the plumb line, 8″, in so short a distance, is the largest on the whole 49th parallel, from the Lake of the Woods to the Pacific. When the cuttings on the parallel from Sumass and the British stations at Semiahmoo met, there was a discrepancy of 114 feet in the twenty miles, and between the United States astronomical station at the east

shore of Semiahmoo Bay, and the British one five miles east thereof, a discrepancy on the parallel of nearly nine feet was found an error quite within the error of observation.

The only other cutting on the whole boundary line west of the Rocky Mountains, connecting adjacent astronomic stations, is between the Similkameen and the Columbia Rivers, a distance of 96 miles. The stations there in order eastward are: Similkameen (U. S.); Lake Osoyoos (Br.); 1st Crossing Newhoilapitkw (U. S.); 2nd Crossing Inshwointum (Br.); 3rd Crossing Statapoosten (U. S.); and on the Columbia (Br. and U. S.) From the point on the parallel at Lake Osoyoos, a line was run east and west 30 1/3 miles, connecting with similar points at Similkameen and at the 1st Crossing. The line was found to strike 509 feet north of the former point and north of the latter 364 feet, showing a marked deflection of the plumb line. When, similarly, an east and west line was run from a point on the parallel at Inshwointum, it was found to be south 300 feet of the point on the parallel at the 1st Crossing, and 180 feet north of the point at Statapoosten.

This shows, therefore, a discrepancy between the latitude at Lake Osoyoos (Br.) and Statapoosten (U. S.) of 814 feet, due to local attraction or difference of local attraction. After verifying the accuracy of the latitude observations, it was decided to adopt the mean parallel, based on the differences found, between Similkameen and Statapoosten—a distance of 71 miles. This is the only part of the whole boundary line between the Lake of the Woods and the Gulf of Georgia, where a mean parallel has been adopted for the boundary, instead of the astronomic parallel. These seventy-one miles were re-cut on the mean parallel. From the extremity of the mean parallel at Statapoosten, an east line was run to the Columbia, where a difference of 112 feet was found between the mean of the British and United States latitude determinations there and the mean parallel. The line (for final boundary) was thereupon deflected from Statapoosten so as to strike the above mean Columbia position of the 49th parallel.

As already stated, the Boundary Commissioners had agreed to understand the boundary laid out by them, to consist of a series of straight lines between the successively marked points, without regard to the distances between these two points or the curve of the parallel in the longer intervals. This they did upon the consideration that it was of the greatest importance that nothing should be left for future discussion of settlement, and that the operations should be final and conclusive. It may be stated that opposite the center of a chord of 25 miles in length, the departure from the 49th parallel would be about 40 yards, and of 12 miles, 9 yards. Both these departures are probably far smaller than the deflection of the plumb line, at the governing astronomical stations.

We have, therefore, in the actual boundary line of British Columbia, a deviation from the 49th parallel, as given in the treaty of June 15th, 1846, in so far, that the straight lines replace the curve of the parallel between all the stations, and, furthermore, that between Similkameen and Statapoosten, the mean parallel was adopted instead of the astronomically determined points.

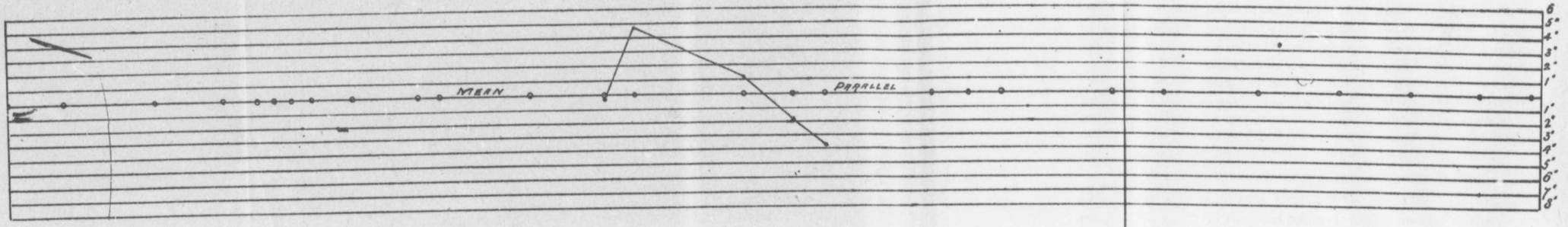
We have followed now the 49th parallel for 1,270 miles, about one-thirteenth of its circumference, and it has disclosed to us some of its vagaries as manifested in the latitude component of the deflection of the plumb line. This boundary line is the longest astronomic one on the earth, the nearest approach to it being the meridian separating West Australia from North and South Australia.

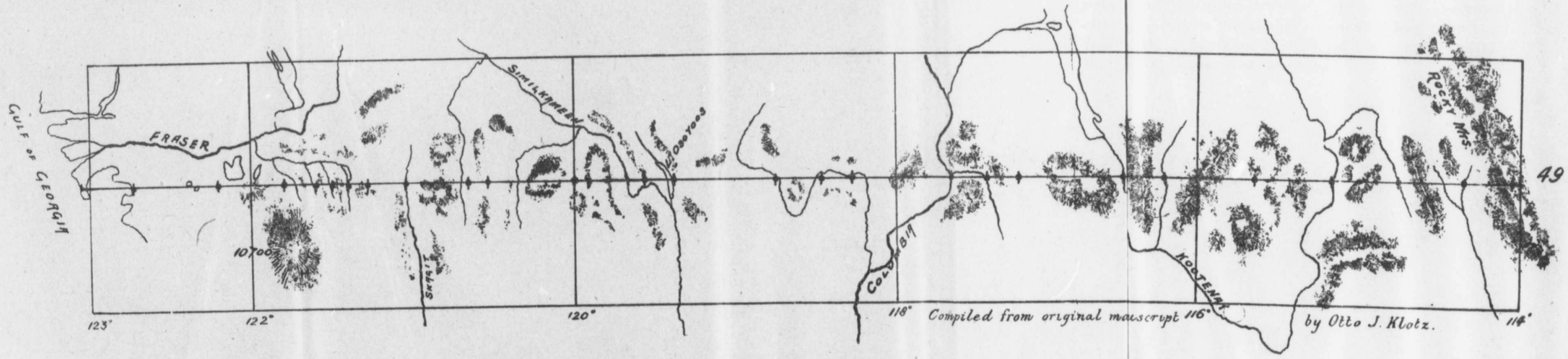
In connection with the deviation of the plumb line it may be interesting to quote a few extracts from Dr. J. B. Messerschmitt's report in the ninth volume of *Das Schweizerische Dreiecknetz, herausgegeben von der Schweizerischen geodatischen Kommission.*

"If we connect all points having the same deflection in latitude we will obtain lines fairly parallel to the direction of the mountains They show plainly and markedly the relative attractions of the Alps and the Jura, as is to be expected, the influence of the former extending close to the foot of the latter. . . . . In the neighborhood of Zurich the deflection is small while at Lucerne it is 6"; at Zugerberg the deflection in latitude is nearly 9"; while at Rigi, which is only 36

km. to the south, it is between 17″ and 18″. As we approach the center of the Alps the deflection decreases, being about zero a little to the south of St. Gotthard. Similar conditions obtain on the south side of the Alps. While at Biasca the deflection is small, it reaches 17″ at Lugano. . . . . These conditions are not, however, confined to Switzerland, but apply equally to the whole Alpine region of Austria, Italy and France, where, however, the data are not as complete as for Switzerland. The direction of the plumb line is always perpendicular to the mountains; the deflection increases rapidly as the mountains are approached, and values as high as 30″ have been obtained, although in Switzerland the maximum is about 20″. If we compare the deflection on both sides of the Alps we obtain a difference of 50″ in a distance of 100 km. Remembering that 1″ in latitude is equivalent to 31 m. linear measure, it will be seen that the distance between two points, one north and the other south of the Alps, determined astronomically will differ from that obtained geodetically by over 1 per cent. That is, in about 62 miles the distances will differ by 5,000 feet, or nearly a mile."

The same law or force which causes the deflection of the plumb line, determines the length of the seconds pendulum, preserves the planets in their orbits, and maintains the stability of the universe—is the law of gravitation. Our earth furnishes us with many interesting problems, and the very discordances observed—apparent though they are—tend to lead us on to unraveling the mysteries and intricacies of nature, and to unfolding the unity and harmony of the cosmos.





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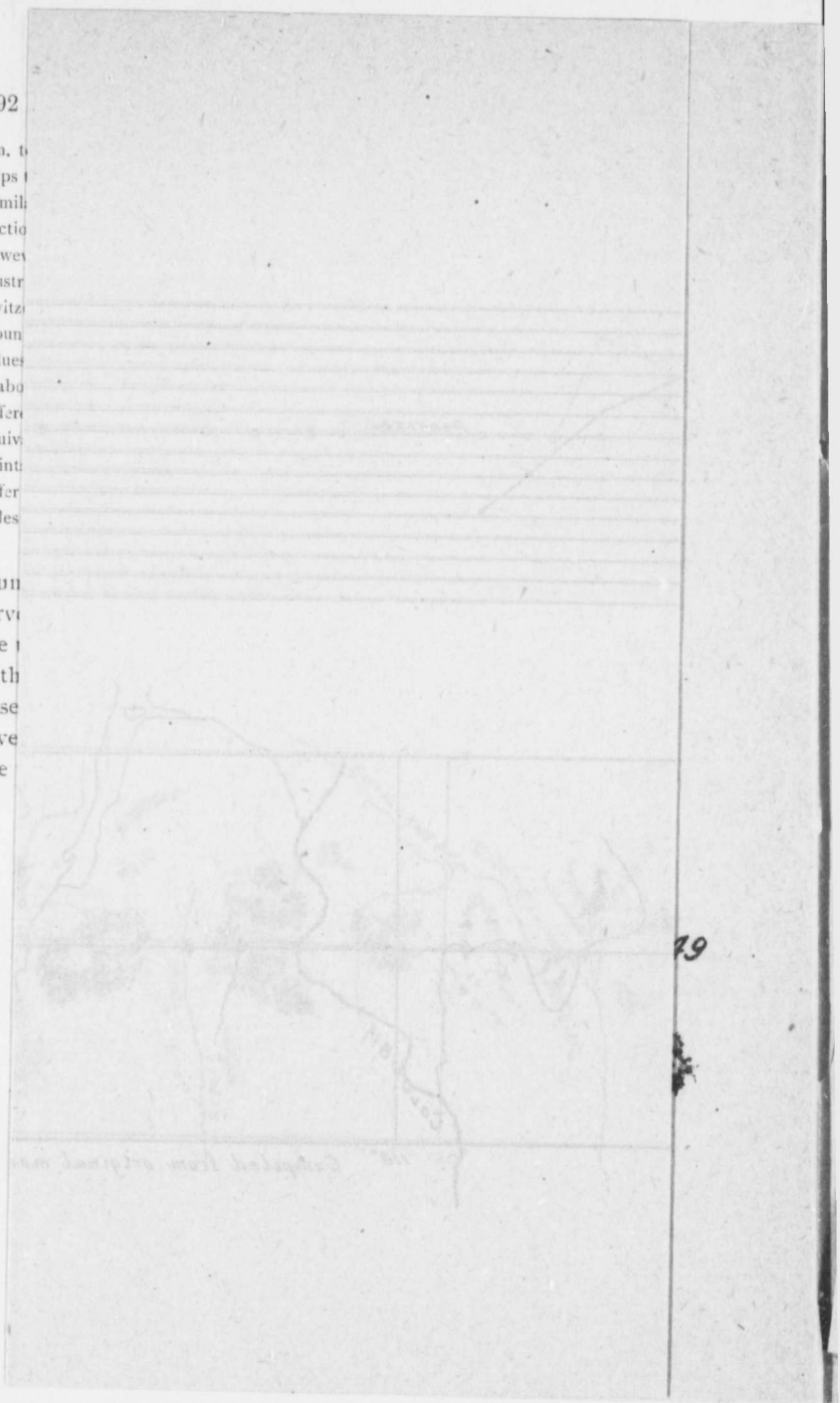

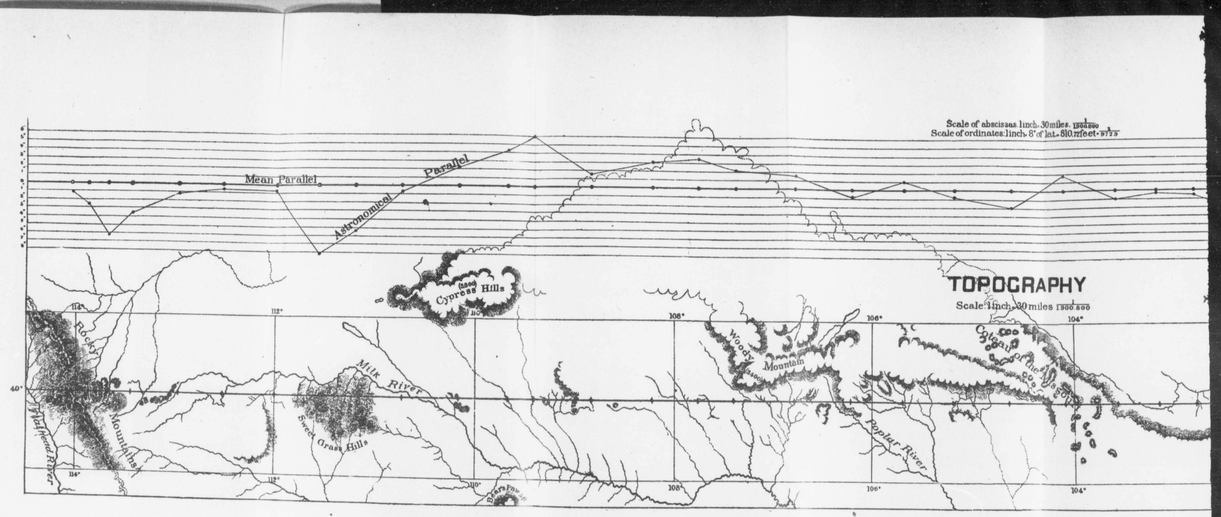

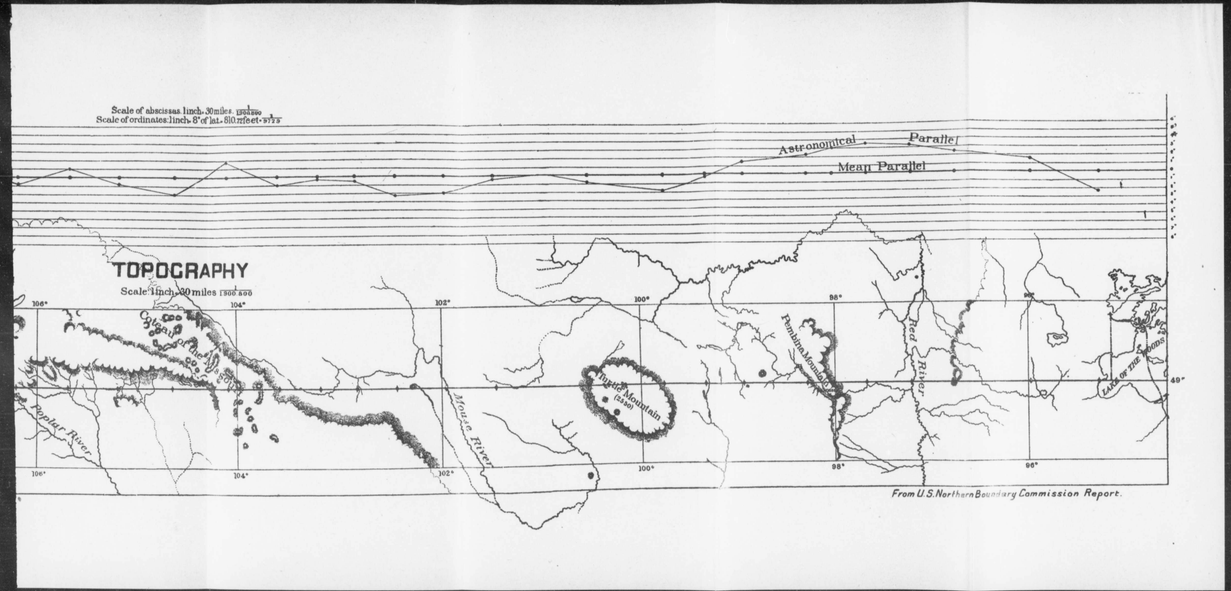

From U.S. Northern Boundary Commission Report.