DETERMINATION OF AZIMUTH, LATITUDE AND LONGITUDE BY ASTRONOMICAL OBSERVATIONS.

A

Thesis

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THESIS

P R E F A C E

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DETERMINATION OF AZIMUTH, LATITUDE AND LONGITUDE BY ASTRONOMICAL OBSERVATIONS.

To the average layman the subject of astronomy and the movements of all heavenly bodies is an unfathomable mystery into which he feels not the slightest interest to delve. To him astronomical research is merely a pastime for the scientist who is possessed of sufficient wealth as to be able to carry on his work for his personal satisfaction. He does not realize that the field of astronomical research has contributed greatly to the store of human knowledge.

To the engineer and more especially the surveyor, a thorough knowledge of practical astronomy is very essential.

The locations of all land lines and other geographical and geodetic data obtained by the Government engineers on the Geodetic Survey, is based on the exactness of astronomical observations.

The locations of all points and places on the earth, the difference in longitude and latitude and the exact time of day can be obtained by a surveyor by observations on certain stars, and so it behooves the young engineer to acquire a thorough grounding in the

basic and fundamental laws which control the movements of the bodies of the celestial sphere.

In taking this subject for our Thesis, it was our intention to accomplish three things by astronomical observations. First - The exact latitude of East Lansing; Second - Checking the Azimuth of a line laid out on the compass; Third - The longitude of East Lansing. We will attempt furthermore to give a description of the subject of practical astronomy that may be readily understood by anyone outside of the field of science.

Practical astronomy treats of the theory and use of astronomical instruments and the methods of computing the results obtained by observations.

That part of most importance to the surveyor is that which deals with the methods of locating points on the earth's surface and of orienting the lines of a survey, and includes the determination of; First, latitude - Second, time - Third, longitude - and Fourth, Azimuth.

It would be well here to give several definitions of the meanings of terms and phrases to be used in this Thesis so that it will be more readily understood. These definitions are taken from Hosmer's work on "Practical Astronomy" and because of the plain and exact language used are set down here verbatim. (See Plate 2)

<u>VERTICAL LINE</u>: At any point on the earth's surface is

the direction of gravity at that point, and is shown by the plumb line, or indirectly by means of the spirit level.

ZENITH-NADIR: If the vertical line at any point be prolonged upward it will pierce the sphere at a point called the Zenith. This point is of great importance because it is the point on the sphere which indicates the position of the observer on the earth's surface. The point where the vertical prolonged downward pierces the sphere is called the NADIR.

HORIZON: The Horizon is the great circle on the celestial sphere cut by a plane through the center of the earth perpendicular to the vertical. The Horizon is everywhere 90° from the Zenith and Nadir. It is evident that a plane through the observer perpendicular to the vertical cuts the sphere in this same great circle. The Visible Horizon is the circle where the sky and sea seem to meet. Projected onto the sphere it is a small circle below the true horizon and parallel to it. Its distance below the true horizon depends upon the height of the observer's eye above the water.

VERTICAL CIRCLES: Vertical Circles are great circles passing through the Zenith and Nadir. They all cut the horizon at right angles.

ALMUCANTERS: Parallels of latitude or almucanters are small circles parallel to the horizon.

POLES: If the earth's axis of rotation be produced in-

definitely it will pierce the sphere in two points called the celestial poles.

EQUATOR: The Celestial Equator is a great circle of the celestial sphere cut by a plane through the center of the earth perpendicular to the axis of rotation. It is everywhere 90° from the poles. A parallel plane through the observer cuts the sphere in the same circle.

HOUR CIRCLES: Hour Circles are great circles passing through the north and south celestial poles.

PARALLELS OF DECLINATION: Small circles parallel to the plane of the equator are called parallels of declination.

MERIDIAN: The Meridian is the great circle passing through the Zenith and the poles. It is at once an hour circle and a vertical circle. It is evident that different observers will have different meridians. The meridian cuts the horizon in the north and south points. The intersection of the plane of the Meridian with the horizontal plane through the observer is the Meridian line used in surveying.

PRIME VERTICAL: Prime Vertical is the vertical circle whose plane is perpendicular to the plane of the Meridian. It cuts the horizon in the east and west points.

LATITUDE: On the earth's surface is the angular distance of the point in question north or south of the equator.

LONGITUDE: The arc of the equator between the primary meridian, which is usually taken through Greenwich, and the meridian of the point in question.

AZIMUTH: (1) Azimuth is the angular distance on the horizon between the meridian and the vertical circle through the point.

AZIMUTH: (2) On the earth's survace, Azimuth is the angular distance measured from the south in a clockwise direction of the point in question.

In making the observations in obtaining the data used in this Thesis, we used the equator system of coordinates on the celestial sphere.

The circles of reference in this system are the equator and great circles through the poles, or hour circles. The first coordinate of a point is its angular distance north or south of the equator. It is called the DECLINATION.

The complement of the Declination is called the POLAR DISTANCE.

The second coordinate of the point is the arc of the equator between the vernal equinox and the foot of the hour circle through the point. It is called

RIGHT ASCENSION.

Right Ascension is measured from the equinox "eastward" to the hour circle through the point in question, it may be measured in degrees, minutes and seconds of arc, or in hours, minutes and seconds of time.

HOUR ANGLE: The Hour Angle of a point is the arc of the equator between the observer's meridian and the hour circle through the point. It is measured from the meridian "westward" from 0 hours to 24 hours, or from 0^{o} to 360^{o}.

The instruments used in making the observations for this Thesis were a transit, with all its accessories including a prismatic eyepiece, chronometer and the data for the observations were figured from the "NAUTICAL ALMANAC AND SOLER EPHEMERIS FOR 1922" issued by the Federal Government.

The line and point used in this work is a line located on the drill field of the M. A. C. CAMPUS, the south point of the line being a copper bolt set in a concrete monument which is set flush with the surface of the ground. This south point is located by the following witness: SW corner of Armory - N 51^{o} oo' E 128.1' feet. N W corner of Gymnasium - N 88^{o} 30' W 146.9' feet. Hydrant N 2^{o} 15' W 168.4' feet.

The north point of the line is an iron bolt set in a concrete monument flush with the surface of the ground, which is located by the following witnesses: S E corner of Dean Bissell's house N 69° 30' W 132.7' feet. S W corner Professor Johnston's house N 81° 16' E 108.4' feet. 30" Hard Maple Tree S 8° 30' E 12.5' feet.

This line is exactly parallel with another line already established. The alternate interior angles between the two different North and South points being 0° 43' 30" (See Plate 1).

In making the observations for Azimuth, Ursa Minorus, Paloris was used. This is a star of the second magnitude which means it is very bright and easily seen with the naked eye. It is a circumpolar star and has a very small orbit being very close to the pole and is the brightest of all the stars in this constellation. This is the star most generally used in determining Azimuth and the "NAUTICAL ALMANAC" gives complete tables necessary to the computing its position in the heavens at any time.

To get the Azimuth of a line on the earth we must get the true Azimuth from observation on some star and by means of a transit project it onto the earth. The true Azimuth of Polaris can be computed for any time of the 24 hours.

From the "NAUTICAL ALMANAC" we first find the RIGHT ASCENSION of the mean sun at Greenwich, this must now be corrected for M. A. C. This correction amounts to 55.52 seconds because M. A. C. is on the 84°30' meridian of longitude and Greenwich is on the zero meridian. This correction is obtained by multiplying the variation per hour of the sun's right ascension by the number of degrees of longitude between M. A. C. and Greenwich expressed in hours - 15° of longitude being equal to one hour of time. This correction is added to the right ascension for Greenwich because we are West of Greenwich which gives us the sun's right ascension for mean noon at M. A. C.

The right ascension of Polaris for the day of observation is then obtained from the table, no correction being used as they are very small, being decimals of a second and would make no difference in the final result. Subtract the Right Ascension of Polaris from the Right Ascension of the Sun which gives the Sidereal Interval. As the table for Azimuths of Polaris at any hour angle and degree of latitude is in Solar time, this Sidereal Interval must be changed into Solar time.

Now choose any convenient time for making

the observation in mean standard time, and as M.A.C. is east of the 90th Meridian, the time interval must be added which for 84°30' is 22 minutes. Now add the mean Solar time for observation as corrected, to the Solor interval obtained above and we have the hour angle of Polaris, the chosen time. From the table of Azimuths already referred to, the Azimuths can be readily obtained.

AZIMUTH.

In making the observations for Azimuth, the following method was used: The transit was set up directly over the center of the south point of the line already mentioned - the plates leveled up, the instrument being set very firmly in the ground. This is very essential for in making the observation, any little jar however small may cause the instrument to go out of adjustment, thus causing an error in the results obtained. The index error on the vertical arc, if any, is very important and should be known and allowances made for it. By means of a flashlight the north point of the line whose Azimuth we were determining, was located and the vertical cross-hair set on it, the plates being set at zero.

The lower plate was now clamped tightly and the upper plate loosened so as to be moved with the tangent screw as the time of observation approached. The star was brought into the field of the telescope, and by means of the tangent screw, the observer kept the vertical cross-hair directly on the star, - his assistant calling out the seconds and giving a tip at the exact time. The reading on the vernier should now check the Azimuth as computed from the tables in in the Almanac for the hour angle assumed. The n to obtain the Azimuth of the assumed line, this reading

will be the number of degrees or minutes from true North. Turn this off, thus obtaining true North, and then the Azimuth of the line in question can be readily obtained by reading the angle between the lines.

LATITUDE.

In making the observation for Latitude, all the above precautions of set-up of instrument and technic of observation should be followed. The compiling and computing of the necessary data is also somewhat similiar.

The Right Ascension of the mean sun at Greenwich being taken from the table, and this corrected for M. A. C. The Right Ascension of Polaris is then obtained for the day of observation and if the observation is made at culmination as was done in the work for this Thesis, the Right Ascension of Polaris is subtracted from the corrected Right Ascension of the mean sun to which has been added 12 hours for lower Culmination. For upper Culmination, the two Right Ascensions are added.

The result is then changed to mean Solar time and then reduced to mean standard time for M.A.C. by subtracting the correction as above. This result gives the exact time to observe.

The Declination of Polaris is then obtained for that Right Ascension from the table, and as lower Culmination was used, this Declination is subtracted from 90° and added to the observed reading on the vertical arc. The result is the exact latitude of the place, i.e. M. A. C.

LONGITUDE

In obtaining longitude it is imperative that the time be exact. The precision of the results depends entirely on the correctness of the chronometer.

As we received our correct time from Arlington at nine o'clock, we chose stars for the observation which transited very close to nine o'clock standard time. Spica, and 1 of the constellation Virgo were used.

The time of transit of these stars being computed from the "NAUTICAL ALMANAC" in the same manner as for Polaris. This must be expressed in mean Solor time for M. A. C.

The transit was set up at an intermediate point on the meridian, and the exact standard time of transit taken. The difference between the observed standard time and the Solar time of transit gives the difference in longitude between the 90^{o} meridian and M. A. C. in minutes of time. The exact longitude of M. A. C. was then found by reducing this difference to degrees and subtracting it from 90^{o}.

AZIMUTH (SAMPLE COMPUTATIONS)

For May 22, 1922

Right Ascension mean Sun at Greenwich	3^h	57^m	19.08^o
Correction for M. A. C.			55.52
Right Ascension mean Sun at M. A. C.	3^h	58^m	14.6^o
Right Ascension of Polaris	1	32	30.46
Sidereal Interval	2	25	44.14
Correction Sidereal Time to Solar			24
Time of observation is 9:30 Standard Time	2^h	25^m	$20.^s$
$9{:}30 - 22 = 9{:}25^m$	9	52	
	12^h	17^m	20^s

Azimuth of Polaris at M. A. C. for an hour angle of 12^h 17^m 20^s= 6.5' East of North

Angle read on Plate 6.5' East of North

LATITUDE (SAMPLE COMPUTATIONS)

Observation on May 22,1922

Right Ascension mean Sun at Greenwich	3^h	57^m	19.08^s
Correction			55.52
Right Ascension mean Sun at M. A. C.	3	58	14.60
Right Ascension of Polaris M. A. C.	1	32	30.46
Add 12 hours for lown culmination	12		
	13^h	32^m	30.46^s
	3	58	14.16
Sidereal Interval	9	34	15.86
Correction Sidereal to Solar		1	34.04
Solar Interval	9	32	41.82
Difference between M. A. C. and Standard		22	1.38
Mean Solar Time of Transit at M. A. C.	9^h	10^m	40.44
	90^o		
Declination of Polaris May 22	88^o	53'	6.74
	1^o	6'	53.26
Observed Angle on Transit	41	37'	
Latitude of M. A. C.	42^o	43'	53'

LONGITUDE (SAMPLE COMPUTATIONS)

June 12, 1922

Spica Declination -10° 45' 26.57"

Right Ascension of mean Sun at Greenwich June 12	5^h	20^m	6.76^s
Correction			55.52
Right Ascension of mean Sun at M. A. C.	5^h	21^m	2.28^s
Right Ascension of Spica at Washington June 12	13^h	21^m	7.13^s
	5	21	2.28
Sidereal Interval at M. A. C.	8^h	0^m	4.85^s
Sidereal to Solar		1	18.64
Solar Time of Transit	7^h	58^m	46.21^s
Watch Time of Transit	7^h	37^m	56^s
(Correction from Arlington at 9:00 P.M. Standard Time 1^m 13^s fast)		1	13
Standard Time of Transit	7^h	36^m	43^s
	7^h	58^m	46^s
	7^h	36^m	43^s
Difference in Longitude between M. A. C. and Madison		22^m	3^s
	90°	00°	00
	5	30'	45
22^m 3^s $=-5^{\circ}$ 30' 45"	84°	29'	15" Longitude M. A. C.

RESULTS OF OBSERVATIONS FOR AZIMUTH

Time of Observation (Standard Time)	Azimuth of Polaris 0°(Expressed in Minutes)	Azimuth of Time 0° Expressed in Minutes
May 22 - 8:30	16.5' W	0'
" " - 9:30	6.5' E	0'
May 23 - 8:30	15.'0 W	.5' E
" " - 9:30	8.'0 E	.0'
May 26 - 8:30	10.5' W	.0'
" " - 9:30	13.0' E	1.0' W
May 27 - 8:30	9.0' W	0'
" " - 9:30	14.5 E	0'
May 28 - 8:30	7.5' W	0'
" " - 9:30	15.5' E	0'
May 29 - 9:00	5.5' E	.5 W
" " - 9:30	16.0' E	.5 W
May 30 - 9:00	7.0' E	0
" " - 9:30	17.0' E	0
June 1 - 9:00	10.5' E	0
" " - 9:30	23.0' E	0
June 6 - 9:00	15.0' E	0
" " - 9:30	28.5' E	1.0' E
June 7 - 9:00	16.5 E	0
" " - 9:30	29.0' E	0

RESULTS OF OBSERVATION FOR LATITUDE

Lower Culmination on Polaris on:	Correction to be added	Observed Angle	Latitude of M. A. C.
May 22	1° 6' 53'	41° 37'	42° 43' 53"
May 23	1° 6' 53'	41° 37'	42 43 53
May 26	1° 6' 54"	41° 37'	42 43 54
May 27	1° 6' 54"	41° 37	42 43 54
May 28	1° 6' 54"	41° 37	42 43 54
May 29	1° 6' 55"	41° 37	42 43 55
May 30	1° 6' 55'	41° 37	42 43 55
June 1	1° 6' 55'	41° 37	42 43 55
June 6	1° 6' 57'	41° 37	42 43 57
June 7	1° 6' 57'	41° 37	42 43 57

RESULTS

RESULTS OF OBSERVATIONS FOR LONGITUDE

From Observations on Spica (See Sample Computations on Longitude)

Longitude M. A. C. $84^{\circ}\ 29'\ 15''$

From Observations on 1 Virgins.

Solar Time of Transit at M. A. C.	8^h	50^m	55
Standard Time of Transit at "	8^h	28	53
		22^m	2^s

$22^m\ 2^s$ of Solar Time is equal to $5^{\circ}\ 30'$

90°	00	00
5°	$30'$	$00'$
84°	$30'$	Longitude of M. A. C.

B I B L I O G R A P H Y

1. Text-Book on Practical Astronomy - By Hosmer.

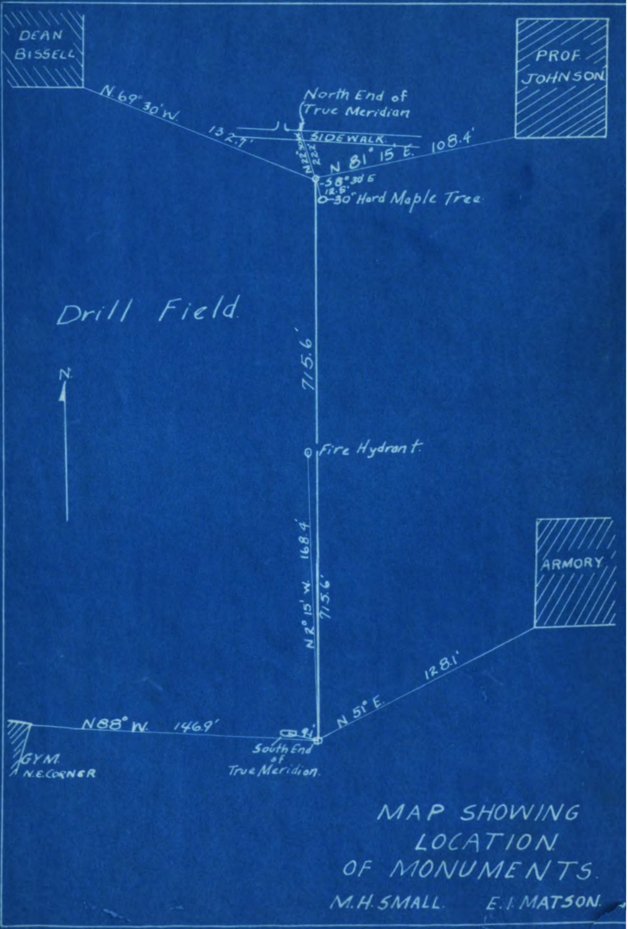
2. Determination of Time, Longitude, Latitude, and Azimuth - Department of Commerce, U. S. Coast and Geodetic Survey - By Wm. Bowie.

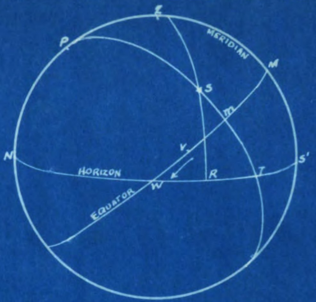
3. Geodetic Survey - By Cory.

4. General Instructions for Field Work - U. S. Coast and Geodetic Survey.

5. Geodesy - Clarke.

PLATE No. 1.


DEAN BISSELL
PROF JOHNSON
N. 69° 30' W.
132.7'
North End of True Meridian
SIDEWALK
N 81° 15' E.
108.4'
30" Hard Maple Tree
Drill Field
N.
715.6'
Fire Hydrant
N 2° 15' W. 168.4'
715.6'
ARMORY
N 51° E.
128.1'
N 88° W.
146.9'
South End of True Meridian
GYM. N.E. CORNER
MAP SHOWING LOCATION OF MONUMENTS
M.H. SMALL.
E.I. MATSON.



THE SPHERE SEEN FROM THE OUTSIDE

THE SPHERE PROJECTED ONTO THE PLANE OF THE EQUATOR

The star S has the altitude RS, azimuth S'R, hour angle Mm, right ascension Vm, and declination mS; the meridian is ZMS'.

M.H. SMALL. E.I. MATSON.