THESIS

A Topographical Survey

of the M. A. C. Campus

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1903

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Topographical surveying
Title M.A.C. campus

-: THESIS :-

A T O P O G R A P H I C A L   S U R V E Y

of the

M. A. C. C A M P U S .

B Y

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B.S

C L A S S '03

THESIS

A TOPOGRAPHICAL SURVEY

of the

M. A. C. CAMPUS.

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This survey was made for the purpose of securing data for the completion of a map of the M. A. C. Campus and farm. On this map to a scale of fifty feet to one inch was to be located accurately by means of a system of triangulation all the numerous buildings, walks, and drives on College grounds, as well as various topographical features and contours. Much work had already been done. A system of six triangles, indicated (see map) by stations A, B, D, E, I, J, and K, connected to a base line along the front of Faculty Row, had been established and plotted on the map, the surveys having been made by students in their regular class work in Civil Engineering. The length of this base, 936.27 feet, was established by taking the mean of many measurements, taken every year since 1892 and the angles of the system were also well established by many repetitions. In the spring term of 1902 the old rough stone monuments, some of which had become covered with sod, were replaced by cement blocks 6" x 6" x 30". This work was done by the classes of '02 and Civils of '03. All the stations were easily located from the old field-notes of the Civil Engineering Department. Large tripods (Fig. I) were set up over these triangulation stations and the point of a plumb-bob suspended over the exact point as designated by a

cross mark on the stone. Four stakes were then driven and strings stretched intersecting at the plumb-line. The plumb-line was then taken up, the old stone removed, and the new monument set in its place flush with the surface. The plumb-line was then let down again, and a punch mark made in the iron bolt in the center of the monument under the point of the bob. Thus the exact point was preserved during the digging and transferred to the new stone. The intersecting strings were simply a check on the accuracy of the plumb, in case the tripod legs were moved slightly. After these new monuments were set the angles were again read and the mean of twelve repetitions recorded.

Our first work was an examination of the map and old field notes in order to find out what work had already been done and to determine upon a plan of procedure. In the transit book belonging to C. E. Dept., marked "Base and References", we found reference to an old Base line as follows. "Runs nearly North and South along the West side of the farm lane. The North end marked: 1st by the center of the bottom of a wine bottle set three feet under the surface of the ground; 2nd by a prick-punch mark in the end of a seven-eight inch cast iron rod fourteen inches long set just above the bottle; 3rd by a cross, cut in a stone set flush with the surface, over the iron rod. Located east of North-east of the sixth tree from the river, at a distance of eight and one-half feet from said tree, and sixteen and one half feet from the wire fence on the same side of the road. We readily found these old marks as recorded,

except that the stone was covered with sod, and replaced them by a monument, using the method described above. The The South end of the base was also referenced in the notes but in such an indefinite manner that it could not be found. The ground for about nine hundred feet south from the above located station was of an even slope and easily accessible by a line of sight from any direction, so we concluded to lay off there a base line in the true meridian by an observation on Polaris. This was found to be impracticable because the south end came in the middle of the road, the farm lane not being truly North and South. We therefore laid out the line parallel to the road. Our work was now, (1) to connect this base by a system of triangulation with the old base above mentioned, (2) to measure the base accurately, (3) to observe the angles of all the triangles, and from the data thus obtained, (4) to compute the length of all the sides and plot the new system on the map. Then the details of topography were to be filled in by a system of stadia traverses. By reference to the accompanying map it will be seen that the area to be covered includes the South-East portion of the Campus, that part of the farm lying North of the Red Cedar River between the Farm Lane and the P. M. Spur, and embracing field No. 6 South of said river and a portion of field No. 8. A careful reconnaissance was made of this area to obtain a familiarity with the general topographical features in order to properly locate triangulation stations. This work took considerable time for we realized that a single station improperly located might occasion several

days labor to clear a line of sight. We also wished to obtain angles not less than thirty degrees or more than one hundred and twenty degrees so that the triangles would be well proportioned; for triangles must be so formed that a small error in measurement will cause the least possible error in a calculated value. This as proved by higher Calculus is when the triangles are as nearly equilateral as possible. The stations also had to be located where they would not be disturbed, and at the same time be accessible with an instrument. Owing to the many buildings and trees we had great difficulty in finding suitable locations, and clear lines of sight, especially where the system crossed the river as the banks were thickly wooded. The instruments used in the field were, an aneroid barometer, a prismatic pocket-compass, a field glass, and flags. We thus located stations, L, M, N, O, P, and Q, forming six triangles (see map), and set monuments at all the triangulation stations. All these stations were located in positions where they would not be disturbed if left flush with the surface except station M in field No. 6 which was set one and one half feet below the surface to avoid the plow. After these menuments were firmly planted, they were referenced in the notes by tieing them to buildings, trees, or any permanent objects near at hand, so that they would not be lost if covered up. As this triangulation system forms the framework of our map, each of its stations must be accurately located, so that a traverse could start from any one of them and the notes taken for making a plot of that particular

vicinity, and many different surveys made in different parts of the system could be connected with this same skeleton framework and so form one united whole.

The angles of the triangles were measured by the method of repetition, taking three readings with the telescope direct and three with the telescope reversed, as follows: We set the instrument over some station, as O to measure the angle POQ (see map), with verniers at zero and sighted on station P. Clamped the lower motion, loosened the upper motion and set telescope on station Q and clamped, read both verniers to eliminate errors of eccentricity, loosened lower motion, and set on station P, clamped and turned upper motion to Q and read angle as before. We repeated the above operations until we had three additions on the limb and then reversed the telescope to eliminate error of adjustment in line of collimation and horizontal axis. Three readings were now taken, adding to those already on the limb. The sum of the readings divided by the number of repetitions gave the mean value or angle. When three angles of a triangle have thus been determined their sum would equal 180° if there were no error. Absolutely correct

results are however impossible and a limit of error of fifteen seconds was allowed. If the observations were all considered equally correct each angle would be corrected by one third of the error, if not they are balanced according to the theory of probable errors, as indicated by the following specimen of notes.

(Sample of Notes) Angle LIK.

Sta.	Index	Ver A.	Ver B.	Mean	Diff	Angle
I	63° 00'	25'	26'	63° 25-1/2'	63° 25-1/2'	)
	126° 30'	21	22	126° 51-1/2'	63° 26'	) **Direct**
	190° 00'	18	19	190° 18-1/2'	63° 27'	) 63° 26' 10"
	253° 30'	15	15	253° 45'	63° 26-1/2'	)
	317° 00'	11	11	317° 11'	63° 26'	) Reverse
	380° 30'	7	7	380° 37'	63° 26'	)

Computation of Probable Error in Angles of the Triangulation.

Formulae

$$E_1 = C' \sqrt{\frac{\Sigma \quad d^2}{n - 1}}$$

$$E_m = \frac{E_1}{\sqrt{n}} = C \sqrt{\frac{\Sigma d^2}{n(n-1)}}$$

n = number of observations.

d = difference between one observation and arithmetic mean.

E = probable error of single observation.

E = probable error of mean.

If the observations are weighed

M = any observation

W = its weight

Weight mean = $\frac{\Sigma (WM)}{\Sigma W}$

$$E = C \quad \frac{(wd^2)}{n-1}$$

$$E = C \sqrt{\frac{\Sigma (wd^2)}{(\Sigma w)(n-1)}}$$

We considered all our observations of equal weight.

Examples of how these formulae are applied.

Angle LIK

Index to Observation	Angle	Arithmetic mean of all Observations	d	d d
1	63° 25-1/2'		+40"	+1,600"
2	63 26'		+10"	100"
3	63 27'	63° 26' 10"	-50"	2,500
4	63 26-1/2'		-20"	400
5	63 26		+10	100
6	63 26		+10	100
			0	4,800 = Σd^2

$$E_{,} = C\sqrt{\frac{d^2}{n-1}}$$

$$E_{,} = .6745\sqrt{\frac{4800}{6-1}} = \pm 20.''83$$

$$E_{m} = C\sqrt{\frac{\Sigma d^2}{n(n-1)}} = \frac{20.83}{\sqrt{6}} = \pm 8.''53$$

Method of applying the probable error is shown by following example.

Consider triangle LIK.

Angle	Mean of six readings	Probable error	Balanced.
KIL	63° 26' 10"	±8.53"	63° 26' 16.86"
IKL	50° 56' 55"	±3.375	50 56 57.72
ILK	65 36 40	±6.74	65 36 45.42
Total Sum	179° 59' 45"	±18.645"	180° 00' 00.00"

180° 00' 00"

179° 59' 45"

15" = error of triangle.

Divide the error of the triangle by the sum of probable errors thus,--

$$\frac{15''}{+18.645} = \pm.805$$

Now multiply the probable error of each angle by the result just obtained and add or subtract the product to the angle according to whether the error of the triangle is negative or positive.

Thus for Angle KIL

.805 X 8.53 = 6.86

63° 26' 10" + 6.86 = 63° 26' 16.86"

In the same manner apply corrections to angles IKL and ILK. The sum of the balanced angles must equal 180°

The base was measured with a 500' tape, which we tested with a K. & E. 100' tape standardized at Washington. The testing was done as follows,-- On as level a piece of cement walk as we could find we laid out 100 ft. with the standard tape at proper tension and supported throughout. Supports consisting of a nail driven into the side of a stake were placed at the ends of this 100 foot length in order to support each end of each hundred feet of the 500 ft. tape on the same level, and leave it unsupported between the ends. Thus each 100 ft. was tested separately by hooking a spring balance to one end and applying tension until the hundred foot length agreed with that on the walk as shown by a plumb bob held beside the tape. These tensions for each hundred foot length were, commencing at the 0 end of the tape, 17, 16-1/2, 17, 16-3/4, and 18-3/4 pounds. The average tension, 17.2 pounds, was that required for the whole tape suspended at 100 ft. intervals. No correction for temperature was necessary in this test as the standardized tape and tape tested were of the same temperature.

To prepare the base for measurement, stakes were set at intervals of 100 ft. along the line and by aid of a level slats were tacked to them so as to support the tape on the same level throughout its entire length. At each end of the tape we set up a board, firmly supported by wires, (see sketch) with a threaded hook at the top by means of which the required tension could be obtained and maintained while points were being transferred to the ground with a plumb bob. The ends of

the base were marked by plumb lines hung as follows: At the north end of the base, as the ground was about five feet below the line, the plumb line was hung from one of the large tripods (used to mark the triangulation stations) and carefully centered over the punch mark in the monument.

At the south end the line passed about twelve inches above the ground so the plumb line was hung from a transit.

Five hundred feet was first measured along the base northward from the south end. Four applications were made by transferring the five hundred foot point with a plumb bob to a board nailed to two stakes driven into the ground. The mean of these four applications was taken as the measurement. The greatest difference between any two of these was not over one-sixteenth of an inch. The remaining part of the line was measured from the north end of the line to the point found by transferring the point from the board up to the tape and the tape read. Four readings of this were also taken and the mean used.

The measurements were as follows.

Measurement	Temperature (F)	Corrected Measurement.
867.880	50°	867.812
867.685	75°	867.791
867.736	75°	867.809
	Mean =	867.804

Greatest variation from mean = .013 ft. = $\frac{1}{66,754}$

We computed the sides of the triangles through the system from the established base along Faculty Row to our base in the Farm Lane. Two of us worked independently with seven place logarithms and checked. The computed length was 867.464 feet, a difference of 36. ft. The nearness of agreement between the measured and calculated lengths determines the degree of accuracy of all previous measurements and calculations. Calculating back from the new to the old base also served as a further check on the work.

To determine the true azimuth of our base line (OP) we took an observation on Polaris from the ~~south~~ north end, station ~~P~~ O, using the Buff and Berger transit. The reflector belonging to the instrument was so heavy that it over-balanced the telescope, so we made a similar one out of white paper. It consisted of a cylinder made of drawing paper inside of which was plaeed a card of bristol board set at an angle of forty-five degrees to the axis of the cylinder. Through the center of the card an elliptical hole, three-eights inch minor axis, and concentric with the outer edge of the card, was cut, to permit sighting through the telescope. A hole in the side of the cylinder permitted light to be thrown upon the card and reflected into the telescope to illuminate the cross wires. Light was furnished by three bicycle lanterns.

The target at the ~~north~~ south end was a box about 6" x 12" x 4", open on one side. On the opposite side a slit one-eighth inch wide and about eight inches long was cut extending from one end through the center of the side. The slot in the box was placed facing the ~~south~~ north exactly over the center of the monuments and carefully plumbed. Within the box and behind the slot one of the lanterns was placed.

Observations were made every five minutes by standard time. With instrument carefully leveled, and verniers at zero, the telescope was pointed at Polaris. With the lower motion clamped the cross hairs were kept carefully on the star by the lower tangent screen until the time keeper announced the time to observe. This he did by counting backwards the last fifteen seconds of the five minutes, thus: "15, 14, 13,-------3, 2, 1, and go!" The upper motion was then loosened and the cross hairs set on the target at the ~~north~~ south end of the base, and then clamped again, and angle read and recorded. The telescope was then turned on the lower motion and sighted at the star, and angle turned and read as before. To eliminate instrumental errors six readings were taken with the telescope direct and six reversed. The true azimuth corresponding to each observation was computed from tables given in the U. S. "Manual of Instruction to Surveyors," and the connection applied with proper sign as shown in form of notes below. The mean of the connected angles is the true azimuth of the base. Knowing the azimuth of the base the azimuth of all the other lines of the triangulation can be determined by computation.

June 15 1903 Still, Warm

Inst } Brown
Ver B }

Ver A } Mc Clure
Index }

Notes Carrel

Time	Index	Ver. A	Ver. B	Mean	Diff.	Azimuth	Cor. Diff
P.M.							
9:07 8:45	0° 30'	7'	7'	0° 37'	0° 37'	34'	1° 11'
9:12 8:50	1° 00'	11	11	1 11	0 34	36	1 10
9:17 8:55	1° 30'	14	14	1 44	0 33	39	1 12
9:22 9:00	2° 00'	15	15	2 15	0 31	41	1 12
9:27 9:05	2° 30'	14	14	2 44	0 29	41	1 10
9:32 9:10	3° 00'	11	11	3 11	0 27	44	1 11
9:37 9:15	3° 30'	5	6	3 35½	0 24½	46	1 10½
9:42 9:20	3° 30'	29	29	3 59	0 23½	48	1 11½
9:52 9:30	4° 00'	18	18	4 18	0 19	51	1 10
9:57 9:35	4° 30'	5	6	4 35½	0 17½	53	1 10½
10:02 9:40	4° 30'	21	21	4 51	0 15½	55	1 10½
10:07 9:45	5° 00'	5	5	5 5	0 14	57	1 11

Mean....1°..10'..50"....

Probable error of a single observation.............

Probable error of the mean = ...

Bearing N.1° 10' 50" W.

Traverse.

A traverse of four sides was run north of the river for the purpose of locating buildings, railroads, fencelines, etc., between the river and that part of the Campus that had been previously tied in. A hundred foot steel tape, and Light Mountain transit were used.

Sample of Notes.

Sta.	Line	Dis	Bearing	Azimuth	Check Angle
1	1-2	596.00	S 82° E	27° 31'	
2	2-3	707.18	S 6° 25' W	117° 11'	
3	3-4	1187.15	N 60° W	231° 1'	
4	4-5	552.07	N 68° 50' E	360° 5'	
		3042.40			

Error of Closure = $\frac{1}{5,850}$

Set transit on station 1, sighted on station 4 with upper motion clamped on zero, (i.e.,- took the first line as the true meridian). Clamped lower motion, inverted telescope, unclamped upper motion, sighted on station 2, read horizontal angles and compass bearing. Lined in chainmen to measure line 1-2, and make offsets from line to tie in buildings, etc. Repeated same operation on all stations.

The Location of Contour by the Stadia Method.

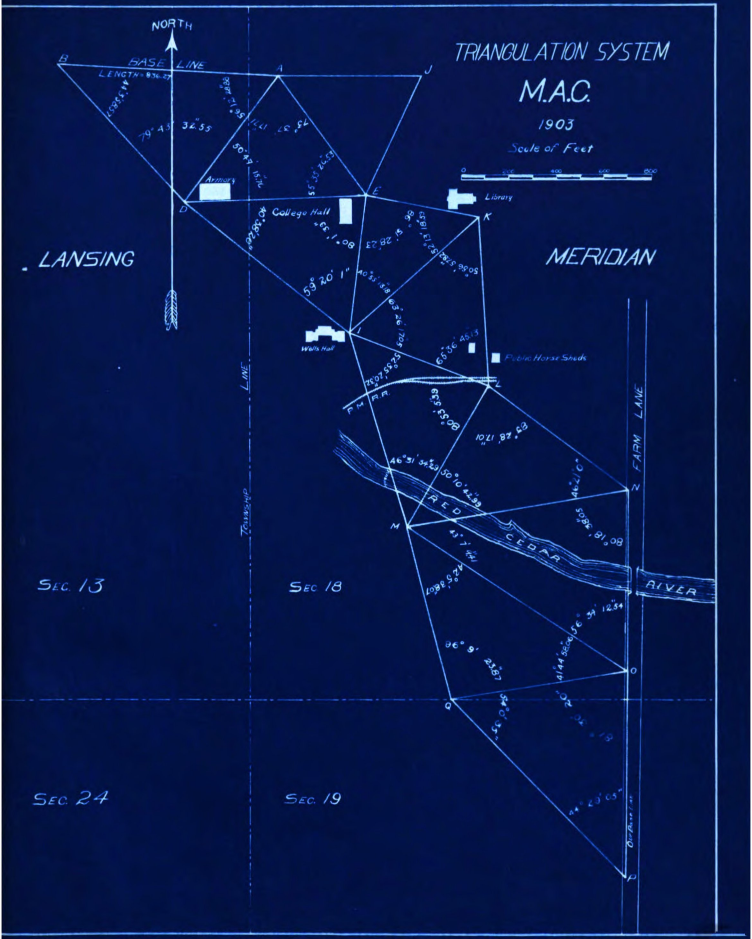
This work may be considered under three heads, viz.,- Observation or field work, Reduction of Notes taken in the field, and Plotting said results on the map. The field party consisted of an observer, a recorder, and a rodman. The instruments used were a light mountain transit and a rod graduated to feet and tenths. The wire interval of the transit was tested, and the space subtended on the rod found to be one one-hundredth of the horizontal distance from the telescope, the horizontal distance being measured from a point f + c = .765 ft. from the vertical axis of the instrument, where f is the focal length, and c the distance from the center of the instrument to the objective. The angle subtended by the cross-wires was about thirty-four minutes. The field work was to obtain the three co-ordinates, as referred to some known point of reference, of a sufficient number of points in the territory gone over to enable contour lines to be plotted. The points of reference used were triangulation stations, whose elevations were determined by running two lines of levels from the bench mark on College Hall. The big Gurley Level was used for this work, after the bubble had been adjusted carefully to the line of sight by the peg adjustment method. These levels checked within .007 and .011 inches in about half a mile run.

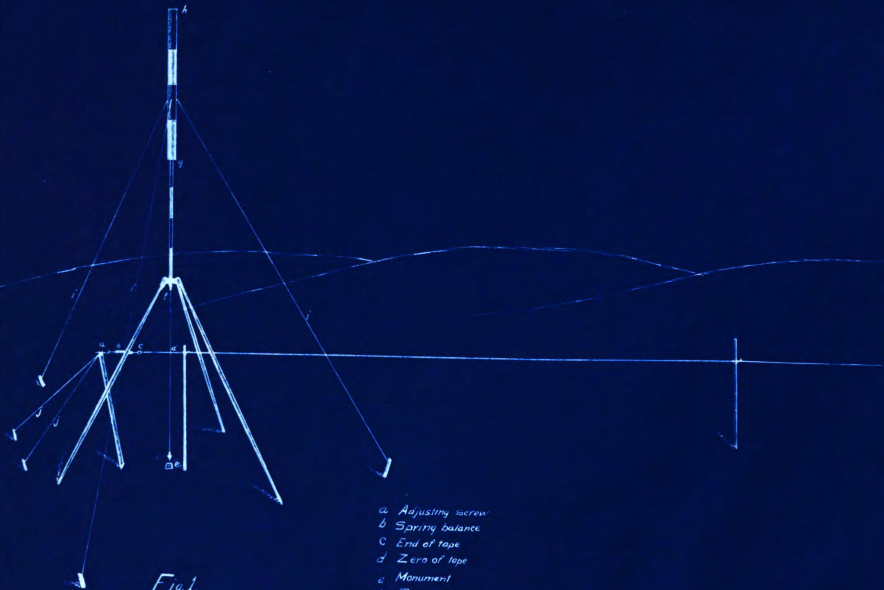
The stadia work was as follows,-- The observer set up the transit over a triangulation station, with the vernier of the horizontal limb at zero, and the vertical circle at zero when the line of sight was horizontal. With the plates clamped in this position the telescope was set to read on the next triangulation station. The lower movement was then clamped and an angle turned off on the horizontal limb to any desired point. In order to get the proper data to show the configuration of the surface, points were taken close together where there was a sudden change in slope and only a few where the slope was comparatively uniform. The height of the instrument above the triangulation station was taken on the stadia rod, and in taking the elevation of points from that station the middle horizontal wire of the instrument is brought to this same division of the rod as it is held on that point, and the vertical angle read. The upper, middle and lower intercepts are also recorded in order to get the distance. The form of notes is as follows:-

Ht. of Inst. =

Object	Hor.	INTERCEPTS			Ver.	Ver. Cor.	Dist.	Elev.
		Upper	Middle	Lower				

A sketch was made on the opposite page to aid in plotting the work. The points taken were numbered corresponding to numbers in the column of objects, and approximate contours drawn in.


TRIANGULATION SYSTEM
M.A.C.
1903
Scale of Feet
0 200 400 600 800
NORTH
BASE LINE
LENGTH = 836.27
Armory
College Hall
Library
Wells Hall
Public Horse Sheds
LANSING
MERIDIAN
TOWNSHIP LINE
FARM LANE
F.M. R.R.
RED CEDAR RIVER
SEC. 13
SEC. 18
SEC. 24
SEC. 19
Old Base Line
79° 43' 32".55
59° 20' 1"



a Adjusting screw
b Spring balance
c End of tape
d Zero of tape
e Monument
fe Plumb line
fh Color pole
iii Guys of wire
jj Brace wires

Fig. 1.

[illegible] USE ONLY