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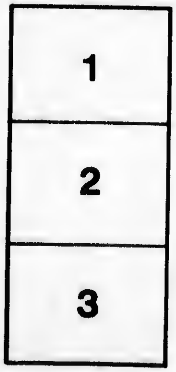
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NARRATIVE

OF THE

OPERATIONS

OF THE

BRITISH NORTH AMERICAN BOUNDARY COMMISSION,

1872-76.

BY

CAPT. FEATHERSTONHAUGH, R.E.

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PAPER VIII.

NARRATIVE OF THE OPERATIONS OF THE BRITISH NORTH AMERICAN BOUNDARY COMMISSION, 1872-76.

BY CAPT. FEATHERSTONHAUGH, R.E.

The boundary between the British possessions and those of the United States on the Continent of North America had, previous to the appointment of this Commission, been marked from the Atlantic Ocean, westward, to the north-west angle of the Lake of the Woods, and from the Pacific Ocean, eastward, to the summit of the Rocky Mountains.

In the interior of the continent between these terminal points, the boundary was unmarked, though determined, geographically, by the Convention of the 20th October, 1818. This portion of the country comprised between the meridians of 95° 14', and 114° west longitude, was, to a great extent, unknown, but was believed to be all prairie land or bare plain, with the exception of the swampy districts between the Lake of the Woods and the Red River of the North. West of the 100th meridian the great American desert, alluded to in most of the books of travellers in these regions, was supposed to lie; further on the "bad lands" of the Missouri were said to be crossed by the line, and further on again were the hunting grounds of the Blackfoot and Blood Indians, who were reported to be unfavourably disposed to intruders. All these obstacles turned out, as will be seen in the course of this narrative, to be overrated. The great American Desert was certainly deserted; but grass, water, and, at one time of the year, buffalo abounded in it; the "bad lands" were small in extent, and the Indians were friendly.

The north-west angle of the Lake of the Woods had been identified and marked by Commissioners from both nations in the year 1826, and from this point, according to the Convention, the boundary was to run due south as far as the 49th parallel of north latitude, and then along the said parallel to the Pacific Ocean. The portion between the Pacific Ocean and the summit of the Rocky Mountains having been marked in 1858-62, the work of the present commission came to an end when the latter were reached.

The staff of the British Commission were the following:—

H.M. Commissioner, Major Cameron, R.A.
Secretary, an officer of the Royal Engineers.
Chief Astronomer } Officers of the R.E.
Two Astronomers }
Two Surveyors.
One Surgeon.
One Geologist and Naturalist.
One Commissariat Officer.
One Veterinary Surgeon.
Four Sub-Assistant Astronomers.
Three Assistants to the Surveyors.
One Assistant Surgeon.

The last fourteen of these offices were filled by Canadian gentlemen, who were nominated by the Government of the Dominion. There were also in the permanent employment of the commission 44 non-commissioned officers and men of the Royal Engineers, one waggon-master, 12 depôt keepers, (who were persons qualified to undertake the care of provisions and to issue stores and rations), and 13 officers' servants.

During the period of work in the field, teamsters, axemen, and labourers were hired for the season at so much a day. The number of these in each year are shown in the tables at the end of the appendix. The detail of the trades of the non-commissioned officers and men of the Royal Engineers, and lists of the instruments and stores brought from England for the use of the commission are given in the same place.

DEPARTURE FROM ENGLAND, 1872.

The Commissioner and the Secretary left England in July, 1872, and proceeded to Washington, U.S. From thence they went to Ottawa, the capital of the Dominion of Canada, and finally started for Red River in the beginning of September.

The officers and men of the Royal Engineers, having with them all the instruments and outfit which had been purchased in England, left Liverpool on the 22nd August, 1872, Captain Anderson, R.E., the chief astronomer, being in command of the party, and they reached Quebec at the end of the month. Hence they proceeded by water to Toronto, on Lake Ontario, thence by railway to Collingwood, on the Georgian Bay, where they embarked in one of the Lake Superior line of steamers, which took them to Duluth, in the State of Winconsin, U.S. The destination of the party for this port had been reported by Captain Anderson to the Major-General commanding the United States troops in the district; and, on arrival, a telegram was received from the Adjutant-General of the division giving the requisite authority to pass through the country, and offering, with great consideration, that an officer of the staff should accompany the party to the frontier. As no peculiar difficulties were anticipated, it was not thought necessary to accept this kind offer, as the doing so would have entailed a long journey upon the officer concerned.

Leaving Duluth by the railway, the party travelled for 30 miles up the gorge of the St. Louis river, the scenery of which is remarkably bold and picturesque, the stream following a number of precipitous descents, broken by large pools of still, clear water, around which immense slabs of rock lie tossed in every conceivable position. The railway runs along the north side of the gorge, and crosses the numerous lateral ravines, which open into it, on high trestle bridges, mostly built on a curve plan, and so arranged that the traveller, looking out of the carriage windows, sees no roadway beneath him but only the rocks, perhaps 100 feet below. Although the delicate but strong construction of these bridges was admired, yet a feeling of relief was experienced when they had been all passed. Emerging on to the level country at the top of this gorge, the North Pacific Railway carried the party due west, to its intersection with the Red River of the north, a distance of 350 miles, the first 150 being through woods and swamps, after which the open prairie was reached.

The first aspect of scenery over country similar to which the party were destined to work for so many miles, could not fail to be interesting, and even impressive; but, as a mere landscape, the prairie, as seen from a small elevation, has few elements of beauty. The spectator appears to be in the middle of a small circle, just as is the case at sea, and the feeling which is induced is that of an oppressive monotony. After about 18 hours travel by rail, the detachment reached Moorhead on the Red River, where they overtook the Commissioner and the Secretary. Arrangements were here made for the transport of the baggage and stores, &c., by carts, along the coach road northwards, and the party commenced their march in the same direction. The road follows the general course of the Red River, running from point to point of the numerous bends of that stream, and on the evening of the third day, the head of the navigation at that season was reached at a place called Frog Point, above which, during most of the year, the water is too shallow for steamers. The men, baggage, and stores were all embarked here, on the "Dakota," one of the Kitson Red River line of steamers. These vessels, on account of the shallowness of the stream and its numerous bends, are of peculiar construction. The hull is very shallow, drawing only about three feet of water, and they have a single paddle wheel placed at the stern. When one of these steamers takes barges or freight boats with her, they are lashed to her sides, or even placed in front of her bows, it being impossible to take them in tow on account of the paddle wheel. In ascending the river when a sharp turn has to be passed, it is usual to run the steamer sideways against the bank in the angle of the bend, get her head round, and start again in the new direction.

After two days steaming the commission arrived at the frontier on the 20th of September, and went under canvass on the prairie on the north side of the line; the United States commission were camped a short distance off, having arrived about ten days before. The Canadian officers and other members of the British commission had also arrived by the "Dakota," or by the previous steamer, and the entire staff was now ready to commence work.

At this time there were only three or four buildings on or near the 49th parallel, where it strikes the Red River. One of these was the Canadian Custom House, another was the Hudson Bay Post, which was surrounded with a palisade; the others were mere huts, inhabited by Half-breeds. The exact position of the boundary was not known; by some persons it was supposed to be three-quarters of a mile north of all these buildings, though the general opinion placed it very much where it was eventually found to be. Major Twining, of the United States Engineers, was already engaged in observations for latitude with the zenith telescope; and the British astronomers commenced to do the same on a meridian conveniently near to that of the American observatory tent.

The group of buildings mentioned above was at that time called North Pembina, the village of Pembina being two miles further south, where the river of the same name flows into Red River. The United States custom house is in this village, and Fort Pembina, which contains a garrison of three companies of United States infantry, is one and a half miles further south again, on the west bank of Red River.

The British and United States Commissioners having agreed upon a plan of operations for the autumn, the British Commission was divided into the following working parties:—

3 Astronomical parties; 3 Surveying parties; Staff.

The astronomical parties were in charge of Captain Anderson, Captain Featherstonhaugh, and Lieut. Galwey, R.E.; and the surveying parties were under Colonel Forrest, of the Canadian Militia, P.L.S.,* Mr. A. L. Russell, P.L.S.,* and Sergeant Kay, R.E., respectively.

Each astronomical party was equipped with a zenith telescope, a portable transit instrument, a sextant, two sidereal and one meantime chronometers, a 7-inch transit theodolite, chain and arrows, &c. Each surveying party had a 5-inch transit theodolite, three prismatic compasses, chain and arrows, sketching cases, and mathematical instruments sufficient for plotting the traversing.

While the various parties were preparing for the field, a snowstorm of great violence commenced on the day following the equinox, and continued for 48 hours. It had been preceded by the passage of large flocks of wild geese to the south, which went screaming over the camps, being generally at a great elevation. This storm, though sufficiently unpleasant, was taken by the local people as a presage of a late winter, and this proved to be the case.

The following plan of operations for the autumn and winter was agreed upon between the Commissioners. The position of the north-west angle of the Lake of the Woods, as marked in 1826, was to be identified, and the necessary surveys of the shore were to be made; the meridian line from here southwards to the 49th parallel was to be traced and marked; the intersection of the western shore of the Lake of the Woods by the said parallel was to be determined by joint astronomical observations; and as many intermediate points as possible between the Lake and the Red River were to be established, taking into consideration the nature of the country and the lateness of the season. The joint determina-

* Provincial Land Surveyor.

tion of the boundary at North Pembina was also to be finished, and the surveys on each side of the line were to be pushed forward in an easterly direction.

The article of the Convention of the 20th October, 1818, under which the Boundary Commissions were constituted, is as follows:—

ARTICLE II.

"It is agreed that a line drawn from the most north-western point of the Lake of the Woods along the 49th parallel of north latitude—or, if the said point shall not be in the 49th 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 His Britannic Majesty and those of the United States, and that the said line shall form the southern boundary of the said territories of His Britannic Majesty; and the northern boundary of the territories of the United States from the Lake of the Woods to the Stony Mountains."

The north-west angle of the Lake of the Woods being considerably to the north of the 49th parallel, a meridian line had to be traced southwards.

In the beginning of October, the main bodies of both commissions started for the north-west angle of the Lake of the Woods, leaving one of the British astronomical parties at North Pembina to finish the observations for latitude; the surveyors on each side had also commenced working in an easterly direction along the 49th parallel. On arriving at the north-west angle, Major Twining and Lieut. Galwey proceeded in boats across the Lake of the Woods to Buffalo Point, where joint observations were commenced for latitude. The commissioners and the two chief astronomers pitched camp at the north-west angle, and a search was commenced for the reference monument erected by the international commissioners appointed under the 7th Article of the Treaty of Ghent. "The most north-western point of the Lake of the Woods," mentioned in the 2nd Article of the Convention of 1818 (quoted above) was agreed and declared by these commissioners to be at a specified distance measured in a given direction from this monument. At the same time the latitude and longitude of the said "north-west point" were given. It was evident that the first method of identifying the "north-west point" was far the most accurate, provided the reference monument could be found. The range of the possible position of the north-west point, in longitude, was fortunately limited by the width of the bay, which was not more than 100 yards, its sides running north and south. Observations for latitude were therefore taken with the sextant, and the position of the reference monument was in this way found within the limits of the error of the sextant observations, and of the width of the bay, supposing that the observations taken at the time when the reference monument was constructed were correct. The probable error of the latter observations was, however, unknown; nor was there any information at that time as to what instrument had been used in taking them. The search for the reference monument occupied three days, at the end of which time some Indians appeared, who said they could point out its site. They accordingly indicated a spot which was covered with water about 13 inches in depth, and here the remains of a square crib of logs were found. This was assumed to be the reference monument, and the position of the north-west point was determined by laying off the six measured courses leading thereto, as specified in the Treaty of Ghent.

Observations for latitude were then taken with the zenith telescope by Capt. Anderson, R.E., by which the latitude of the north-west point, found as described in the preceding paragraph, was determined to be 3·7 seconds greater than it was stated to be by Dr. Tiarks, the astronomer to the commission under the Treaty of Ghent.

It was afterwards ascertained that Dr. Tiarks had used a sextant, and that his observations had been taken, not with a view of determining the absolute position in latitude and longitude of the spot in question, but only its position relatively to another point, which appeared to have equal claims to be considered the north-west angle of the lake. The discrepancy, however, is very small, and the position of the north-west point, as determined from the spot where the remains of the crib of logs was found, was finally agreed to by the Commissioners of both nations. The work was proceeded with at the time on the supposition that such would be the agreement on the subject, and a meridian line was laid off by the astronomers of both commissions, passing through the north-west point.

About the beginning of November, the two astronomical parties at Buffalo Point had completed their observations, and were back at the north-west angle. The United States commission then withdrew from the field, and retired to winter quarters at Detroit on Lake Erie. Lieut. Galwey and his party returned to North Pembina by the same way that they had come, and proceeded along the 49th parallel about 20 miles eastward, to a well marked ridge, which runs from south to north, being the edge of the Red River valley, and also the eastern limit of the prairies. Lieut. Green, of the United States Engineers, had traced an easterly line, tangent to the 49th parallel at Red River, as far as this, and for about 14 miles beyond it to a place called Pointe d'Orme, where the boundary strikes the Roseau River. Lieut. Galwey established an astronomical station on the ridge, and commenced observing about the middle of November; having determined the latitude, and erected a substantial mark, he returned to North Pembina.

During the time that Captain Anderson was observing for latitude at the north-west point of the Lake of the Woods, his party were engaged in cutting through the woods in order to prolong the meridian line southwards. There were a number of Chippewa Indians camped at the angle, and twelve of the strongest looking were hired as axemen. Many days passed, however, before they could be got to understand that the work had to be done regularly, and continued for so many hours a day. They would commence in the morning sometimes with great vigour, but would soon stop, light a fire, and sit round it smoking; then when, after much trouble, the non-commissioned officer or sapper in charge had got them to work again, they would suddenly break off and proceed gravely to Captain Anderson's tent, perhaps some two or three miles off, where they would ask for more pay or more food. After a fortnight, only half-a-dozen of these men were able to continue at work, the others breaking down through want of stamina. They were all miserably clad, and the working in the icy water of the still unfrozen swamps was very severe upon them; they were, however, useful in carrying loads when the camp was shifted southwards along the line, or when supplies were being brought up. About three weeks after the cutting had been commenced, the frost set in, and greatly improved matters by giving a hard and dry footing, the timber became less thick and of smaller size, and three white men having been engaged as axemen, the work progressed more quickly. As the Lake of the Woods was approached, the woods merged gradually into small half dead tamaracs, which were replaced in the immediate vicinity of the shore by willow bushes. The length of this cutting was 16 miles and 397 feet, the ground passed over was all swampy, with the exception of a ridge of red granite (in situ) 6 miles south of the N.W. Point. The timber was birch, cedar, and tamarac.

On the 21st November the cutting was finished, and marks having been left by which the permanent iron monuments might be erected as soon as they could be provided, Captain Anderson withdrew his party and returned to North Pembina. Here observations for longitude were commenced, the local time being compared by means of the electric telegraph with that of Chicago in the State of Illinois, U.S. The local time at North Pembina was obtained with a portable transit, Lieut. Galwey taking the observations; while the electric signals for comparing the chronometer with that at Chicago were sent by Captain Anderson. Mr. Lindsay Russell, Deputy Surveyor General of the Dominion of Canada, undertook the necessary work at the Chicago end of the wire. The weather was unfavourable, being cloudy and very cold; but the result was satisfactory, the probable error being about two seconds of arc, or 130 feet.

Meanwhile Captain Featherstonhaugh, who had finished the observations for latitude at North Pembina, took his party to Lake Roseau, which is about 60 miles east of the Red River, in order to establish an astronomical station, and mark the boundary in the vicinity. Between the Lake of the Woods and Pointe d'Orme on the Roseau river, mentioned just now, there are, on the boundary, about 50 miles of almost continuous swamp, in the midst of which are ridges covered with valuable pine timber. Some firm ground was reported to exist on the shores of Lake Roseau, which was represented on the maps as being intersected by the boundary. Captain Featherstonhaugh and party, accompanied by a guide, after a long detour to the south to avoid being entangled prematurely in the swamps, reached the lake and found that the parallel was 6 miles north of it. After some trouble, a gravelly ridge was discovered to the northwest, which was sufficiently near to the parallel of 49 deg., and the astronomical instruments were set up here on the 27th October. Considerable advantage was derived in getting through the soft parts of the journey from the presence of a pair of oxen amongst the teams. These animals, though apt to be looked upon as encumbrances when they are in company with horses because they travel slowly, and can only do 15 miles a day, will take a load through bogs, in which the latter are quite helpless. On the 17th, an aurora of remarkable brilliancy was observed at a place 8 miles south of Lake Roseau; besides the usual bow and streamers, an arch of light about two degrees wide was formed passing through the zenith from east to west. A constant wave or pulsation of luminosity advanced from the eastern end of this arch and travelled slowly by successive impulses along it. The effect lasted about three quarters of an hour, and although there was a very bright full moon, the aurora quite held its own in vividness.

A few Chippewa Indians were seen about here, but they appeared to be an idle set, without anything striking in their appearance or bearing. They subsist chiefly on fish caught in the lake, a resource which does not always keep them from want.

After completing the observations for latitude, Captain Featherstonhaugh set his men to cut east and west tangent lines (*i.e.*, straight lines tangent to the parallel) through the woods, the intention being to cut about ten miles to the east, and then to work westward as far as Pointe d'Orme. It was soon found, however, that the muskegs or swamps which lay to the east were so continuous that progress during the open season would be very slow indeed, and it was resolved to work only westward, in which direction the trees were much larger, and there was some sort of foothold to be obtained. These muskegs are four or five feet deep in many places; they have on the surface a skin of sod which scarcely supports the weight of a man, and when it is pierced the muddy water rises in the hole nearly to the top. A person breaking through goes down to his middle, and has some trouble in getting out again. The westerly line being continued, considerable difficulties were shortly experienced in the work, the frost which set in on the 10th November having been unfortunately preceded by snow, which for some time prevented the ground from freezing. The men were unskilled in the use of the axe, and the swamp-holes between the trees, which it was impossible to avoid, kept them constantly half wet through. This, with the thermometer at zero, or but a little above it, could not fail to be a serious thing, and, besides the direct suffering from the cold, many were attacked with diarrhœa, one man becoming dangerously ill with congestion of the liver. Anxiety was always felt also as to the safety of the supply teams, which had to traverse 100 miles of open country, where a snowstorm might prove dangerous. The cutting, however, was continued, and after about 4½ miles had been completed through the spruce and tamarac, the party, to their great satisfaction, emerged on to the open surface of the great Roseau swamp. This was then just frozen over, and, as far as the eye could reach, the glare ice stretched away to the horizon towards the south and south-west, with small tufts of grass here and there, and thin wreaths of snow curling up before the wind that swept across it. Desolate as the aspect was, the change was welcomed from the wet and fatiguing work in the woods, and the line was quickly taken across the open, the sick man being sent back to head-quarters, and the guide directed to find a direct road along the parallel from Pointe d'Orme. A day or two of the great cold now set in, giving the finishing touch to the swamps and rivers, and causing the party to wish for the shelter of the woods again. On days like this, when protected from the wind, any one will get along tolerably well, though the thermometer be 20 deg. or 30 deg. below zero, but the slightest breeze produces great discomfort, and it is very difficult to pay the proper attention to surveying operations. On several occasions the eyelids would feel as if they were about to be frozen down, the ends of the lashes becoming tipped with ice; the first realization of this produces unbounded surprise to the person concerned.

About the middle of December, Captain Featherstonhaugh's party struck the end of a line which Mr. Russell's men had cut for a distance of six miles westward from Pointe d'Orme, and the Lake Roseau astronomical station was thus connected in longitude with North Pembina. There still remained nearly thirty miles immediately west of the Lake of the Woods, over which the line had to be traced, if possible. Colonel Forrest and his surveying party who had traversed the shore of the lake from the north-west angle southwards to the Buffalo point astronomical station, were now at work cutting from the latter place westward, but no news had been received of their progress. Major Cameron becoming, however, anxious as to the welfare of those in the field, desired that the work should cease, if the exposure was likely to continue so severe, and Captain Anderson, who had just completed the observations for longitude at Red River, set out for Pointe d'Orme with Mr. Herchmer, the commissary, in order to be able to report upon the advisability of persevering. Upon conferring with the officers who were at this place, it was concluded that the work could go on, the principal astronomical observations being finished, and the health of those concerned having been good since the ground had all become frozen. In accordance with this opinion, measures were taken at head-quarters to stock depôts at Pointe d'Orme and at Pine River, north of Lake Roseau, and parties of axemen were sent to construct a log hut for this purpose at each place, stables being also commenced at the former spot.

The survey of the 6-mile belt north of the boundary was now continued towards Pointe d'Orme, and the line which had been traced across the prairies from Red River to the same place requiring to be checked, the two astronomical parties commenced this work. Unfortunately the weather became colder and colder, the thermometer registering 51 degs. below zero of Fahrenheit on the 23rd of December, and it became difficult to take the most simple observations of stars for azimuth with the proper precision, owing to the freezing of the lubricating oil in the internal parts of the instruments, and of the oil in the lamps illuminating the field of view. Lieut. Galwey's party, being on the perfectly open prairie immediately east of the Red River, were particularly exposed during this severe spell.

About the end of the year, no news having been received for some time from Colonel Forrest, who had hitherto drawn his supplies from the government depôt at the north-west angle of the Lake of the Woods, Captain Anderson, with a dog train and some provisions, set out for Lake Roseau, and travelled up the East Roseau River to the 49th parallel. Colonel Forrest was found to be about five miles to the east, and having relieved the wants of his party, Captain

Anderson returned towards Pine River, and was met whilst on Lake Roseau, by the terrible storm of the 7th, 8th, and 9th of January, which prevailed over the whole of Manitoba and Minnesota. For three days, with the thermometer at 20 deg. below zero, the wind blew with extraordinary force, raising mists of fine snow from the surface, so that the air became of a milky opacity, and objects were invisible at a few yards distance. In Minnesota* eighty persons were frozen to death, many of them being children on their way home from school; and a coach-load of passengers, as well as the horses, suffered the same fate. Captain Anderson and those with him took refuge in one of the small islands of poplar near the shores of the lake, and being able to keep a fire alight, escaped without harm. The parties at work on the prairie fortunately took the alarm in time, and got back to their camps; but two men, one of them a sapper, who were driving in a waggon a few miles from North Pembina, were obliged to come to a halt, cut the horses loose, and remain wrapped in their buffalo robes for two days and nights inside the waggon, without food or fire. They eventually reached head-quarters without having suffered serious injury.

After this, for the remainder of the winter, the weather was fine, and the lengthening days and bright sun made matters more cheerful; but the cold continued steadily until the equinox, the thermometer falling as low as 40 deg. below zero even as late as the 1st of March. The parties, however, being now well sheltered, were more comfortable than would be imagined. The perfect stillness of the woods disarms the most extreme cold of half its severity, and the dark green foliage of the fir and pine is a pleasant relief to the eye, where all else is an endless glare of white. The spruce boughs laid on a waterproof sheet, furnish dry and comfortable couches on the surface of the snow itself, and an ample supply of good firewood is found on the outskirts of the growing timber. At night the trees, under the influence of the frost, crack with surprising loudness, the effect being like that of pistol shots heard at a little distance. Canadian grouse and prairie fowl are tolerably numerous; they sun themselves on fine days, sitting on the tops of the trees; they feed on berries, and are in fairly good condition. Butcher birds and woodpeckers are also seen, and the snow is covered in many places with the tracks of rabbits. Large game are very scarce; even the Indians never seemed to find any moose, though one or two were known to be about Lake Roseau.

Mock suns and mock moons were frequently seen, and on one occasion two mock Venuses were visible. This is believed to be a rare occurrence. On these occasions the air was observed to be filled with floating spiculæ of ice, which settled gradually down when they attained a certain size. Sometimes just after dawn a peculiar effect was observed, due to the presence of these spiculæ. From the point of the horizon above the yet unrisen sun, a prismatic beam of light extended 30 deg. or 40 deg. towards the zenith, and to the right and left two similar beams, only not so vivid, reached nearly the same altitude. The three beams stretched higher and higher as the sun approached the horizon, until the

* This number is given in the United States official account of the calamity.

real and the two mock orbs rose together, each sending the prismatic rays both upwards and downwards. The effect gradually faded away after this as the day advanced. After Christmas, snow shoes came into general use, the men soon learning how to walk in them; indeed there is little difficulty in doing so. It is a mistake, however, to suppose that these contrivances enable a man to travel over snow with as much ease as he would over grass. In some cases where a track is partially beaten, or in the spring of the year when there is a crust on the surface, very quick walking can be accomplished by their aid, but under ordinary circumstances, all that a snow shoe does is to enable a man to progress slowly where, without them, he would not get on at all.

During February and March, the remaining portions of the boundary between the Lake of the Woods and the Red River were cut through the woods and temporarily marked with posts of 8 in. diameter. The survey of the 6 mile belt north of the line was also completed, and nothing remained to be done in this part of the country except the putting up of the iron pillars and permanent monuments. This was postponed until the next year.

By the 1st of April the parties had all returned to North Pembina, where they were lodged in quarters which had been built by a contractor from Fort Garry during the early part of the winter. These buildings, which were named "Dufferin," are situated on the left or western bank of the Red River, about two miles north of the boundary; they can accommodate about 11 officers, 80 men, and 180 horses or oxen. There are also three stores, containing 5,000 square feet of flooring, and a bakehouse capable of baking 200 loaves (of 1½ lbs.) in one batch.

During the next six weeks, preparations were made for the summer season's work, for which the necessary supplies had been ordered from St. Paul in Minnesota, U.S. Mr. W. Boswell, the veterinary surgeon, brought from Ontario in Canada a train of 180 horses for the commission. After leaving the railway at Moorhead, they were taken up the coach road along the banks of the Red River; but this stream having risen about 30 feet, as is usually the case in spring, had so flooded the country that men and horses had to be constantly swimming the numerous coulées or watercourses which run into the main stream. After a laborious journey, the train arrived safely at Dufferin.

The United States commission arrived at Fort Pembina, U.S., at the end of May, and a plan of operations was agreed upon for marking the boundary across the prairies. The following was the general arrangement:—The latitude was to be determined by astronomical observations at intervals of 20 miles along the parallel, and the points so determined were to be connected by surveyed lines. In taking 20 miles as the intervals between the astronomical stations, the time of observing at each station, and the time of connecting two stations by survey, had to be considered as well as the relative accuracy of each operation. With the zenith telescope, the time occupied in determining the latitude of each station might be assumed as 7 days on an average, three clear nights being sufficient for the observations.

The connection of two astronomical stations was effected by laying off a line from one of the stations at right angles to the meridian, and prolonging this line until it struck the meridian of the second station, the whole distance being chained, and pickets left in the ground. The proper offsets to the parallel were then measured wherever permanent marks were intended to be erected. The average progress of such work was 5 miles a day; so that of two separate parties, one running the line as it was called, and the other observing for latitude, the former would complete its work first. But in the British commission, the astronomical party had to do both, so that the time question was not of such direct weight, although it was of course evident that the fewer the astronomical stations the quicker would the whole work be done.

This was a reason for not putting the stations closer together than 20 miles; but other considerations prevented their being placed much further apart. The probable error, that is to say, the measure of accuracy of the determination of the latitude of a station by the zenith telescope, was expected to be about 10 feet, and, as a matter of fact, it was rarely found to be greater, and in most cases less. The error in laying down the direction of the line might be assumed at 5 seconds, which would produce a deviation of 1½ inches a mile, or 2½ feet in 20 miles, and the error of prolonging the line was expected not to be greater than one minute of azimuth at the end of 20 miles, which would be equal to a deviation of 30 feet. It may be remarked, however, that the error in running the line was very rarely more than 30 seconds at the end of 20 miles, and generally less.

About two thirds of this latter deviation could be got rid of by taking fresh observations for direction and correcting the intermediate pickets, so that there remained 10 feet of uncertainty in the position of any point on the latter portion of the line; that is to say, the determination of all the intermediate points by survey was as accurate as if astronomical observations had been taken at each of these points, supposing the direction of the plumb-line to strike the earth's surface at the same angle over the whole span of 20 miles; or, in case of any variation, supposing it to vary regularly from one end to the other. (See the remarks in the Appendix on the deviation of the plumb-line.)

If the stations had been at a greater distance apart, say 30 miles, the deviation in running the line would have been, of course, one half greater; it would have been often necessary to go back to correct errors, and the work would have been altogether less manageable. Other reasons for the interval adopted were, that it was considered desirable that the different parties should not be more than a day's march from each other, and that the whole commission should not cover more than a certain span of country at any one time.

The adopted interval of 20 miles was of course not rigidly adhered to. Astronomical stations were placed at well marked natural features, such as the banks of rivers, the edges of mountainous districts, &c., irrespective of the precise mileage in longitude, but the average of 20 miles was observed throughout the first summer's work. This average was increased to 21 miles during the last summer's work, because this number was a measure of the whole distance that remained to be done.

The permanent marks along the boundary were agreed to be placed at intervals of one mile between the meridians of 96 deg. and 99 deg. west longitude, which are the east and west limits of the province of Manitoba, and at intervals of three miles in the country west of 99 deg. The former set of marks were to be iron pillars firmly fixed in the ground; the latter were to be mounds of stones wherever these could be procured, or, failing them, of earth.

Drawings of the iron pillars are given in Pl. X.

It was further agreed that the astronomers of the two commissions should take alternate stations, each party making good the connecting survey up to that 20 miles west of it. An exception was made in the case of the first two stations west of the Red River, at which the astronomers of both commissions took independent observations. The surveyors covered a width of six miles north and south of the line, the British and American parties working each on their own side. Table 3 gives a detail of the British parties, shewing their transport and camp equipage.

The nature of the boundary extending for a long distance across an uninhabited and unknown country in which no supplies would probably be obtainable, the shortness of the summer season, and the scarcity of wood and water, combined to render it necessary for the work to be done with as much expedition as was consistent with efficiency; at high pressure, so to speak. Under such circumstances, it was desirable that the astronomical parties, whose progress regulated that of the whole commission should not be delayed even for a day by having to explore for water or to take preliminary observations before setting up the zenith telescope, which it was desirable to place as nearly on the 49th parallel as possible. It was also necessary that depôts of provisions should be established without delays at the proper intervals, and that the roads to these depôts should be practicable for heavy teams. It was evident that mismanagement or mistakes on these points would produce great delay and extra expense, and a reconnaissance party was accordingly formed, consisting of 20 scouts—mounted men—with sufficient transport to carry food for a fortnight, if necessary. Captain Anderson, who, as chief astronomer, was in charge of the field operations of the commission, adopted the plan of taking this reconnaissance party on ahead of all the others about 100 or 150 miles along the 49th parallel, making a sketch of the country as he travelled, and keeping his course by sextant observations for latitude and time. Having with him four mean-time pocket chronometers, whose rates were known, he obtained the longitudes of particular points with sufficient accuracy to enable him to mark on the ground the sites for the astronomical stations at the average intervals of twenty miles, and to select and map down the positions for the depôts where water was permanently to be found. On returning to the starting point of the reconnaissances, the travelling rates of the chronometers were checked by the local time, and in this way very accurate sketches were prepared, tracings of which were furnished to the officers in charge of the different parties, so that they were always well informed as to the nature of the country they were about to traverse. By this means also, an early knowledge of the main features of the six-mile belt being acquired, the amount of survey work that would have to be done was estimated, and the necessary arrangements made.

By the first week in June, both the commissions had set to work, and the boundary was marked across the western side of the Red River valley as far as Pembina Mountain, which is a sudden rise of about 300 feet in the prairie level, and is really a sort of step or escarpment, having no western edge, only an eastern one. Being, however, intersected, where the boundary strikes it, with numerous ravines which stop the prairie fires coming from the west, it is covered with timber and bush, and has the appearance, as seen from the east, of a mountainous ridge. One of the British astronomical parties detached part of its complement to cut and trace the line through the eight miles of wood which occur here; while the main bodies of the two commissions, diverging round the north and south edges of the timbered land, crossed the Pembina River, and took up astronomical stations across the sixty miles of prairie which intervene between it and Turtle Mountain, where a site for a depôt had been selected by the British reconnaissance party.

Turtle Mountain is a well wooded district, consisting of numerous small hills, which gradually rise to as much as 500 feet above the plains, and are covered with poplar, birch, and oak. Between these hills are countless swamps and lakes, the water being unable to get away. The shape of the mountain, as seen from the west, is very like that of a turtle, a smaller detached ridge representing the head, and the name is derived from this resemblance. At the middle of July, nearly all the British and United States parties were assembled round the north-eastern skirts of the mountain, and the escort of cavalry which accompanied the United States commission was also encamped here. Grass, fuel, and water were abundant, but the plague of flies was almost intolerable; the horses, which could not feed properly, suffered considerably in condition, and all hands had to wear mosquito veils and gauntlets. The number of mosquitoes in the summer in these countries is quite incredible, and the reality is worse than the anticipation. It may suffice to say that oxen have been known to be choked by them, and that on a still warm night the noise they make beating against the outside of a tent, resembles that of rain. The only time that there is any relief from them is in the middle of the day, when the heat of the sun prevents their appearing; a moderate breeze will also keep them quiet.

The 1st British astronomical party which had established the point where the boundary enters the mountain from the east, was charged with taking the line into the interior, working westward. One of the United States parties travelling round the north side of the woods, determined the position of the 49th parallel on the western edge of the mountain, and commenced to cut in an easterly direction, so as to meet the others half way. The dense growth of poplar and bush which were met with on both lines, and the frequent swamps and pieces of water which the boundary traversed, caused this work to progress but slowly; roads or bridle paths had to be cut round the impassable portions, and the soft places "corduroyed," to enable the pack animals to get over them. The interior of the mountain is, however, singularly beautiful, owing to the graceful outlines of the hills, covered with leafy poplars, and the perfect stillness of the lakes, the shores of which are clothed with foliage down to the water's edge. From a high point in the cutting about three miles from its commencement, the mounds, marking the 49th parallel on the prairie to the eastward, could be seen stretching in a gentle but well defined curve for a distance of 15 miles, thus giving the spectator a very graphic idea of the size and figure of the earth.

Seeing that the work of cutting through these woods would be a tedious but practicable operation, Captain Featherstonhaugh divided his party in two, and taking with him about ten men and his astronomical instruments, started for the plains further west, leaving the remainder in charge of Mr. W. F. King, sub-assistant astronomer, to continue the cutting and tracing of the line to the halfway point. As matters fell out, however the United States party who were working eastward, met at the end of 10 miles with such large lakes, that although they crossed them and marked the line on the eastern margin, they went no further, and Mr. King, to complete the work, had to carry on his cutting for 24 miles, which he finished at the end of September.

Meanwhile, the reconnaissance had been carried 150 miles further west, and the astronomical parties of both commissions had taken up their stations across the plains for nearly this distance. The Souris River which runs through about 300 miles of this country, was crossed by the boundary four times, and proved a great resource to the expedition. This stream, which is scarcely entitled to be called a river, if its width and volume of water are considered, flows for most of its course at the bottom of a valley averaging a mile in width, with high and steep banks. The actual watercourse is fringed with oak and poplar, which supplied the parties with fuel. Above the third crossing, however, the trees disappeared, and this spot, which was the site of one of the principal depôts, was named Wood End in consequence. The work advancing steadily by 20-mile spans, reached this point at the end of August, and Lieut. Galwey, R.E., took up an astronomical station at the foot of the Grand Coteau, which here crosses the boundary in an oblique direction. This remarkable range of hills runs for some hundreds of miles across the plains from south-east to north-west, starting from latitude 44 deg. near the Missouri, and extending far into the British territories. From a little distance it resembles a well defined coast-line seen from the sea; it is, like the plains at its foot, perfectly bare of trees, and looks, perhaps, even more desolate than they do. The interior of the Coteau has been aptly described by Mr. G. M. Dawson, the geologist and naturalist of the boundary commission, as a "confusion of abruptly-rounded and tumultuous hills," the tops of which are stony; but the sides and the small basins between them have some good soil, and there are numerous swamps and lakelets. At the time that the boundary commissions entered the Coteau, the grass over the whole country was beginning to burn, and it was with some difficulty that the different parties obtained pasture. The autumn fires, driven by high winds, sweep over the surface with great rapidity; and although, from the shortness of the grass in these latitudes, there is not much actual danger to life, the tents of a pitched camp may very easily get burnt if a good look out be not kept. One of the astronomical parties, caught by a change of wind, was regularly "stampeded" one day when on the march; the other, from the same cause, had a desperate fight with a fire they had themselves lighted to leeward; and one of the surveying parties had to tear down their tents and get everything across the friendly stream of the Souris, losing some of their clothes in the process. Getting clear of the Coteau, which is about thirty miles wide, the different parties were on the prairie once more; but they had passed the watershed, and the streams now flowed south to the Missouri. However small these might be, they had one quality, which the stagnant Souris had lacked for so long—they ran—and the difference was very welcome. Some wood also was found in the big ravines, and the members of the commissions had began to congratulate themselves on being in a more comfortable part of the country, when on the 22nd of September, a snowstorm of the same violence and suddenness as that which occurred at Red River on the same day in the preceding year, burst upon them. At this time the different parties were at or on their way to their final stations for the year, and every day was of importance, considering the long journey of 400 miles that they had to make back to the settlements. The storm, however, put a stop to all work for nearly a week, and those who were fortunate enough to be near any ravines, took shelter in them; this weather was particularly severe upon the horses, which had to be kept tied up to prevent their running away, it being difficult to find for them any grass long enough to cut. Horses when exposed to these storms, will, if they get loose, run for miles straight before the wind, and it is necessary to tie them up securely, to avoid losing them altogether.

After the weather had moderated, there remained one or two weeks' work before turning eastward, and Captain Anderson, after making arrangements for the provisioning of the parties of the British commission during this time, started on the fifth and final reconnaissance of the year. Reaching station No. 23, which was at the 408 mile point from Red River, on the 2nd of October, he pursued his journey westward for about thirteen miles, and on attaining the summit of a high ridge running north and south, came suddenly on the eastern edge of the "bad lands." These extraordinary surfaces are due to the rapid waste of the soft clayey tertiary formations by the melting snow water and the rains in the spring of the year. Steep irregular hills of clay, to quote Mr. Dawson again, on which scarcely a trace of vegetation exists, are found, separated by deep, nearly perpendicular sided, valleys, which are furrowed from top to base by innumerable runnels, converging into larger furrows below; the scarred and seamed conical masses, and the glare of the white clays of which the whole surface is composed, give a very peculiar aspect to the landscape. Progress with wheeled vehicles was here quite impossible without more road-making than there was time for; but the 430 mile point was reached on horseback, and the site of station No. 24 was selected and marked as the first of the ensuing season.

From this point Captain Anderson turned northwards, in order to reconnoitre a site for a principal depôt amongst the valleys of the Woody Mountain range, which is about twenty miles north of this part of the boundary. Reaching the summit of these hills, an extensive view was obtained of the surrounding country; to the west, a wide and precipitous ravine appeared to cross the line at a distance of about fifteen miles, while to the north was a level plain, stretching to the horizon. The ravines below the feet of the party were well wooded, but were now filling up with drifted snow, and some buffalo were seen taking refuge in them. Turning eastward from this wild spot, Captain Anderson proceeded to explore the hills, in order to find the camp of the Half-breeds, who were known to spend the winter in one of the valleys. Some Sioux Indians, who were met travelling towards the south, pointed out the right direction, and the place was reached after a day's journey. About eighty families of Half-breeds, who migrated from the Red River valley, form a sort of settlement here in the winter time residing in huts. In the summer they abandon their dwellings, and go out on to the plains near Milk River, taking their women and children with them, it not being considered safe to leave them unprotected at Woody Mountain. Having found a suitable site, with wood and water, for a large depôt for the next season's work, and having determined its latitude and longitude, Captain Anderson started for the Red River on the 8th of October, and gathering up with him on the way all the survey parties, depôt keepers, etc., who still remained in the field, he reached Dufferin on the 31st of October, the two astronomical parties and some of the others having arrived shortly before.

Thus ended the first summer's work, during which the two commissions had established twenty-one astronomical stations, and chained and marked 408 miles of the boundary, of which 43 were cut through woods. The country had also been surveyed for a width of 6 miles north and south of the boundary, each commission working on its own side. In the case of the British parties, the width of 6 miles was extended to 15 in some places, and they traversed, with the theodolite and chain, 857 miles, covering with their work a total area of 3,004 square miles. The chained and marked tangent lines were used as bases for the survey, and the traversing along the important watercourses was in all cases commenced from and closed upon them.

The commissariat arrangements during the season may be briefly described. The total length of the line of work was 408 miles in longitude, and about 430 by the actual routes travelled. Along this distance four principal depôts were established, viz., at Pembina Mountain, Turtle Mountain, second crossing of the Souris, and Wood End, the intervals from one to the other being about 90 miles. Provisions were hauled to these depôts by the commissariat horse-trains of 30 Whitewater waggons, and by a hired train of 17 Red River carts. Sub-depôts were made between the principal ones, viz., at Long River, at the first crossing of the Souris, and on the Grand Coteau. These places were chiefly used for storing oats and small quantities of rations for the teamsters of the supply trains as they passed to and fro.

Each party had one or two special waggons told off to it for keeping it supplied with food. These waggons travelled backwards and forwards from the party to the nearest depôt.

Rations.

The ration of food allowed to each man was :—

- 1½ oz. apples (dried) .... daily.
- 4 oz. biscuits .... daily.
- 16 oz. flour .... daily.
- (4 lbs. of baking powder to every 100 lbs. of flour.)
- 2½ oz. cheese .... daily.
- 1 oz. oatmeal ....
- $\frac{1}{200}$ gal. pickles, or ¼ pint of vinegar .... weekly.
- 16 oz. meat .... daily.
- ½ oz. pepper .... daily.
- ⅓ oz. salt .... daily.
- ⅔ oz. soap .... daily.
- 3 oz. sugar .... daily.
- $\frac{1}{100}$ gal. syrup .... daily.
- 1 oz. tea .... daily.
- ½ oz. tobacco .... daily.
- ½ oz. mustard .... weekly.
- 4 oz. beans (dried) .... daily.

Matches as required.

All these articles were not issued daily to each man, but these were the relative proportions allowed. The total weight of food per day was about 40 oz.

For each horse the daily allowance was 9 lbs. of oats; the Red River ponies received none during the summer.

For the use of the animals on the journey homewards, hay stacks were made at certain spots, at intervals of about forty miles; but, unfortunately, some of these were destroyed by the prairie fires.

The operations of the commission for 1874 were arranged to be carried on in a very similar manner to those of 1873. Depôts were to be established in succession at intervals of 80 miles, from which the parties should draw their provisions. As the work, however, would commence at a point 430 miles from the Red River, and constantly recede still further, it was necessary to have a new base upon which the expedition could rely for the summer and autumn of 1874, and also for the ensuing winter, should any work remain to be done during 1875. Woody Mountain—where there was an ample supply of wood, and where pemmican and dried buffalo meat could be obtained, if required—was chosen as the new base, and a contract was made with a merchant at Helena, in the State of Montana, U.S., for the supply of 29,000 bushels of oats, to be delivered by him at the mountain on the 15th of June, 1874. A large number of additional waggons and draught oxen having been purchased, (see the Tables), five months' provisions for the whole expedition were packed early in May, and at the same time the parties were equipped and went under canvass, ready to start as soon as the grass should be long enough for the animals to feed on it. The two Canadian gentlemen who had filled the posts of surveyors during 1873, having retired from the commission, Lieut. Rowe, R.E., who had arrived from England in August of that year, and had taken part in the astronomical work in September and October, took over charge of the surveying operations, and the three survey parties were amalgamated into one under him. The six-mile belt of survey from Woody Mountain up to the Rocky Mountains, was ordered to be reduced to three miles.

Preceded by a road-making detachment, which bridged the streams and corduroyed the swampy parts of the last year's trail, the parties of the commission left the Red River on the 20th of May, under the charge of Captain Anderson, and on the 3rd of June found themselves on the banks of the Souris River, which at this time of the year was 55 yards wide, and 7 or 8 feet deep. As there were more than 100 waggons, spring carts, etc., and large quantities of stores, it was thought advisable to bridge the stream, which was done by constructing cribs of wood, which were sunk at suitable intervals, and which carried the superstructure. Having crossed over, the commission parties pursued their journey somewhat more rapidly than before, the oxen improving daily in condition and travelling power, when on the 11th of June a most unfortunate accident happened to Lieut. Rowe, who, by the falling of his horse, was so severely injured, that it was considered unsafe to move him from the spot for some days. Dr. Burgess and Captain Ward remained with him until he was able to be taken on to Woody Mountain, six weeks afterwards.

The train, proceeding on its journey, arrived at the foot of the Grand Coteau on the 13th of June. Here the two astronomical and the surveying parties were detached, and followed the old track along the parallel across the Coteau; the remainder, with the commissariat train, took the Trader's road, which runs in a north-westerly direction along the foot of the hills to Woody Mountain. On the 20th of June, just a month after leaving Red River, the parties commenced work at their respective stations, and about a week or ten days later the United States' commission which had come up from the line of the Missouri River, appeared on the parallel, and at once commenced operations, so that by the 5th of July three astronomical stations had been established, and 80 miles of boundary had been chained and marked. In this part of the work the great ravine of Frenchman's Creek, or White Mud River, was crossed. This immense trough is 6 miles wide and 320 feet in depth below the prairies on either side; its eastern edges are precipitous. The whole floor of the valley is cut up into gullies and slopes of shale, and the stream itself rushes over a pebbly bed in a smaller ravine at the bottom of the big one. No passage for wheeled vehicles could be found down these cliffs on the line, and the British parties had to use a pass about 16 miles to the north, the United States' commission finding one almost the same distance to the south. Getting clear of this obstacle, the two commissions with their next stations covered the plateau which extends from Frenchman's Creek to Milk River; the surface of this plain is composed of white clay, in which the grass grows sparingly, and in which water is very scarce. At this time of the year, in the height of summer, the direct heat of the sun, aided by the reverberation from the soil, was oppressively great, and the aspect of the country was more like a desert than any that had been previously traversed. The supply of wood now totally failed, and the cooking was done by using the buffalo chips, which lay scattered in great profusion over the ground; strange to say, however, it was here, where game appeared to be least likely to be found, that the buffalo were first encountered. In July, when the pools of water are fast drying up under the sun, and when the grass of their more southern pastures has been consumed, these animals make their way northward to the fertile valleys of the Saskatchewan and its tributaries. They appear to cling to the line of the Milk River, probably because they depend upon its water. With the buffalo were found their constant attendants, the Indians, both Sioux and Assinebonies. These people were well clothed and armed, and appeared to have plenty of food; they always begged for a small quantity of tea, sugar, and flour, and were particularly keen after matches, which they evidently valued highly. They asked numerous questions about the objects of the expedition, and appeared relieved to hear that no idea of a railway lay at the bottom of it. As far as could be known, the fact of a boundary being marked between the British and American territories seemed to be welcome to them, and it is said that they were rather disappointed that a wall or continuous bank was not set up across the plains, a thing which they had been led to expect. It was on this clay plateau also that in the middle of July an extraordinary swarm of grasshoppers was met with; the ground was covered with them, and the air was so full of them, that the appearance was exactly like that of a snow storm, to which they have often been compared by travellers.

Reaching the Milk River, which Captain Anderson had reconnoitred for forty miles of its course before finding a crossing place, the commissions passed by a large camp formed by the Half-breeds from Woody Mountain and from the valley of Frenchman's Creek. There were about 200 tepees or tents, each containing a family, and it was estimated that there were 2,000 horses, ponies, etc., belonging to the band. The camp was a large rectangle, the sides of which were formed by the tents and carts, and the animals were driven every night into the enclosure thus provided. These Half-breeds are educated to a certain extent; they profess the Roman Catholic religion, and there was a priest with them at this time; they keep up a sort of military discipline founded on mutual consent, and the necessity of defending themselves from the Indians; outlying videttes are regularly maintained at some miles from the camp, so as to give early notice of the approach of any party sufficiently numerous to be formidable to them. In the summer time these people hunt the buffalo for the sake of its flesh, which they dry or convert into pemmican; in the autumn and early winter they kill them for the sake of the skins, which are taken during the ensuing spring to the Missouri and to Fort Garry, where they are exchanged for groceries, clothes, and ammunition.

Crossing the Milk River at a point about eight miles south of the line, the astronomical parties took up their stations over the country between the gorge of this stream and the West Butte. The valley of the Milk River is another of those rugged and impassable troughs cut out in the soft cretaceous formations by the action of water; it is about a mile wide and 300 feet in depth, the sides being precipitous and of a dark and gloomy tint. There are numerous tributary ravines, which enter the main gorge at right angles; these contain narrow buffalo paths, along which the herds pass in search of water, or in order to cross to the north. The stream itself winds from side to side of the bottom of the valley, and is fringed with timber where the boundary strikes it. The survey party, unfortunately still deprived of the superintendence of Lieut. Rowe, but very ably directed by Mr. W. A. Ashe, sub-assistant astronomer, had here a hard piece of work with the traverse of the tortuous watercourse and the rugged cliffs on each side of it; they carried it, however, to a distance of ten miles up stream, the general course of the river coming from the west after a few miles northing.

The plains between Milk River and the Three Buttes are a sort of neutral ground between the Indian tribes, and are generally left unoccupied by them; the Sioux and Assinebonies do not appear to cross to the west bank of the stream, and the Blackfeet, who cling to the skirts of the Rocky Mountains, rarely approach the Buttes. As a consequence, perhaps, of this state of things, this strip of country was, in July, 1874, full of buffalo, which were slowly moving north in large herds; from them the different parties obtained ample supplies of fresh meat, which, although not equal in quality to the flesh of the deer and antelope, was preferable to the hard beef that the much travelled oxen afforded. On this part of the boundary, and on this part alone, rattlesnakes were found; they were not numerous, but were tolerably large; they lived in holes on the open plain, and always seemed to get out of the way without attempting to strike even when a horse stepped over them by accident. The rattle they make is very rapid, and appears to fill all the air without coming from any particular spot; it resembles the sound of a pot boiling over.

At the end of July the two commissions were all encamped round the foot of the Sweet Grass Hills; Major Cameron and the United States' Commissioner, Mr. Archibald Campbell, both passed on their way to the Rocky Mountains about this time, and the work was made good up to the westernmost Butte on the 30th of July. These isolated masses, called on the maps the "Three Buttes," but known by the hunters and Half-breeds as the "Sweet Grass Hills," are three distinct peaks, which rise to a height of 3,000 feet above the plains at their feet. Seen from the north, they have a grand and majestic appearance from the contrast they present to the monotonous level of all the surrounding country. Their sides are clothed with pine timber, and numerous springs issue from them; the water from these running down in small rivulets on to the plains is soon swallowed up by the arid soil. At a short distance to the north of the boundary here, the bodies of about twenty Crow Indians were found who had been killed by the Blackfeet in the preceding autumn. It appears that the vanquished party had stolen some horses from the others, and, being pursued, had been overtaken before they had reached the shelter of the hills; small rifle pits had been scratched up by them in haste when they had had to turn and fight, but they had been overpowered. The bodies had been stripped, scalped, and hacked about a good deal; there were one or two very large men amongst them.

From some high ground near the West Butte depôt the Rocky Mountains could be seen lining the western horizon, the snow and ice on their summits being clearly distinguished in the morning sun. The reconnaissance party pushing on to St. Mary's River, which is about twenty miles from the mountains, found a suitable site for a depôt and an astronomical station between them and it, and the commissariat train were at once sent on to this spot with thirty days provisions for the working parties. The distance from the West Butte was about 80 miles. During the first half of August the astronomical stations and tangent lines were completed across this span, and the survey party commenced the traverse of St. Mary's River, their work being extended again to a width of six miles north of the line, for the remaining part of the boundary. A further reconnaissance shewed that the 49th parallel, striking an immense mass called Mount Wilson, passed over the crest of it, and intersected on its further side a large piece of water called Waterton Lake; it then followed an inaccessible ravine for about nine miles, till it reached the watershed ridge, on which a monument had been erected by the Boundary Commission of 1861. It was agreed that the British astronomical parties should take up two stations, one at the point already mentioned at the depôt west of St. Mary's River, and the other on the eastern flank of Mount Wilson, the tangent lines being traced and chained up to the latter. The United States' Commission were to determine the position of the boundary on Waterton Lake, and the connection, in longitude, with the terminal monument of 1861 was to be effected by traversing round the northern side of Mount Wilson and up the Kootenay Pass. Major Cameron indeed endeavoured to find a direct route along the boundary from Waterton Lake westward; but although he nearly reached the terminal monument, he could not quite do so, and it was evident that chaining would be impossible except up the pass. In accordance with these arrangements, the three last stations of the work were established in the third and fourth weeks of August, some triangulation having to be done from the zenith telescopes to the parallel, on account of the difficult nature of the country preventing the instruments being taken as near to the line as usual. It was now the end of the summer, but the weather was still clear and warm, and the beautiful scenery, amidst which the parties suddenly found themselves, contrasted strongly with the monotonous plains on which they had been working for so long. Instead of short and scanty herbage, the grass was now luxuriant and rich; clear and impetuous streams took the place of muddy and stagnant pools, and the eye was once more rejoiced with the sight of trees and foliage. Wild fowl and dusky grouse abounded, and the rivers were full of salmon trout of from 3 to 5 lbs. in weight.

The direction of the mountain range is from south-east to north-west; the boundary, striking it obliquely, passes about six miles north of Chief's Mountain, which stands out into the plains at right angles to the main chain; the line then crosses the immense mass of Mount Wilson, which fills up seven miles in longitude, and falls into Waterton Lake. This beautiful piece of water, which is 9 miles long and about 1 mile wide, lies between mountains, whose sides rise precipitously for 3,000 or 4,000 feet from the water's edge, and resembles somewhat the Lake of Lucerne, in Switzerland; the view also, from the top of one of the mountains at its northern end, is, in some respects, like that from the Righi. On one side nothing is seen but a crowd of mountain peaks filling the whole perspective; on the other, a level plain stretches to the horizon, and seems to differ only in colour from the sea. The lake, lying immediately below the feet of the spectator, lends its beauty to the scene, and a unique grandeur is derived from the reflection that the mountains extend in unbroken series to the Pacific Ocean, 400 miles away, while the plains, bare and treeless, stretch for twice that distance in an opposite direction.

Following the Indian trail up the Kootenay Pass, Captain Anderson, with Mr. Dawson, the geologist, and the reconnaissance party, crossed the watershed into British Columbia, and coming upon the old trail of the Boundary Commissions of 1861, followed it to the terminal monument, which is situated on a very curious saddle-back, with precipitous sides, the mountain tops to the north and south rising straight up from it. Owing to its sheltered position, the monument was in perfect preservation, and a survey was carried back from it to the point where the Kootenay Pass trail crossed the watershed. Mr. Ashe's party, bringing their traverse up the pass from the plains, reached this point on the 27th of August, and the connection between the work of the two Commissions was thus completed. The United States' survey parties having triangulated from the north end of the lake down to the astronomical station on its western shore, connected the latter with the terminal monument by another route.

Meanwhile the two British astronomical parties had completed their last stations, and after about ten days spent in cutting through the dense woods on the foot hills of the mountains, and triangulating up the difficult valley of the Belly River, had made good the boundary up to the sides of Mount Wilson.

Nothing more remained to be done in the mountains, and after a day or two spent in visiting the Lake and the Kootenay Pass, the parties struck their camps and commenced their homeward march. It was not without reluctance that the beautiful and luxuriant scenery of the mountain valleys was left behind, and the dreary plains once more entered upon; but all knew how long a journey lay before them, and how suddenly and unmistakeably the winter might commence, so that, once started, the hope of getting back in good time was an efficient stimulus to travelling; the horses and ponies were also in remarkably good condition from their fortnight's repose and good living. The two astronomical parties were the first to leave, having still to put up the stone mounds as far as the commencement of the season's work; this was left to be done on the return journey, in order to economize time; they travelled along the line doing alternate parts of the work, and camping together at night. The buffalo were found in vast herds on the same ground as before, but appearing now to be stationary or inclining towards the south, and numerous as were the carcasses of those killed by the Indians and Half-breeds, the survivors were so countless, that the loss appeared insignificant by comparison. Captain Anderson with the survey and the reconnaissance parties, left the mountains on the 20th of August, and gathering up with him the depôt-keepers and men as he went along, followed the main trail back to Woody Mountain, which he reached on the 16th of September. There he was joined by the astronomical parties under Captain Featherstonhaugh and Lieut. Galwey, who had passed Frenchman's Creek by the southern crossing, and having erected the last of the stone mounds, arrived at the rendezvous on the 19th of September.

The united parties, numbering 167 officers and men, and about 200 horses and ponies, with 100 waggons, carts, etc., commenced the last half of the homeward journey together, under Captain Anderson; the Commissioner and Captain Ward having started back a short time previously, travelling light with two or three attendants only. The usual equinoctial storm was now daily expected, and other sources of anxiety were not absent, a telegram having been received, viâ Fort Benton, on the Missouri, to the effect that the Crees, who inhabit the country north of the line, intended to attack the Commission Train on its way eastward. Notwithstanding these expectations of unpleasant occurrences, nothing could have been more successful or enjoyable in its way than the march proved to be. The snowstorm did not come, the Crees kept their distance, and the weather remained warm and fine up to the very end. Haystacks had been made at the end of each probable day's march, near water, so that the animals were always well supplied with food during the night, without the risk of leaving them to graze after dark; and when they arrived at Dufferin, the horses, despite their march of 800 miles, were in perfect condition. Passing, in due course, the now familiar camping places of Wood End, the Souris River crossings, Turtle Mountain, etc., it was not without regret that they were left behind for the last time; and, despite the many disadvantages of the prairie and plains, there is no doubt that persons who have spent much time on them, acquire a sort of attachment to them that more pleasing landscapes fail to inspire. What the reason of this may be it is difficult to say; but the feeling is probably the same as that which a sailor has for the sea.

On the 11th of October the train reached Dufferin after a march of 860 miles by road, which had been accomplished in forty-three days, including halts.

The work done by the two Commissions in 1874 was as follows:—17 principal astronomical stations were established by observations with the zenith telescope; the connecting sight lines between the stations, extending over 339 miles, were chained throughout; a final span of 20 miles in the Rocky Mountains, which was impassable, was covered by traversing, and the country on each side of the line was surveyed for a total width of 6 miles up to St. Mary's River, and for a width of 12 miles between it and British Columbia. Meteorological observations were taken at the West Butte during the month of August, and barometer readings for altitude above the sea were obtained over the whole of the country traversed. Magnetic observations for dip and declination of the needle and for total magnetic force, were taken at Turtle Mountain, Wood End, the Three Buttes, and the Rocky Mountains; these observations, combined with those taken previously at the Lake of the Woods and at Dufferin, form a complete series, from which the curves of magnetic force have been laid down on the map of the country.

After the return to Dufferin, three small parties were sent out to put up the iron pillars along that portion of the boundary which forms the southern limit of the province of Manitoba. The sites of these pillars had been marked by temporary mounds and stakes by the British astronomical parties in the preceding spring; one half of the whole number of pillars having been set up, viz., every other one, the remainder were put in by the United States' Commission in 1875.

This completed the field work of the Boundary Commissions.

A. F.

POSTSCRIPT.

By Captain S. Anderson, R.E.

The foregoing paper has been limited to an account of the executive work of the Boundary Commission, and the names mentioned are those which naturally occur in the course of the narrative. It is the wish, however, of myself and the other R.E. Officers concerned to express here how much we were aided in our respective parts of the work by the Canadian Officers of the Commission. Without their thorough and efficient co-operation and assistance, the marking of the Boundary would have taken a much longer time, and would have been a much more arduous task to us.

The following are the names and appointments of the officers of the Commission nominated by the Dominion of Canada:—

Executive.—Surveyors.—Lieut. Colonel Forrest, of the Canadian Militia, P.L.S., and Mr. A. L. Russell, P.L.S. These gentlemen were in charge of surveying parties during the winter of 1872 and the summer of 1873.

Sub-Assistant Astronomers.—Messrs. G. F. Burpee, W. F. King, W. A. Ashe, and G. C. Coster were attached to the astronomical parties as assistants to the astronomers. They had charge of the computations, reductions, &c., and the subsidiary observations for time were sometimes taken by them. Mr. G. F. Burpee had charge of part of the surveying work during the winter of 1872. Mr. W. F. King superintended the tracing and cutting of the Boundary through Pembina Mountain and Turtle Mountain, the latter being a long and difficult work. Mr. W. A. Ashe had charge of all the surveying work in 1874 owing to the accident which happened to Lieutenant Rowe. Mr. D'Arcy East (late R.A.) was employed first as surveying officer, and latterly (1874) as Commander of the Scouts. With him was associated Mr. G. G. Crompton (late R.N.), who conducted many of the reconnaissances of 1874.

Administration.—Commissariat.—Mr. L. W. Herchmer (late 46th Regiment) was the Commissary of the Boundary Commission. The line of supplies which he had to maintain was, in 1873, 400 miles long, and, in 1874, it extended to 860 miles. Mr. Herchmer, in carrying out his work, made many hard journeys, with only one attendant, through the heart of the Indian country.

Medical Department.—Dr. T. J. W. Burgess, M.B., was surgeon to the Commission, and took part also in the botanical researches. He had under his charge during the progress of the work many serious cases of sickness and of severe injuries. Under his skilful treatment all his patients recovered. Dr. T. Milman, M.D., Surgeon's Assistant, was in medical charge of the parties in the field during most of the season of 1874.

Veterinary Surgeon.—Mr. W. G. Boswell, in addition to the usual duties of his appointment, was charged with the selection and purchase of the transport animals, horses, oxen, and dogs, and of the waggons and carts composing the transport train of the Commission. Mr. Boswell, in carrying out the duties of his department, made extensive journeys through Canada, Minnesota, and Montana.

Natural History.—Mr. G. M. Dawson, geologist and naturalist to the Commission, examined the whole of the country traversed. Mr. Dawson, whose name is well-known in connection with these sciences, has published in Canada an exhaustive report on the geology and flora of the Boundary Line.

S. A.

APPENDIX.

Methods of Astronomical Observations.

Latitudes. The method of determining the latitude which was agreed to be pursued by the two Commissions was by observations of the differences of the zenith distances of north and south stars with the zenith telescope. This instrument is of American invention, and is exclusively adopted in the United States Coast Survey for the determination of latitudes; its use and theory are described in Vol. II. of Chauvenet's "Practical and Spherical Astronomy." The reasons which led to the adoption of this instrument for the work of the boundary survey were its portability, the simplicity both of the observations and of the subsequent computations, and the accuracy of the results. Table 9 of this Appendix gives the abstracts of the observations taken by the astronomers of the British Commission with this instrument, shewing the number of observations at each station, the number of days on which observations were taken, the total time occupied in completing each station, and the probable error of the results. Consideration of this table appears to show that the performances of the zenith telescope justify its selection for a work of the nature of the Boundary Commission.

The zenith telescopes used by the British Commission were three in number, two of them having been made by Würdemann, of Washington, U.S., in the year 1860, and one by Messrs. Troughton and Sims, of London, in 1872. They were 32 inches in focal length, with object glasses $2\frac{1}{2}$ inches in diameter. Each instrument was packed in two cases, which weighed, when full, 78 lbs. and 120 lbs. respectively.

The number of stars used by the British Commission for the latitude observations was 167 in all. The places of 66 of these were taken from the Nautical Almanack or from the Greenwich catalogue of the epoch 1864; 30 from the Greenwich catalogue, epoch 1860; 18 from the Greenwich catalogue, epoch 1850; and 53 from the British Association catalogue of the epoch of 1850.

The relative weights assigned to these catalogues were taken into account as follows*:—

Let $\epsilon\ \delta$ be the probable error of the declinations in each catalogue, then the assumed values of $\epsilon^2\ \delta$ are:

* See Chauvenet, Vol. II., par. 233.

Greenwich catalogue of 1864, Nautical Almanack of current year, Greenwich catalogue of 1860, with 4 or more observations .... 0·25

Greenwich catalogue of 1860, with less than 4 observations, Greenwich catalogue of 1850, with 6 or more observations .... 0·40

Greenwich catalogue of 1850, with less than 6 observations.......... 0·50

British Association catalogue, with the additional modern authority of Argelander (2), Bessel, Brisbane, Henderson (2), Johnson (2), Pond, Rumker, Taylor (5), Wrottesley (2) .... 0·70

British Association catalogue, on the authority of Bradley, Piazzi, and Taylor .... 1· 0

British Association catalogue, on the authority of Groombridge alone.. 2· 3

When a star was found in more than one of the catalogues, the place assigned to it by the one having the most relative weight was used.

Deviation of the plumb-line.

The commonly received idea of a parallel of latitude is that of a circle on the earth's surface, formed by the intersection with it of a plane parallel to the plane of the equator; the 49th parallel of north latitude being therefore such a circle 49 degrees north of the equator. The only way of determining a first point on this or any parallel, is by finding a point whose zenith is the required number of degrees from the celestial equator. It is then assumed that the plumb-line from the point in question to its apparent zenith is truly vertical, and that the point on the ground is the same number of degrees from the terrestial equator that its apparent zenith is from the celestial one; but experience has shewn that this is not the case. The plumb-line can, strictly speaking, never be said to be truly vertical; local attraction, due to irregularities in the density and figure of the earth, pull it to one side or the other, and as there is no check on this, the absolute amount of the deviation at any one spot cannot be ascertained; but when a connection is made by actual survey between two points, situated at some distance apart, whose latitudes have been determined astronomically, the relative deviation of the plumb-line at the two spots is at once apparent. Deviations of this kind were almost constantly found to occur on the boundary line, so that the parallel passing through one station would not, if continued with the proper curvature, be identical with the parallel passing through the next station, and so on. Under these circumstances, it was a question for consideration whether the points determined astronomically to be in latitude 49 deg. N., should be simply joined, or whether a mean line parallel to the equator should be adopted.

On the British side, the opinion of the Astronomer Royal was obtained, and he recommended that in no case should there be any departure "in the smallest degree from the points determined by the actual use of astronomical instruments."

It was agreed between the British and United States Commissioners that the astronomical determinations of each station should be adhered to, and the intermediate monuments and mounds between the stations were set up on lines having the same curvature as the 49th parallel of latitude, but not parallel to the equator. Had the boundary been marked throughout on a curve parallel to the equator, not more than a very small portion of it would have had, astronomically, the latitude of 49 deg., and the work would have taken much longer to do.

The subject of deviation of the plumb-line is discussed in Article 86, Vol. I., of Chauvenet's work, before alluded to.

Table 10 of this Appendix gives a list of the station errors, showing how much each station is north or south of station No. 1.

Longitudes. The determination of the longitude at North Pembina, in November, 1872, was effected by comparing, by means of the electric telegraph, the local time with that of the observatory at Chicago, in the State of Illinois, United States, the length of the electric circuit being about 950 miles.

The local time at North Pembina was obtained by observing transits of standard nautical almanac stars with a portable transit instrument of 30 inches focal length, and an object glass of $2\frac{1}{3}$ inches in diameter. This instrument was constructed by Messrs. Troughton and Sims, in 1872. A box sidereal chronometer, by Sewill, was used on this occasion.

Time observations. The local time for the reduction of the zenith telescope observations was obtained by the use of the sextant, either by day or night, by the transits of zenith stars observed with the zenith telescope, or by transits observed with the portable transit. The latter instrument was, however, rarely mounted for this purpose; the other methods, though inferior, being sufficiently accurate.

Stands for large instruments. The stands upon which the zenith telescopes and the transit instruments were set up, were designed and constructed by Messrs. Troughton and Sims, of London. A drawing of the stand made for the portable transit instrument is given in Pl. IX. The dimensions of the metal top plates are adapted in plan to those of the iron stand, in whose pillars are the V shaped bearings in which the transit telescope revolves. This iron stand was of the kind shown in Pl. V. of Chauvenet, Vol. II. The wooden stand was so arranged that the weight fell nearly equally upon each foot, as is evident from the diagram plan. A small movement in azimuth was obtained by the V shaped grooves in the metal top plate being made moveable along slots in the plate itself.

For the zenith telescope the stands were somewhat smaller, but were similar in general construction. The instrument itself being a circular one, revolving on a central pillar, the weight was always equally distributed between the three foot screws which carried the pillar; the plan of the top plate of the wooden stand was, therefore, an equilateral triangle, and no movement in azimuth was of course required for the V shaped grooves.

The stands packed quite flat when they were taken to pieces, and were transported very easily; the weight of those for the portable transit being about 170 lbs. each, and of those for the zenith telescope about 140 lbs. It was at first supposed that logs of wood would be more suitable whenever they could be obtained; but this was found to be an error. What was required was not stability against a horizontal disturbing force, but against the tremors of the ground, produced by the necessary movements in the observatory tent. A post inserted in the ground has its sides in contact with the soil, and every footstep on the surface above is transmitted directly to them; the wooden stands were free from this effect, because their construction allowed of their being insulated as it were. This was done by digging a hole in the middle of the observatory tent, 2 feet square and 18 inches deep, the floor of the hole being levelled; the foot plates were then bedded carefully, each in its proper place, and the stand placed upon them. Any tremor from the surface of the soil was caught by the sides of the hole, or, if it did go as deep as its floor it could hardly affect the foot plates, as it would travel laterally underneath them. As a matter of fact, these stands were perfectly steady; they were used for 2½ years, and carried over nearly 3,000 miles of country without suffering at all in serviceability. Two posts, each 8 feet long and 2 feet in diameter, would have weighed 1,600 lbs.; whereas the two stands only weighed 310 lbs., and being in parts they could, if necessary, have been carried wherever men could climb.

Observatory tents. A photograph of one of the observatory tents is given at the end of this paper. The tent is shewn as if it opened at the sides, and this was the original construction, but it was found that this was very inconvenient, the guys being much in the way of a person entering the tent at night, and there being a danger of his striking the instrument, which, when adjusted for observing a star of moderate elevation, pointed towards the doorway. The sides of the tent walls were therefore sewn up, and a door opened in one end. The roof opening was about 2½ feet wide, and for this width, the roof when closed, was double, so as to keep out rain, each flap being buttoned or buckled down to the tops of the tent walls; when the roof was to be opened, the flaps were unbuttoned from the walls and were then pulled back by halyards passing through single blocks fastened to the tops of the tent poles. When the roof had to be closed, the flaps were pulled forward again by other halyards. There were four single blocks in all, and four halyards, two of each being outside the tent, and two inside.

Azimuths. The true direction of the connecting sight lines between the astronomical stations was obtained by one of three methods. 1st, by laying down a meridian with the portable transit instrument, and turning off an angle of 90° on a 7-inch transit theodolite; 2nd, by observation with the 7-inch theodolite of the horizontal angular distance at a known time between a circumpolar star at or near its elongation, and a fixed referring object on the earth's surface; 3rd, by the same operation as the last, using a circumpolar star, at any part of its course, as the point of reference.

The first of these methods was the most accurate, and was often used at the initial point of the connecting sight lines, where they were tangent to the parallel. It required more preparation than the other two methods, which were well adapted for checking the direction of the sight lines as they progressed.

Reconnaissance observations. The observations for latitude and longitude taken on the reconnaissances for fixing the approximate position of the astronomical stations and making a sketch map of the country, were taken with an 8-inch sextant, the sun and the stars being both used. The 8-inch sextants, specially made by Messrs. Troughton and Sims for this expedition, were very good instruments of their class; with them a set of ten observations on a north and on a south object for latitude could always be depended upon within 100 yards. In cases where combined observations of objects on both sides of the zenith could not be obtained, the instrumental error of the sextant, which had been investigated, was applied. On the march the instruments were carried in a light spring waggon, and were always at hand for taking observations on the sun during the day at the hours best suited for finding the time and latitude.

For the longitudes, the local times were compared with that brought forward on four mean-time pocket chronometers, whose travelling rates were ascertained by taking them back to the starting point and observing for time there, after each reconnaissance. The resulting longitudes so obtained over long distances of 100 miles and upwards, served as a check on the survey. The reconnaissance sketches were made with the aid of a small prismatic compass.

Method of working practised by the astronomical parties.

The method of working generally practised by the astronomical parties was as follows:—On approaching the site selected for an astronomical station, usually at about 3 p.m., though sometimes much later, the first step was to select, for the observatory tent, an elevated spot from which an uninterrupted sight line could be obtained to a distance of about three-fourths of a mile, either due north or due south. The camp was then pitched at a short distance off, so that neither the north or south, nor the east or west lines from the observatory tent came within 100 yards of it.

The true time of the last astronomical station having been brought forward on a pocket mean time chronometer, or sometimes on an ordinary watch, the sidereal chronometer was started by it, allowance being made for the difference of longitude obtained from the reconnaissance sketches, and observations for time on the sun in the west were taken with a sextant for combination with equal altitudes the next morning. The zenith telescope was next mounted and adjusted, the direction of the meridian being obtained by observation of the transit, according to the time by account, of a circumpolar star as soon after sunset as practicable.

When darkness had set in, the latitude observations were commenced, a correction to the approximate time being soon obtained by taking transits of two zenith stars, and were continued throughout the night until dawn began to appear, the meridian being also altered if necessary during the course of the observations. The next morning equal altitudes were taken on the sextant corresponding to those obtained the previous evening, and the true chronometer error during the night being now known, the computers could set to work at once to reduce the latitude observations. A first value of the latitude of the zenith telescope was obtained before the afternoon, and a spot was selected the proper distance north or south of it, so as to be nearly on the 49th parallel, and, if possible, on the meridian of the instrument, from which point the sight line, tangent to the parallel, should be commenced; a view of nearly a mile due east or west, and also north or south being essential. The seven-inch theodolite was mounted here, and as soon as Polaris could be found in the evening, an approximate meridian was established and a mark set up. The theodolite was then replaced by the portable transit instrument which was directed on this mark. All this could generally be done without interfering with the zenith telescope observations for latitude, which it was important to complete as soon as possible. These were continued on the second night without interruption; but, in the early part of the evening, and from time to time during the night, opportunities would occur for observing the transits of stars across the meridian of the transit instrument. The azimuth of this meridian was thus obtained within one or two seconds, or less, of arc, with much less trouble and fatigue to the eye than is involved in the use of a circular instrument. The reading of the fine divisions of a metal arc by artificial light is a great strain upon the sight, and is to be avoided whenever observations of more importance are to be made soon afterwards.

On the second day the computations were continued, and preparations were made for commencing the sight line to connect with the station to the west. For this purpose the seven-inch theodolite was placed over the spot where the portable transit had stood, and an angle of 90° was turned off to the west, giving a line approximately tangent to the parallel. A mark was set up on this line at a distance of about three-quarters of a mile, or more, if possible. The angle between this mark and that in the north was then read off on different parts of the arc, and in reversed positions of the face of the instrument, and the mean of these angular readings combined with the azimuth of the meridian, gave that of the sight line, which was generally a few seconds north or south of west. The sight line was now ready for prolonging westward, its deviation being left uncorrected, but being taken into account in computing the offsets to the parallel. On the third night the zenith telescope observations were continued and completed, subsidiary observations for correcting the constants of the instrument being taken if required.

On the third and fourth days the computations were finished and checked, and as soon as the final value of the latitude of the zenith telescope was obtained, the required measurement to the parallel was made, and the mound marking the station erected. During the fourth and fifth nights additional observations for azimuth were taken, as well as any additional ones required for the latitude. The sidereal time was obtained from day to day by equal altitudes of the sun, and also by observations of the transits of zenith stars at night; sextant observations of stars for this purpose were rarely resorted to, as they would have occupied time required for other purposes.

The time of completing a station, which, according to the above description, would be four days and five nights, was actually always more than this. Sometimes the first night could not be used for latitude observations, owing to the party having arrived too late at the station to make the necessary preparations, and one night out of three was generally cloudy or unfavourable to observation owing to thunderstorms or gales of wind. The average time necessary to complete one station was seven days during the summer months. In order to provide against delays from cloudy weather, it was always the object of the officer in charge of the astronomical work to obtain as early as possible an approximate value of the latitude, within 20 or 30 feet, and an approximately true meridian; having obtained these, the tangent line could be commenced, and, in the event of cloudy weather setting in, could be prolonged for nine or ten miles, while, if the sky remained clear, the astronomical observations were carried on to completion. It may be remarked, that though clouds were not unfrequent, rain, except during thunderstorms, was unknown in the summer months.

When the astronomical station was completed, and the mound marking the parallel erected, the camp was shifted to some spot where water was to be had, about half way to the next astronomical station. During the march, the line was run with the seven-inch transit theodolite from the initial point, or from wherever it had been already taken to while the party was encamped at the station. From the new camping ground the line was continued as far as the next astronomical station, if possible; but if it was not within working distance, the camp was again shifted to an intermediate point. The prolonging of the tangent line was done with the seven-inch transit theodolite, each point in advance being determined by two observations with different faces of the instrument, to eliminate the residual collimation and errors of level adjustment. The time occupied in running an average distance of 20 miles of line was about four days, to which three more must be added for laying down the offsets from the tangent to the parallel, where the monuments or mounds were to be erected—viz., at intervals of three miles--and for constructing the mounds themselves.

The offsets from the tangent line to the parallel were computed as follows:—
Each offset consisted of the following elements:—

C, a constant element, being the distance of the initial point of the tangent line north or south of 49°.

δ P, the distance measured along a meridian between the tangent line and the parallel, which interval increases as the square of the distance from their point of contact.

δ A, the correction to be applied to the tangent line for any small deviation from its true direction.

δ E, the proportional part of the station error due to the deviation of the plumb-line, and including also the probable errors of the astronomical observations at each station.

C, of course required no computation.

δ P, was computed according to the following formula:—

$$- d L = K B \cos Z + K^2 C \sin Z + h^2 D$$

where $d L$ = difference of latitude of the two points, K = length of side connecting them,

$$B = \frac{1}{R \text{ arc } 1''}$$

$$C = \frac{\tan L}{2 N R \text{ arc } 1''}$$

$$D = \frac{\frac{3}{4}\, e^2 \sin L \cos L \text{ arc } 1''}{(1 - e^2 \sin^2 L)^{\frac{3}{2}}}.$$

$$h = K\, B \cos Z$$

$$R = \frac{a\,(1 - e^2)}{(1 - e^2 \sin^2 L)^{\frac{3}{2}}}$$

$$N = \frac{a}{(1 - e^2 \sin^2 L)^{\frac{1}{2}}}$$

A = equatorial radius of the earth = 6974127·31 yards; e = eccentricity = 0·081696830; Z = azimuth of tangent counting from south around by west, whence west = 90°; east = 270°.

This formula becomes in the present case — d L = K^2 C; or, taking offset in yards = d, distance along tangent line = D, log d = 2 log D + 2·915491.

If d and D are taken in chains, log d = 2 log D + 1·342423.

δ A = D sin A, A being the azimuthal error of the tangent line, D the distance from the initial point.

$\delta E = \frac{D.E}{X}$, E being the station error, X the distance between the two stations.

It was convenient to call northern offsets +; southern offsets —; δ P was always +; the others might be either.

Azimuth observations were taken at or near the end of the line to verify its direction, and any small error which had accumulated in the process of laying it down was distributed over its whole length.

When this work was finished, the party started for their next station, about 80 miles further west, on arriving at which the same process was re-commenced.

Astronomical observations in cold weather.

In using astronomical instruments when the thermometer is down to zero of Fahrenheit or below it, the oil with which the internal bearings are lubricated is partially frozen, and the motions of revolution become very stiff. With theodolites the best remedy is to take them to pieces and carefully remove all the oil; the freedom of motion will then be restored. With the zenith telescope it is not advisable to do this, but the evil is less as the greater momentum of the parts overcomes the resistance offered by the congealing oil, and force can be used with less danger to the correctness of the observation, which is not one of azimuth. Precautions have to be taken, however, against the freezing of the lamps, and of the oil in the works of the chronometers. The best way of doing this is to erect a small tent sufficiently near to the observatory to be within reach of the voice at its ordinary pitch; in this tent, which is warmed with a small stove, are the assistant with the chronometer and note-book, and another person whose business it is to keep always ready a spare lamp to replace the one at the instrument as soon as its oil freezes. The observer in the large tent has thus, during the intervals of work, a ready source of warmth to which he can resort, and he is not troubled with considerations as to the welfare of his assistants. By using these precautions, observations were frequently taken during the winter of 1872, throughout a great part of the night, when the thermometer was 30° below zero of Fahrenheit, without any one suffering serious inconvenience.

The instrument on these occasions was a 7-inch theodolite in the open air, the tent with the stove being placed near it. The plan of using merely an open fire, however large, was liable to failure, as it afforded little or no protection to the chronometer, of which the rate, when it is exposed to severe cold, will vary seriously. For accurate time-observations when records of fractions of seconds are required, it would be difficult, however, to separate the observer and the chronometer without using an electric chronograph.

Tables. Tables were prepared for facilitating the computations. These were:—

I. Table of factors for collimation, level, and azimuth errors of a transit instrument, computed for latitude 49° N, for the visible heavens. The same for the five circumpolar stars for every 10″ of change of N.P.D. during the season.

II. Azimuths of Polaris (at a mean declination) for hour angles, from 0 to 12 hours, computed for every 10 minutes for lat. 49° N. This table was used for laying down an approximate meridian.

III. Differential table of refractions for zenith telescope observations. See Chauvenet, Vol. II., chapter on zenith telescope.

IV. Values of $\frac{\sin^2 \frac{1}{2} t}{2 \sin 1''} \sin 2 \delta$ up to 1 minute of time.

V. Values of $\frac{2 \sin^2 \frac{1}{2} t}{\sin 1''}$ up to 5 minutes of time.

VI. Values of $\frac{\cos \varphi \sin \text{N.P.D.}}{\sin 2 D}$ for lat. 49° N, from N.P.D. + 6° to N.P.D. + 76°.

VII. Values of $37{\cdot}5 \sin^2 1'' \times t^3$ up to 30 minutes of time. This and the three preceding tables were used in connection with the zenith telescope observations.

IX. Azimuths of eight circumpolar stars at elongation, for every tenth day during the season, for latitude 49°, and for every mile north of it up to 6 miles.

X. Approximate time of the above elongations after noon on any day of the year.

This table was formed by computing the sidereal interval between the upper transit and elongations of each star, and adding or subtracting this interval to or from its R.A. Turning the result into mean time, and adding to it the mean time of the preceding sidereal noon (taken from the Nautical Almanac), the sum was the mean time of the elongation, *i.e.*, it was the time by an ordinary watch. The object of this table was to enable any one who was not possessed of the means of obtaining the true local time to know, without computation, when to be ready to observe a circumpolar star at elongation. Such a person could always set his watch with sufficient accuracy by the rising or setting of the sun.

Forms. Printed forms were prepared in England for recording the astronomical observations; the computations were much facilitated by this.

Star places.

The apparent places in declination and right ascension of the stars used in the zenith telescope observations were computed beforehand for every tenth day throughout the working season; from these the places for any night were found by interpolating to first differences.

General remarks on the use of the zenith telescope.

An instrument of the size of the zenith telescope may have its focussing tube moveable by a large mill-headed screw, or it may be arranged so that, when once focussed, it is held by capstan-headed screws. If the latter plan be adopted, there will be no danger of the length of the focus being altered by accident, but occasionally it will be found that the instrument is slightly out of focus, owing to change of temperature. A good plan is to focus the instrument on a cold night, and again on a warm one, noting the temperatures, and to observe in each case for the value of the revolutions of the micrometer. Two different values will be obtained, that at the lowest temperature being the highest. A table may then be formed of the micrometer values for each degree of temperature intermediate between those at which the observations were taken, the change in the values being made proportional to that of the temperatures. If the instrument has a mill-headed focussing screw, the observer can now adjust for distinct vision every night, or two or three times in a night, noting always the temperature, and using in the computations the corresponding micrometer values.

As with the zenith telescope, the accuracy of the observations depends greatly upon the true value of the micrometer revolutions, it is advisable to take the additional precaution of equating the north and south zenith distances of the stars on which the final result depends.

The opening of the roof in the tent or house in which the observations are taken, should not be too narrow. On one occasion, owing to a desire to use the same tent opening for two large instruments, the line of sight from the zenith telescope passed within 3 inches of the canvas on one side. It was found that the observations gave very bad results, and the arrangement had to be altered. A similar case is recorded in the preface to the Greenwich catalogue of 1860 as having occurred there. It appears that the currents of warm air passing round the edge of such an opening produce irregular refractions, and the line of sight should have 12 inches of clear space on each side of it.

Observations during twilight are not reliable. There is always a temptation to take them, especially immediately after sunset, because the night is lengthened by so much; but it is best not to do so, because, in the first place, the focus of a large instrument rapidly changes at this time owing to the fall of temperature, and does not attain a constant state till darkness has quite set in; in the second place, owing to the sun illuminating the upper portion of the atmosphere only, there is a lateral irregularity of refraction, which cannot be taken into account, but which makes itself felt in the results. This was especially noticed in azimuth observations.

The maker of a zenith telescope should construct the striding level of adequate size; it should be as long as possible consistent with the dimensions of the instrument; if it is too short it gives the observer a great deal of trouble.

Before taking a series of observations with the zenith telescope, a programme should be ruled out in the note-book; this programme should contain—

1. The time at which each star will come into the field of view.
2. The setting on the vertical arc.
3. The zenith distance of the star.
4. The micrometer division near which the star will appear.
5. The B.A.C. number of the star.
6. Whether the star is north or south of the zenith.
7. A place where the actual time of observation will be entered.
8. A place where the reading of the micrometer will be entered.
9. A place for the readings of the level.
10. A column for remarks.

There will thus be ten columns, and the programme should include every star that is expected to be observed during the night; then, if only one pair is obtained, a fresh programme should be ruled out for the next night, otherwise there will be confusion.

By following this plan exactly, much trouble will be saved both to the observer and the computer.

Portable transits. Portable transit instruments should have two lamp stands, so that when the instrument is reversed, it may not be necessary to change the position of the stand, in doing which there is much danger of altering the azimuth.

Transit theodolites. Transit theodolites which are to be used for taking azimuth observations at night, should be so constructed that they will swing over when the diagonal eye-piece is being used.

The verniers should not be underneath the ends of the axis of the telescope, because it will then be nearly impossible to read that one over which is the lamp which illuminates the field of view. An illuminating lamp should not fit the cup of its stand too accurately, because, when it gets hot, it expands, and thus cannot be got out of its stand if required. All astronomical instruments should have the illumination of their fields of view examined before they are removed from the maker's hands. This seems to be a small detail, but, in reality, bad illumination is a serious defect, and difficult to remedy.

Computers. A computer should be a neat and quick writer; he can be taught everything else as the work proceeds.

List of equipment, &c. Some lists of equipment are given in the tables at the end of this paper; some others, not necessary to put in detail, are

Medical Equipment.—This consisted of two complete sets of Messrs. Savory and Moore's medical field panniers, Nos. 1 and 2.

Photographic Equipment.—This consisted of two sets of field equipment, selected by Captain Abney, R.E.

Signalling Equipment.—This consisted of 6 of Walker's lime lights, with the necessary stores.

Norton's Tube Wells.—Two pumps complete.

Chemical Equipment.—Blow pipe, test tubes, reagents, &c., for examining minerals.

TABLE I.

Return of the Non-Commissioned Officers and Men of the Royal Engineers serving with the North American Boundary Commission, showing their Regimental Rank and Trades.

Nos.	Rank.	Trades.	Abstract of Trades.
1	Sergt. Major.	Mason	1 Baker
1	Qr. Mr. Sergt.	Clerk	2 Bricklayers
2	Sergeants	Clerk	5 Carpenters
		Surveyor	6 Clerks
4	Corporals	Clerk	1 Mason
		Smith	4 Photographers
		Smith	1 Saddler
		Surveyor & Draughtsman	1 Sawyer
4	2nd Corporals	Smith	2 Shoemakers
		Saddler	6 Smiths
		Clerk	8 Surveyors from Ordnance Survey
		Clerk	2 Surveyors from Chatham
5	Lce. Corporals	Bricklayer	1 Tailor
		Surveyor	3 Tinsmiths
		Baker	1 Wheelwright
		Surveyor	
		Surveyor & Draughtsman	44
27	Sappers	1 Bricklayer	Amongst the four photographers there were 1 millwright, 1 wheelwright, 1 carpenter, and 1 surveyor; 2 shoemakers were also surveyors. Of the above, 1 clerk, 1 shoemaker and surveyor, and 1 tinsmith became casualties during the first six months, and were replaced by 1 harnessmaker, 1 shoemaker and photographer, and 1 tailor.
		5 Carpenters	
		1 Clerk	
		4 Photographers	
		2 Shoemakers & Surveyors	
		3 Smiths	
		5 Surveyors	
		1 Tailor	
		3 Tinsmiths	
		2 Wheelwrights	
44			

REMARKS.—The men having two trades were employed at either as required; one tailor not being found sufficient, another was applied for when a casualty occurred.

One of the non-commissioned officers was a certified instructor in military signalling, including the use of the lime-light apparatus.

TABLE II.

Return of the Clothing and Equipment of the Non-Commissioned Officers and Men of the Royal Engineers on duty with the North American Boundary Commission.

Nos.	Articles.	Remarks.
1	Jacket, Norfolk, blue tweed...	
1	Jersey, woollen	
1 pair	Trowsers, blue tweed............	Each non-commissioned officer and Sapper took with him also the regimental clothing which he had in wear at the time, except his busby and knapsack.
1 „	Trowsers, serge	
1	Cap, Glengarry	
1	Cap, blue worsted	
1	Mackintosh overcoat............	
1 pair	Waterproof leggings	
1 „	Boots, knee	
1 „	Boots, ankle........................	
1	Fur cap	
1	Comforter	
1	Black neck-tie	
1	Waterproof sheet	
1 pair	Blankets, grey, field service...	
1	Sea-kit bag	
1	Lancaster rifle, Snider	
1	Sword bayonet for ditto	
1	Revolver, Dean's.................	
40 rounds	Snider ammunition	
24 rounds	Revolver ditto	
1	Skin jacket	
1 pair	Skin Trowsers......................	Winter clothing provided at Red River.
1 „	Skin mits............................	
1 „	Woollen mits	Worn inside the skin mits.
1	Great coat with hood, (Hudson's Bay pattern)	
1	Buffalo robe	
3 pairs	Blankets	
	Mocassins as required	The work in the woods and swamps during the winter was very destructive of mocassins, a pair of which would sometimes scarcely last a fortnight.
	Snow shoes	The snow shoes were apt to get broken in walking through bush and windfall; on an average, two pairs were used by each person during three months of the winter of 1872-73. N.B.—The clothing, as it wore out, was replaced by articles procured from Canada, which were fitted by the tailors.

TABLE III.

Detail of the parties of the North American Boundary Commission at work in the field during the Summer of 1873 and 1874.

PERSONNEL.	Officers.	Staff and N.C.Os.	Men.	Horses.	Ponies.	Oxen.	Vehicles.	Tents.
Commissioner's Party.								
Commissioner	1	..	..	1	..	..	..	..
Secretary, Captain Ward, R.E.	1	..	..	1	..	..	..	..
Clerks	..	1	..	..	..	..	..	..
Photographers	..	..	4	..	..	..	..	..
Teamsters	..	..	9	..	..	..	..	..
Cooks	..	..	1	..	..	..	..	..
Servants	..	..	2	..	..	..	..	..
Storeman	..	..	1	..	..	..	..	..
Whitewater waggons	..	..	..	4	..	..	2	..
Red River carts	..	..	..	..	5	..	3	
Spring waggons	..	..	..	2	..	..	2	[illegible]
Bell tents	..	..	..	..	..	..	..	[illegible]
H. B. Cy. "	..	..	..	..	..	..	..	7
Lumberers "	..	..	..	..	..	..	..	2
Chief Astronomer's Party.								
Captain Anderson, R.E.	1	..	..	1	..	..	..	..
Commander of Scouts	1	..	..	..	1	..	..	..
Leaders of "	..	4	..	..	[illegible]	..	..	..
Scouts	..	..	26	..	26	..	..	..
Teamsters	..	..	4	..	..	..	..	..
Servants	..	..	1	..	..	..	..	..
Whitewater waggons	..	..	..	6	..	..	3	..
Spring waggons	..	..	..	2	..	..	2	..
Water cart	..	..	..	1	..	..	1	..
Bell tents	..	..	..	..	..	..	..	3
1st Astronomical Party.								
Capt. Featherstonhaugh, R.E.	1	..	..	1	..	..	..	..
Mr. W. F. King	1	..	..	..	..	..	..	..
Mr. W. A. Ashe	1	..	..	..	..	..	..	..
Senior Non.-Com. Officer	..	1	..	..	..	..	..	..
Royal Engineers, rank and file	..	..	7	..	..	..	..	..
Storeman	..	..	1	..	..	..	..	..
Teamsters	..	..	7	..	..	..	..	..
Cooks	..	..	2	..	..	..	..	..
Servants	..	..	2	..	..	..	..	..
Axemen in Turtle Mountain	..	..	7	..	..	..	..	..
Whitewater waggons	..	..	..	10	..	..	5	..
Spring waggons	..	..	..	2	..	..	2	..
Water carts	..	..	..	2	..	..	2	..
Bell tents	..	..	..	..	..	..	..	3
H. B. Cy. "	..	..	..	..	..	..	..	9
Lumberers "	..	..	..	..	..	..	..	3

TABLE III.—Continued.

Personnel.	Officers.	Staff and N.C.Os.	Men.	Horses.	Ponies.	Oxen.	Vehicles.	Tents.
2nd Astronomical Party.								
Lieutenant Galwey, R.E.	1	..	..	1	..	..	..	..
Mr. G. Burpee..................	1	..	..	..	..	..	..	..
Mr. G. C. Coster..................	1	..	..	..	..	..	..	..
Computers	..	1	..	..	..	..	..	..
Senior Non.-Com. Officer	..	1	..	..	..	..	..	..
Royal Engineers, rank and file	..	..	7	..	..	..	..	..
Storeman	..	..	1	..	..	..	..	..
Teamsters..........................	..	..	6	..	..	..	..	..
Cooks	..	..	2	..	..	..	..	..
Servants	..	..	2	..	..	..	..	..
Whitewater waggons............	..	..	..	10	..	..	5	..
Spring waggons	..	..	..	2	..	..	2	..
Water carts........................	..	..	..	2	..	..	2	..
Bell tents.................	..	..	..	..	..	..	..	3
H. B. Cy. "	..	..	..	..	..	..	..	9
Lumberers "	..	..	..	..	..	..	..	3
1st Surveying Party.								
Colonel Forrest	1	..	..	1	..	..	..	..
Topographers	..	1	1	..	2	..	..	..
Surveyors, Chainmen, &c......	..	..	6	..	..	..	..	..
Storeman.......	..	..	1	..	..	..	..	..
Teamsters..........................	..	..	2	..	..	..	..	..
Cooks	..	..	1	..	..	..	..	..
Servant.............................	..	..	1	..	..	..	..	..
Spring waggons	..	..	..	1	..	..	1	..
Red River carts	..	..	..	..	3	..	3	..
Water carts........................	..	..	..	1	..	..	1	..
Bell tents.................	..	..	..	..	..	..	..	1
H. B. Cy. "	..	..	..	..	..	..	..	3
2nd Surveying Party.								
Mr. A. L. Russell............	1	..	..	1	..	..	..	..
Surveyor's assistants	..	1	..	..	1	..	..	..
Topographer	..	1	..	..	1	..	..	..
Surveyors, chainmen, axemen, &c.	..	..	10	..	..	..	..	..
Storeman	..	..	1	..	..	..	..	..
Teamsters	..	..	2	..	..	..	..	..
Cook	..	..	1	..	..	..	..	..
Servant	..	..	1	..	..	..	..	..
Spring waggon...............	..	..	..	1	..	..	1	..
Red River carts	..	..	..	..	3	..	3	..
Water carts	..	..	..	1	..	..	1	..
Bell tents............	..	..	..	..	..	..	..	1
H. B. Cy. "	..	..	..	..	..	..	..	3
3rd Surveying Party.								
Sergeant Kay, R.E.	..	1	..	1	..	..	..	..
Surveyors, R.E.	..	..	7	..	..	..	..	..

TABLE III.—Continued.

Personnel.	Officers.	Staff and N.C.Os.	Men.	Horses.	Ponies.	Oxen.	Vehicles.	Tents.
3rd Surveying Party continued.								
Teamsters	..	..	2	..	..	..	..	..
Cook and storeman	..	..	2	..	..	..	..	..
Axemen	..	..	2	..	..	..	..	..
Spring waggon	..	..	..	1	..	..	1	..
Red River carts	..	..	..	..	4	..	4	..
Water carts	..	..	..	1	..	..	1	..
Bell tents	..	..	..	..	..	..	..	1
H. B. Cy. "	..	..	..	..	..	..	..	3
Special Survey Party.								
[illegible]	1	..	..	..	..	..	..	..
[illegible]eer	..	1	..	..	..	..	..	..
Cha[illegible], axemen, &c.	..	..	8	..	..	..	..	..
Storem[illegible]	..	..	1	..	..	..	..	..
Cook	..	..	1	..	..	..	..	..
Bell tents	..	..	..	..	..	..	..	1
H. B. Cy. "	..	..	..	..	..	..	..	3
Surgeons' Party.								
Dr. T. J. W. Burgess, M.B.	1	..	..	1	..	..	..	..
Dr. Thos. Millman, M.D.	1	..	..	1	..	..	..	..
Teamsters	..	..	5	..	..	..	..	..
Servant	..	..	1	..	..	..	..	..
Spring waggons	..	..	..	2	..	..	2	..
Spring carts	..	..	..	2	..	..	2	..
Ambulances	..	..	..	4	..	..	2	..
Water carts	..	..	..	2	..	..	2	..
Bell tents	..	..	..	..	..	..	..	1
H. B. Cy. "	..	..	..	..	..	..	..	2
Lumberers "	..	..	..	..	..	..	..	3
This party was equipped so that if required, it could be divided into two sections, each complete in itself; each ambulance had a complete set of panniers.								
Geologist's Party.								
Mr. G. M. Dawson	1	..	..	1	..	..	..	..
Assistant	..	..	1	..	..	..	..	..
Teamsters	..	..	2	..	..	..	..	..
Servant	..	..	1	..	..	..	..	..
Red River carts	..	..	..	..	3	..	3	..
Bell tents	..	..	..	..	..	..	..	1
H. B. Cy. "	..	..	..	..	..	..	..	1
Lumberers "	..	..	..	..	..	..	..	1
Commissariat Trains.								
Commissary, Mr. W. Herchmer	1	..	..	1	..	..	..	..
Quartermaster Sergeant	..	1	..	..	..	..	..	..

TABLE III.—Continued.

PERSONNEL.	Officers.	Staff and N.C.Os.	Men.	Horses.	Ponies.	Oxen.	Vehicles.	Tents.
Commissariat Trains continued.								
Teamsters	..	..	44	..	...	...	...	...
Servant	..	..	1	..	..	...	...	...
Whitewater waggons	..	..	..	26	..	48	36	...
Red River carts	..	..	..	..	14	...	14	...
Bell tents	..	..	..	..	..	...	...	1
H. B. Cy. "	..	..	..	..	..	...	...	7
Lumberers "	..	..	..	..	..	...	...	12
Water carts	..	..	..	1	..	...	1	...
Veterinary Surgeon's Party.								
Vet. Surg. Mr. W. G. Boswell.	1	..	..	1	..	...	...	...
Waggon master	..	1	..	...	..	...	...	...
Teamsters	..	..	2	...	..	...	...	...
Servant	..	..	1	...	..	...	...	...
Whitewater waggons	..	..	..	2	..	...	1	...
Red River carts	..	..	..	..	2	...	2	...
Bell tents	..	..	..	...	..	...	...	1
H. B. Cy. "	..	..	..	...	..	...	...	2
Lumberers "	..	..	..	...	..	...	...	2
Depôts.								
Depôt keepers	..	7	..	...	..	...	...	...
Artificers, Royal Engineers	..	1	8	...	..	...	...	...
Axemen and labourers	..	..	18	...	..	...	...	...
Haymakers	..	..	4	...	..	...	...	...
(1873) Total	18	23	230	100	59	48	112	93
(1874) Total	16	22	219	114	55	210	179	66

N.B.—In 1874 there was only one survey party, which was under Lieutenant Rowe, R.E. The increase in the numbers of oxen and waggons was on account of the long distance (800 miles) over which supplies had to be carried. The decrease in the number of tents was because bell tents were almost exclusively used, instead of the H. B. Company pattern.

TABLE IV.

ASTRONOMICAL INSTRUMENTS.

No.	ARTICLES.	No.	ARTICLES.
3	Zenith telescopes	6	Large stands for astronomical instruments
2	Transits, 30″ with 2½″ apertures on portable iron stands	1	Alt-azimuth, with vertical circle, 14″ in diameter
1	Transit	6	Chronometers, box, regulated to sidereal time
1	Transit, small	12	Chronometers, pocket, regulated to mean solar time
6	Sextants, 8 inch	3	Observing tents
6	Artificial horizons, mercurial, with roofs		
6	Iron bottles containing mercury		
6 sets	Spare glasses for roofs of artificial horizons		

TABLE V.

Surveying Instruments.

No.	Articles.	No.	Articles.
18	Prismatic compasses in sling cases	3	Transit theodolites, 7″
36	Pocket compasses, magnetic	1	„ „ 6″
5	Abney's Levels	4	„ „ 5″
2	Pocket Sextants, best	4	Everest's „ 4″
6	Sketching cases, large	6	Azimuth compasses in boxes
6	„ „ small	6	Telescopes, small, in sling cases
1	Binocular glass, with hinge	4	Watches, Russell's
5	Binocular glasses in sling cases	1	Chain, steel, standard in box
12	66 feet chains and arrows	6	Flags, black, large
6	Tapes, 100 feet	6	„ „ small
6	„ 50 feet	6	„ white, large
6	Portable levels in wood frames	6	„ „ small
6	Telescopes, naval, with caps and slings		

TABLE VI.

Magnetic Instruments.

No.	Articles.	No.	Articles.
1	Vibration apparatus	1	Azimuth compass
1	Portable declinometer	1	Dip circle and tripod stand

TABLE VII.

Meteorological Instruments.

No.	Articles.	No.	Articles.
4	Standard barometers with brass tripod stands, fitted in leather travelling cases	3	Regnault's hygrometers, with one thermometer to each
		3	Glaisher's rain gauges
2	Mountain barometers with brass tripod stands, fitted in leather travelling cases	2	Metal aspirator jars, with taps and India-rubber tubing
		6	Maximum thermometers
2	Brackets with bronzed fittings for two barometers	6	Minimum ditto
		2	Long ditto, ranging to 150° below zero
6	Earth thermometers in brass frames, with moveable cover and fitting to enable each to be inserted 1, 2, or 3 inches in the earth	2	Solar radiation in vacuum thermometers
		2	Anemometers, Robinson's
		8	Extra glasses for water cups of hygrometers
3	Earth thermometers in brass frames for use at depth of 3 feet	6 Pairs	Gold band aneroid barometers, selected, R.E. pattern, the pairs adjusted to shew the same readings
2	Standard wet and dry bulb hygrometers		
6	Common ditto		

TABLE VIII.

Scientific Books and Forms.

No.	Articles.	No.	Articles.
6	Nautical Almanacs, 1872	1	Verification of La Caille's arc of the meridian
6	" " 1873	1	Longitude of Valentia—Astronomer Royal
6	" " 1874	1	Magnetism—Airy
6	" " 1875	3	Tables of barometric corrections to 32 deg. Fahr.
1	B.A.C. Catalogue, 1850	400	Forms No. 1 for transits of stars
3	Greenwich Catalogues, 1850	800	Forms No. 2. Observations for latitude with the zenith telescope
3	" " 1860	500	Forms No. 3. Observations for latitude with the alt-azimuth
3	" " 1864	100	Forms No. 4. Observations for latitude with the transit instrument placed in the prime vertical
2	Bessel's Refraction Tables, modified and expanded, being the appendix to the Greenwich Observations of 1853	100	Forms No. 5. Errors and rates of chronometers
6	Geodetical Tables, Ordnance Trigonometrical Tables	200	Forms No. 6. Comparisons of chronometers with standard
2	Logarithms of Sines and Cosines of Time	200	Forms No. 7. Longitude by transfer of chronometers
3	Tables of Logarithms—Babbage	200	Forms No. 8. Longitude by moon-culminating stars
3	" " —Dupuis	½ ream	Apparent places of stars, for zenith telescope observations
12	" " —5 figure	200	Form A. Latitude by meridian observation of sun or star
3	Practical and Spherical Astronomy—Chauvenet, 2 vols.	200	Form B. Time by equal altitudes of sun or star
6	Practical Astronomy—Loomis	500	Form C. Time by altitudes of east and west stars
2	Plane and Spherical Trigonometry—Chauvenet	500	Form D. Latitude by circum-meridian altitudes of sun or star, and by altitudes of Polaris at any time
3	Practice of Navigation, Raper		
7	Shadwell on chromometers		
3	Shortrede's tables		
5	Admiralty Manual of scientific enquiry		
3	Meteorology—Kaemtz		
3	" Practical—Drew		
3	" —Herschel		
3	" —Buchanan		
3	Outlines of Astronomy—Herschel		
3	Popular Astronomy—Airy		
3	Heather on mathematical instruments		
3	Hygometrical tables		

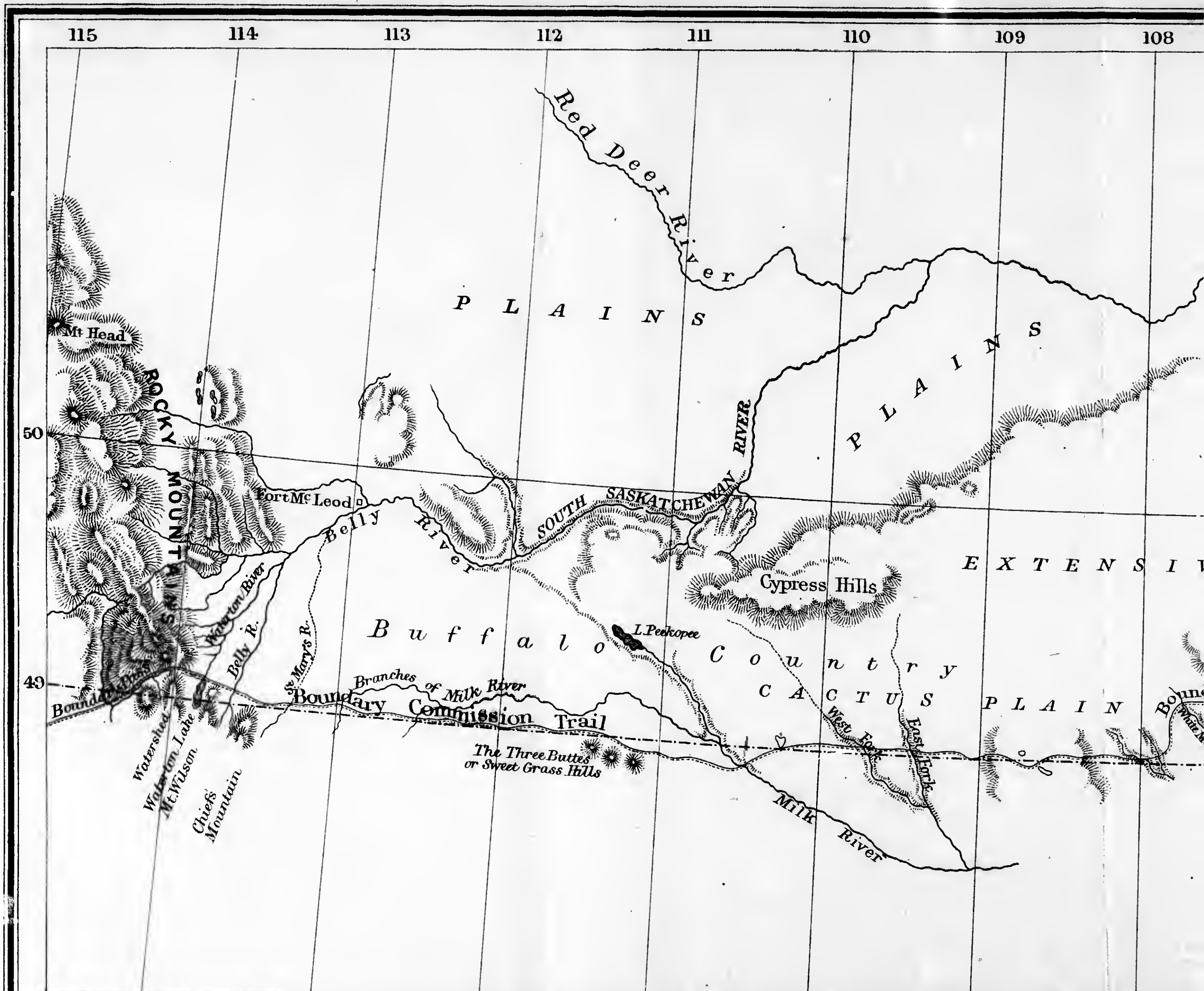
TABLE IX.

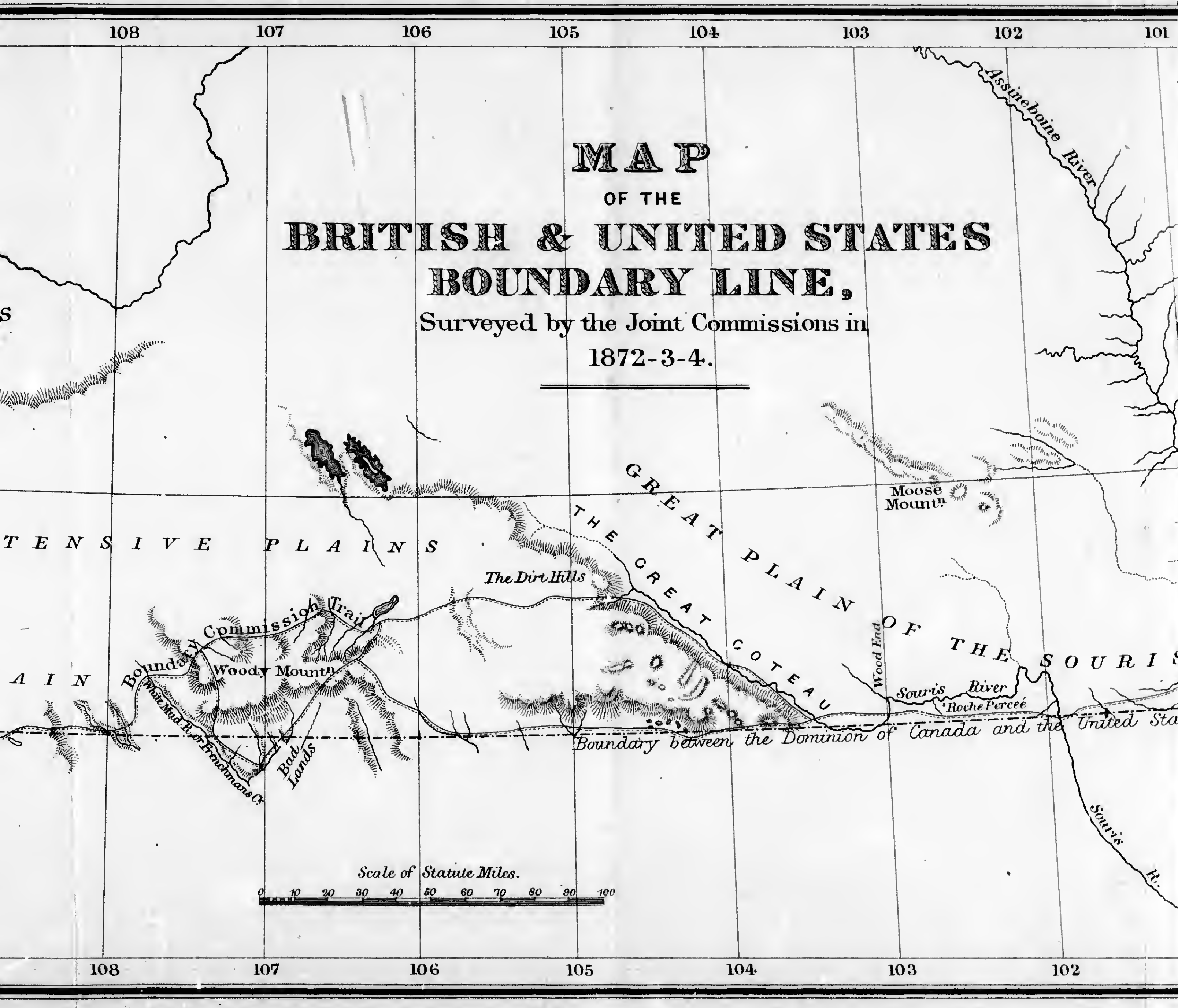
Abstract of the Observations for Latitude, taken with the zenith telescope, by the Officers of the British North American Boundary Commission, 1872-3-4.

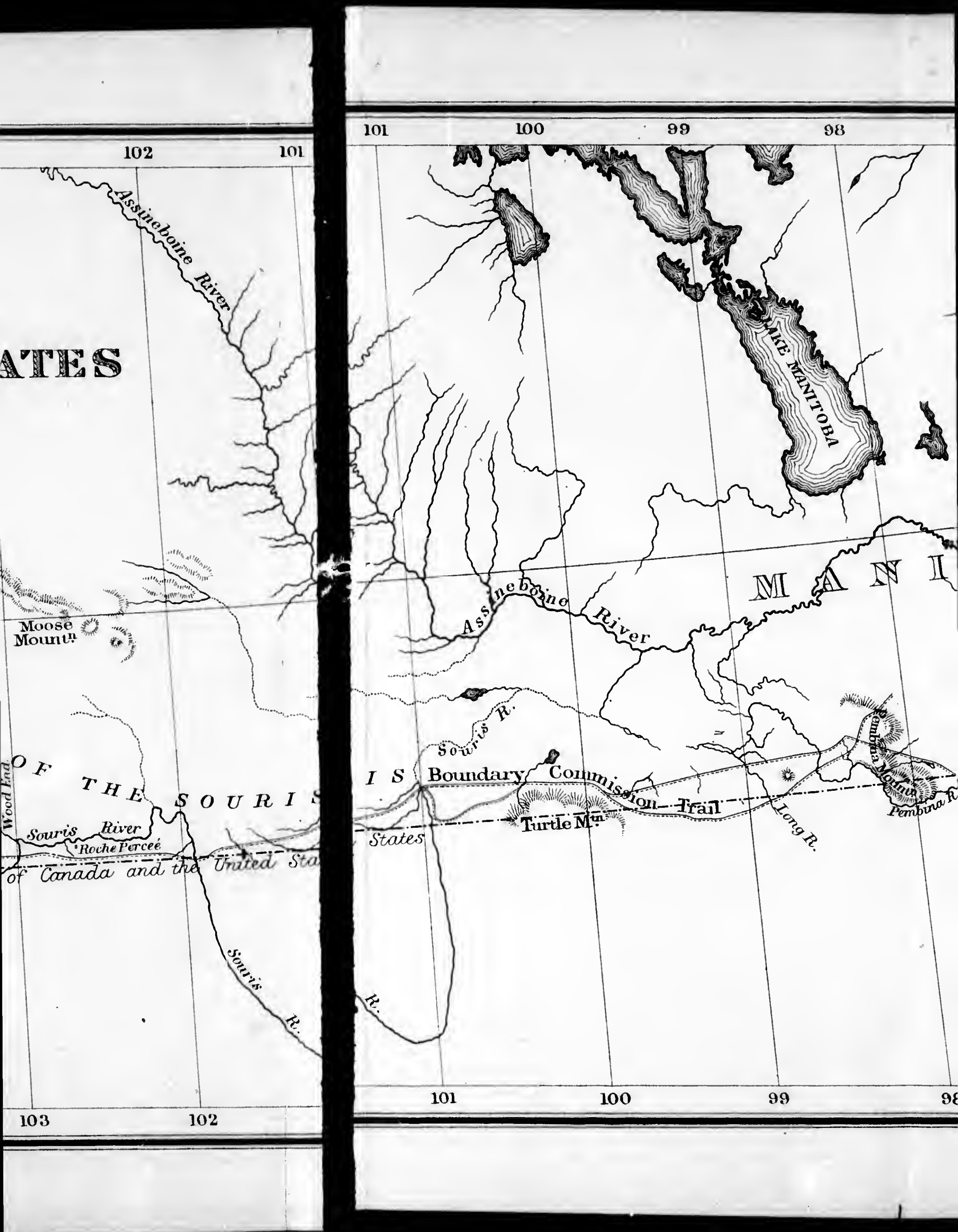
No. of Station.	SITUATION.	Number of Observations	No. of days of Observation.	No. of days at station.	Probable error of result.	REMARKS.
					Feet	
	North West Angle of the Lake of the Woods....	66	5	23	13	Winter.
1	Buffalo Point	94	5	10	8·88	Autumn.
2	Pine River	66	4	17	11	Winter.
3	West Roseau	78	3	6	10·23	Winter.
4	Pembina	77	7	16	9·42	Autumn.
5	Pointe de Michel	74	3	7	14·18	
6	Pembina Mountain, E...	93	4	10	10· 5	
9	....	92	4	6	9·02	
10	Turtle Mountain, E.....	86	4	5½	10·45	
12	Souris River, 1st Crossing	90	4	11	7·09	
14	" " 2nd "	97	3	8	11·14	
16	Short Creek	98	4	8	10·84	
18	Le Grand Coteau	91	3	5½	7·09	
20	Big Muddy	70	5	6½	9· 4	
22	West Poplar River	78	5	9	9·83	
24	Little Rocky Creek	83	8	12	8·16	Weather cloudy.
26	Cottonwood Coulé	87	5	9	7·70	Ditto.
28	....	66	3	6	5·85	
30	West Fork, Milk River ..	85	3	5	6·48	
32	Milk River, West Bank..	65	3	6	6·84	
34	West Butte	85	3	5	5·26	
36	South Branch of Milk River	66	3	5½	6·77	
38	Chief Mountain	79	3	6	5·16	
39	Belly River	76	3	5½	9· 3	

PL. VIII.

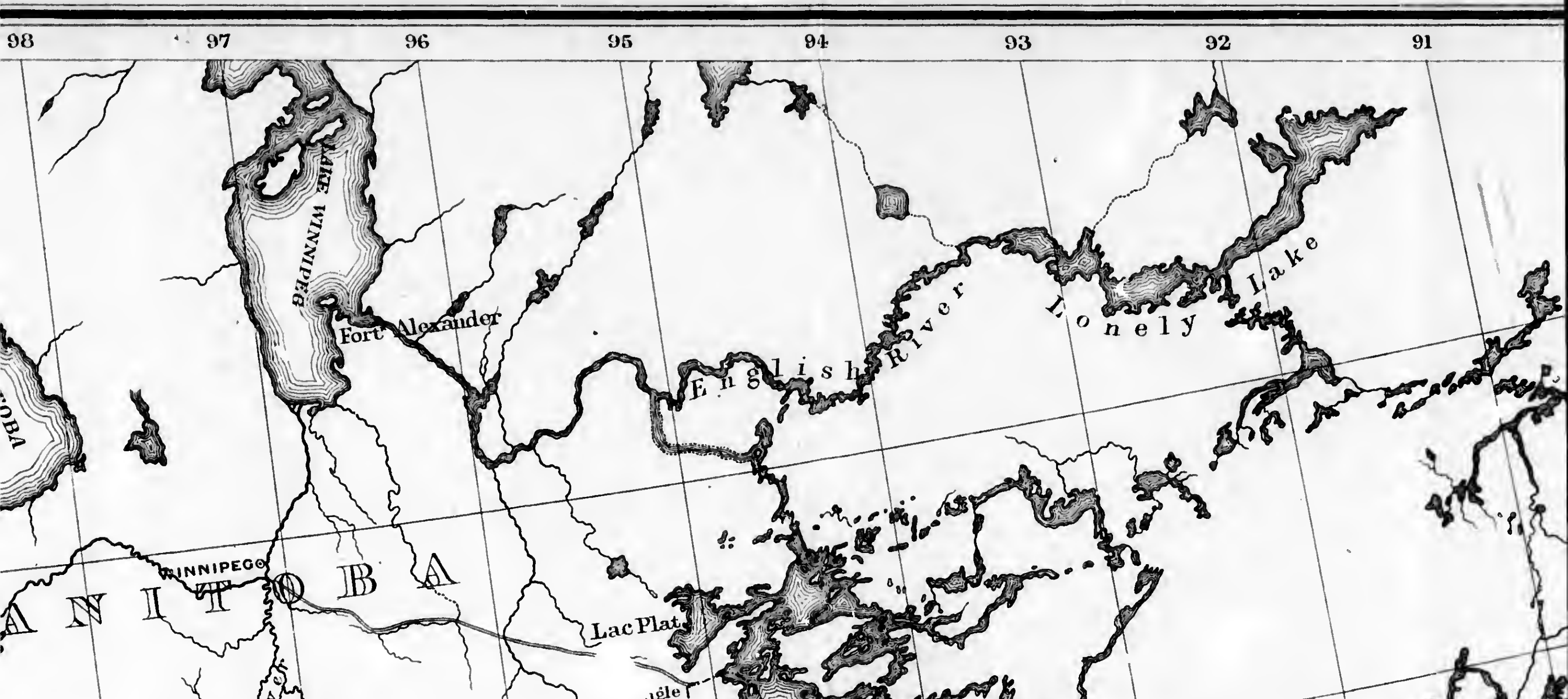
THOS KELL, LITH. 40, KING STREET, COVENT GARDEN.


115
114
113
112
111
110
109
108
Red Deer River
PLAINS
PLAINS
Mt Head
ROCKY MOUNTAINS
50
Fort Mc Leod
Belly River
SOUTH SASKATCHEWAN RIVER
EXTENSIV
Cypress Hills
Waterton River
Belly R.
St Mary's R.
Buffalo Country
L. Peekopee
49
Branches of Milk River
Boundary Commission Trail
CACTUS PLAIN
West Fork
East Fork
The Three Buttes or Sweet Grass Hills
Watershed
Waterton Lake
Mt. Wilson
Chief's Mountain
Milk River
114
113
112
111
110
109
108


108
107
106
105
104
103
102
101
MAP
OF THE
BRITISH & UNITED STATES
BOUNDARY LINE,
Surveyed by the Joint Commissions in
1872-3-4.
Assineboine River
GREAT PLAIN OF THE SOURIS
THE GREAT COTEAU
Moose Mountn
TENSIVE PLAINS
The Dirt Hills
Boundary Commission Trail
Woody Mountn
AIN
White Mud R. or Frenchmans Cr.
Bad Lands
Wood End
Souris River
Roche Percée
Boundary between the Dominion of Canada and the United Sta
Souris R.
Scale of Statute Miles.
0 10 20 30 40 50 60 70 80 90 100



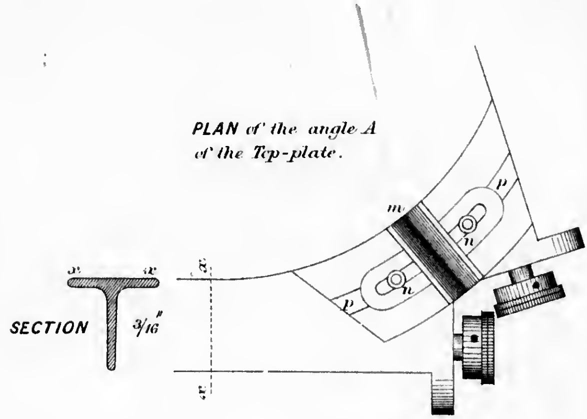
102
101
100
99
98
Assineboine River
ATES
LAKE MANITOBA
M A N I
Moose Mount.n
Assineboine River
Sour is R.
Wood End
OF THE SOURIS
IS Boundary Commission Trail
Souris River
Roche Percée
Turtle Mtn
Pembina Mountn
Pembina R.
Long R.
of Canada and the United States
Souris R.
R.
103
102
101
100
99



98
97
96
95
94
93
92
91
LAKE WINNIPEG
Fort Alexander
English River
Lonely Lake
WINNIPEG
MANITOBA
Lac Plat
Red River
Roseau River
Buffalo Point
LAKE OF THE WOODS
Swamps
Dufferin
Pembina
Pembina R.
Boundary Commission Trail
Rainy Lake
Rainy River

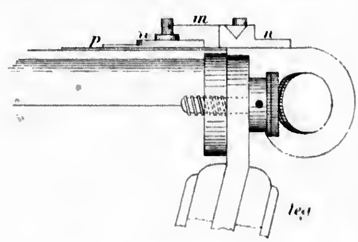
PL. VIII.

THOS KELL, LITH. 40, KING STREET, COVEN. GARDEN



PLAN of the angle A of the Top-plate.

The V shaped groove m and the plate n are cast in one piece and are moveable along a slot in p.



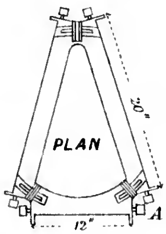
ELEVATION, shewing one of the legs screwed on

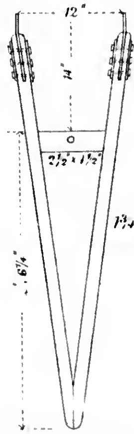
Scale of the above, /4 full size.

THOS KELL, LITH 40, KING STREET, COVENT GARDEN.

WOODEN STAND FOR A PORTABLE

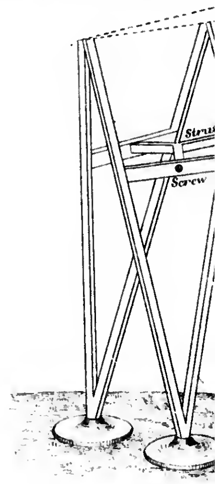
TOP-PLATE (*Gun Metal*)





PLAN OF LEG
(*Wood*)

ELEVATION *of legs whe*



NOTE. *The two other legs are one inch longer than that shewn in the figure and are of greater width at top in order to fit the sides of the top-plate*

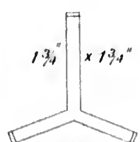
FOOT  PLATE

PLAN

(*Cast iron*)

ELEVATION

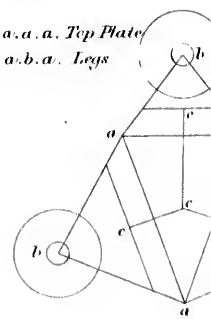
STRUT



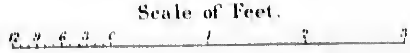
PLAN

Diagram Plan of Stand

a. a. a. Top Plate
a. b. a. Legs

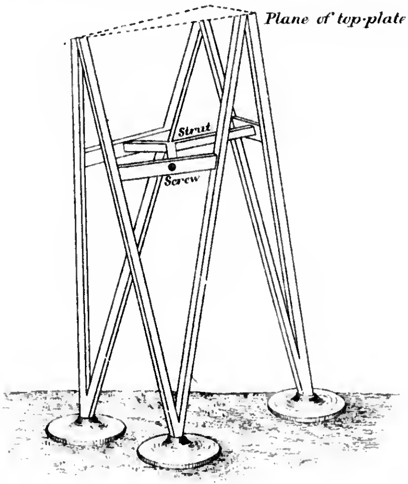


Scale of Feet.

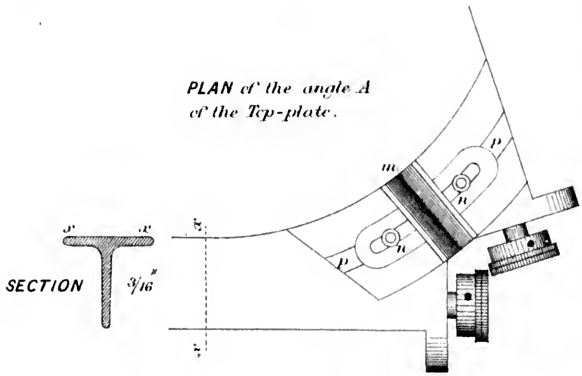


. A PORTABLE TRANSIT INSTRUMENT.

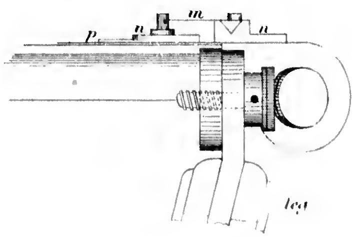
ELEVATION of legs when put together



PLAN of the angle A of the Top-plate.



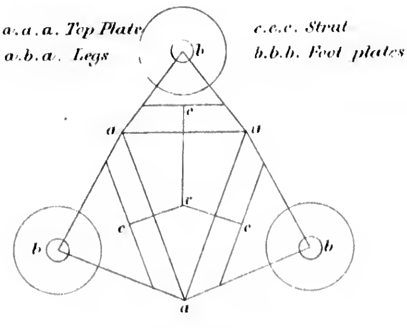
The V shaped groove m and the plate n are cast in one piece and are moveable along a slot in p.



ELEVATION shewing one of the legs screwed on

Scale of the above, 1/4 full size.

Diagram Plan of Stand, when put together



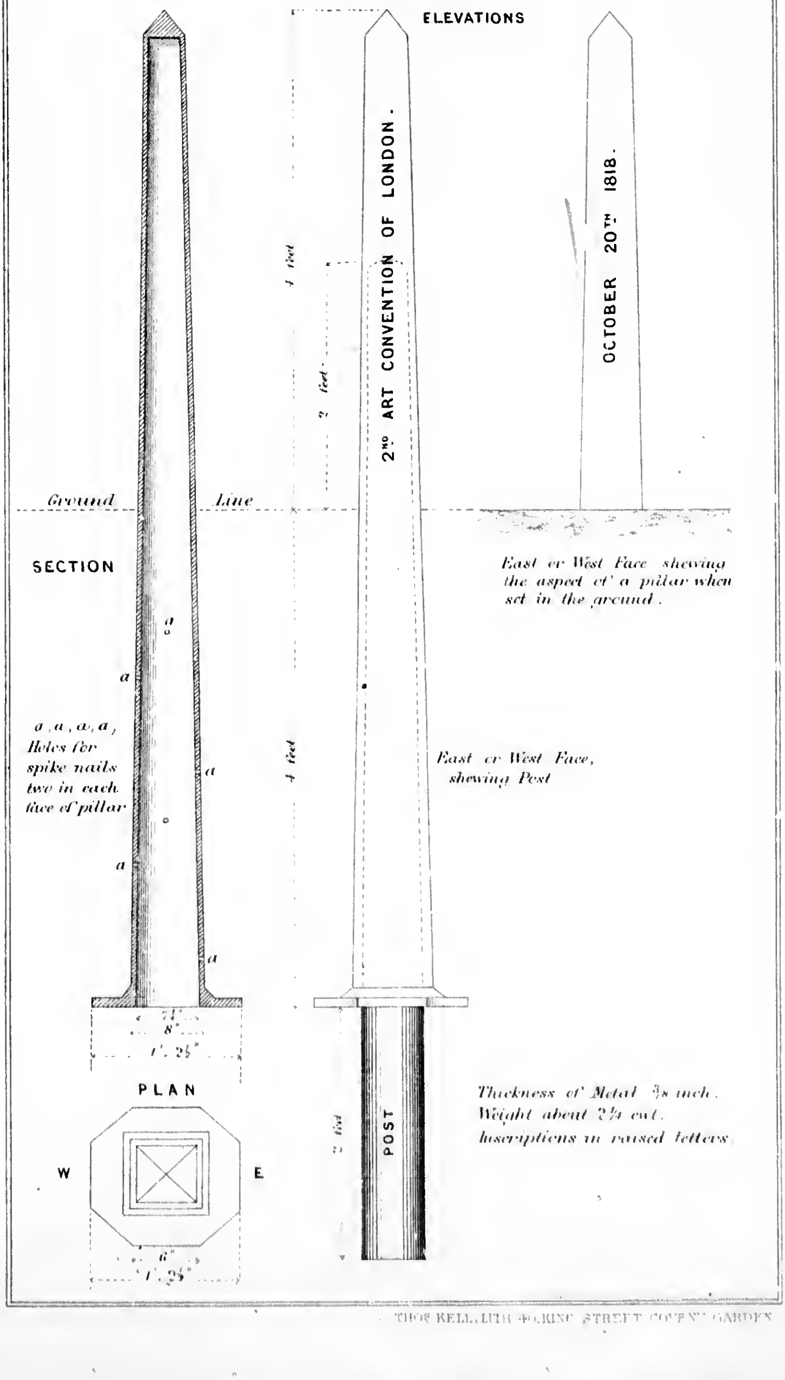
THOS KELL, LITH 40, KING STREET COVENT GARDEN.

PILLAR MONUMENTS

PL. X.

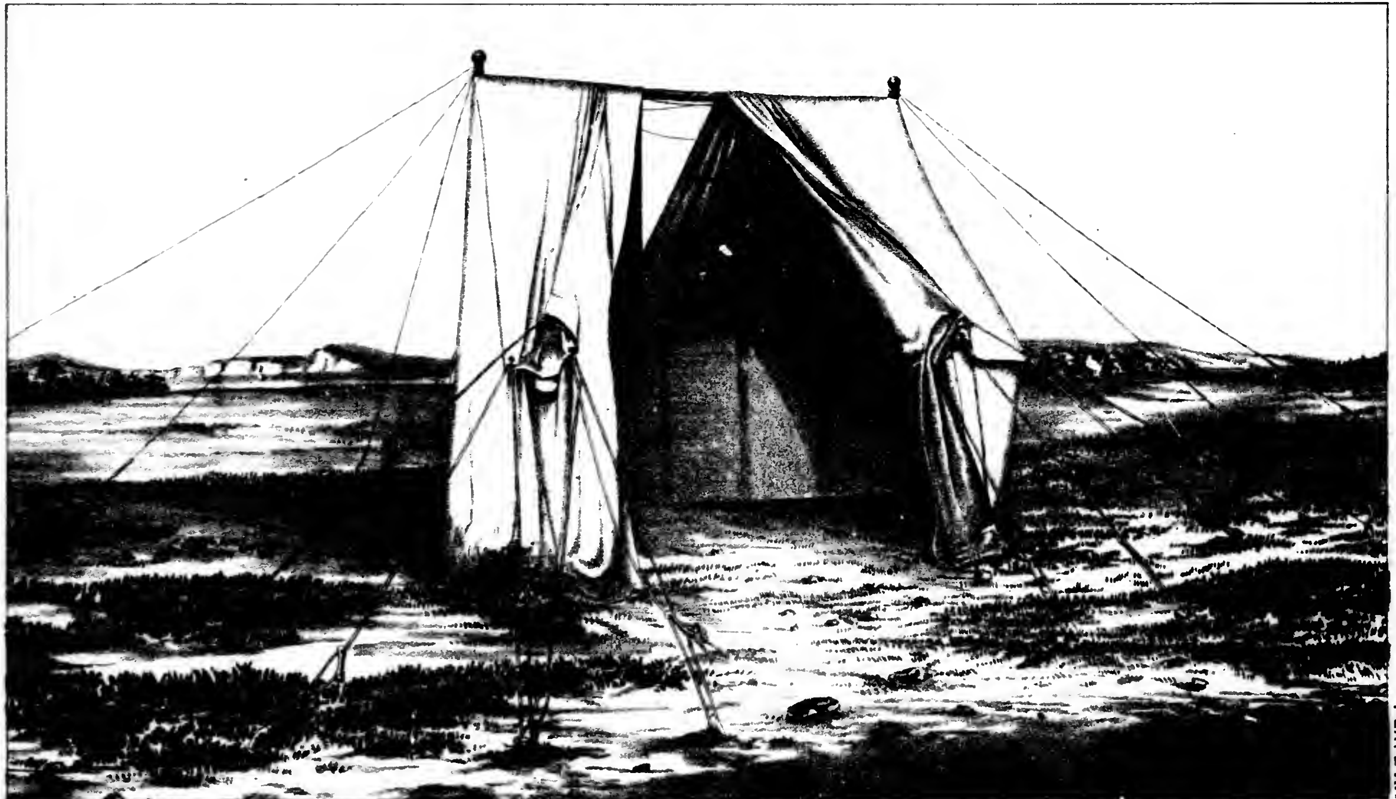
CAST IRON.

Scale. 1/10.



THOS KELL, LITH 40, KING STREET COVENT GARDEN

PLATE XI.



Litho S.M.E.

TENT — 10 ft. Square in plan, Poles 10 ft. high, Wall 4 ft. 6 in. high.

TABLE X.

List of the Astronomical Stations, shewing their distances from Station No. 1, their longitudes and their positions North or South of a small circle passing through Station No. 1, and parallel to the Equator.

Nos.	Distance from Station No. 1		Distances N. or S.		By whom observed.	Longitudes West of Greenwich.		
	Miles.	Links.	Feet.			deg.	min.	sec.
N. W. Angle.					British.	95	8	56· 7
1	0	0	0		B. and U. S.	95	16	55·26
2	31	7205	388	N	British,	95	59	00·99
3	68	1283	470· 2	N	do.	96	46	51·85
4	88	4936	556· 1	N	B. and U. S.	97	13	51·50
5	108	5962	588· 4	N	do.	97	40	25·16
6	124	0002	533· 3	N	do.	98	00	32·96
7	135	6307	459· 5	N	U. S.	98	16	06·29
8	165	1305	376· 7	N	do.	98	54	52·06
9	183	3911	213· 4	N	British.	99	19	02·36
10	203	7729	54·15	N	do.	99	46	04·26
11	238	1510	154·91	N	U. S.	100	31	13·86
12	258	744	240·21	N	British.	100	57	29·76
13	281	1973	203·31	N	U. S.	101	28	02·96
14	303	7150	40·01	N	British.	101	57	56·06
15	325	3846	7·85	N	U. S.	102	26	25·16
16	343	2892	183·45	N	British.	102	50	00·86
17	359	3254	203·25	N	U. S.	103	11	11·26
18	377	2977	138·85	N	British.	103	34	53·66
19	400	4925	414·06	N	U. S.	104	05	33·96
20	426	5035	40·36	N	British.	104	39	53·56
21	451	1841	152·49	N	U. S.	105	12	21·36
22	473	3454	334· 9	N	British.	105	41	39·16
23	496	6906	157·29	N	U. S.	106	12	34·36
24	522	4742	390· 7	N	British.	106	46	31·46
25	550	6740	436· 9	N	U. S.	107	23	48·16
26	567	3881	543· 6	N	British.	107	45	45·86
27	588	1931	540· 9	N	U. S.	108	13	09·26
28	615	3202	397· 1	N	British.	108	48	59·56
29	642	218	836	N	U. S.	109	24	7·76
30	655	2357	669· 3	N	British.	109	41	38·16
31	677	281	446	N	U. S.	110	10	19·46
32	702	3023	166· 6	N	British.	110	43	46·06
33	723	383	304· 3	S	U. S.	111	11	2·56
34	739	5780	571· 2	S	British.	111	33	02·66
35	760	3160	167· 7	N	U. S.	112	00	19·46
36	785	279	182· 7	N	British.	112	32	50·36
37	804	3361	116· 7	N	U. S.	112	58	25·16
38	825	6138	112· 5	S	British.	113	26	35·26
39	836	3385	383· 5	S	British.	113	40	38·96
40	846	240	10· 6	S	U. S.	113	53	19·66
41	853	2529	134· 6	N	B. and U. S.	114	02	56·46

NOTE.—Station 41 was observed by the Joint Commission of 1861.

PAPER IX.

THE RECENT TRANSIT OF VENUS.

By Captain ABNEY, R.E.

It may be of interest to cast a retrospective glance on the late Transit of Venus, recording, as far as is at present known, the results obtained, and also to leave on record the names and stations of the observers and their assistants, as so many of the corps were engaged on the work.

Some eighteen months before the actual transit took place, the Astronomer Royal commenced his selection of observers to represent the English expeditions, and it is no secret that he endeavoured to secure the services of a far larger number of Artillery and Engineer officers than he was finally able to send out. As it was, the vacancies almost at the last minute were filled up by civilians who had had some previous training in astronomy. As will be seen by the annexed table, besides two Artillery officers, (both of the Marine branch) three Engineer officers were engaged in the expeditions, and the photographic assistants, to the number of fifteen, were wholly supplied by the corps. To Chatham the Astronomer Royal also looked for giving the necessary instruction in photography, and at one time in our photographic school we had 18 men training for this special work, besides 5 officers and civilians at the observatory. Fortunately Lieut. R. Darwin, R E., threw himself into the photographic work, and took a great deal of the manipulative instruction into his hands, aiding most essentially in the matters of photo-heliograph drill, and amending the processes to be employed. At Greenwich a certain amount of hesitation was felt in adopting a dry plate process at first, as all recent eclipse work, and the sun diagrams taken at Kew, and subsequently at the Royal Observatory, had been taken by the wet method. It was only after we had successfully worked out a dry plate process, known as the "albumenbeer" process, that it was finally determined to adopt this method. Its advantages consist in an absolute impossibility for the films to shrink during manipulation (a matter of the highest importance where exact measurements have to be taken), whilst at the same time the plates could be prepared weeks or months in advance; in fact in Egypt, during the transit, we exposed plates which had been prepared at home months before. The dry plate process employed is given in the appendix, and I believe it to be thoroughly reliable for all classes of work. The training of the Sappers commenced on the 1st January, 1874, and with the aid of the photo-heliograph lent by Sir G. Airy for the purposes of instruction, they were *au fait* at the process about May, soon after which the first expedition started for Kerguelin's land. During most of that time Lieut. Darwin was able at intervals to come to Chatham, keeping up his work at the Observatory at Greenwich at the same time.

I need not enter into the details of the instruments employed at each station. Suffice it to say that each party was furnished with an altazimuth, a transit instrument, and equatorially mounted telescopes (none less than 4½-inch) for each observer. The amount of forethought necessarily expended on the supplies and comforts for each expedition was immense, and none laboured so hard as Captain Tupman, R.M.A. He had been nominated by the Astronomer Royal as chief of the transit of Venus parties, and to him all looked for completing each outfit. It was an arduous task, but not quite an unthankful one, as owing to his readiness to afford help and information, the parties after their return had no omission to reproach him with. The arrangements also involved a large increase in the work of the Astronomer Royal and of his chief assistant, Mr. W. H. M. Christie; their kindness and attention to the wants of all smoothed away difficulties after difficulties as they cropped up.

The Astronomer Royal had chosen the stations for the English parties principally to obtain results by Delisle's method, which was dependent on the accurate observation of the times of 1st or 2nd apparent internal contact of Venus with the limb of the sun, together with a close determination of the longitude of each station. If a figure be drawn showing the double zone formed by the shadow of Venus, and remembering that the planet crossed over the northern half of the sun's surface, it will be seen that certain places in the northern hemisphere would come into apparent internal contact with the inner zone sooner than localities in the southern hemisphere at ingress, whilst at egress the reverse would be the case. The difference in time of the observed contacts furnish the data by which the planet's distance (and hence the sun's distance) can be calculated. A glance at the accompanying map will show that the Russian Government expeditions occupied a line across Siberia and on to Japan, and it will be further noted that, owing to the prevailing bad weather, and to the low altitude of the sun, in the majority of cases the observations were unsuccessful. In Egypt, however, where there were parties of various nationalities, the necessary contacts at egress were observed, and they give ample data for Delisle's method, when the southern stations, which observed the same contacts, are taken into consideration. The most favourable stations, where successful observations for Halley's method were taken, will be at once seen in the map; that is those where the *difference* of the length of the chords, as measured by the interval of time elapsing between internal and external contacts, is greatest. For both methods it will be seen (if the observations have been well made) that the stations marked "successful" will give pairs, which, when combined, should give an accurate determination of the planet's distance. It can hardly be expected, however, that some discrepancies may not arise with visual observations, but supposing that one half have to be rejected, yet, if the chances of error at each particular station be calculated, it will be found that there still remain abundant observations for the purpose required.

The phenomenon of the black drop or ligament connecting the planet with the sun's limb at the time of contact in very many stations was missing. This, together with the light ring round Venus, caused by its atmosphere, it is believed puzzled many observers, and perhaps may have caused them to record contact a little late. In one case, from my own knowledge, one observer was so engrossed in watching the line of light round the planet's edge, that he failed to record contact till 20 seconds after it had actually taken place.

Photography, however, cannot err in this manner, and from the results produced at various stations, there seems to be an absolute certainty that the correct time of contact at these stations will be known. Photographs of the sun, when visible, were taken by the English parties at intervals of every two minutes while the transit was taking place. The planet's central distance from the sun's centre is now being accurately measured, and it has been found that such measurements are comparable to the $\frac{1}{40}$th second of arc, a result which is four times better than was anticipated. It may prove that the photographic results are more reliable than those obtained by the eye observations; at all events, it is presumable that they will be equally trustworthy, and will therefore be great checks on the accuracy of the latter. The spectroscopic observation of the contacts has led to a supposition that the diameter of the sun's disc which emits so-called actinic rays is not quite coincident with that which emits the visual rays. Be this well founded or not, it is quite evident that the times of contact formed photographically must be comparable, whilst those arrived at by visual observations may have to be taken by themselves.

The longitudes of the English stations, except one, were obtained by the method of observing moon culminating stars and the transit of the moon, and involved an arduous series of observations extending over several lunations.

The exceptional station referred to was Cairo and Egypt generally, where the telegraph was used for obtaining true Greenwich time. All the Egyptian localities selected were connected by telegraph, and thus no difficulty was found in accurately determining the longitude of both Thebes and Suez. In the map it will be seen that some stations obtained their longitude by chronometers. The number of chronometers used ensured accuracy, and the longitude obtained by this method may therefore be relied upon.

My thanks are due to Captain W. A. Orde Browne, late R.A., for the loan of a tracing of a map showing the successful observing stations. A reduction of his original map appeared in *The Engineer* last year.

W. de W. A.