Course material from Geology 11 - Mapping - 2. 1945-1954

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[s.l.]: [s.n.], 1945-1954

GEOLOGY 11
Final Examination
May 12, 1955

Total points = 67

1. (5) A magnetic reading has been taken at N.18°E.

   The declination = 5°W.

   True bearing = ____________.

2. (5) (Underscore correct word)

   a. A magnetic bearing is taken at latitude 40°N., longitude 70°W. The declination at this point is 13°W. If a bearing is taken at latitude 50°N., longitude 70°W., the declination will be smaller / larger.

   b. If a bearing is now taken at latitude 40°N., longitude 75°W., the declination will be smaller / larger than at latitude 40°N., longitude 70°W.

3. (1) The isogonic chart for 1940 can / cannot be used for obtaining the correct declination at a point in 1955.

4. (4) The distance between two points is to be determined by pacing. Give two ways of correcting for the slope of the ground.

   1.

   2.

5. (4) Give <u>in proper succession</u> the steps necessary in adjusting the striding level of the telescopic alidade.

6. (3) a. In order to determine slope distance from true distance, it is necessary to know:

b. The formula used in calculating slope distance is

____.

7. (2) A shot is being taken with the telescopic alidade. The distance is too great for a half hair reading. The more accurate method to use is the(Stebinger drun,quarter-hair shot.) (Underline correct answer)

8. (5) Stebinger drum problem

a. Top hair on top of 12' rod.
Middle hair below visible portion of rod.
Stebinger drum read 0.27.

b. Middle hair on 2' division.
Stebinger drum reads 0.49.
Instrument is level.

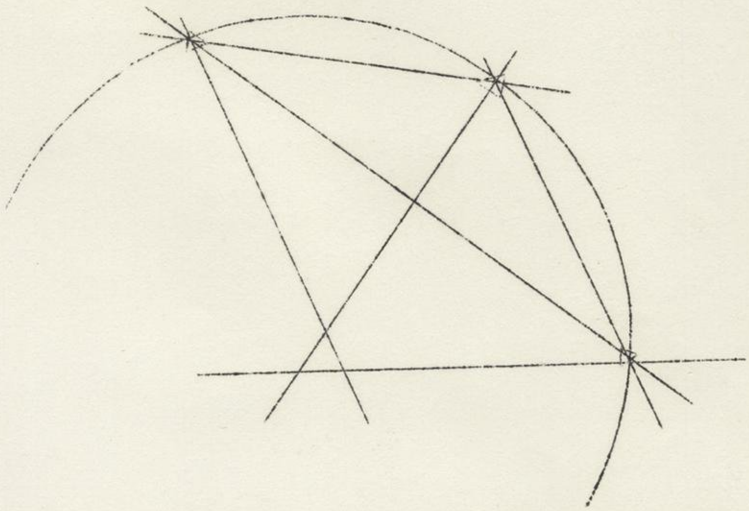
8. Continued

c. Stebinger drum reads 0.71.
Middle hair at 3.4'.
Height of instrument is 3.5' above station which is occupied.

Stadia distance to rod is ______________.

Difference in elevation is ______________.

9. (3) Locate the point sought.



10. (3) List three methods of tying in known elevation to a barometer survey.

1.

2.

3.

11. (5) In running a barometer survey with an instrument calibrated at 50^{o}F. this following information is obtained:

Sta. 1	Sta. 2
Temp. = 67^{o}F.	Temp. = 69^{o}F.
Barometer reads 317'.	Barometer reads 439'.

The true difference in the elevations of sta. 1 and sta. 2 is

______________________.

12. (3) List in order the steps involved in determining the difference of elevation by the step method. Assume that the point shot is lower than the instrument station.

13. (2) a. In mapping an area, selection of too large a scale is wrong because:

b. Selection of too small a scale is wrong because:

14. (2) You are working in an area of local magnetic attractions. What method of telescopic alidade traversing will you use?

15. (3) a. In space below draw a diagram to illustrate what is meant by the turning point method of traversing.

(2) b. How could you check periodically during the traverse to make sure no serious errors have been made?

16. (2) The (vertical angle scale, Stebinger drum) method is more accurate for measuring vertical angles.

17. (3) Draw and label a diagram showing the system of land division of the U. S. Land Survey.

18. (10) Opposite each item put a check in the appropriate column.

Item	More important in small scale mapping	More important in large scale mapping
1. Holding rod precisely vertical	______	______
2. Resection	______	______
3. Setting point on table directly over point on ground.	______	______
4. Use of large plane table	______	______
5. Use of cover sheets	______	______
6. Correction for paper distortion	______	______
7. Establishing triangulation net	______	______
8. Special care in pricking in points	______	______
9. (f + c) correction	______	______
10. Stebinger drum methods	______	______
11. Level shots	______	______
12. Taping distances	______	______
13. Use of high quality plane table paper	______	______
14. Large number of shots per unit of area	______	______
15. Preliminary reconnaissance	______	______
16. Accurate determination of stadia interval	______	______
17. Adequate signal system	______	______
18. Detaile notes by rodman	______	______
19. Correction for curvature of the earth	______	______
20. Use of barometer, hand level, and brunton	______	______

GEOLOGY 11 -- MAPPING

April 13, 1954

First half final exam (3 credits)
STOP-LOOK-READ. Write on 20 questions only and please indicate on cover which you left out. Be brief and to the point showing computations. Use diagrams.

(1) You must traverse along a railroad with telescopic alidade. Explain trouble you may anticipate and how to avoid it including change in notes.
(2) What is a SIDESHOT, how computed, what for, danger in keeping notes.(tel. alidade)
(3) You have no tables or standard time. How can you tell when Polaris is true north or allow how long it will be before it is. Diagram.
(4) You have a Brunton compass and are informed that the magnetic declination is 10 deg. East. Diagram relation of dial to line of sight when set to read true directions.
(5) You are to survey section 18 of a township. Diagram where it is in township and explain what distances between corners may be abnormal. Diagram.

(6) Diagram a normal U.S. section divided into 40 acre tracts with their legal descriptions.
(7) In keeping notes for telescopic alidade traverse explain why rule for algebraic signs of backsights is different than that of foresights. Diagram.
(8) During a traverse with telescopic alidade you catch sight from a table location of a distant point already on your table. What should be done? (Rodman cannot be sent)
(9) If you are to use air photography in finishing your map, list three kinds of locations which should be made by sideshots with telescopic alidade.
(10) You neglected to check the stadia interval constant of your telescopic alidade and assumed it to be 100. Later you found it really is 102. What effect on elevations obtained by (a) vertical angles, (b) Beaman arc, (c) level shots?
(11) Referring to 10 state effect (a) on scale of map, (b) on upper or lower wire shots.
(12) Full interval = 10.0 ft. Telescope level, Upper wire reads 11.0 ft. Net difference instrument to bottom of rod, up or down from table. Diagram.
(13) Full interval = 7.0 ft. Middle wire on 14.0 ft. Angle reading 32-52 stadia conversion factor = 5.00. Net difference to bottom of rod, up or down. Diagram.
(14) Half interval = 12.0 ft. Lower wire reads 13.0 ft. Telescope level. Net difference to bottom of rod, up or down from table. Diagram.
(15) You are to measure a line somewhat over 1500 feet long using 100 foot steel tape. You have 11 pins. How keep track of correct number of tape lengths and excess over last one. Diagram.
(16) Diagram two different ways in which ground directions are recorded with different types of compasses in common use on land.
(17) You have a plane table with built in compass and wish to use telescopic alidade. (a) (b) What two courses will avoid an error. (c) State its cause.
(18) If you could walk along a contour line always in same direction give rule for position of higher land.
(19) What is the STEP METHOD with telescopic alidade. What limits its use?
(20) Telescopic alidade full' interval = 5.0 ft. Beaman arc = 40 Middle wire on 8.2 ft. Net difference to bottom of rod, up or down from table. Diagram.
(21) You are running a compass traverse and note the following readings (azimuth): Sta. 1 to 2 = 220; 2 to 1 = 40; 2 to 3 = 100; 3 to 2 = 260. Explain. Diagram.
(22) (a) What is the horizontal correction factor with telescopic alidade and (b) where are the correct horizontal distances used?
(23) Explain the basic idea of finding difference of elevation on overlapping vertical air photographs. Diagram this principle not details of formula.

(24) What are two general methods of locating contours in field.
(25) Define: (a) stereoscope, (b) parallax, (c) principal point.

FOLLOWING FOR THOSE WHO MISSED ONE OR MORE SHORT QUIZZES. Low grades are not misses!

(a) Diagram system of base lines and principal meridians of U.S. Land Survey showing numbering of townships and ranges.
(b) One mile on photo vertical measures 2.0 inches, camera focal length = 6 in. Elevation at which taken?
(c) You are retracing an old survey and find compass declination is not that of original survey. Why?

GEOLOGY 11--MAPPING.

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Second half final examination, 3 credits.
Write on 20 questions only and please show on cover which you left out.

(1) In a telescopic alidade traverse of a railroad at 6 setups the height of table above the rod points was omitted. Effect on final elevation, high or low? 1/4 = 9.0

(2) A 3600 ft. shot was made with tel. alidade. Interval reading? Probable error in reading rod was 0.1 ft. Probable error in elevation difference? Plus or minus? Stadia conversion factor = 10.00 .1 x 4 x 10. = 4.

(3) Explain what limits accuracy of elevations obtained from intersection survey with telescopic alidade.

(4) Diagram the effect of a hill on course of a section line shown near border of a "vertical" air photograph.

(5) Diagram two ways in which directions can be read with Brunton compass, mentioning why each is used.

(6) Diagram two ways in which you use Brunton compass to measure slopes.

(7) The net differences with angles and Beamans check well in a traverse yet both vertical and horizonal closure are poor. Explain.

(8) A telescopic alidade party neglected to plat true horizontal distances. State effect on (a) differences of elevation, (b) map scale, (c) horizontal closure.

(9) Why do telescopic alidade traverses in very rough country commonly show poor vertical closure compared to those over flat land?

(10) From your field experience compare advantages and disadvantages of Beaman arc compared to angle method for inclined shots.

(11) Under what conditions is a "vertical" air photograph a correct map of the land?

(12) Compare advantages and disadvantages of azimuth system of recording directions compared with other type of compass dial.

(13) Explain why the graduations and direction letters on a compass dial are not the same as those on the ground.

(14) What limits accuracy of determinations with hand level?

(15) Make a plan by which a union of three two-man parties with three barometers could carry out a "two base" barometric survey of their combined areas.

(16) State what limits accuracy of telescopic alidade survey in (a) differences of elevation, (b) accuracy of horizontal closure.

(17) You are given a topographic map of an area to use in examining its geology or other resources. State two ways in which you can test this map for accuracy.

(18) State the two things which must under no circumstances ever be omitted in legend of a map.

(19) The allowable vertical closure of a telescopic alidade traverse is not in direct proportion to its length. Explain why.

(20) State two major factors which affect accuracy of distance determination by pacing.

(21) You must measure on a slope with steel tape. Give two ways in which you can correct for the error due to slope.

(22) State why it is necessary to understand the U. S. Land Survey in making a map.

(23) Compute how far apart are 20 foot contours on a 4 degree slope (a) in feet, (b) in inches on map with scale 1/24000. One degree slope = 1.75 percent.

(24) What is limit to accuracy of elevation determination with barometer? 285'

(25) Explain method of finding a land corner by pacing with Brunton compass. Diagram how you set compass. .14+"

GEOLOGY 11
MAPPING

Calendar 1953-54

Text: Low, Planetable mapping. Purchase of other books is not advised. References are given to Lahee, Field Geology with pages in 1931 edition in ( ), also U.S. Army Technical Manual 5-230. Both are in library, also some copies of an old mimeographed outline, portions of which are currently ready for reissue. Keep your laboratory and field directions, for they add much to published material. Read up in advance of class meetings, for short quizzes will be given from time to time, either with or without notice. Note list of problems due each week. All problems must be originals, not copies, unless permission is given in advance. All must be either handed in directly to the instructor in charge or folded and put into box provided in room 211. If more than one sheet, use staples not paper clips. Paper on cloth must not be folded.

Feb.	9	Organization
	11	Barometer 195-206; Lahee; 426-432, 461-490 (436-467)
	16	Hand level Lahee 459-461 (406-409)
	18	Plane table 18-35; Problems 1, 2, 3
	23	Planetable, cont. 78-93
	25	Telescopic alidade 35-62; Problems 4, 5
Mar.	2	63-69, 73-78, 93-106, 207-216
	4	123-167, 221-229; Problems 6 or 8
	9	Air photographs 230-245; Lahee: 536-558; Tech. Man. 5-230; 74-99
	11	245-276; T.M. 5-230; 161-212; Problems 7, 8 or 16
	16	T.M. 5-230; 212-258
	18	Six weeks exam; Problems 8 or 16
	23	Review of exam
	25	Contour maps, etc. 167-194, 277-325
	30	U.S. Land Survey 1-17
Apr.	1	Distance, scales, etc. 69-73; Problems 9, 10 or 16
	6	Compass 217-220; Lahee: 420-426, 443-459, (426-436) (502-512)
	8	Review Problems 11 or 16
	13	First half final exam for 3 credits "What must be known before going into field."
	15	Briefing for trip. Deposit of $20.00 must be made by noon, April 16. Problems 12, 13, 16, (18, and 21 if possible)
	17-24	Trip to Devils Lake (exact dates subject to change)
	27	Review of trip
	29	Second half final exam for 3 credits, "What should have been learned in the field."

Assignments for 4 credits only. Meeting place to be announced. Read parts applicable to each day from at least one of the following references. Quizzes may be given with or without notice.

May 4 Review of examination
6 Radial line adjustment

11 Use of stereoscope (review parallax formula)
13 Adjustment of horizontal map from photographs - tilt problem, etc.

18 Mapping from vertical photos continued, making mosaics
20 Contouring methods--tilt cont.

25 Obliques.
27 Use of oblique photographs and trimetrogon method

June 1 Rectification of obliques, continued--ground photo method
3 Review

12 Final exam (4 credits) 3:50 P.M.

References:

Bagley, J. W., Aerophotography and aerosurveying, 1941
McCurdy, P. G., Manual of aerial photogrammetry, 1940
Pendleton, T. D., Map compilation from aerial photographs; U.S. Geol. Survey Bull. 788, pp. 379-479, 1928
Sharp, H. V., Photogrammetry, 1940
Smith, H. T. U., Aerial photographs and their applications, 1943
Talley, B. B., Engineering application of aerial and terrestrial photogrammetry, 1938
U.S. Coast and Geodetic Survey, Manual of coastal delineation from aerial photographs, 1947.
U. S. War Dept., Advanced map and aerial photograph reading. Basic field manual 21-26.
Field service pocketbook 21-35 - Sketching
Technical manual 5-230, Topographic drawing

Hand in original sketches with your final maps, including all construction diagrams. In accordance with U. W. rules, laboratory work for either 3 or 4 credits should not be accepted after 5 p.m. June 4. Late work may involve an "incomplete". All grades must be in by June 15.

Supplies needed: 2 or 3 sheets of cross section paper; Engineers Triangular scale; small protractor; pencils, 4-H and 6-H; ruby eraser; art gum eraser; 2 triangles, 6" or 8". (1 45°, 1 30°-60°); several sheets tracing paper 8½" x 11"; field note book; India ink; ruling pen; small lettering pen like crow quill with holder. Optional: Slide rule (simple); erasing shield.

GEOLOGY 11
MAPPING

Six weeks examination
STOP-LOOK-READ. Write on 20 questions only and please list on cover those you left out. Show computations and BE BRIEF omitting everything not called for.

(1) Explain two ways in which planetable can be oriented in the field.

(2) Diagram two methods of traverse survey with planetable.

(3) Diagram essential construction of hand level including field of view. Explain clearly.

(4) Lacking a known level line how can you find a level line to adjust hand level? Diagram.

(5) Explain the basic principle of correction of barometer readings by curve.

(6) How measure height of hill with hand level working alone? Diagram.

(7) Give three ways of giving scale of a map.

(8) Explain one practicable way of compensating for weather changes when using barometer alone and no known elevations can be reached except at start and end of day's route.

(9) Define: (a) "vertical air photo", (b) "principal point" of air photo.

(10) Define: (a) "parallax", (b) "plumb point" of air photo.

(11) Explain with diagram the physical cause of stereovision.

(12) Scale of map given as 1/126720. (a) How many miles to one inch?, (b) How many feet to one inch?

(13) Define: (a) "full interval", (b) "stadia constant".

(14) What are major advantages of planetable survey over map compiling from notes?

(15) Which distance, "slant" or "true horizontal" is found with planetable intersection survey?

(16) Explain difference between "apparent distance" and "slant distance".

(17) Why is there a "striding level" on telescopic alidade?

(18) (a) How is the striding level adjusted? Diagram (endwise adjustment only; (b) If cannot adjust, do what?

(19) First cross check reading 900; estimated correction -- 50 ft; second reading same point 920; Second correction? Elevation?

(20) You are to measure distance across a wide river using planetable and open sight alidade. You can cross only once and no recognizable point is present on far side. Do what?

(21) Accepting the fact that weather varies what really limits accuracy of barometer?

(22) In a certain area a television tower on top of a building is visible from many places; what advantage will it be to your map to locate it by planetable intersections? Explain briefly.

(23) A mile on a vertical air photo measures 6 inches. State fractional scale and feet to one inch.

(24) What weather instrument might be used to advantage in connection with a barometer? Survey. Why?

(25) State two major advantages of the barometer over other instruments.

GEOLOGY 11
MAPPING

Problem 1 (edition 1950)

Object: Theory, construction, and use of aneroid barometer.

Material: Sheet of cross section paper, pencil, eraser.

Method.

Theory of Barometer. A small difference in atmospheric pressure, dP is equal to weight of a corresponding unit column of air of height, dh. Air has a density of ρ and a weight of $\rho . g$, where g is the acceleration of gravity. Hence $dP = -\rho . g . dh$ where the minus sign indicates an inverse relationship. Now the value of density may be expressed by the equation $\rho = \frac{P.m}{R.T}$ where P = atmospheric pressure, m = gram molecular weight of air (28.9), R = universal gas constant, and T = absolute temperature of air. By substitution: $dP = -\frac{P.m.g.dh}{R.T}$

Solving for dh: $dh = -\frac{R.T.dP}{m.g.P}$ where R and g are constants.

Now for relatively small differences of elevation the above direct relationship holds. The error is less than 5 feet in a height of 500 feet. But for a larger range it is necessary to resort to the integral calculus and to sum up the values of difference of elevation for a given difference of pressure. Then it appears that : $h_2 - h_1 =$

$-\frac{R.T}{m.g} \log e \frac{P2}{P_1}$, where h_2 and h_1 are elevations of two stations, and P_2 and P_1 the respective pressures observed at each. Variables besides pressure which should be determined are absolute temperature and humidity of the atmosphere. As noted above the gram molecular weight of air is 28.9 whereas that of water vapor is 18. Neglect of the factor of amount of water vapor in the air (relative humidity) causes an appreciable error. Temperature determination is more difficult for there is no way to get the average temperature of all the air above a station. Usually the average of ground readings at two stations is used.

Types of barometers. The mercury barometer is out of the question for field work and the same applies to certain new barometers where electric heat control is needed. Ordinary aneroid barometers measure pressure by change in shape of a metal case from which the air has been partially exhausted. In the old style models movement of the side of this vessel is magnified on a scale by means of a moving pointer which cannot be locked. The Paulin barometer gives a reading by measuring the pressure of a spring when the index pointer shows that the lid of the vessel has been brought back to standard position. This arrangement has the advantages of removing friction in bearings and in being locked between stations. Both types have an elevation scale which is not one of equal parts as demonstrated above. A few instruments have a mechanical means of compensation for the logarithmic relationship. All instruments are supposed to be compensated for their own temperature and have an elevation scale corrected to a certain temperature of the air.

Field Use. If the temperature and humidity of the atmosphere were fixed quantities barometric surveying would be ideally simple. Unfortunately they are not and besides this, the movement of air causes pressure change, especially when that movement is vertical. On a windy day there are marked horizontal differences in atmospheric pressure at different localities as well as pressure changes due to motion. Although readings may be partially compensated for both temperature and humidity changes the procedure is laborious, and error increases rapidly with distance between stations What is the easiest and best method is that discovered by Gilbert (Gilbert, G.K., New Method of Measuring Heighths by means of the Barometer: U.S. Geol. Survey 2nd Ann Rept., pp. 406-566, 1882) Procedure is illustrated by the diagram. Three instruments and observers are needed so that the method is expensive. Watches must be set to same time and readings made simultaneously. But by means of relative proportion both temperature and humidity changes are then cancelled out. Recording barographs might be substituted for the base stations but in general these are not accurate enough. (Fig. 1) (on following page)

Some have tried a single base station with either observer or recording barograph but horizontal changes in pressure, temperature, and humidity are not easily eliminated in this way. Lahee's method (Lahee, F.H., The barometric method of geological surveyings ---: Economic Geology, 15: 150-169, 1921 ; Field geology, 467-489, 1941) depends upon checking the field readings against known elevations. Although most barometers have an elevation scale which can be set to read correctly at the start of a day or any other time, it is best not to do this. Keep the 0 of the scale set constantly to a given point and apply a correction to all readings. Times of observations must be recorded and as many points of known elevation read at during the day as is possible including points established on previous days surveys. Comparison of readings with the facts are then computed. Although Lahee did otherwise, it seems best to give a minus sign to all corrections which must be subtracted from the field reading of the barometer to give true elevations and a plus sign to corrections which must be added. When the days work is completed a curve is plotted (see Figs) using time in one direction and corrections in the other. The drawing of this curve through the fixed points, commonly called straight checks, is a matter of judgment and is the real limit to accuracy of results. Obviously, the shorter the intervals between straight checks the better the results. However, experience demonstrates that atmospheric changes often occur in waves thus making results uncertain. Lahee also improved his method by taking readings on revisiting as many of the previously unknown stations as possible. Two, three, or more readings at different times then are available for the same point. They must be so corrected as to yield the same final elevation every time since there cannot be more than one elevation for the same point. These readings are commonly called cross checks and give the net change of error due to atmospheric changes between the different times of visit, although not the absolute value of the corrections. Use these readings to aid in shaping the curve between straight checks. Corrections obtained by straight checks must never be changed. Choose one point of a cross check where you conclude that the preliminary drawing of the curve of corrections must certainly be essentially right. Read the indicated correction for that time, then by taking the difference between the first cross check reading and the second compute what the correction must be at the time of the second reading to yield the same final elevation both times.

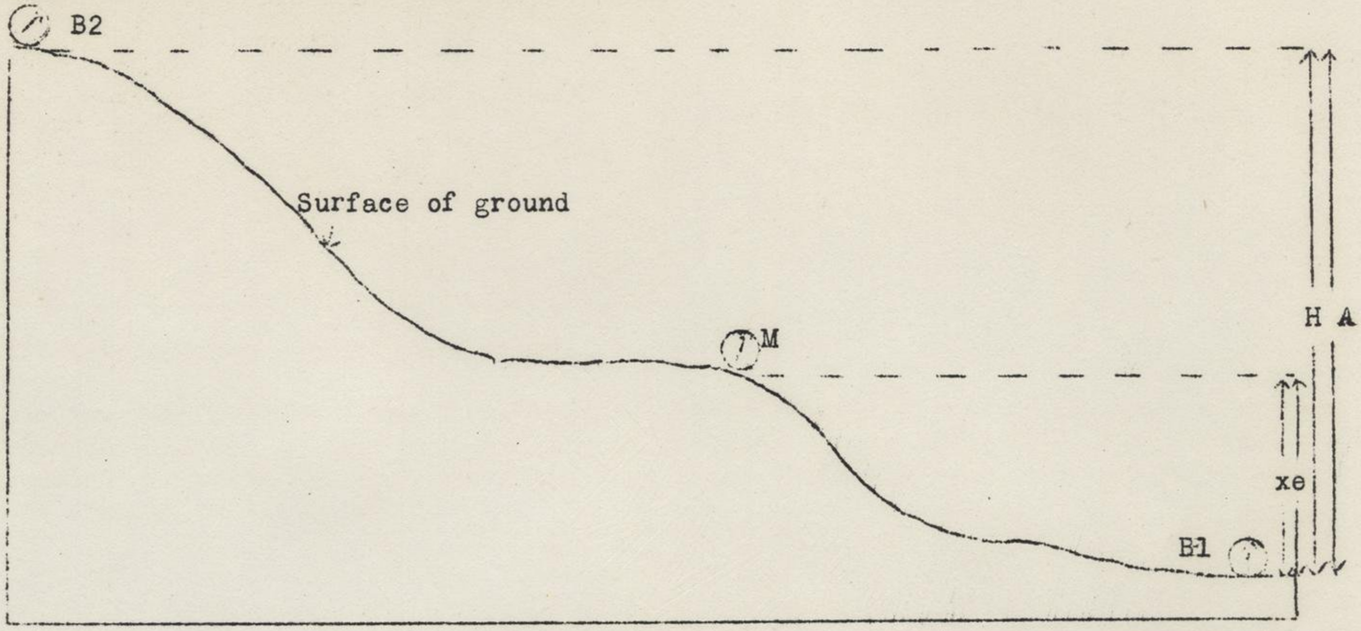


Figure 1

Gilbert's two base method of barometric surveying. B_1, B_2 = barometers at two base stations. M = moving barometer at station with unknown elevation. A = difference of elevation of B_1 and B_2 found by leveling. H = difference of elevation of two base stations from difference between simultaneous barometric readings at both. e = difference of simultaneous barometric readings at lower base station and at unknown point. x = true difference of elevation of unknown point above lower base. By simple proportion A:H:: x:e or expressed in another way, H/A = e/x Hence x=A.e/H which can easily be solved with ordinary slide rule. No other corrections are needed if the bases are properly spaced and not too far apart horizontally. Example: H = 1000', A = 1100', e = 650', x = 715'. Add sea level elevation of lower base if known. Others who have unknowingly hit upon the same method in recent years have used a much more complicated method of notes and computations.

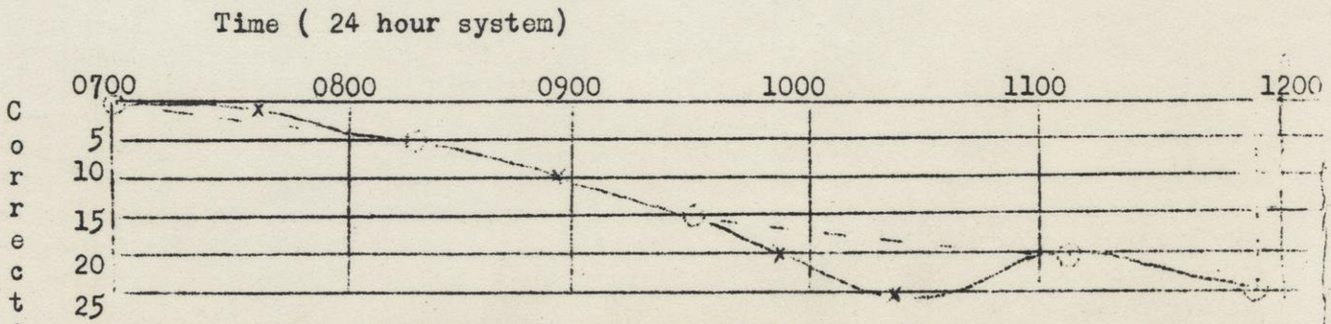


Figure 2 Lahee's method of correction of barometric readings. See next page for data. Straight checks enclosed by circles; cross checks shown by x's. Curve drawn from straight checks only is broken; revised curve after considering cross checks is solid. Study carefully to see just how these curves were constructed. Here minus corrections were shown below 0 line; this is not essential although it is customary.

Station	time	Reading	Correction	Elevation
1	0700	800	0	800
2	0735	835		
3	0815	925	-5	920
4	0850	1000		
5	0930	945	-15	930
2	0950	855		
4	1020	1015		
6	1105	870	-20	850
7	1155	935	-25	910

The are the notes from which curve of Figure 2 was constructed.

Elevations given are straight checks.

Readings at Stations 2 and 4 are cross checks. Evidently the second reading at each must show 20 and 15 feet respectively of increase in the value of the correction required to yield the same elevation each time. Note how each such net difference was applied to the curve.

the second compute what the correction has to be at second visit to give same elevation Plat this correction at proper time and alter the curve to fit. If this fit seems to introduce an unreasonable irregularity into the curve try altering the first point of the check. During and after a thunderstorm air pressure is greatly disturbed and the down-rush of cold upper air may cause part of the curve to be almost vertical. Readings at such times are worthless. The graphic method of correcting from cross checks used by Lahee is all right but is more difficult to learn than this arithmetic method. Lahees method compensates only partially for the scale errors introduced by changes in temperature and humidity. The element of judgment in using cross checks limits accuracy of results.

Temperature and humidity corrections. Under conditions of either extreme temperature, extreme humidity, or very high local relief or a combination of more than one of these corrections for both temperature and relative humidity are desirable. Temperature of air changes the value of the foot divisions on the scale by about 2/10% for every degree Fahrenheit that the air temperature is above or below that for which the instrument was calibrated. Paulin instruments are supposed to be correct at 10° C or 50° F., most others at about 70° F. Various schemes have been suggested for correcting readings for temperature of which the simplest is to correct the apparent differences of elevation between each pair of successive readings by the mean of the two temperature readings after subtracting from each the calibration temperature. The result of this temperature multiplied by 0.002 is either added to or subtracted from the apparent elevation, depending upon whether the air temperature was above or below the calibration value. Then the readings of the instrument after the first are adjusted to agree with the revised differences. See below. Since the effect of revision is carried forward a single mistake is perpetuated. After checking computations, a curve is drawn from the revised readings and elevations computed for other times than those at which checks were obtained. A somewhat similar procedure could be used for humidity adjustment which has the same effect. Since the gram molecular weight of water vapor is only 6/10 that of air it is evident that a correction factor of (1 + 0.6 specific humidity) must be applied.

Example of temperature corrections. In Hill's method the idea is to compute the apparent difference of elevation for each pair of stations, giving it the sign which it needs to give the second elevation when applied to the first. Then correct this difference for the average temperature then prevailing. Add correction if temperature is above 50F. (for Paulins) and subtract if below. Note that in applying this correction you pay no attention to the algebraic sign of the apparent difference. Because this apparent difference is used to obtain the correction, the result can never reverse the sign. Keep the same sign for both apparent and corrected differences figuring them to single feet. Study the following example.

Temperature correction = apparent difference x .002 x (average temperature F -50 F)

Hill's method is published by the makers of Paulin barometers.

Station	Time	Bar. Feet	Temp. F.	Av. Temp. F.	Av.Temp. - 50	Apparent dif. feet + or -	Temp. Corr + or -	Corr. Diff + or -	Adj. Bar. Feet
1	0750	1540	70						1540
				71	21	190	8	198	
2	0805	1730	72						1738
				74	24	10	0	10	
2	0905	1740	76						1748
				77	27	260	14	274	
3	0915	1480	78						1474
				79	29	75	4	79	
1	0955	1555	80						1555

Then draw a new curve using the adjusted figures instead of original readings. Remember that these revised elevations are no more correct than were the original readings, namely to nearest five feet!

Specific humidity, q, is defined as density of water vapor in a mixture divided by sum of density of dry air plus density of water vapor as above. $q = \frac{\rho w}{\rho d + \rho w}$

Humidity determinations necessitate carrying wet and dry bulb thermometers or some equivalent instrument. The making of this correction will increase apparent differences of elevation when humidity is high. Apparently few persons have ever attempted this very important correction. Computation is simplified by using tables of equivalent temperatures, that is temperatures which dry air would have to possess to be at the actual density. Correction would then be made in the same way as for temperature only.

Study the accompanying examples carefully. Then draw the curves from following data making both on some paper. Show curve derived from straight checks only by broken line; that from straight checks plus cross checks with solid line. Compute elevations of all the unknown stations and compare differences between results based on each curve. Return data sheets filled out. CAUTION: Do not use too fine a scale for corrections; one space for 5 feet is enough. Also do no show corrected elevations any closer than the readings in the field. ~~Whe re readings~~ were taken only to nearest 5 feet final elevations should be rounded off in the same way. Experience demonstrates that even with frequent checks and good instruments few barometric elevations are correct to the nearest foot; about 5 feet above or below the true elevation is close to actual results. Observations of the same point on several days are needed to obtain positive results.

GEOLOGY 11 Problem 1 Data sheet A

The following are actual barometric readings taken in northeastern Wisconsin. At several times during this day points of known elevations were visited and the departure of the barometer reading from these was recorded. These are often called "straight checks". If a number must be subtracted from the reading of the barometer it is called a minus quantity or minus correction; if you had to add to the instrument reading to get the true result this would be a plus correction. It is customary to place minus corrections below the line of 0 correction and plus corrections above that line. This is not esential. Times are given in the 24 hour system here. Lay out hours horizontally remembering that they are divided into 60 minutes and so do not use dedimal divisions of hours. Next lay out your vertical scale of CORRECTIONS, not readings. Do Not exaggerate this too much. Since field readings were to nearest five feet do not try to compute final results closer than that. If you use one division on the cross section paper for 5 feet it will be easy to do this. Your final results are, after all, only estimates of the real figures. Draw the curve of probable correction values between straight checks as smooth as possible. Compute the corrections for the times of observations. Record in proper column and compute the final elevations in proper column TO NEAREST FIVE FEET ONLY.

Location	Check	Time	Bar. read	Correction	Bar. Elev.	Known Elev.
Gillett	o	0850	800		-----	801
Suring	o	1000	820		-----	803
1		1040	930			
2		1050	880			
3		1053	820			
4		1105	870			
5		1110	850			
6		1115	830			
7		1130	870			
8		1235	850			
9		1345	910			
10		1400	925			
11		1408	940			
12		1410	950			
13		1415	960			
14		1425	1010			
15		1445	950			
16		1515	920			
17		1525	920			
18		1535	930			
19		1555	950			
Breed.	o	1600	960		-----	879
20		1603	975			
21		1610	950			
22		1620	920			
23		1640	940			
24		1655	955			
25		1700	970			
26		1702	965			
R.R. crossing	o	1707	950		-----	868
27		1710	960			
28		1730	975			
Suring	o	1755	880		-----	803

o = straight check NEATNESS COUNTS!

GEOLOGY 11 Problem 1 Data sheet B

These are the same readings as on sheetA with the added information that several locations were read more than once during the day. It is obvious that any location can have only one elevation. Hence you mus^t adjust your curve to bring this about without introducint any violent changes or irregularities if it is possible. The DIFFERENCE of the two readins must then be the difference of the two correction values. Be sure you apply this difference correctly. But you will wonder which of the t^wo original readings is correct. In some instances one of the two readings or cross checks is just before or just after a straight check. Obviously the correction thus is fixed and the other correction is made to agree. This is the case with Station 4 here. With the other cross checks the matter is not so simple. Refer to your first curve and adjust it without doing anything which looks improbable. Change of atmospheric pressure is most rapid during the heat of the day hence the first reading is generally preferrable. Sometimes it is necessary to change both ends of the cross check. Remember - only one elevation for the same place and all elevation to nearest 5 feet only!

Location	Check	Time	Bar. read.	Correction	Bar. Elev.	True Elev.
Gillett	o	0850	800		-----	801
Suring	o	1000	820		-----	803
1		1040	930			
2		1050	880			
3		1053	820			
4	x	1105	870			
5		1110	850			
6		1115	830			
7	x	1130	870			
8	x	1235	850			
8	x	1330	900			
9		1345	910			
10	x	1400	925			
11		1408	940			
12		1410	950			
13		1415	960			
14		1425	1010			
7	x	1428	930			
15		1445	950			
10	x	1455	940			
16		1515	920			
17		1525	920			
18		1535	930			
19		1555	950			
Breed	o	1600	960		-----	879
20		1603	975			
21		1610	950			
22		1620	920			
23		1640	940			
24		1655	955			
25		1700	970			
26		1702	965			
R R crossing	o	1707	950		-----	868
27		1710	960			
28		1730	975			
4	x	1740	940			
Suring	o	1755	880		-----	803

Compute as before and fill in blanks. Compare with results without the cross checks. What is maximum difference?

GEOLOGY 11

MAPPING

Problem 2, edition, 1941

Object: Inspection and use of aneroid barometers.

Material: Old style aneroid barometer and Paulin aneroid barometer, pencil.

Method: Look over the two instruments. Try the old style aneroid by reading position of the hand when held first in a horizontal position and second in a vertical position. If the instrument is working properly there should be a difference. When you use the instrument always use the same position. When reading aneroids do not bend over or lay them on the ground but always hold at same level above the ground wherever it seems most convenient to read. Now tap the instrument and see how this affects the needle. Try to learn just how hard taps are needed for your particular aneroid as they differ. Then try turning the outer or foot scale by moving the rim. This is done in order to set the instrument for different weather conditions. If the aneroid you have fails to respond properly to tapping or turning return it for adjustment. PLEASE DO NOT TAKE APART YOURSELF either now or in field. That is a shop job with proper tools. Study the foot scale and see how it is numbered. Is it a scale of equal parts? We have no use for the inch scale which runs in opposite direction. Next take the Paulin instrument and look it over. Open the case by the single snap and do not touch the two buckles. Do not use the screw driver, if any. Note the knob in center with attached index arm, also the balance indicator at one side. Keep top of instrument always level. Turn knob until balance indicator is EXACTLY on the mark. Turn so that the pointer of the balance indicator moves from + to -. If you go too far move back and do over again. After doing this read the pointer on the knob. Try balancing several times until you get the same result. Note that the index pointer can go around twice. Is it a scale of equal parts? Read inside scale and study to see how divided. Note that in setting the balance pointer there is a mirror behind it. Get the reflection of the pointer out of sight when setting. Note that index pointer is shaped like a knife. Read when it looks narrowest. These provisions are to remove error from reading at an angle (paralax). Whenever you move from one place to another be SURE TO TURN THE KNOB AS FAR TO THE LEFT AS IT WILL GO. Now you are ready to try the two aneroids over a known difference of elevation. Go first to basement and read both. The old style will need both a few minutes to "settle", also tapping, if correct difference is obtained. Return to basement and see if you check. Read to nearest five feet. Several round trips may be needed to get familiar with the two kinds of aneroids. Record your readings on bottom of this page. Numbers of old instruments are on backs not on cases. Numbers of Paulins are in ink inside cover. HANDLE ALL ANEROIDS WITH CARE.

Old style No....... Paulin No.......

Basement	5th	Diff.	Basement	5th	Diff.
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....

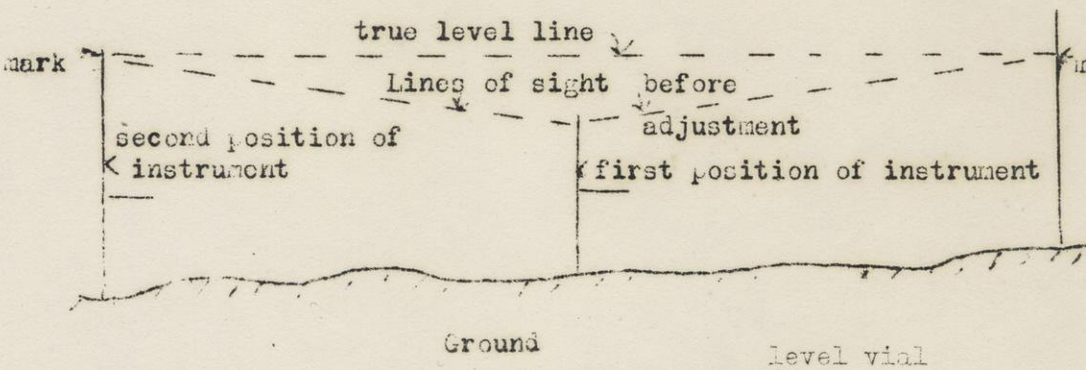
DATE........ NAME.............

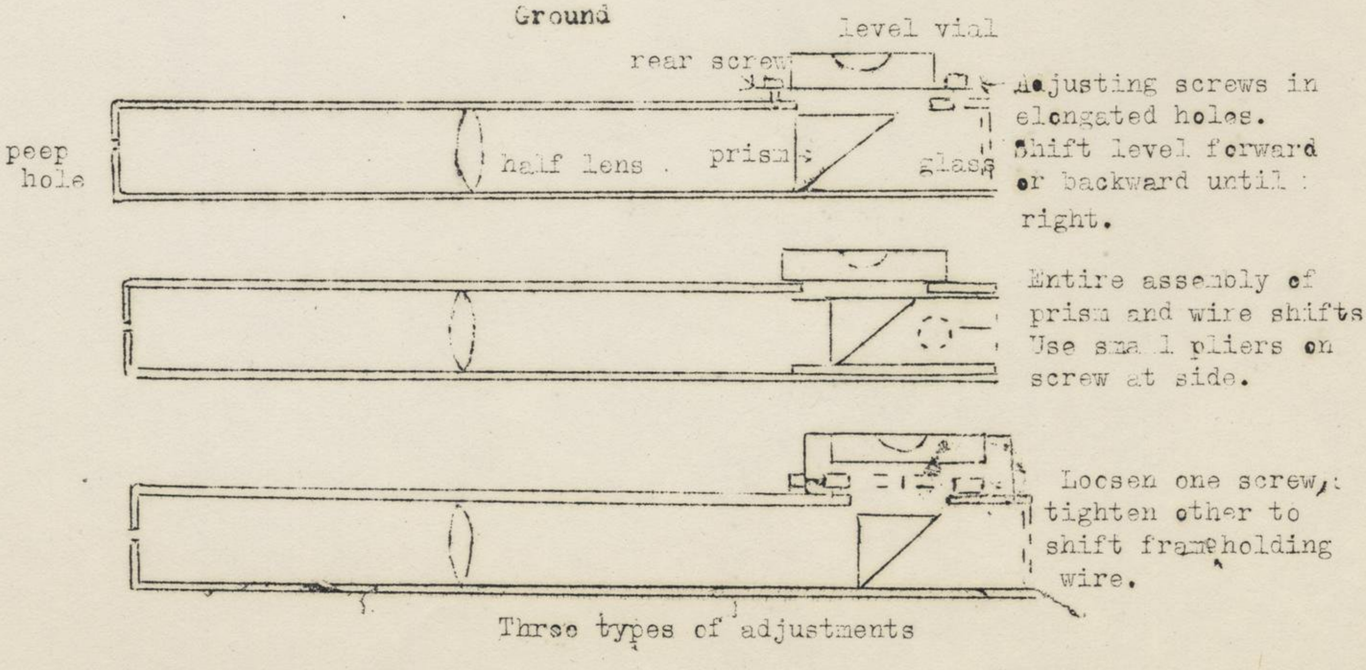
GEOLOGY 11
MAPPING
Problem 3, edition of 1938

Object: Adjustment of hand (Locke) level.

Material: Hand level, small screw driver,

Method: First look over the instrument and see how it is made. Look through it and note that half of the field of view is taken up with the image of the bubble as seen through a lens. Why is a lens needed? Some instruments have the wire for the line of sight just below the bubble and others have it in the front of the tube or box. Some have a sliding eye piece which pulls out mainly to make a longer line of sight. Now go to the museum or the hall and select two walls or other marks as far apart as possible. Pace distance between them. Stand at middle. Sight each in turn. You can mark where line of sight hits in any convenient way. A good way in the museum is to set the bottoms to window shades at this level. Study diagram below to see how these two points are on same level regardless of the adjustment of your level. Now go to one of the end points and stand so that your eye is just on its level. Sight the other end point and adjust instrument so that line of sight hits the point when bubble is on center. Some levels adjust by moving the sliding box which contains the mirror (prism) and wire. In these, this assembly is clamped by a screw on one side of the front. Others move the wire only by means of screws at both ends of the level vial case. Tighten one when you loosen the other. The screws are brass and are small. DO NOT USE MUCH FORCE. Tighten with finger tips only, not full strength of hand. On completion bring instrument to be checked and sign name on this sheet for record. It will be returned later.





Three types of adjustments

GEOLOGY 11
MAPPING
Problem 4, Edition 1941

Object: Use of plane table-intersections.

Material: Plane table, open sight alidade, sheet of wrapping paper, 15 " x 15", tape (one for class), plumb bob, markers for stations, hard pencil, eraser.

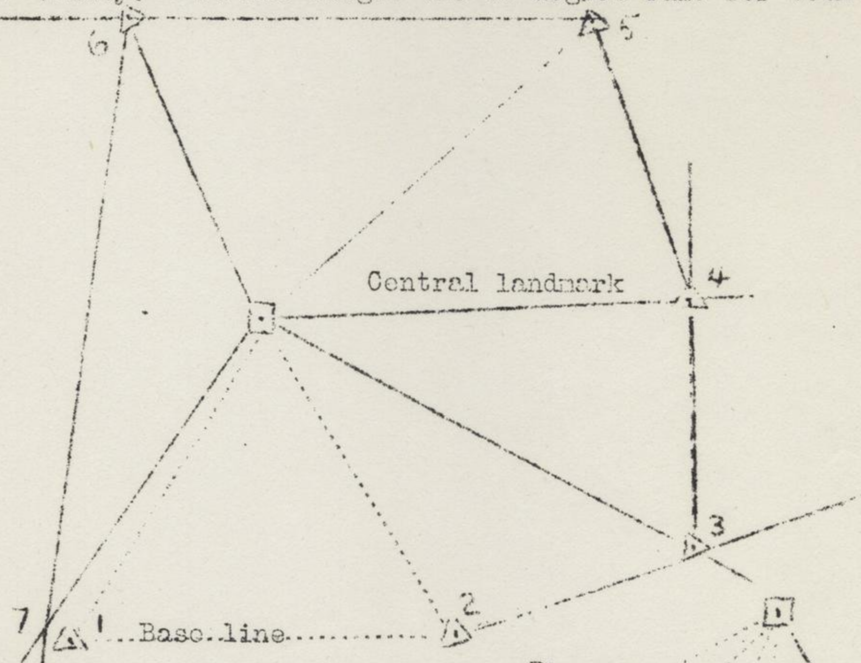
Method: The object of this work is to learn the basic idea of intersections or graphic triangulation with the plane table starting from two stations the distance between which has been measured with the tape. Such a survey will locate all the other stations, without any more work than taking sights to them. The work will be done in the museum in order to force the season by indoor work. Moreover, the first work is much better done where it is warm and dry than on the campus as formerly. Several stations have been located by driving thumb tacks into the floor. Using screws, put paper over the compass which will not be used. When you set up a table put one leg on the floor. Then grasp the other two legs one in each hand and leaning so that you can look over the top set it as level as possible judging from level objects seen across it. Use the plumb bob to see that the point on the map which is to represent the station on the floor is not over an inch off a vertical line. Greater care is needed here than outdoors on account of the very short distances involved which make any error into a much larger angle than outdoors. Line up your table with the sides of the room as well as you can and mark the north side of the paper. PLACE YOUR NAME ON THE MAP FIRST. Now having set up table over the first available station mark its location on the map taking care to leave space for the expected remainder of the stations. Make a mark vertically above point on the floor. Mark every point where the table is set up with a fine dot surrounded by a small and neat triangle. Use the alidade to sight other stations. Be sure you use the end with the string or wire at the front. This must be drawn through the initial station; either side of the alidade may be used. If there is no other plane table on a station set a marker on it and sight that. If someone else is using a station have him hold a pencil over his map location for you to sight. At every station be sure to draw lines to EVERY other station you possibly can. Now choose the adjoining station which you will call the other end of your baseline. Measure distance to it with tape if not yet known and plat along appropriate line on your map on scale of 1 inch = 10 feet. Move table to this station and set up so that this point is directly above the floor location with table in correct position. To get table into correct position or ORIENTATION lay alidade along line which represents the base and swing table into correct position. Guard against the common error of getting the table twisted 180 degrees in doing this! Now sight all the stations you can see. Wherever two (or later more) lines drawn to a previously unoccupied station intersect you have a new map location of a station. Until occupied by the table enclose these points in squares; after occupied change to triangles. Be sure all lines are sharp, narrow, and definite. Use chisel point on pencil. There is sandpaper below each table. Remember that all lines drawn to the same station should intersect at the same point if work is accurate. Do not consider that an accurate location has been secured until at least three lines so intersect and the angle subtended by them is not less than 30 degrees. The more 90 degree angles you can get the better. When you have finished with the sights from the other end of the base move to a well-located station from which inspection of the map indicates you will get good intersection angles on other points. Continue thus until the stations have all been located. Remember that your decision as to order of location of table will affect the accuracy of the map. When done, study the results to see what stations are well located and which are weak. Can you plan how to strengthen their locations? Remove map from table to hand in. Leave all lines on it. Indicate scale. Please remove all markers from museum floor to places where they will not bother visitors. Leave thumb tacks in floor. No smoking in museum.

GEOLOGY 11
MAPPING
Problem 5 Edition 1941

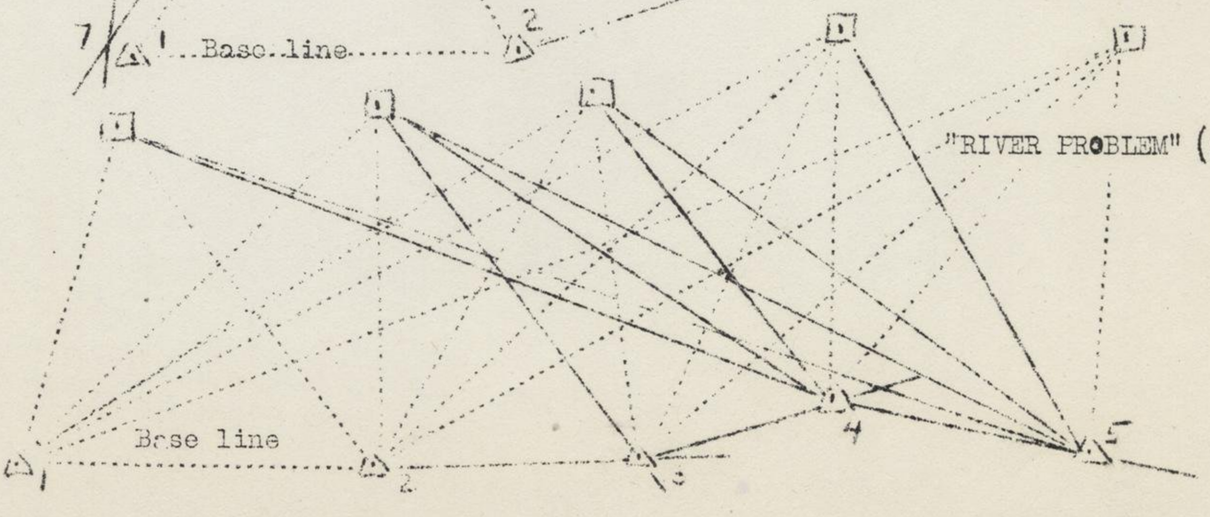
Object: Use of plane table-resection.

Material: Same as for Problem 4 except new sheet of paper.

Method: Read outline on subject of "resection." A plane table survey is often speeded up by use of resection. Two specific problems are here outlined both of which may be done indoors. First, survey around a hill or prominent landmark, using only one measured base. Second, survey along a valley where only one base is measured and the river cannot be crossed. In the diagrams triangles indicate table locations and squares with dotted lines leading to them, points determined by intersection and on which table is not set. Remember that a sight to a new table location enables one to orient the table either on the location or on any part of this line. Sights taken from one of these new locations at a previously located point through its map location provided they intersect the orientation or foresight line serve to fix the location of the new point by resection. Study the diagrams; note that base line is indicated and that sight from it for intersections are dotted. Sights for resection are solid lines. You should draw all lines full. Shape of figures need not be same as given in diagrams. Numbers indicate order in which stations are occupied. In first problem note error at finish (closure) and account for it. Criticize probable accuracy of second compared with Problem 4. Now do both problems. Suggest that in first one of the central lights or mastodon supports be used for the middle point. X In second, use window locks for the inaccessible points on one side of the "valley." X Do not forget the 30 degree rule for both intersection and resection.



"HILL PROBLEM"



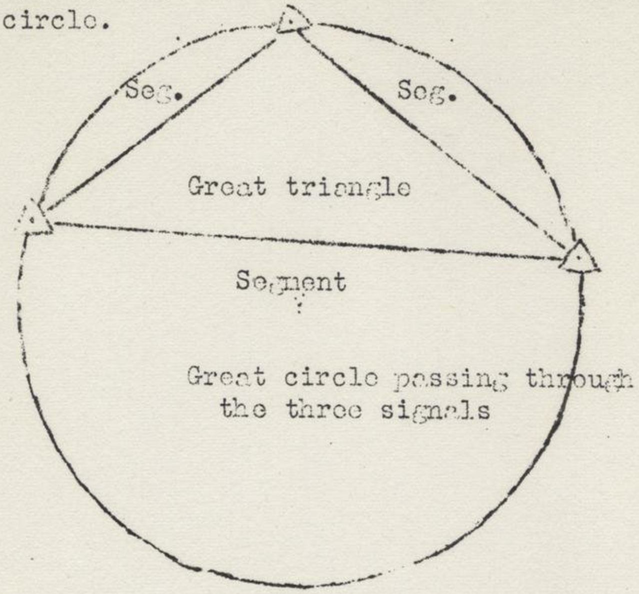
"RIVER PROBLEM" (OMIT)

GEOLOGY 11
MAPPING
Problem 6, Edition, 1941.

Object: Use of plane table-three and two point problems.

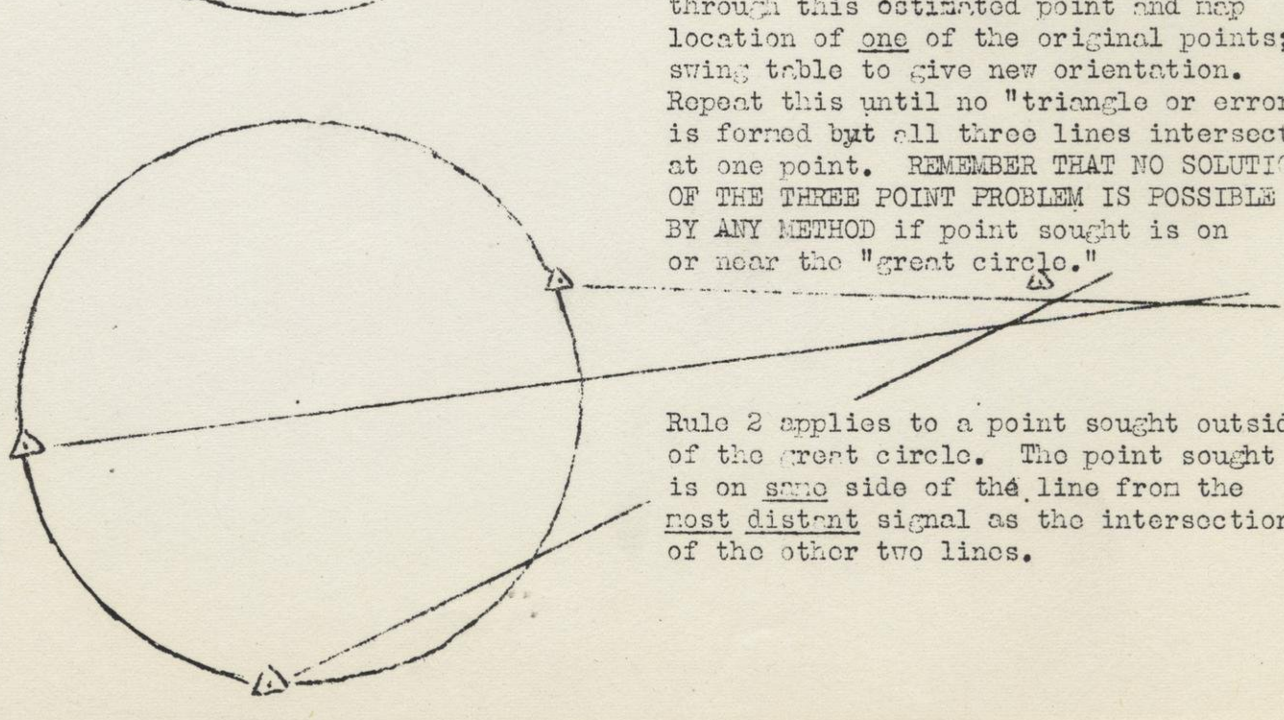
Material: Plane table, new sheet of paper, open sight alidade, markers, pencil, eraser, tape line, dividers.

Method: The object of the three and two point problem is to locate oneself with the table from either three or two points which are already on the map; it is impracticable to visit any of the points and the point which you desire to locate has never been sighted from any other station before. The solution of these problems enables one to set up and locate the table say in the middle of an open spot provided two or more already located points can be seen. Provided compass orientation is possible, two points are enough if properly located. The following methods do not use the compass. Whenever a location has been secured, it should be checked by sights to any other stations than those used which happen to be visible. First try LEHMANN'S METHOD OF THE THREE POINT PROBLEM as this is most common. Choose three permanent marks like steam pipes, lights, etc. Use tape to measure distances between them. Plot on your map with scale on alidade and dividers to strike intersecting arcs. Scale 1 inch = 10 feet. Draw great circle.



Definitions. Rule 1: the true location or "point sought" always lies on the same side (measured as you face the signal on the ground) of each line on the table which you have drawn with trial orientation and alidade directed at the signal through its map location and is distant on the table (measured at right angles) from that line in proportion to the distance from the signal.

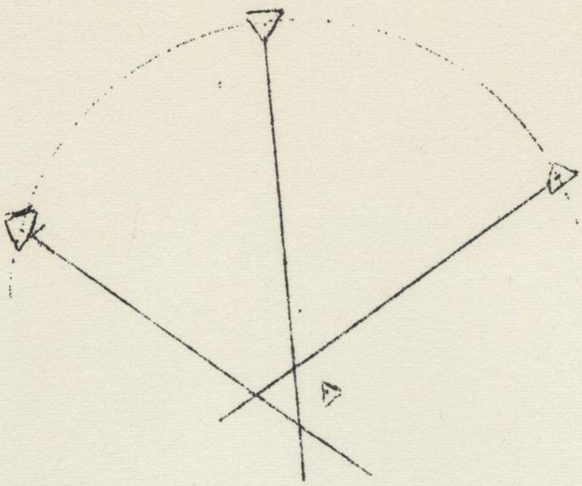
Set up table as nearly oriented by guess as possible; draw the three lines through map location of each point. Use this and other rules to obtain a trial location of point sought. Lay alidade through this estimated point and map location of one of the original points; swing table to give new orientation. Repeat this until no "triangle or error" is formed but all three lines intersect at one point. REMEMBER THAT NO SOLUTION OF THE THREE POINT PROBLEM IS POSSIBLE BY ANY METHOD if point sought is on or near the "great circle."



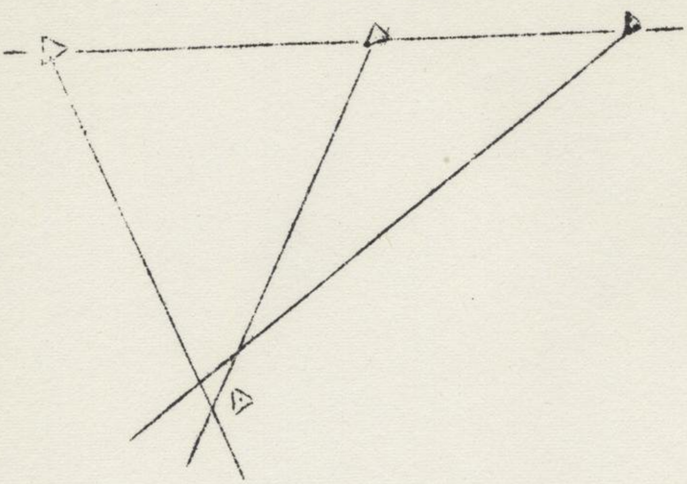
Rule 2 applies to a point sought outside of the great circle. The point sought is on same side of the line from the most distant signal as the intersection of the other two lines.

Problem 6, p. 2-

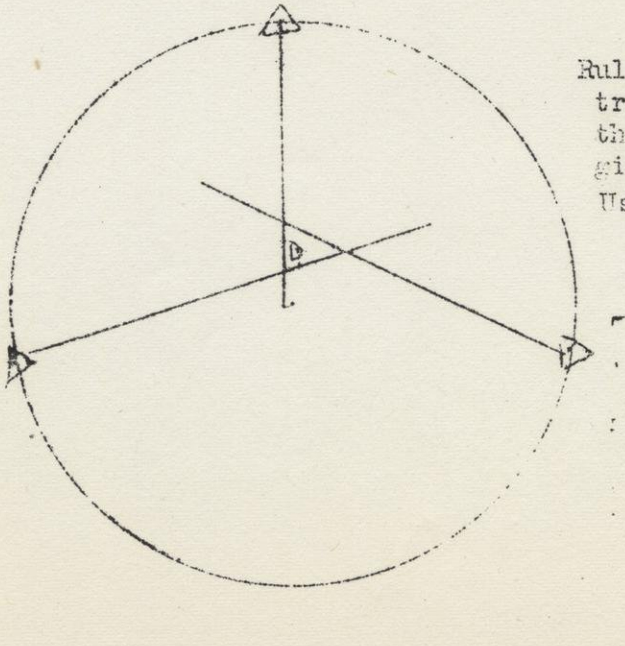
New stencil, 1941



Rule 3: point sought is in segment of great circle. The point sought is on side of line from middle of three points OPPOSITE to intersection of other two lines. Use same triangles as for Rule 2.



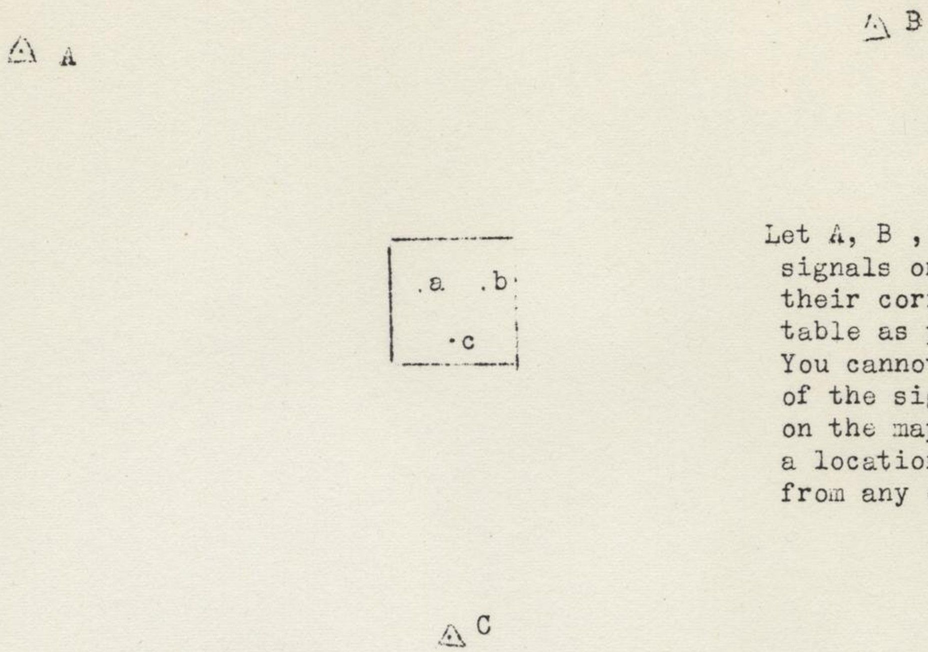
Rule 3, special case with all points in line, that is on the circumferance of a circle of infinite diameter. See above. Lay out a new line of marks along one of the walls.



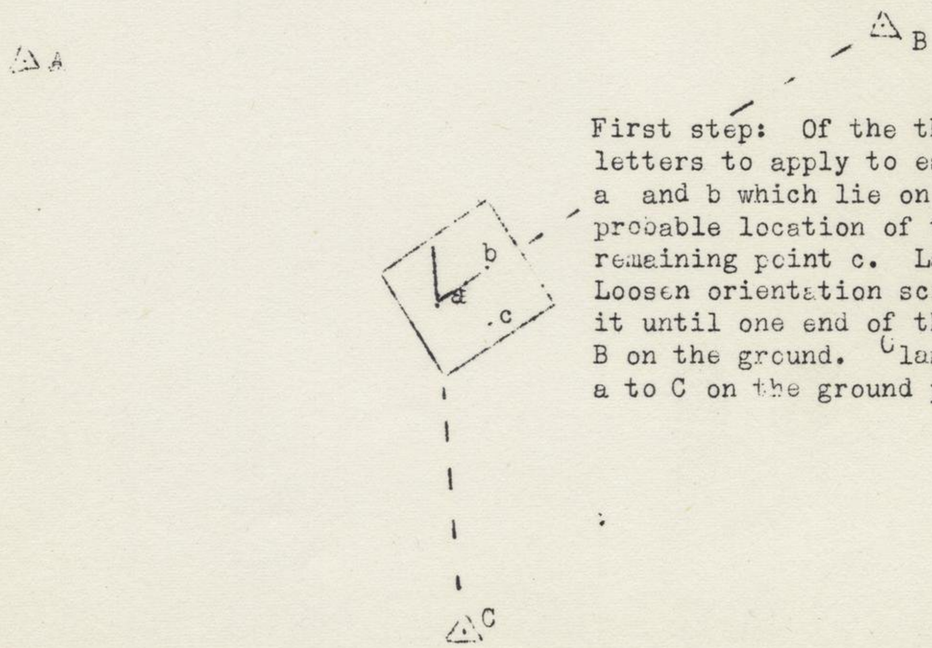
Rule 4: point sought is within great triangle. The point sought is within the triangle of error. This condition gives the best determined location. Use same triangles as for Rules 2 and 3.

Problem 6, p. 3, edition 1949

BESSELS METHOD of solution of "Three Point Problem"
First plot accurately another trinagle on same sheet or on other side. Use same markers as before. If desired draw "Great Circle"
The following diagrams show BOTH markers and plane table. The solution illustrated is for a "point sought" within the "great triangle"
DO THIS CASE? ALSO ANOTHER OUTSIDE GREAT CIRCLE



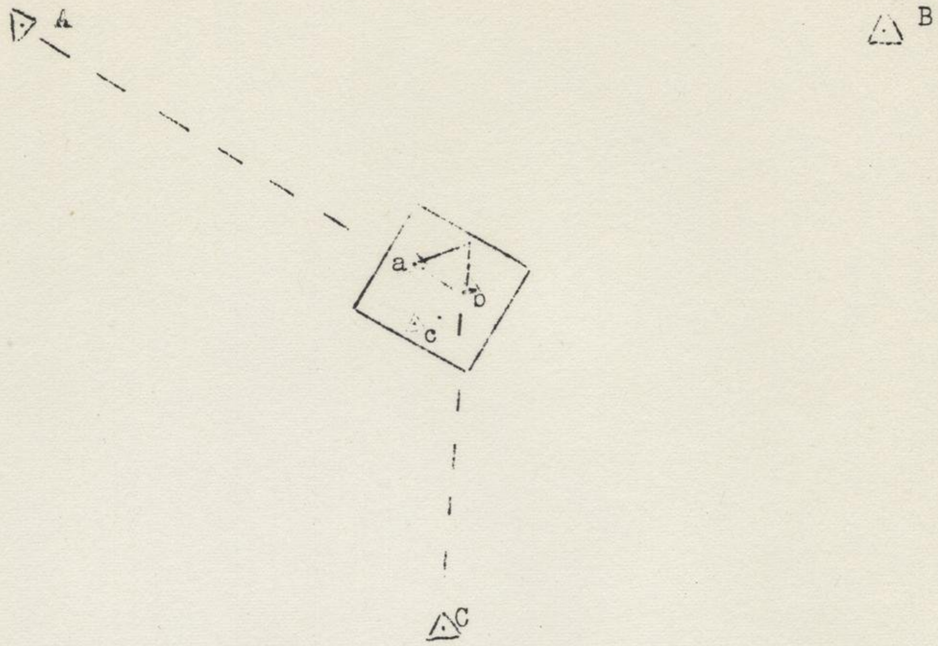
Let A, B , C represent the three signals on the ground and a, b, c their correct locations on the table as previously determined. You cannot set up the table on any of the signals but you must locate on the map the place where it is, a location which was never sighted from any other station before.

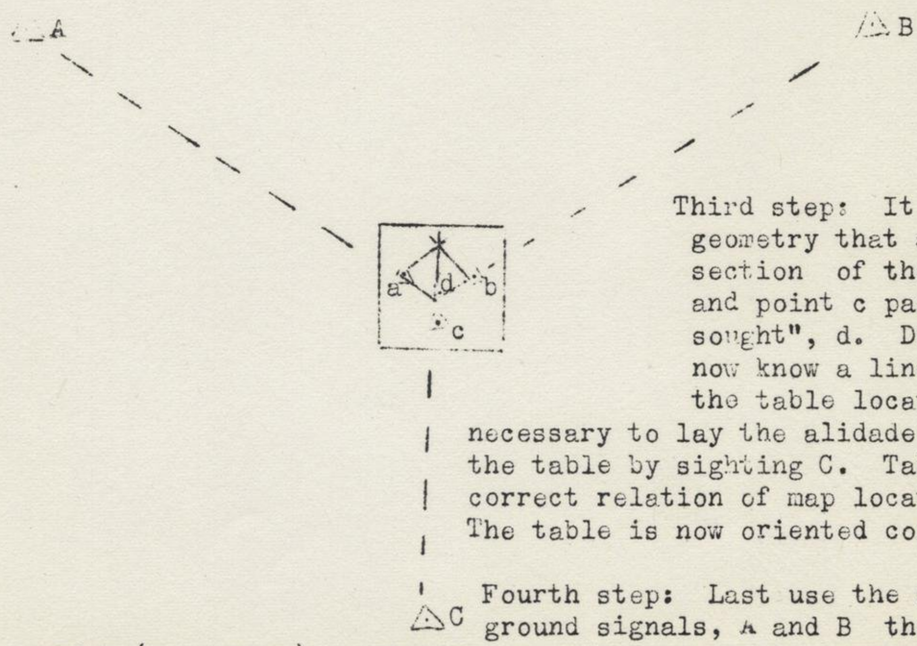


First step: Of the three map points choose letters to apply to each. Call the two points a and b which lie on a line not too near the probable location of the point sought. Call the remaining point c. Lay alidade on line a-b Loosen orientation screw under table and swing it until one end of the line a-b is directed to B on the ground. Clamp and draw a ray through a to C on the ground paying NO ATTENTION TO .

Problem 6, p. 4, edition 1949

Second step: Reverse alidade on line joining a to b on table. Loosen orientation nut. Swing table until a is directed to A as shown. Then remove alidade from line and use it to draw ray through b when sighting C again paying no attention to c on the map. NOTE: If it should happen that the two rays do not intersect within the area of the map change the position of the letters denoting both ground and map points correspondingly. Then repeat process.





Third step: It can be proved by plane geometry that a line joining the intersection of the two construction lines and point c passes through the "point sought", d. Draw this line. Since we now know a line along some point of which the table location lies it is only necessary to lay the alidade on this line and orient the table by sighting C. Take care not to disturb correct relation of map locations to ground signals. The table is now oriented correctly.

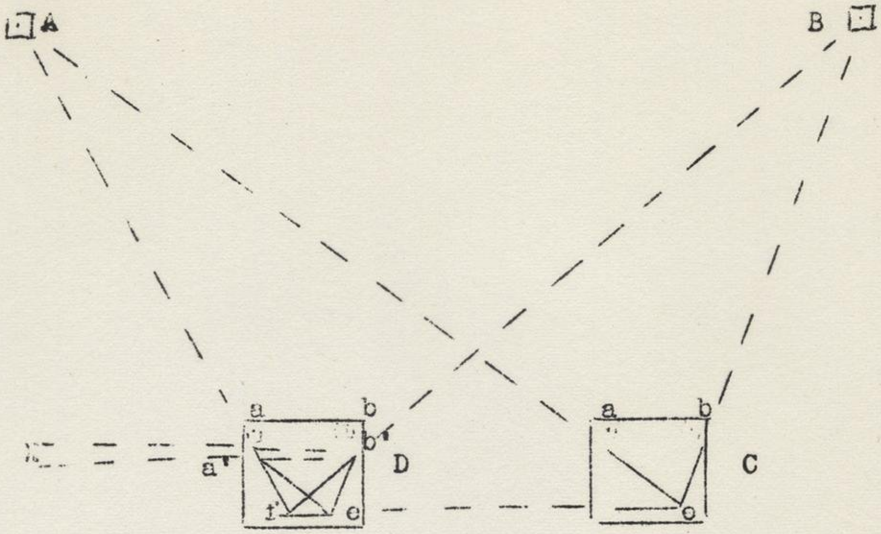
Fourth step: Last use the alidade to sight the other ground signals, A and B through their map locations a and b (resection). All three rays from A, B, C through a, b, c should intersect at the same point. If they do not you have made a mistake at some point of the operations. Recheck each step and find where you went wrong.

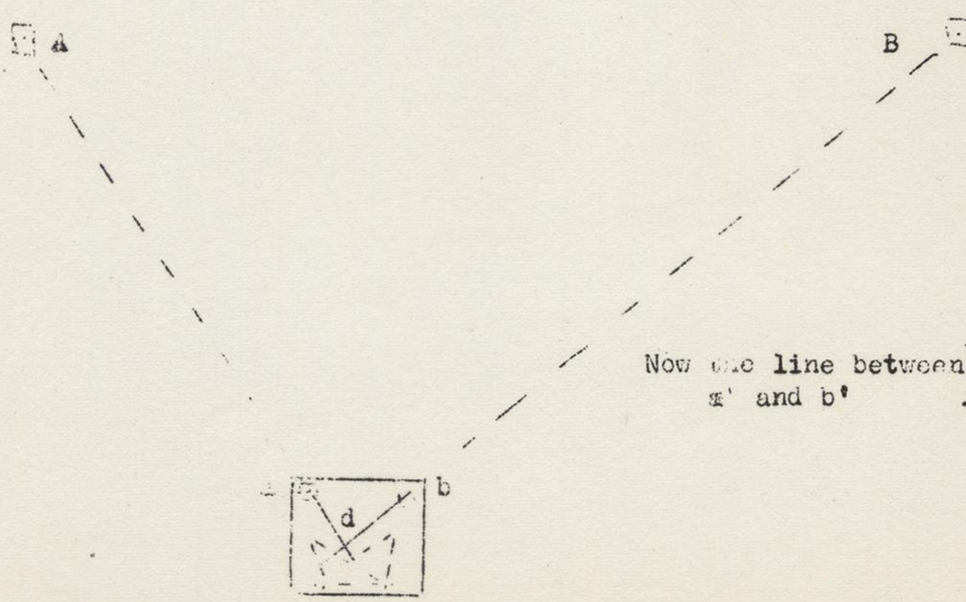
Note the advantages of this method. It is often useful to locate an outcrop on a map or to locate a new station at a point which could not be sighted before. It is most valuable in areas of local magnetic disturbance.

DO NOT FORGET THE SECOND CASE OF THIS PROBLEM, outside "great circle".

Two point Problem

It sometimes happens that one wants to locate oneself on the map when only TWO already located points can be seen. If the compass can be used the table is orientated with it and resection lines drawn through both signals to their intersection which is the "point sought." Unfortunately the compass cannot be used everywhere. Then the method following can be employed. Let A and B represent the two signals on the ground and a and b their map locations. Required the map location of table at C. This spot has not been sighted before. In some unoccupied corner of the map (here lower right), make a constructional station location (here e). The table is then oriented as closely as possible by guess. Then sight with alidade at both A and B through e and draw the solid lines shown. PAY NO ATTENTION TO THEIR MAP LOCATIONS. Now choose another station (here D) from which good intersections can be obtained on A and B and which can be seen from C. Call distance between C and D your "constructional base line". This distance need not be measured but can be laid off on the table by guess when D is sighted and the third solid line is drawn. Next move table to D and orient by backsight along the line drawn from C, thus making the table parallel to its first position when at C. Then from the constructional location for D (here f) draw lines toward A and B again paying no attention to a and b. Do just as if you were starting a new map. The intersections of these lines with those drawn from e given constructional locations for A and B here called a' and b' is parallel to the line A-B on the ground.





Now the line between a' and b' } b' is parallel to the line A-B on the ground. Required to place a-b on the map parallel to line A-B on the ground. To do this, place alidade on line b'-a' and note (or mark) a point on ground at some distance called X. Then move alidade to line b-a and turn table until line of sight hits X. Table is now oriented and the construction diagram, shown in dotted lines in second diagram, has served its purpose. Then resect and find d, the true map location of D. Ordinary plane table resection will then serve to locate the map position of C which is not shown on diagram.

End of Problem 6, edition of 1941.

GEOLOGY 11
MAPPING
Problem 7, edition, 1941.

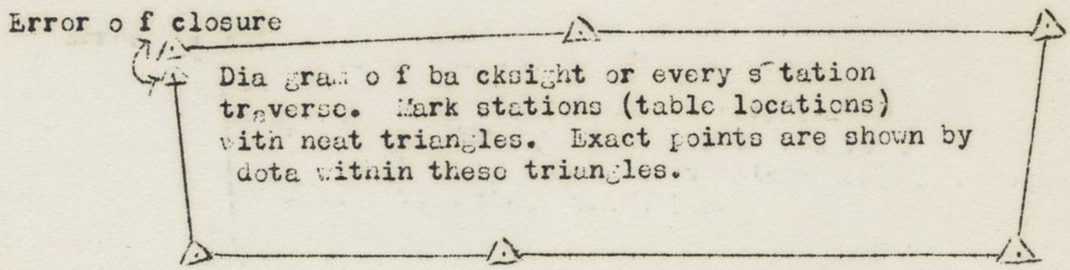
Object: Use of plane table-traversing.

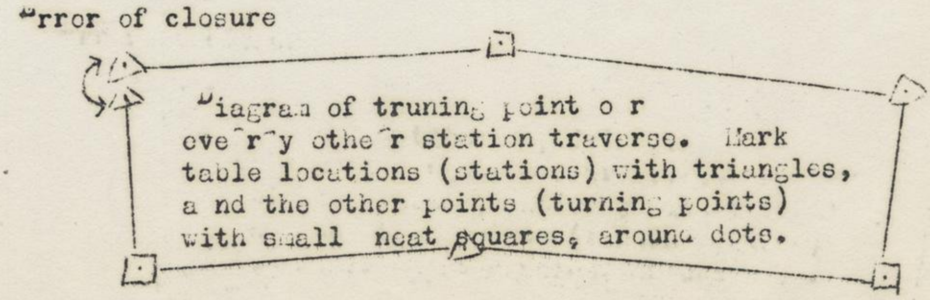
Material: Plane table, sheet of paper, open sight alidade, markers, pencil, eraser, plumb bob, tape line.

Method: Traversing is the operation of surveying a trail or road where condition of the country prevents use of intersection methods. It consists in going from one station to another measuring the distance in any convenient way and the angles between straight lines between stations with the plane table. Two methods are possible for orienting the table at each station: (a) backsight as used in intersection methods to last station occupied (which is commonly the only one visible), and (b) the compass. Make a traverse survey of the stations in the museum used in Problem 4 going around the outside of the room. Scale as before 1 inch to 10 foot. Measure distance with tape or obtain from diagram. Make a round using backsights for orientation. Bring survey back to starting point and show failure to close (if any). Show this by two locations for this spot connected by double ended arrow and labeled "error of closure".

Next, on another part of the same sheet make a second round. Since we cannot use the compass indoors a substitute will be necessary. Here we will line up the table at each station by use of the floor boards. Sight down over edge at floor to orient table. Note that when you use this method you do not set up at every point but at every other one. When you set up at a point to which you have measured the distance but not the direction, get your location by resection after orienting the table. Sights toward a station not yet occupied are called fore-sights. Sights from an unknown location back to a known are called backsights. Note that this kind of traverse consists of making alternate foresights and backsights. Note error of closure and consider which system seems better for accuracy and which better for time saving. Get oral directions for work on campus.

End of indoor work with plane table. Save directions. Be prepared to discuss in class the various methods with their advantages and disadvantages. Why could you not use the compass?





GEOLOGY 11
MAPPING
Problem 8, Edition, 1941

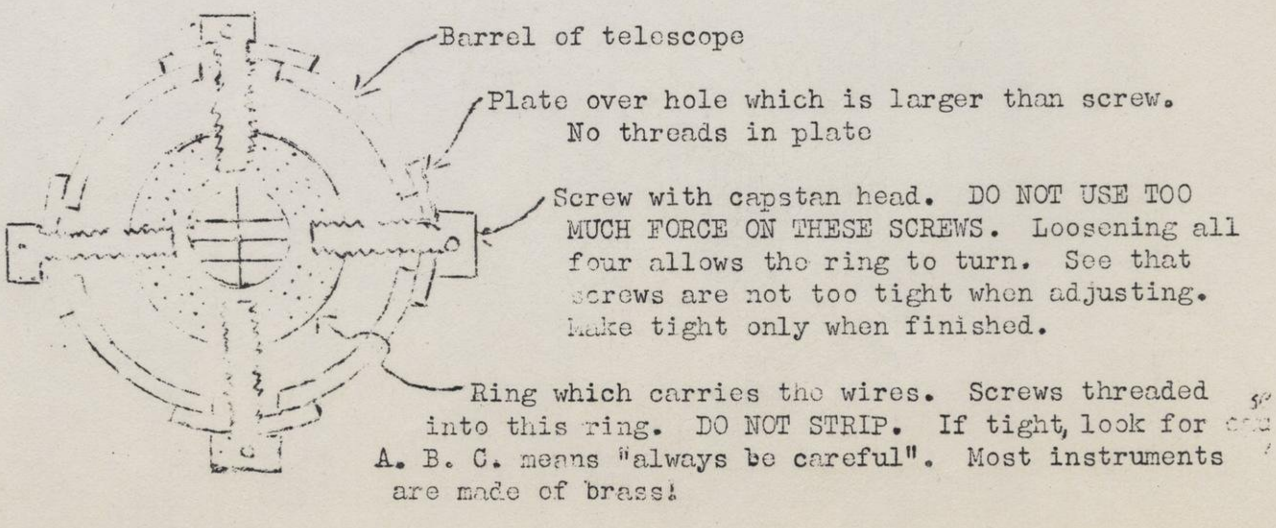
Object: Adjustment of telescopic alidade.

Material: Telescopic alidade, small screw driver, adjusting pin.

Method: The telescopic alidade is an expensive and precise instrument. Learn to handle it carefully. Many things can be done with it. Try to think in terms of instruments and to realize just WHY each thing is done. The first requisite in the use of any instrument is to put it into adjustment and then to see that it stays in that condition. Read over outline carefully, but these instructions are more up-to-date. Some alidades do not have all the attachments listed.

(1) Focusing the telescope. Point the telescope toward the sky and turn the knurled ring around the eyepiece until the wires appear black and sharp. Be careful not to unscrew the eyepiece but to move it in and out. Now focus the telescope (by means of the knurled head on the side) on some definite object more than 300 feet distant. It will be necessary to open a window to see such an object. Focus until when the head is moved slightly from side to side the wires do not appear to move even if this makes the distant object slightly out of focus. Run the objective in and out from proper position until desired result is secured. Last, refocus the eyepiece slightly until the distant object is sharp and the wires will then become sharp. Having once secured such focus of the eyepiece it will not be always correct for your eyes. Young persons have more trouble getting this focus than do older ones on account of the greater amount of flexibility of their eyes. These instruments are much harder to focus than are most transits and levels. Be sure you can see all the wires -- three horizontal and one vertical. Remember that others using the instrument will have to change this focus so become proficient at resetting it quickly. After your eyes begin to tire, you will have to refocus.

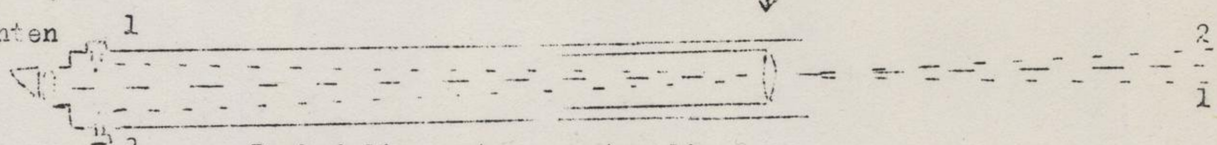
(2) Alignment of cross wires. Loosen the knurled ring in front of the support in center of telescope and turn the telescope as far as it will go in either direction. Set on a level table and set one end of the vertical wire on a sharply defined object. Elevate or depress the telescope by loosening the clamp on the horizontal bearings so that the vertical wire passes by the point. If it coincides with the point throughout its length the position is correct. If not, consult following diagram to find construction. Slightly loosen all four screws and gently move the entire ring into proper position. Tighten all screws before checking. Repeat if necessary.



(3) Adjustment of line of sight or Collimation.
Loosen the knurled ring in front of the horizontal axis until the telescope can be turned on its axis in the sleeve which supports it. Set the instrument on a firm foundation so that it will not slide easily. Use paper, sheet of fiber, etc., to insure friction. Point the intersection of the middle horizontal wire and vertical wire at some definite object as far distant as possible. The corner of a window in another building or at opposite side of a large room is often a good mark. In bringing this intersection to line up with the mark loosen telescope clamp until telescope is nearly on desired point, then clamp and finish pointing with "slow motion" screw, the one which carried a graduated drum on it. CAUTION. Never try to move the telescope too far with slow motion alone but use only for final adjustment; try to keep the arm which this screw pushes in the middle of its swing. EXTRA CAUTION: The slow motion screw is returned by means of a spring on the other side of the arm; make all adjustments by turning slow motion screw to the right thus pushing against the spring. When you have to move in other direction do so but go <u>too far</u> so that final adjustment will always be by tightening (turning to right). If you do not follow this rule the telescope will move unexpectedly and make work inaccurate. Having set the center intersection on the selected point revolve the telescope 180 degrees (as far as it will go). During this process hold the prism on the eyepiece (which makes things look right-side up although right and left are interchanged) so that you can keep your eye constantly on the intersection of the wires. Be certain you do not disturb the focus of the eyepiece or mistake the wires you are looking at. If the intersection remains in the same place the instrument is in adjustment. If not, let us say that the horizontal wire has moved up. To correct this loosen the adjusting screw at bottom (telescope still in same position) and tighten the one on top opposite until the wire moved halfway back to the mark. Reset on mark and again reverse telescope. Continue until final adjustment is reached. BE CERTAIN THAT ADJUSTING SCREWS ARE TIGHT when you finish for otherwise they would soon jar loose and your work would have been thrown away. In adjusting position of vertical wire do not follow same rule for screws but tighten and loosen in way to move wire in direction opposite to apparent movement away from the mark. <u>Do</u> <u>not</u> use all your strength on the little brass screws but use <u>discretion</u>. When finished check vertical position of vertical wire (Adjustment 2).

Eyepiece with prism ↓ Objective ↓

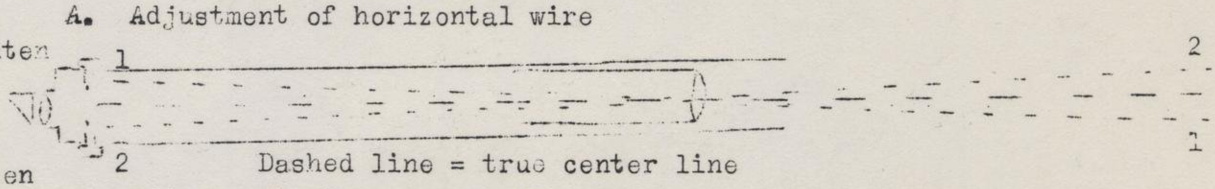
Tighten



Loosen Dashed line = true center line

A. Adjustment of horizontal wire

Tighten



Loosen Dashed line = true center line

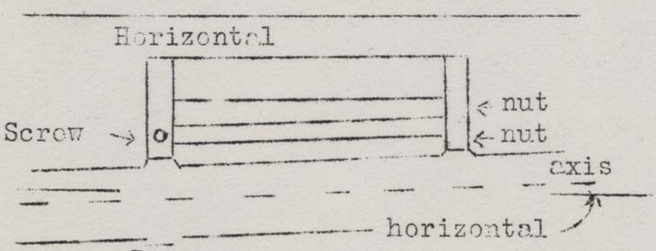
Adjustment of vertical wire

Note: Numbers 1, 2 refer to positions of telescope; directions for movement of adjusting screws refer to position 2

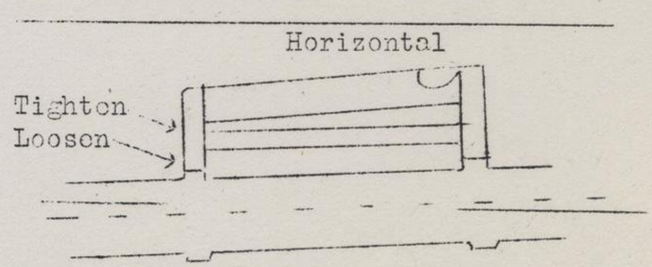
Note that with horizontal wire the prism makes the upward movement appear correct but that with vertical wire a real movement to left appears like a movement to the right. Diagrams show why wire must be moved only halfway back toward first position since reversal doubles the error.

(4) Adjustment of striding level

The striding level is the removable level which fits onto the post on top of the telescope. It is in this form both to make the instrument smaller when being carried and to facilitate adjustment. Its purpose is to level the telescope for use as a level. The object of the adjustment is to make the level indicate correctly when the line of sight is level; in other words to make the axis of the level vial parallel to the axis of the telescope. Place the alidade on any firm support which is approximately level. Take the striding level off its storage and set it in place on top of the telescope. Bring the bubble to center by means of clamp and slow motion making last movement of latter a right-handed one. Now release the level and replace on telescope with ends reversed. If the bubble centers the level is in adjustment. If not note from the diagram that the error is doubled by reversal. To adjust move the bubble HALFWAY back to center with slow motion. Then use adjusting pin depending on which type of instrument you have to bring it the rest of the way to center. With Gurley instruments note that there are two adjusting nuts at one end of the level which are turned by inserting the pin in holes. Both are on the same screw so that when you loosen one the other must be tightened. The bubble is very sensitive and great dexterity is needed to get the adjustment. When finished <u>both nuts must be tight</u> else they would soon jar loose and your labor would have been wasted. With the other instruments use the screw driver on screw below level at end where there are no screws in the side of the frame. This screw works against a spring so that the last movement <u>must always be to the right</u>. If necessary go too far so you can finish by tightening. Otherwise the adjustment will not last. When you have recentered the bubble repeat for a check for it is rare to get it right the first time. If it is necessary to repeat several times it pays to remove the release mechanism. To do this unscrew the pin and then press back the spring. Lay the parts in a safe place while working. Care must be taken to avoid distortion of the level by heat from the hands. When adjusting in field it is sometimes necessary to allow the level to stand half an hour between adjustments. Do not take this time in the laboratory, however. Before getting final precise adjustment check lateral adjustment. To do this use screw driver to remove the pin on top of the telescope on which the level rests. Now place the striding level on the telescope, hold gently with one hand, center bubble, and then rock the level back and forth around the telescope for about 30 degrees each way. The bubble should remain centered. If it does not use screw driver to loosen screw opposite to one used for adjustment. Then loosen and tighten the side or horizontal screws until the vial is in such a position as to stand this test. Make sure that <u>all three screws are tight</u> when you finish and then repeat the regular adjustment until the level meets all tests. Be sure to replace all parts removed during the adjustment. The striding level adjustment is the most frequently needed of all adjustments. Be sure you can do it with reasonable speed and with certainty; this will save much time in the field.

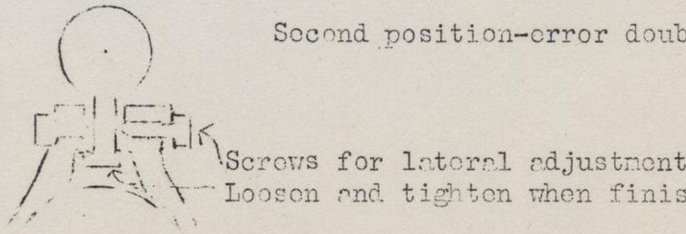


First position



Second position-error doubled.

Diagram to show lateral adjustment



(5) Adjustment of control or index level
Originally alidades were made with the striding level only. It is possible to work with this only for when vertical angles are read two readings of the arc and vernier are made: one with telescope pointed at object sighted, and another with striding level centered. This method is slow and when the Beaman arc is used becomes nearly impossible. A level was then added on the index so that regardless of the position of the table (which is almost never exactly level in all directions) readings of vertical angles can be made without bringing the telescope back to level This speeds up work. Be sure you understand just what this level is for; beginners sometimes forget to use it for every sight. The adjustment is to make this level indicate correct vertical angles. It must make the index on a Gurley read 50 degrees on the angle scale and 50 divisions on the Beaman arc scale when the striding level is centered at the same time it is. After having made and checked the adjustment of the striding level set the arc to read these figures while the striding level is centered. It is not necessary to have the alidade on a level support to make this adjustment. In setting the striding level do not forget to make the last motion of the slow motion screw to the right. Follow same rule with the screw which controls the index level. Do not confuse these two screws. If the index or control level does not come to center under above specified conditions make it do so with either pair of adjusting nuts. Be certain that the nuts you used are tight when you are through for otherwise your labor will be wasted. Note differences in types of arcs in instruments by different makes.

(6) Adjustment of gradienter (Stobinger Drum) or slow motion screw.
It is possible to work with an alidade without using the slow motion screw for anything but what its name implies- to finish setting either the line of sight or level. But in many instancesit is very handy to use this screw to measure the angle through which it has turned the telescope. To do this the makers have supplied a drum on the screw which is divided into 100 parts. This drum is loose on the screw so that you can hold the latter and turn the drum to read 0 or any other desired figure. A metal strip placed at right angles to the drum above it serves to record the number of whole revolutions made. The limit of turns is about 10. The makers intend that the revolution of the drum will turn the line of sight over a distance of one foot at a distance from the instrument of 100 feet. Use steel tape to measure 100 feet from center of instrument. Hold a leveling rod vertical at this point. Set the middle wire on the lower mark of a foot division using right-handed motion of screw. Set drum to 0. Turn to right exactly one revolution. Record reading of middle wire. Repeat several times. Accurate focusing is essential to accuracy of this test. Average results. If the average is not exactly one foot proceed to adjust. The slow motion screw is mounted in a brass bushing which is clamped with a nut at the front end. Note that its center is not that of the bushin that it is eccentric. Use a thin flat wrench to loosen the nut and then turn the bushing until it raises or lowers the position of the slow motion screw. Raising increases the amount of throw.for a revolution and lowering visa versa. Check adjustment after movement until it is right and the nut is left firmly set. This adjustment is rarely needed. DO NOT DO THIS ADJUSTMENT NOW vut be familiar with its purpose.

(7) Adjustment of circular or bulls eye level. (NOT TO BE DONE NOW)
The adjustment of the circular or bulls eye level can only be made in the field for it requires the use of the plane table which it would be unsafe to set up on the flo Set the alidade with its center of gravity over the center of the plane table. Center the striding level. Next reverse position of alidade but do not turn the board. If the bubble moves bring it half way back with the slow motion screw on the alidade and the rest of the way with the leveling head of the board. Turn alidade 90 degrees and repeat this process. Continue repeating it with turns of 90 degrees until board is really level. Now center the circular level by turning screws in its base.

GEOLOGY 11
MAPPING
Problem 9, edition, 1941

Object: Measurment of distances with telescopic alidade by different methods.

Material: Telescopic alidade, miniature rod, sheet of paper for notes, pencil.

Method: Read pages 25 to 27 in outline. Set the alidade on table or other firm and reasonably level support hwere you can see the rod indoors at a distance of not less than 40 feet. Set the rod up vertically. This rod is exactly 1/10th the size of rods used in the field. Look at it and notice the lack of numbers. This is because numbers cannot be seen at long distances. Except for the fifth and tenth foot solid black and white foot divisions are shown. The fifth and tenth feet are subdivided with diamonds the diagonal sides of which each covers 1/10th foot. Note that inches cannot be used on such a rod and be sure you know why this is. The rod is so made that it can be used either end up. It is intended to put the black end up when against the sky and the white end when the background is trees or rocks. When you read for distance endeavor to set one wire to a foot division in such place that the other wire (either a full, half or quarter interval away) will fall on a subdividea foot. If you cannot do this learn to estimate the number of tenths of the fractional foot. Get familiar with the rod so that when you go outdoors you will feel at ease with it. Get a good light on the face of the rod and remember that when you get outdoors it will help a lot to get the sun to shine on the face of the rod whenever possible. MAKE ALL COMPUTATIONS IN ROD UNITS not actual distances.

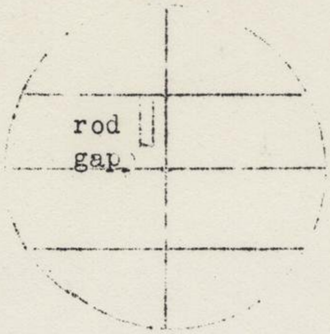
Method (1) Loosen the knurled ring in front of the horizontal axis and rotate the telescope until the wires which usually are horizontal are now vertical. Have someone hold the rod for you. Choose a permanent mark for one end of the line to be measured; Shift the telescope on the table until one of the now vertical wires rests on this mark. Motion your assistant to move the rod, holding it vertical over until it is lined in with another vertical wire. Either the half or full intervall can be used. Which seems the more accurate? Notice that you will have trouble in motioning at first since the instrument reverses right and left. Getting used to this is the reason for doing this method indoors. When you have lined in the rod check position of first vertical wire to see that instrument has not moved. Then have your assistant measure distance horizontally between the mark and rod. Multiply rod divisions by 200 if half interval was used and by 100 if full interval was employed.

Method (2) Have your assistant hold the rod horizontally at such a distance that it will fail to span the full interval, say the length of the hall or museum. Line in one wire (wires as in previous method) at an end of the rod. Motion assistant to place rod its own length to one side so that full interval may be read. The same could be done if rod had been too short for a half interval. Notice that this method avoids signals when used in field but is limited to light conditions under which divisions on the rod can be seen. Make appropriate computation of distance.

Method (3) This method is used when you can see less of the rod than will span a quarter or a half interval. Use wires in normal position. If you have trouble in using the imagination cover enough of the rod with white paper held by thumb tacks so that above condition is met. In this method we will use the drum on the slow motion screw or gradienter to measure the angle subtended by the gap between the end of the rod and the wire on the other side of the half interval, one wire having been set on one end of the visible portion of the rod. Routine: Set top or middle wire on top of visible part of rod using slow motion (See fig. 1): Read and record the drum, setting it to 0 is desired; tighten screw until ~~cert~~ lower wire is on bottom of visible part of rod (see fig. 2); read and record

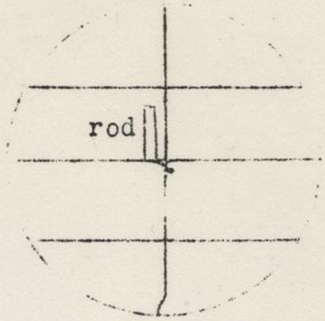
Tighten the screw the same number of divisions as the difference of these two readings (see fig. 3); read on the rod the number of feet and tenths which the last movement carried the wire above the base of the visible portion of the rod; add this distance to the length of the visible part of the rod; multiply this sum by 200 to obtain distance.

Fig. 1



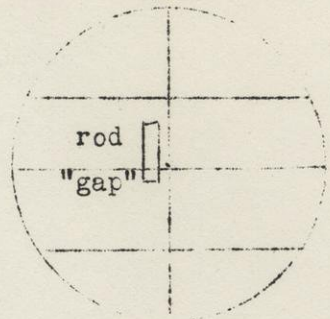
Wire set on top of rod

Fig. 2



Telescope turned through angle of gap

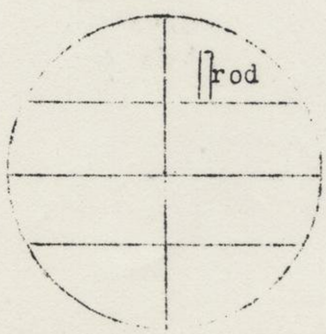
Fig. 3



Telescope turned by same angle as over gap thus finding value of this angle in feet.

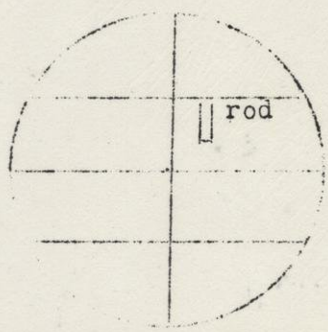
Method (4) This method depends wholly on the adjustment which makes the full revolution of the drum turn the line of sight over 1 foot at a horizontal distance of 100 feet. One turn also swings the wires over a full interval. Again assume that you cannot see enough rod to span a half interval. Routine: Set top wire on bottom of visible part of rod; read and record drum, setting it to 0 if desired; tighten screw until same wire is at top of visible part of rod; read and record drum; repeat with other two wires; average results; divide length of visible rod by drum reading (in which a full revolution is called 1.00) and multiply result by 100 to get distance.

Fig. 4



First position of top wire

Fig. 5

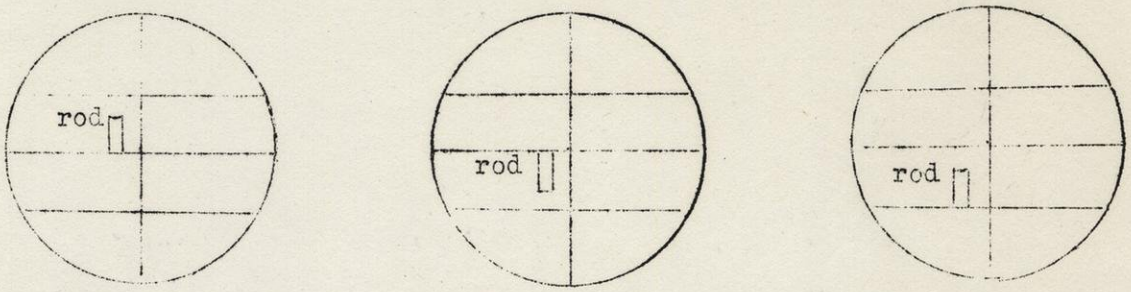


Second position of top wire after tightening slow motion screw (drum).

(5) Method 5 depends upon finding what fraction of the half interval is covered by the visible portion of the rod and thus computing by proportion what length the rod would have to be to cover the entire half interval. Thisis done by use of the drum on the slow motion screw. The proportion is as follows- Observed or visible length of rod: half interval reading: drum reading obtained by swinging a wire over the visible length of rod: drum reading obtained by swing a wire through a half interval. Grasp the fundamental idea before trying this method; do not try to memorize the set routine. See figures. Set top or middle wire on bottom of visible part of rod; read and record drum setting to 0 if desired: tighten slow motion screw until same wire is on top of visible part of rod: read and record drum, the difference of readings measures angle obtained in swinging over visible length of rod; continue tightening slow motion screw until next lower wire is on bottom of visible part of rod; read and record drum; take difference of first and last drum readings which represents drum reading for a half interval swing. This should be exactly 0.5 turn if instrument is in adjustment. Now solve the proportion letting x = length of rod necessary to span half interval. Multiply result by 200 to obtain distance.

Hand in all notes and include a discussion of probable accuracy of the different methods which you can use when either distance or obstructions to the view prevent the rod from covering even a half interval. Consider what method or methods employ the longest line of measurement. What methods might not work because the rod can be seen only down a narrow lane through woods or brush? What methods depend upon the accuracy of the adjustment of the slow motion screw drum? What methods could be used if all but one of the wires were broken? What methods depend upon prearrangement with the rodman? Remember that all use of the drum depends upon having the clamp on the horizontal axis tight.

Fig. 6 | Fig. 7 | Fig. 8



First position of telescope. First reading of drum.

Second position; drum change indicated angle subtended by rod.

Third position; difference of this drum reading and first indicates turn over a half interval.

NOTE: Methods outlined above are not commonly used now that alidades are made with "quarter intervals." Old style instruments without a drum on the slow motion screw can use only methods (1) and (2). In the field beginners ought not to attempt very long shots at first!

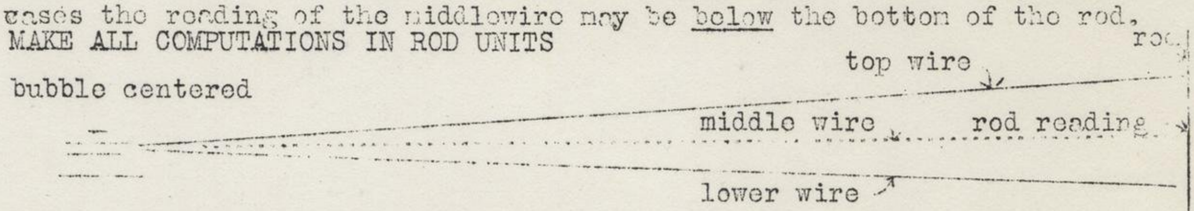
GEOLOGY 11
MAPPING
Problem 10, edition 1941

Object: Determination of differences in elevation with telescopic alidade.
Material: Telescopic alidade, adjusting tools, miniature rod, sheet of paper, stadia slide rule, pencil, reading lens.

Method: First check the adjustments of your instrument and adjust if needed. The determination of differences of elevation with the telescopic alidade is one of its most important functions. There are several distinct methods and it is absolutely essential that the student understand <u>all of them thoroughly.</u> You can get by without knowing all the ways of measuring distance but not if you do not understand all the ways of measuring elevations. Difference of level is measured between center of instrument's horizontal axis and where middle wire strikes the rod. The rod is then used to obtain the total or net difference of level between instrument and ground where rod is held.

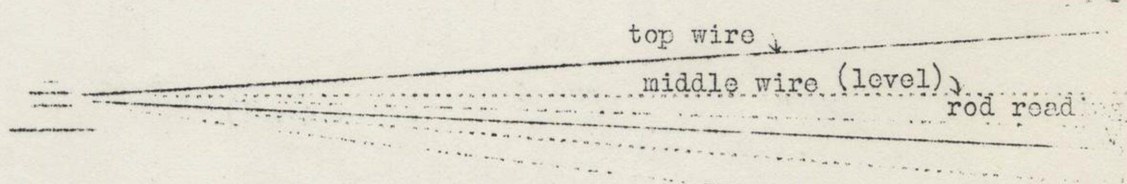
(1) Levelshots. Set up the rod in a position where you can strike it with the middle wire when the telescope has been leveled with the striding level. Make reading and compute how much below the level of the instrument the botton of the rod is. This is the simplest possible case and the alidade is then used just like an engineers level or hand level with the rod. Getting of "level shots" is not confined to cases where the middle wire strikes the rod.. Move your rod slightly so that it is either too high or too low for the middle wire to hit it with telescope level but in such position that another of the wires does strike it. Now read the distance by raising or lowering the instrument until the full (or half) interval can be read, moving it by means of clamp and slow motion screw. Note that in actual practice this would be done first since you should always <u>read the distance first</u> and no attention is paid at that time to the level. Then center striding level again and read where a wire strikes the rod. Obtain what the reading of middle wire would have been had rod been long enough to be hit by applying the half interval reading on the rod to the reading of upper or lower wire. The two cases are illustrated below. Note that in some cases the reading of the middlewire may be <u>below</u> the botton of the rod.

MAKE ALL COMPUTATIONS IN ROD UNITS



Method of obtaining difference in level between instrument and bottom of rod with telescope level (level shot)

ground

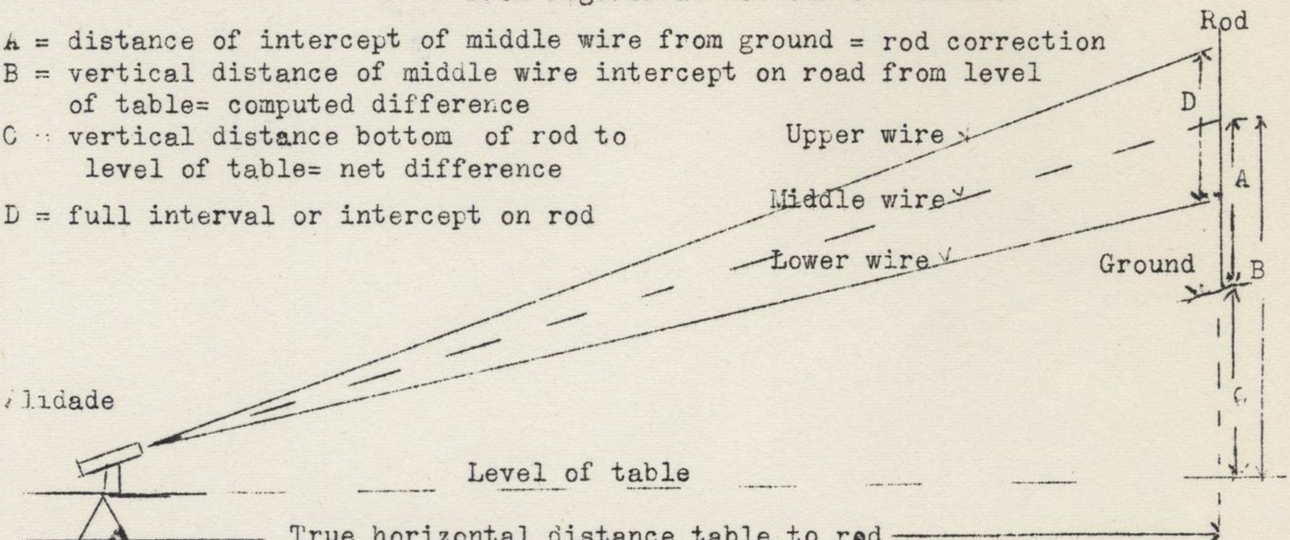


Method of obtaining difference in level between instrument and bottom of rod with telescope level (level shot) but WHEN MIDDLE WIRE DOES NOT STRIKE ROD.. Note position of the three wires when DISTANCE was read. Upper and lower wires there shown in dot-dash lines. Compute what reading of middle wire with level telescope would have been had rod extended far enough. To do this add the HALF INTERVAL to actual reading of lower wire with level telescope. Do not make such shots until you have had some experience!

(2) Vertical angle rod readings. Now place the rod far enough either below or above the level of the instrument that you cannot hit it with level telescope. Read full interval in usual way. Set the middle wire on any convenient foot division such as 5, 10, or top of rod. Record what division it is on. Next center the bubble on the index (control level), IN THE FIELD THIS MUST BE DONE FOR EVERY SHOT since the plane table is never exactly level. Read the degree scale. This is the scale at the left which has a vernier on the index arm. It is a scale of equal parts. It is divided to half degrees. (These remarks apply to the Gurley instruments; the K. and E. has the degree scale in the middle with the 0 at the bottom and a double vernier). Look out for the "false 0 " on the Gurley vernier whose purpose is a mystery. It is best to use a lens for reading. First get the right number of degrees and half degrees (30 minutes); then estimate about where the 0 line falls; look along the vernier until you find a line which coincides with one of the divisions of the main scale; the vernier reads to single minutes. Add its reading to the number of degrees and half degrees on the main scale paying no attention to what division on that scale happens to coincide. The reason for the estimate of the vernier reading is to facilitate looking for the coinciding lines. Having obtained this reading subtract 30 degrees from it. If the remainder is positive the line of sight is inclined up; if it is negative it is inclined down from the instrument. Next use the stadia table to compute the vertical difference.

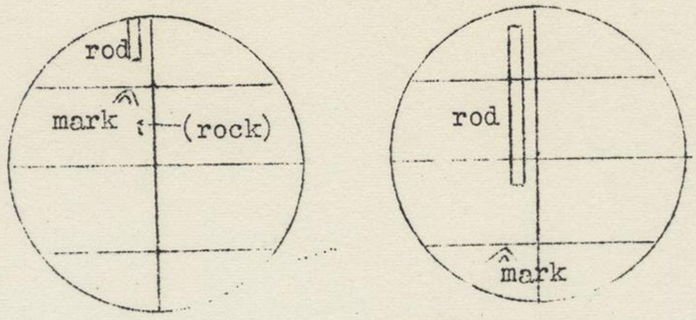
. Record this, now correct to get the vertical difference to bottom of rod. Repeat process setting middle wire to a different point on the rod; correct to bottom of rod and compare results. Compute true horizontal distance to rod. from figures at bottoms of columns.

A = distance of intercept of middle wire from ground = rod correction
B = vertical distance of middle wire intercept on road from level of table= computed difference
C = vertical distance bottom of rod to level of table= net difference
D = full interval or intercept on rod



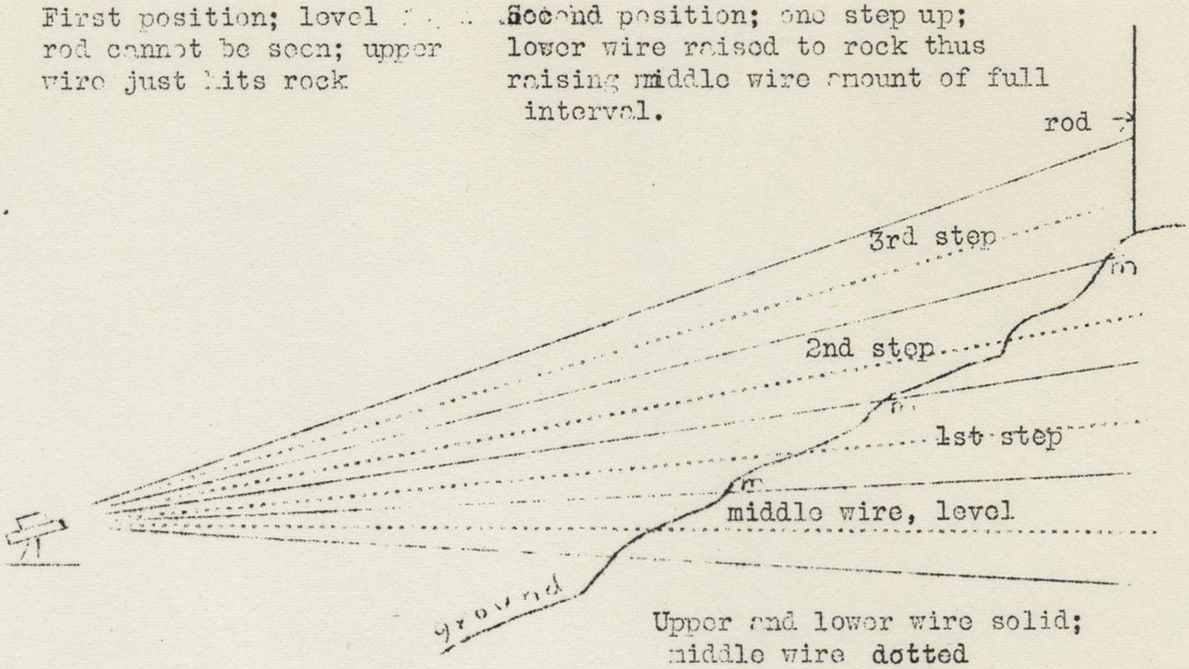
The above method is the most common but it involves reading the vernier and considerable computation.

(3) Stop method. If you read distance and think that your telescope is near enough level to get a level shot but when you try it find that it is impossible, the "stop method" comes into play. Look at where your wires fall as shown in following diagrams. Say that the top wire hits top low to strike the rod. Notice some permanent object on which it does fall. Use the slow motion screw to turn the telescope up (tightening as usual) until the lower wire is on the same mark. You have now raised the middle wire by an amount equal to the full interval which you read first before you tried for a level shot. Notice that this shift is accomplished without taking your eye from the instrument. Now if the middle wire hits the rod record its reading and make appropriate computation of how high the place on the rod is above the instrument.



First position; level ... rod cannot be seen; upper wire just hits rock

Second position; one step up; lower wire raised to rock thus raising middle wire amount of full interval.



Upper and lower wire solid; middle wire dotted

The above diagram illustrated the step method where the telescope had to be raised through three steps to hit the rod. Note that each step raised the middle wire by the amount of the full interval for the distance in question. This full interval reading was obtained when the distance was read.
The step method is very rapid and computation is easy but it is limited to about six (6) steps either above or below the level position. Notice that you have to level the telescope before starting the step method. When it is necessary to step down you will be loosening the slow motion screw; then go too far each time and come back by tightening the screw. This will increase accuracy. With the small angles of this method correction to horizontal distance is not needed.
(4) The Beaman arc. The Beaman arc is the scale which is found at the right of the arc on Gurley instruments and at one end of the arc on the K. and E. Notice that it is not a scale of equal parts and so has no vernier. The idea of the Beaman arc is exactly the same as that of the step method illustrated in above diagram. The difference is that instead of looking through the telescope and moving the wires over a full interval by watching certain hap-hazard marks on the ground the movement is measured by a scale on the arc. The Beaman arc is ... limited to small angles from horizontal. Inspection of above diagram shows by it is not a scale of equal parts. The arc reads from 0 to 100 or(0 to 50) so that the middle or level point is 50 instead of 30 on the anglescale (Gurley construments only). Routing of observation is as follows: Read distance as usual; center control level; look at Beaman arc and with slow motion screw move telescope until it reads a whole number; then look through telescope and record where middle wire hits the rod. Computation is exactly the same as with the step method; difference of elevation between instrument and middle wire= full interval multiplied by number of divisions away from 50 (= number of stepp). If this proceedure fails to get middle wire on rod then change to another division.

Note that the Beaman arc requires no computer, merely simple arithmetic. Note how easy the scale is to read. The objection is that it holds the rodman longer on station since you have to take your eye off the instrument to set the telescope on a whole number on the arc. Correction of horizontal distance with Beaman arc is accomplished by means of an auxiliary scale. On the Gurley instruments this is above the other scale. On the K. and E. it is at left end of arc and is marked "Horizontal". It gives percentage that must be subtracted from apparent horizontal distance to give real horizontal distance or percent that horizontal distance is of apparent distance, or percent that horizontal is of apparent distance.

(5) Drum method. Since one drum revolution is intended to throw the line of sight over one foot at a distance of 100 feet it is clear that one turn throws the line of sight over a full interval at any distance if it is in adjustment. In other words each revolution of the drum is equal to one step and to one space on the Beaman arc. Although not generally used the drum will measure differences in elevation if the angle is not too great. Up to nearly 10 turns it will measure "steps" quite well. The main advantage is that it measures <u>fractions</u> of steps so that the middle wire can be stopped at any convenient reading on the rod. It is more convenient to use it going up from level but it works better than the step method when the rod is below the instrument. In this case you can start with wire on top of red and tighten screw until striding level is centered. Note how whole turns are read on the horizontal scale above the drum. Computation is exactly the same as for step method and Beaman arc except that fractions of turns are used. Try this method with rod both above and below level of instrument. Check results by another method or better two other methods. Always tighten and be sure striding level is adjusted.

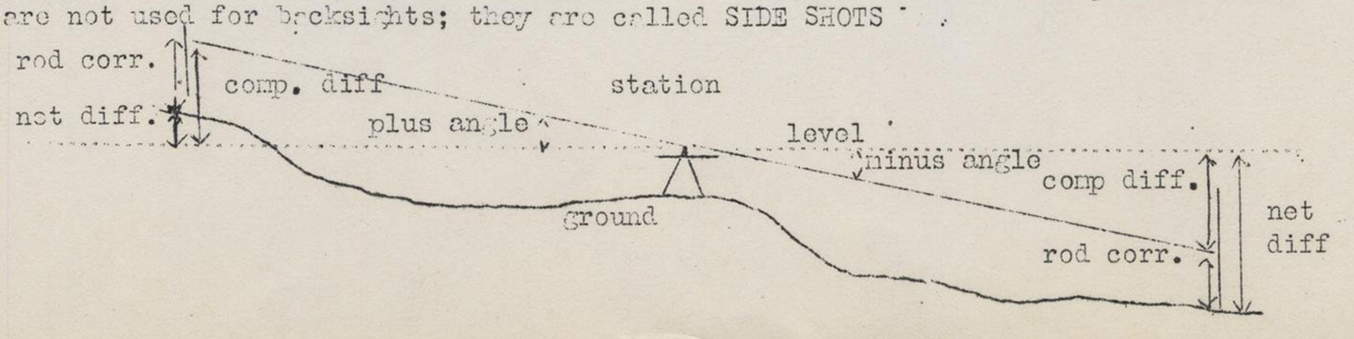
Hand in your results. Be prepared for exam questions on relative advantages and disadvantages of the different methods. Some students have confused the Beaman arc and angle methods. How do you tell the scales apart? Be prepared for catch questions such as "How do you read the vernier of the Beaman arc?". With which methods can you choose the point on the rod where you will set the middle wire? With which methods must you read the middle wire where it happens to fall? What is the striding level for? What is the control or index level for? When must it be centered? Compare relative speed of Beaman arc and angle methods counting time rodman is held on his station. What is advantage of level shots? What do you do if another than the middle wire hits the rod on a level shot? Could same correction be made with shots on an angle? How do you know what full interval reading is to use it in computations, what other term is sometimes used for "full interval"?

GEOLOGY 11
MAPPING
Problem 11, edition, 1941

Object: Computation of notes taken with planetable and telescopic alidade traverse using degree scale or vertical angle system.

Material: Cox stadia slide rule, pencil, eraser; these blanks are to be filled out and handed in.

Method: The plane table with telescopic alidade is used both to make a map, measuring distances either with stadia rod or by intersection, resection, etc., and to measure elevations. When used for a traverse it is almost universally the every-other-station method where the table is oriented with the compass on the base of the instrument. These notes were taken on such a traverse. In this method the table is never set over either starting or ending points of the traverse. The rod is held on the starting point and the table is set up some distance away. After the table is oriented with compass a sight for distance and elevation is made to the starting point thus locating it by resection. Such a sight to get position and elevation from a previously determined point is called a BACKSIGHT(B.S.). Next the rod is sent ahead along the route to some convenient location. There it is set up and its location and elevation determined with the alidade. Such a sight to a previously unknown point is called a FORESIGHT (F.S.). The point where the rod was held is called a TURNINGPOINT (T.P.). The rodman stays at this point while the instrument man brings the table past him and sets it up at some point ahead on the line to be traversed. Then a backsight is taken to the turning point again after compass orientation of the table. Then a foresight is made and so on until either the initial point or end of the survey is reached. The last reading must always be a foresight. In the following notes the vertical angle of the telescope was read on the degree scale with its vernier which reads to minutes. The middle wire was set on the rod wherever convenient after the distance had been read; then the rodman was signaled to move if it was a backsight or to lay down the rod if a foresight had just been taken; next the control level was centered and the vernier read. During times that the rodman was walking the instrument man subtracted 30-00 degrees from the angles and made the computations. The computation of distance (as it appears from the stadia reading) and vertical angle gives the difference in elevation of the instrument and the point on the rod where the middle wire hits; this is called the COMPUTED DIFFERENCE. Now what is needed for computation of elevations is not this quantity but the difference of elevation between the instrument and the bottom of the rod; this is the NET DIFFERENCE. The reading of the middle wire above the bottom of the rod is called the ROD CORRECTION. Study the diagram below and see that if the sight is uphill from the instrument the rod correction is <u>subtracted</u> from the computed difference to get the net difference; if the sight is downhill the rod correction is <u>added</u> to the computed difference. Uphill is a + angle; downhill is a - angle. In the case that the telescope was level and the middle wire was read there is no computed difference. In case another than the middle wire was read with telescope level the computed difference is equal to the half interval rod reading found when getting the distance. Elevations of the instrument are here called STATION elevations for in other problems the term HEIGHT OF INSTRUMENT is used in another sense. In these notes the elevation of the ground at stations is not shown. Sometimes foresights are taken to points which are not used for backsights; they are called SIDE SHOTS .



In the notes the locations of stations are commonly denoted by letters and of turning points by numbers. It is possible to compute notes without any more rules than have been given above; all that is needed is to keep one's head as to the proper time to add and subtract. Experience has shown, however, that few beginners can do this for long, especially if the weather is bad or if tired at the end of the day. It is therefore absolutely necessary to memorize the following rules which are based on the diagram given on the last page and on simple algebra.
(a) Give the vertical angle which is obtained by subtracting 30-00 degrees from the observed or oblique angle (this is not necessary with the K. and E. instrument but with it you have to notice when it is pointed up and when down) the algebraic sign of the remainder. Uphill angles are then + and downhill are -.
(b) Give the computed difference the same sign as that of the vertical angle in the case of foresights and the <u>opposite sign</u> in the case of backsights. This may easily be remembered by thinking that backsights are taken looking the opposite way from the direction the survey is going. This is the reason for keeping distance readings in separate columns for foresights and backsights. A little study of the diagram will show how this rule is derived.
(c) Give the rod correction a + sign for all backsights and a - sign for all foresights including sideshots. This rule is arbitrary but is the same as for leveling.
(d) Combine the computed difference and rod correction by algebraic rules to get the net difference with proper sign.
(e) In case of level shots when middle wire is read carry over rod correction with sign unchanged into net difference column.
(f) In case of level shots when other than middle wire is read treat readings of upper wire (recorded by placing capital U before rod correction) as + angles and of lower wire (recorded by capital L) as - angles and then apply same rules as if angles had been read. Make no change in rod correction column but place half interval in computed difference column with appropriate sign and apply usual rules.
(g) When computing elevations notice that each is derived from the last before by applying the net difference. If net difference is - subtract from proceeding elevation; if + add it. Notice that elevations alternate (where there are no side shots) between those of turning points and those of stations and that they are kept in separate columns.
(h) Notice that signs for degrees and minutes are <u>never shown</u> for fear of confusion with figures 0 and 1 but that the two are separated by a -. Do not omit 0 after a decimal point and in case of minutes 00. In case of readings of less than 10 minutes write 05, etc.

Caution: Do not carry computations of net differences to closer than tenths of feet. Remember that results can be no more accurate than the original data. Remember the error on the computer: "rod reading" means full interval X 100. In case of distances over 1000 feet compute the difference for 1000 feet; then the difference for the amount over 1000 feet and add the two quantities. Notice that notes do not show the corrected horizontal distance. This is used <u>only</u> for platting on the plane table.

Problem 11, data sheet   Edition 1953

NAME

Compute the following actual field notes. Those used for Problem 12 were taken along same line of survey. DO NOT compute elevations until you have checked the net differences in the two problems and see that there is no large difference in any pairs of shots. A good idea is to rule your scratch sheet into squares and keep computations separate and in order. Do not compute true horizontal distances for such are used only in platting on the planetable. When you come to computing elevations the best idea is to arrange a column on scratch paper and give the + or - sign before each net difference. You will make fewer mistakes in this way than in trying to carry across from one column to another. Remember that almost all large errors are made in computation rather than in reading or recording. The more you do in computing here the quicker it will go in the field and there computations must be done at once (not in office only). The method of computation is based on long experience and is better than Low's. Show all signs. + or - Carry elevations to nearest tenth of foot.

Stadia constant (stadia interval factor) = 100.0

Loc.		Interval		Angles			Diff. elevation			Elevation	
Sta	T. P.	B. S.	F. S.	Oblique	Diff	Factor	Comp.	Rod corr.	Net	Sta.	T.P.
A	B.M.	7.2		30-00	0	0	0	M3.0			1593.0
	1		4.0	30-00				M11.0			
B	1	12.0		31-50				M2.0			
	2		3.4	30-00				M2.5			
C	2	7.3		28-40				M6.0			
	3		5.6	30-00				M7.0			
D	3	2.6		30-00				M1.3			
	4		12.0	30-00				L12.0			
E	4	4.2		30-00				M1.1			
	5		2.9	30-00				M5.7			
F	5	4.4		30-00				M8.3			
	6		7.6	30-00				M12.0			
G	6	5.5		30-00				M2.6			
	7		9.0	31-08				M12.0			
H	7	2.3		32-10				M3.0			
	8		5.9	31-10				M7.0			
I	8	2x6.5		30-00				M3.5			
	9		9.7	30-00				M4.0			
J	9	2.6		31-45				M3.0			
	10		3.8	30-00				M6.6			
K	10	3.5		30-00				M9.0			
	11		4.0	30-00				M11.5			
L	11	2x8.8		30-50				M2.0			
	12		3.0	31-47				M3.0			
M	12	7.2		29-05				M13.0			
	13		2x6.0	28-06				M8.0			
N	13	10.0		28-51				M12.0			
	14		2x6.6	30-00				L13.4			
O	14	7.3		31-10				M9.0			
	15		5.4	27-52				M8.0			
P	15	2x12.0		29-05				M10.0			
	16		4.8	30-00				M9.5			
Q	16	2x11.3		32-20				M13.0			
	17		3.3	28-50				M10.0			
R	17	2.5		30-00				M0.7			
	18		10.6	30-00				M1.3			
S	18	3.3		30-00				M5.2			
	19		8.4	30-00				M7.0			
T	19	3.7		30-53				M4.0			
	20		7.5	32-24				M10.0			
U	20	2.1		30-33				M1.1			
	21		3.9	31-43				M4.3			

GEOLOGY 11

MAPPING

Problem 12, edition 1948

Object: Computation of notes taken with planetable and telescopic alidade using Beaman arc system.

Material: Pencil (soft), eraser, scratch paper.

Method: The field routine was: (1) read distance, generally with top wire on top of rod, (2) level index bubble, (3) set telescope so that it is on a Beaman division, because with uneven divisions no vernier is possible and fractions would have to be estimated which is not close enough, (4) read where middle wire cuts rod, that is the rod correction of the notes. Note that columns in notes are essentially same as for angle method. The distance is not put down but instead the FULL INTERVAL reading, or distance/100. Some people call the "computed difference" the "product" because it is the result of multiplying the remainder (after 50 is subtracted) from the arc reading by the full interval reading. Note that this is the same computation as with both "step" and "drum" methods, in other words one "Beaman" = one step = one drum revolution of 100 units. The only difference is that the Beaman arc serves for all angles whereas the other methods are limited to low angles. Rules for signs are exactly the same as with angles.

For backsights sign of product or computed difference is OPPOSITE to sign of remainder when 50 is subtracted from arc reading.

For foresights (including sideshots) the signs are the SAME.

All rod correction readings on backsights are +

" " " " foresights are -

Net difference is algebraic sum of computed difference and rod cor.

Upper wire = + ar difference (remainder). Lower wire = - dif.

KEEP YOUR SCRATCH NOTES IN A SYSTEMATIC WAY.

Problem 12 Data sheet, edition 1953

NAME

Compute the following checking net differences with 1953 editon of Problem 11
Use same suggestions for computation Carry results to nearest tneth foot.
Show all signs. Make sketches if desired

Loc.		Interval		Beaman arc		Diff. elevation			Elevation	
Sta.	T.P.	B.S.	F.S.	Arc	Diff.	Comp.	hod corr.	Net	Sta	T. P.
A	B.M.	7.2		50	0	0	M3.0			1593.0
	1		4.0	50			M11.0			
B	1	12.0		53			M1.4			
	2		3.4	50			M2.5			
C	2	7.2		48			M9.0			
	3		5.6	50			M7.0			
D	3	2.6		50			M1.3			
	4		12.0	50			L12.0			
E	4	4.2		50			M1.2			
	5		2.9	50			M5.7			
F	5	4.4		50			M8.3			
	6		7.6	50			M11.8			
G	6	5.5		50			M2.6			
	7		9.0	52			M12.2			
H	7	2.2		55			M6.8			
	8		5.9	52			M6.8			
I	8	2x6.5		50			M3.5			
	9		9.7	50			M4.0			
J	9	2.6		53			M3.0			
	10		3.8	50			M6.6			
K	10	3.5		50			M9.0			
	11		4.0	50			M11.5			
L	11	2x8.8		52			M12.0			
	12		3.0	53			M3.0			
M	12	7.2		48			M10.0			
	13		2x6.0	46			M0.0			
N	13	10.4		47			M1.0			
	14		2x6.6	50			L13.8			
O	14	7.3		52			M9.0			
	15		5.4	47			M12.0			
P	15	2 x12.0		49			L12.0			
	16		4.8	50			M9.5			
Q	16	2x11.3		54			M12.0			
	17		3.2	48			M11.0			
R	17	2.5		50			M0.7			
	18		10.6	50			M1.0			
S	18	3.3		50			M5.2			
	19		8.4	50			M7.0			
T	19	3.7		51			M1.0			
	20		7.4	54			M9.0			
U	20	2.1		51			M11.0			
	21		3.9	53			M4.3			

Problem p 2 edition 1948

Name ______________________________

Notes by Twenhofel and Hanners

Locations		Distance	Angles		Comp Diff	Elevations					
						Sta Oc			Sta std		
Sta Oc	Sta std	feet	Oblique	Diff	Diff Elev.	Ground	H I	Inst.	Ground	H F	Flag
W Ba	E Bl	2330	40-30				4			10	
	D D	2610	39-39							7	
	S E B	3290	38-17							10	
	D G	5230	34-01							6	
	T	1140	45-33							2	
	E Ba	2190	31-00							2	
	B M	1360	30-49						992	14	
E Ba	W Ba	2190	28-53				4			2	
	T	3100	35-02							2	
	S B	2120	40-27							15	
	E B	2420	39-17							10	
	D D	1680	43-37							7	
	S E B	1490	46-37							10	
E Bl	W Ba	2330	19-31				4			2	
	T	3440	28-06							2	
	S B	4310	30-02							15	
	R R	5110	28-35							4	
D D	W Ba	2610	30-22				4			2	
	S B	3780	29-50							15	
	R R	4530	28-08							4	
S E B	W Ba	3390	31-46				4			2	
	T	4340	27-50							2	
	S B	3470	39-18							15	
	D G	2340	27-27							6	
	R R	3680	27-24							4	

Note: S C = not established - Sights to D D from E Bl and S E B were omitted except for direction. [illegible]

GEOLOGY 11

MAPPING

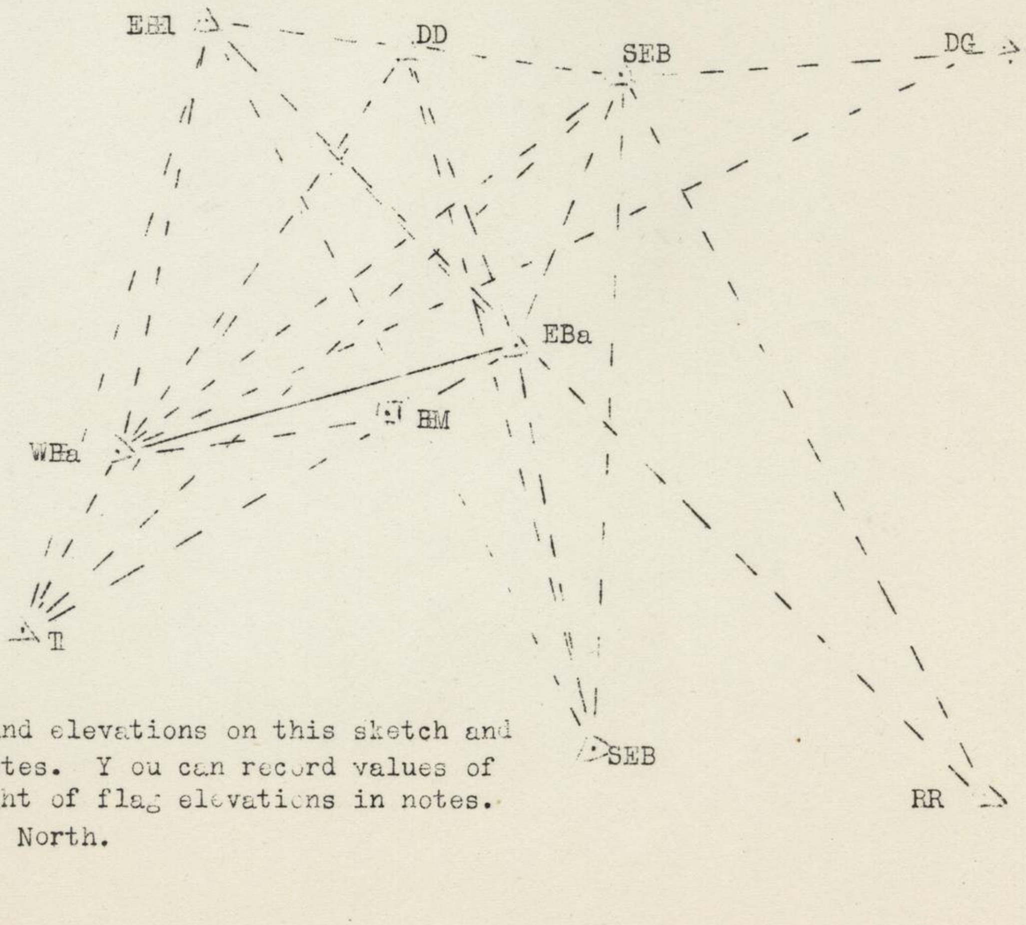
Problem 13, edition, 1948

Object: Computation of planetable survey where distances were found by intersections and differences of elevation by vertical angles.

Material: Table of tangents, pencil, eraser; blanks on page 2 to be filled in and handed in.

Method: The sketch below shows the lay-out of the survey which was started from a baseline measured with a steel tape. First two columns give locations abbreviated to initials. Distances are true horizontal. Oblique angle is angle read with middle wire on flag of station sighted. Angle difference is obtained by subtracting 30-00 from these readings. Computed difference is obtained by use of table. Multiply horizontal distance by tangent of angle difference. H. I. column gives height of instrument above ground. Elevations of station occupied are given both for ground and instrument and must differ by this figure. Computations are made to nearest foot only. Column H. F. gives height of flag at stations sighted above ground so that elevations of ground and flag must differ by this amount. No rules for signs are needed; simply keep your head. If work is well done the elevations of different stations should not differ over 5 feet when derived from different sources. Place most reliance on low angles. Scale 1 in. = 1000 ft.

Dg and RR are located only roughly. Where should these observers have gone next and what shots should they have tried? What shots did they omit?



Enter your ground elevations on this sketch and hand in with notes. You can record values of tangents at right of flag elevations in notes.

Top of sketch is North.

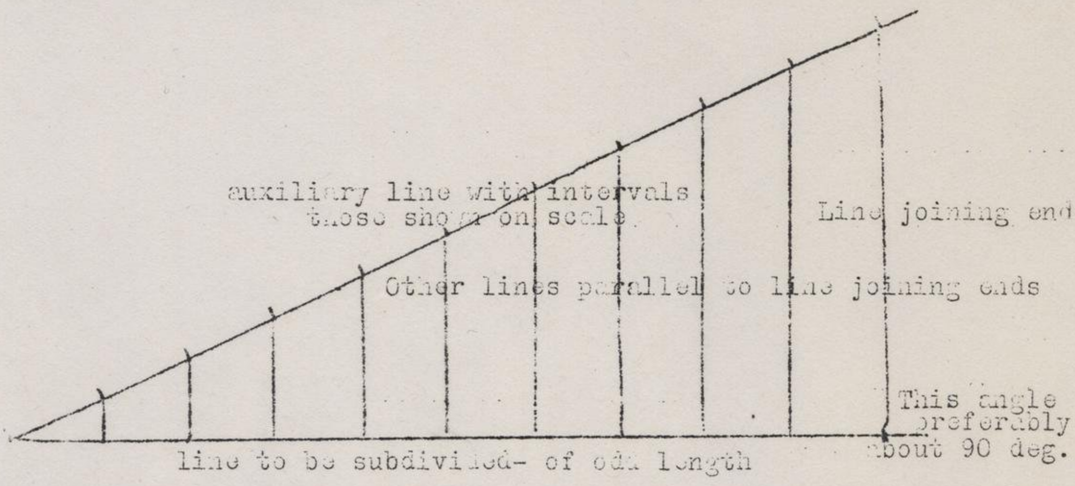
not used

GEOLOGY 11
MAPPING
Problem 14, edition, 1930

Object: Construction of scales showing (a) map or horizontal distance of 20 foot contours on different slopes, and (b) 10 foot differences of elevation on a one degree slope, both for map scale 1 inch = 1000 feet.

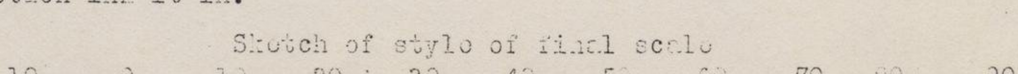
Material: Sheets of plane bond paper, hard pencil , scale of inches showing tenths or other decimal divisions, eraser, two triangles

Method: Scales showing horzontal spacing of contours and of units of elevation for given map scales and slopes are military inventions but can be used by geologists much more widely than they are. For simplicity we will first take up the second kind of scale; this is known as a one degree slope scale. A one degree slope is one of one vertical unit in 57.3 horizontal units or 1.75 vertical units in 100 horizontal units. From this information compute how many feet horizontal distance to 10 feet vertical distance. Next it is neccessary to compute how far this is on the map scale of 1 inch = 1000 feet. If we diesire to make this scale to show 100 foot total difference in elevation or 10 spaces take 10 times the above figure. Measure off such a line using due care. For the map distances change the feet of the original computation to inches. Next subdivide this 100 foot scale into ten equal parts. The scale which you have will not show the points which you will have to mark therefore proceed as follows. See sketch. From one end of the line to be subdivided lay off a line at an angle. On this line lay off ten divisions which are shown on your scale. Choose divisions and angle so that outer end of this auxiliary line is nearly vertically above the other end of the line to be subdivided. Now join the outer ends of both lines. Then through the marked subdivisions of the auxiliary line pass lines parallel to this line thus subdividing the line desired. This method works best when the lines intersect at about right angles. It is much more accurate than the other way



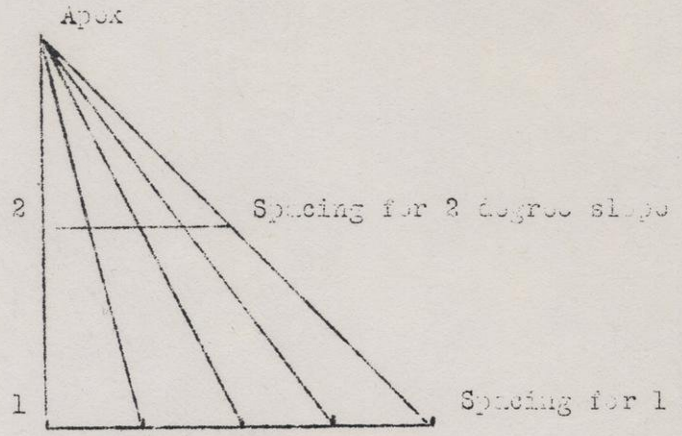
Use same method to subdivide one of the end divisions into 10 equal parts. Now transfer final job to edge of a fresh sheet of paper using all possible care. Number the divisions placing the 0 at the division between the 1 foot units and the 10 foot spaces. This subdivided portion of the scale should be placed at left end of final scale. Number the other divisions from 10 to 90. When this scale is complete it is possible to measure with it the difference of elevation between any two designated points on the map of scale 1 inch = 1000 feet if there is a 1 degree slope between them. If the slope is greater than one degree the reading is multiplied by the number of degrees to obtain the true figure. This scale is to be pasted on edge of an opensight alidade so after inspection ink it in.

Sketch of style of final scale

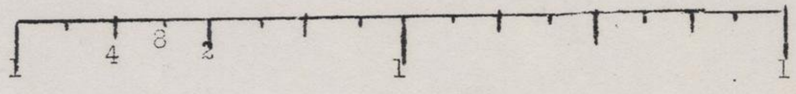


Notethat it is undesirable to show one foot units all along the scale in order to save labor in construction; read the number of tens on right portion of scale and excess less than 10 on the subdivided portion to left of 0. The one degree slope scale is a handy way of measuring either (a) difference of elevation when distance on map and vertical angle are known, or (b) distance on map where difference of elevation and vertical angle are known.

Instead of using the one degree slope scale it is sometimes more convenient to have a scale which shows the map spacing of contours on slopes of known amount. This can be used to put in contours when you know the angle of a slope but not its full extent. The following method of construction was devised by W. J. Mead during the World War. Lay off a horizontal line parallel and close to one end of a sheet of paper more than 10 inches long. On this line lay off, using the one degree slope scale already drawn, the spacing of 20 foot contours on a one degree slope, map scale 1 inch = 1000 feet. Show about 4 such spaces. At left end of this line, held so that it is at bottom of the paper, erect a perpendic On this lay off preferably 10 inches although any even number of inches will do. Join this point with straight lines to the several points on the horizontal line as shown in sketch which is not to scale. Now to find how far apart 20 foot contours will be on a 2 degree slope divide the vertical line in half and draw a line parallel to the original or base line. To find how far apart on a three degree slope lay off such a line one third of the way from the apex to the base. Do this for all degrees up to 12.



Now this diagram would be awkward to carry in the field so it is best to use its data to construct another kind of scale which can be pasted on edge of alidade. If we make a scale for contours on an 8 degree slope it is evident that by using every other mark we could space them on a 4 degree slope and by using every fourth one we could place them on a 2 degree slope, etc. Use above diagram to lay foo a scale for 1, 2, 4, 8 degrees, another for 3, 6, 12, another for 5, 10. This will give all angles except 9 and 11 which may be estimated when needed. Use style suggested below. Be sure you know what these scales are for and how they may be used to save time and increase accuracy in the field.



Contour spacing scale-style only, not correct size

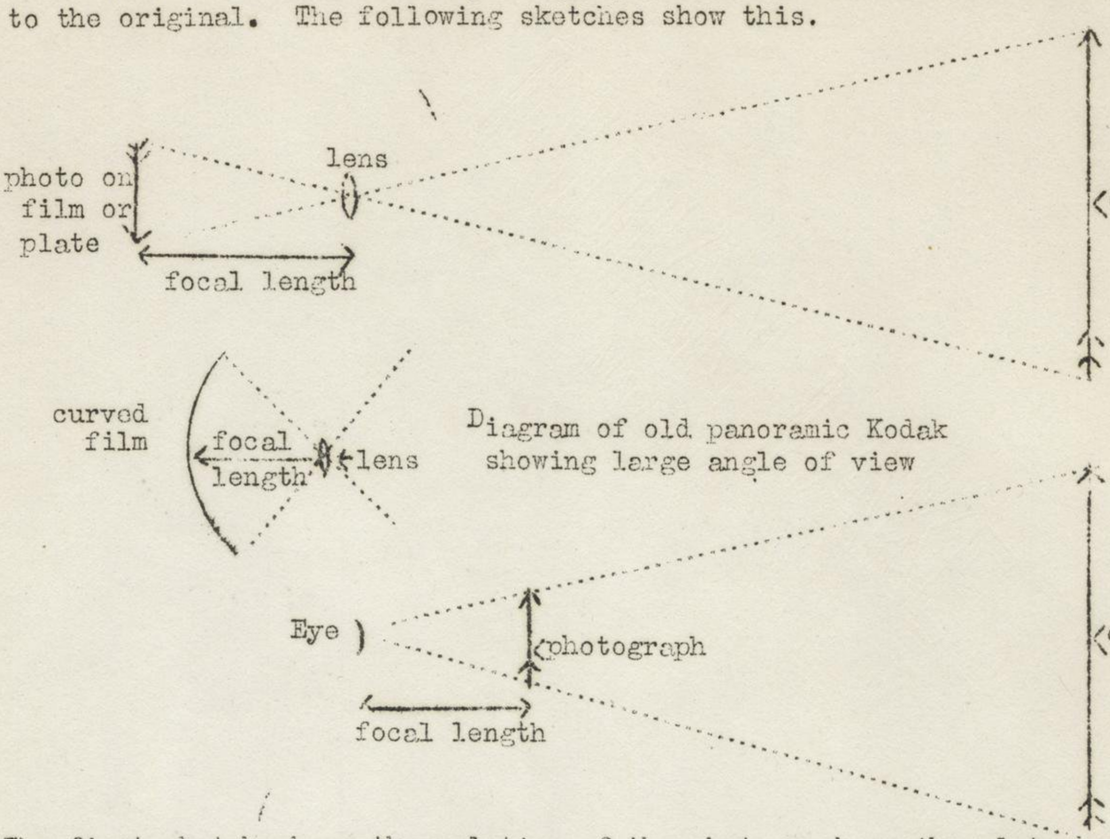
Keep these scales short as only a limited amount of space can be devoted to them

GEOLOGY 11
MAPPING
Problem 15, Edition, 1941.

Object: To draw a map from photographs taken from the ground.

Material: Hard pencil, eraser, scale giving tenths or other decimal divisions of inches, protractor, paper either plain or cross section.

Method: It is first necessary to grasp the mathematical relation of a photograph to the original. The following sketches show this.



The first sketch shows the relation of the photograph on the plate or film to the original, or object, provided an ordinary camera was used and placed with axis level. The sketch applies to either a vertical or a horizontal plane. Note definition of <u>focal length</u>. It is essential to grasp the following ideas. (a) Every photograph with the axis horizontal shows a portion of the ground which is shaped like a triangle. (b) In a photograph all objects which have the same horizontal angle, away from the vertical plane through the axis line lie in the same straight line on the picture. (c) All points on the level of the camera are in a horizontal line called the <u>horizon line</u>. (d) In a photograph taken with horizontal axis, both vertical angles are shown by distances from the horizon line or vertical plane which are proportional to the <u>tangent</u> of that angle. (An exception to the last statement is the old Panoramic Kodak; in this instrument, illustrated in the middle sketch, the film was curved in a semi-circle to secure a larger angle in each picture than is possible with an ordinary camera. Its horizontal angles were <u>directly</u> proportioned to distances on the photograph. All points with the same horizontal angle lie in same vertical line. All points with same vertical angle lie along a line which curves farther away from the horizon line with increasing distance from center vertical line with ordinary camera (straight lines with Panoramic Kodak - sketch, next page.) The lowest sketch illustrates another fundamental idea, namely that if the photograph were transparent and held in front of the human eye at a distance equal to the focal length of the camera it would just match with the original if the observer were on the same spot as the picture was taken from.

Laying out the map. Two different kinds of photographs are available: (a) some sets of views taken in Alaska with the old Panoramic Kodak, and (b) some photographs taken at Devis Lake with an ordinary camera. Note carefully which you have. Look over the available data which includes the distance apart of some of the camera stations and the compass bearings of some of these and other lines. Without such auxiliary data no map could be made. In practice ground control is made by either transit or plane table. Some elevations are also supplied. Points shown in more than one photograph are in some cases marked in the pictures. The first step is to lay out the skeleton of the map (control points). Look over the photographs and decide what part of the paper you should start on. Plat compass directions of other camera stations first. Now at every station lay off a line for the vertical axial plane of the camera for each picture. To locate this line accurately extend a line to another station near to this plane. On one side of a sheet of paper mark the focal length; on adjacent side of same paper, at right angles to first side, mark the distance on picture between the other station and the axial plane measuring same in direction parallel to horizon line. Now fit the triangle to the extended line in proper relation to bring line at right angles to axial plane at distance from picture station equal to focal length. See diagram below. Now extend this line and call it the picture plane. It is where you would put a transparent picture to just cover the original view with your eye at station. To obtain angle of rays to any object in a picture, measure horizontal distance from vertical axial plane and plat on picture plane of the map. Join this point to picture station and you have same result as if you had sighted an alidade on a plane table. Obviously, the intersection of such lines from different stations gives locations just as do intersections on the planetable. It constitutes indoor planetabling. The advantage is that time spent in the field is greatly reduced but time in the office is much increased. Certain climates make this desirable.

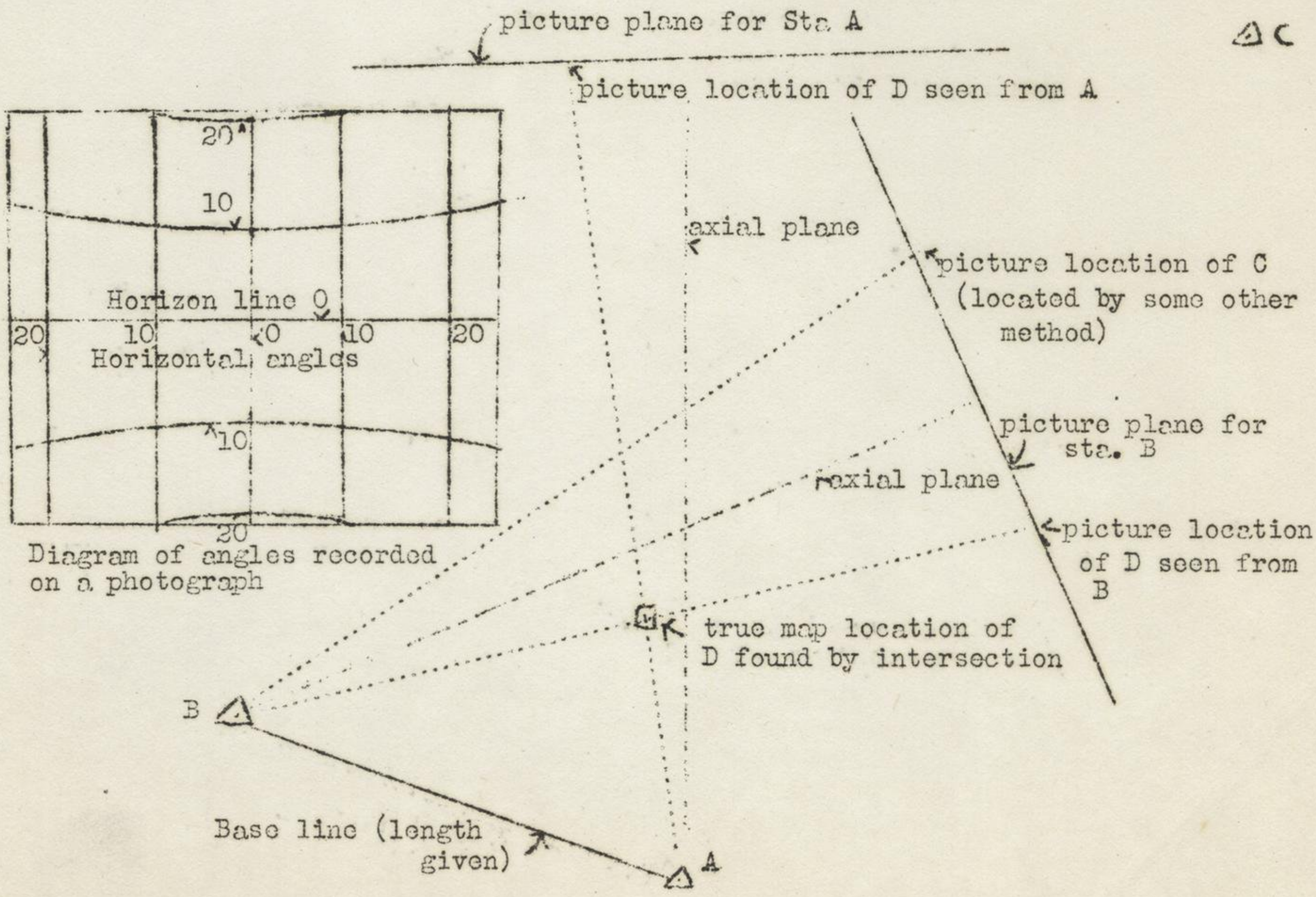
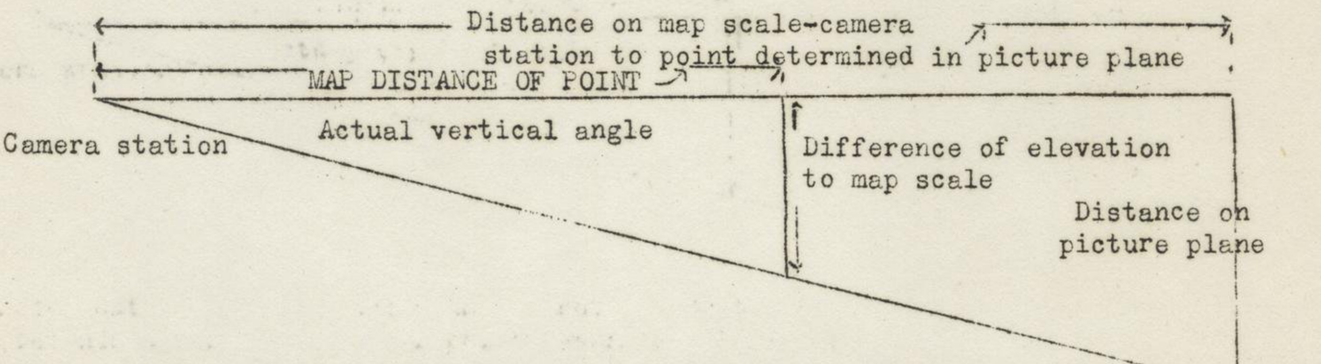


Diagram of angles recorded on a photograph

Finding elevations. The elevations of some of the camera stations are given, otherwise no map could be made. After you have located enough points to enable you to make a good map it is time to find difference of elevation of these points as compared with known places. The most practical way of doing this is to solve the problem of finding elevations from known distance and known angle. The distances can now be taken from the map, working from a picture where the elevation of camera is known. The angles can be determined from the picture. To do this a right triangle is solved. One side of this, say the horizontal base, is the distance from the location of the station on the map to the platted position of this point in question on the picture plane. The other side, at right angles to the above, (the vertical side) is the picture distance of the point in question above or below the horizon line shown on the photograph. The third side or hypothenuse joins the last point with the other end of the horizontal side. The angle at the last point is the actual vertical angle which would have been measured had you sighted the point in question from the camera station. It is not desirable to measure this angle in degrees. The problem can be solved graphically. On the horizontal line of the triangle plat the map distance of the point in questio n as transferred with dividers or otherwise. Use the same scale as used for the map to scale vertical distance above or below this point to the hypothenuse. This is the difference of elevation and should be properly applied to the elevation of the camera station to get desired elevation. Note that with an ordinary camera the distance from the station to the picture plane is not constant but increases toward the sides of the picture. It is therefore necessary to use several triangles for each picture. In the case of the Panoramic Kodak the focal length was constant. This instrument is now obsolete.



Note that line to picture plane is not always the same but depends upoint relation of point determined from central vertical plane.

Drawing contours. When all points have been platted with elevations it is time to start drawing contours. The problem of sketching lines of equal elevation is the same as that met with in the field with ordinary surface surveys. Before accepting any location it must be checked in more than one photo of the same area wherever possible. Never draw contours where you cannot see the ground in at least one picture. Try to make the drawing an real interpretation of the ground form and not a mechanical interpolation between known points. Note that if two views are taken from each camera station with camera on same level and separated by 50 feet or more ground distance these can be used in an ordinary stereoscope thus getting a better idea of topographic form than can be observed either with the unaided eye or on a single photograph. All that is needed for a ground photographic survey is an ordinary camera properly equipped to take distant landscapes. The camera must be levelled for every exposure. Panchromatic film with a red filter is best. Some form of ground control must also be surveyed to find position and elevation of as many camera stations as poss ible. Use of photography on the ground is still a good method for surveying some areas. End

GEOLOGY 11

MAPPING
Problem 16 and 16a, Edition 1950

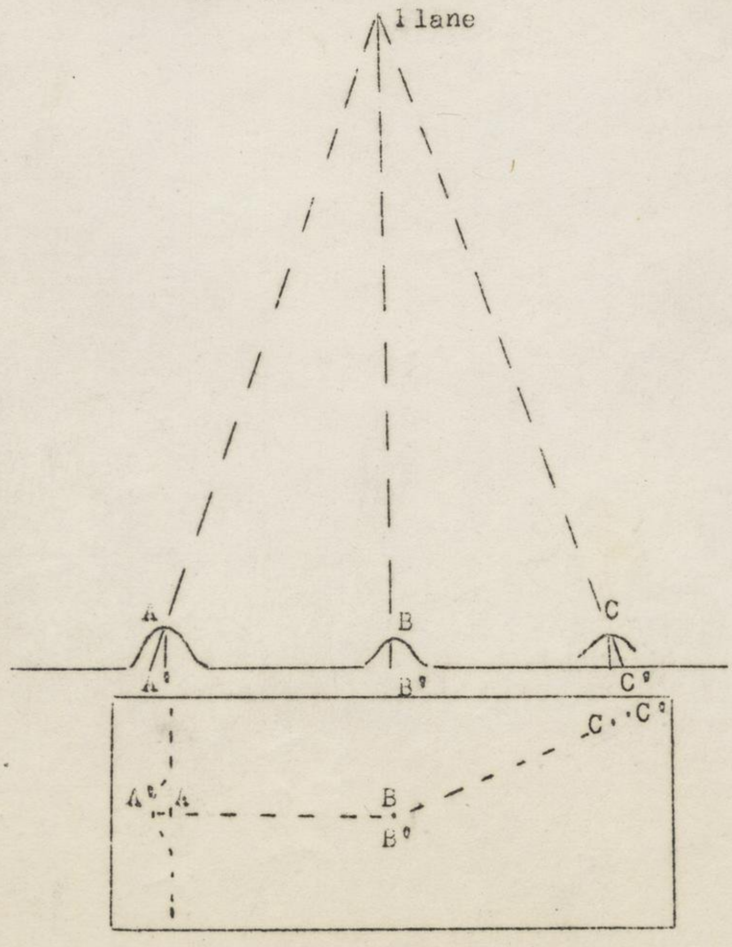
Object: To draw a map from aerial photographs.

Material: Hard pencil, eraser, scale, stereoscope with parallel arm (stereocomparagraph), magnifier, triangle, tracing paper (about $8\frac{1}{2}$ x 11"), photos, map with elevation data.

Method: Photographs taken from the air may be divided into (a) obliques with camera axis tilted downward and (b) verticals taken with camera axis as nearly vertical as possible. Obliques are taken up in Problem 17. Read TM 5-230, pp. 188-249.

Vertical Pictures: Every vertical picture is a complete and accurate map of the area shown, provided that (a) the camera axis is exactly vertical and (b) the land is essentially a plane. The scale of this map is fixed by the elevation at which the picture was taken in relation to the focal length of the camera. In actual practice, however, it is very difficult to meet these conditions precisely. Obviously if the land is not flat, the tops of hills are shown at a larger scale than are the lowlands. Check the scale of your photographs by measuring several known distances. If you do not get the same result in different parts of the area at the same elevation, the camera was tilted. A line on the land surface which is straight but runs up and down hill is not straight in the picture. The amount of curve due to differences of elevation increases radially away from the center of the photograph as shown in the following figures:

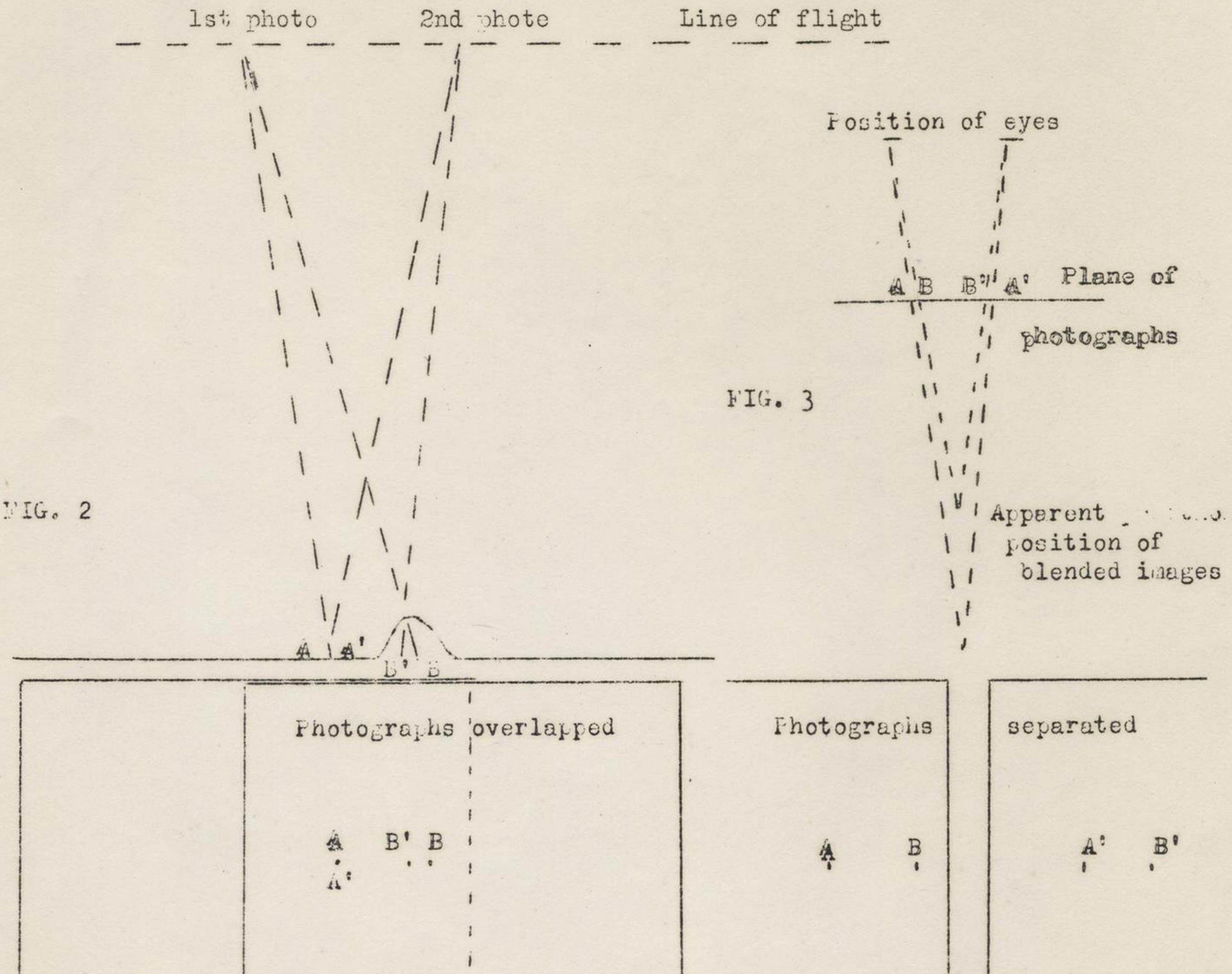
FIG. 1



Note distortion of straight line across hill at A and that C' is displaced from C along a radial line from center of photograph.

Three hills rise from a plain. The one vertically below the camera has its top B shown on the picture in the same place as if it had been at plain level B'. But the hills near the sides of the picture have their tops A and C. displaced outward from the center of the view to A' and C'. The distortion of straight lines across each hill is also shown.

Stereoscopic effect. Photographs are taken in the air at horizontal distances such that each overlaps the adjacent ones by 60 per cent or more. Were the land all flat you could not tell any difference in one picture from another of the same spot, but where there is relief the relative positions of high and low points differ in the overlapping pictures.



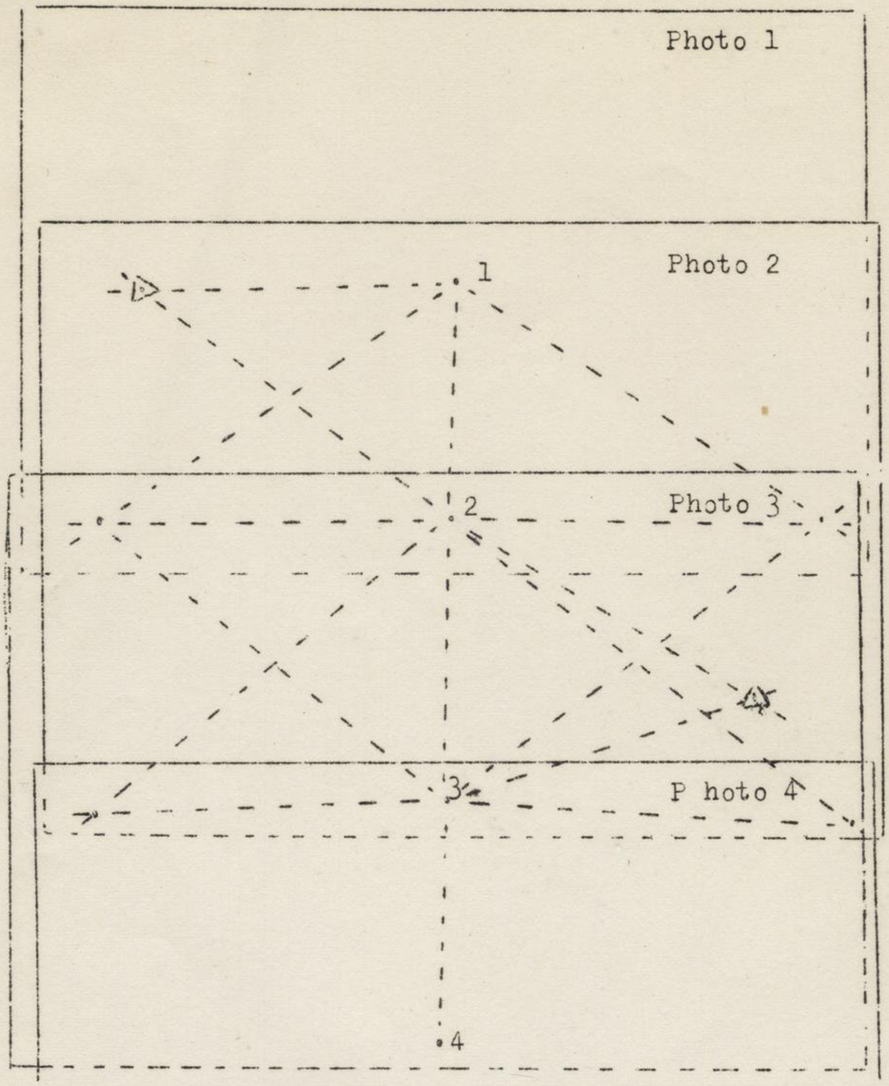
Now place a pair of adjacent photos so that the common areas are next to one another. Shift one or both until you see some of the highlights double. Make these coincide and the fused image will look like a relief model. Keep looking as if you were in the plane at a great distance from ground until you can get the effect. The mirrors or lenses serve only to separate the eyes so that each sees only one picture. A similar result may be obtained with two magnifiers or by holding a paper between the eyes. In these cases the common points in the pictures must be eye distance (about 2½") apart. It is possible to dispence with the paper. Put the common points of two pictures about 2½ inches apart. Slowly raise the pictures into the line of sight with eyes relaxed (daydreaming). This does not injure the eyes but considerable practice is needed. The closer the eyes come to the picture the better the stereoscopic effect. Note that two other images, one on either side of that in relief, are seen. These do no harm to the eyes. Shift photos until you get relief effect.

Map location of points. NOTE: Actual construction done only for problem 16a but all must know the principle.

The rays drawn from the center of the photograph (which was vertically under the plane and is found by intersecting lines either between marks in the margins or the corners) to objects seen in the picture represent true angles just as though you had set up a plane table there and sighted those points through an alidade. The map location of this center or principal point may be found by passing the rays to three recognizable points in the picture which had previously been located on the ground through the plotted map position of those points. This is merely solving the "three point problem". This orients the photograph in respect to the map control. Now rays may be drawn on tracing paper from the picture center to unknown points, mainly hill tops. Mark on each ray apparent position of point using a small definite dot for each but extend lines. Next comes the problem of correctly locating the next overlapping photograph. Find its center as before. Locate this point on the first photograph. If the centers are both at the same elevation then the distance between them is the correct map distance. But if the elevations differ a correction must be applied. Draw the line between the two centers on your map. Use this line to orient the tracing over the second picture. Shift along this line until rays from center of second picture to known points already correctly located pass through the map locations. One such intersection would be enough to give map location of the second center but two properly located off to the sides are much better. Note similarity to plane table method of location of unknown point. You may also find correctly located points such as section corners in the second picture. See TM 5-230 pp. 188-212.

Show on your final map to proper scale the locations of section corners as given by U. S. Land Survey. These will be your control points. Draw radial lines from centers of each photograph to those on your tracings. When agreement on intersections has been reached prick through proper map locations onto your final sheet. The chief error in such "plane tabling from the air" is tilt of the photographs. But compare it with error in doing the same work on the ground!

FIG. 4 Radial line adjustment



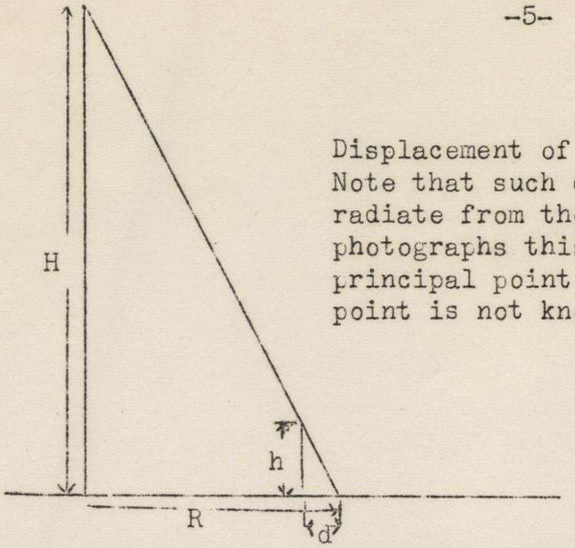
This shows method of tying together photos in the same flight. There are two control points shown, here marked with triangles. These have been shown on final map underneath the tracing paper.sheets with radial lines. Note the points which are common to three photos as these are very important. The same points also show in adjoining flights and serve to connect the two flights. Center of Photo 4 is also shown as in preparation to extend the assembley. Note that line of flight is not always straight. See how use of slotted templets would help a big job but take too much time to prepare for a small one. See following directions for how to mark centers of photos (principal points).

Be sure to understand that directions hold over distances and that all lines to a certain location must intersect at same point.

In problem 16a the photos will cover two adjacent flights. Flights are commonly made going either north or south with an overlap of about 30%. After arranging the tracing paper sheets (templets) you will soon realize the advantage of the slotted templet system. This was at first done with cardboard sheets cut with a special punch along the radial lines. These sheets conceal the basemap and are thrown away when it is finished. Hence metal arms which may be clamped into propr relation to one another have displaced cardboard. No templet need be made for problem 16 since it would add little to accuracy of results but a width of only two miles should be mapped to avoid distortion due to relief and tilt which affects the sides of the photos most.

Distortion due to relief. Displacement of points due to difference of elevation above or below the normal or datum plane is along lines which radiate outward from the point vertically below the camera. It is commonly assumed that this plumb or nadir point coincides with the center or principal point. The actual displacement depends upon the proportion: altitude of plane, H: difference of elevation, h:: radial photo distance of point, R: displacement from true position, d. In solving this note that each pair of terms must be in same units, for instance if H = 14000 feet, and h = 200 feet, then R and d must be expressed either both in inches or both in millimeters. In this case if R = 100 mm. then d = 1.43 mm. and if h is above the datum plane the true location of the point must be moved along the radial line toward the principal point by this amount. See figure 5 on next page.

FIG. 5



Displacement of a point in photograph due to relief. Note that such dsiplacements are along lines which radiate from the plumb or nadir point. For most photographs this is not far enough from the center or principal point to make a material error if the nadir point is not known.

Setting up photographs. Even if you find your photos already set up on a board you should understand just how this was done. Look over the books of instructions. The "principal points" are all marked with red circles. Note the marks in margins or corners which were used to locate these. If you are using the Abrams instrument you should mark the line between the principal points with a sharp hard pencil, Turn the y dial (motion across line of flight) to read 0. Place instrument over a sheet of white paper and turn up the right hand marker about 4 complete turns. Then adjust left hand marker on its y axis until the two dots blend as one when you look at them through the lenses. If you wear glasses you may have to leave them off while working. Choose place on the board where the parallel arm will allow the instrument to cover the common part of the pair of photos. Lay down the left photo and turn until the line joining the centers (principal points) is on the line of the two dot markers. Staple down left corners of this photo. (Directions say use tape but this may cause more injury than do staples.) Now set the right photo over the left so that when left marker dot is on principal point of left photo the right dot is on principal point of the right photo and the two lines joining the principal points coincide. Another way to set up photos is to use front edge of the instrument as a straight edge; this is more rapid but less accurate. Next look through the lenses and see that you get good stereoscopic effect without eye strain. You may have to shift the right photo keeping it in same alignment. When satisfactory, staple down temporarily and flap over the edges to see that there is no "blind spot". Another shift may remove such, but you must not adjust without leaving enough space on the x motion to allow of moving the right dot by turning to left to allow of placing it on lowest points on the photos. Distance between common points must not exceed 2.45". Now practice reading from the dots. Whenever you look at the dots they will blend into one (unless too far apart). Practice looking at the ground at the same time; then when the dots blend into one it will appear to touch the surface. At first it is best to blink from one eye to the other to see that each dot is set at the same object in the two photographs. First try this on road intersections and other definite points. When you have the dots coinciding make the dial read 0 by turning its edge. Study map of area to find a road intersection near one edge of the area whose elevation is known. 0 dial on it. Now shift to other side of the area and see if you still have the dots coincide on an object at nearly or exactly the same elevation. If they do not one picture is tilted with respect to the other. Effect of tilt is largely, although not wholly, eliminated by following Abrams method as described on pp. 16-17 of their manual. Stick a needle through check point on one side; then turn around this axis until you get same parallax reading at the other check point. Then restaple. A tolerance of about 0.05 mm. is allowed in this measurement, otherwise it must be repeated. Always check back on first point again.

If you are using the Fairchild instrument you will find it easier to set up the photographs. Lock the parallel arm. Then line up left photo with the common principal points under the scale at the back. Staple down at once. Then measure map base or distance between principal points in millimeters. The corresponding points on right photo are then lined up in same way along same straight line and its map base is measured. Note that with this type of instrument you do not overlap the photos. To get proper distance for stereo vision do the same as with the other type. Place white paper below the dots and then make them blend by use of the large adjusting knob underneath the center. Now remove paper and shift right photo along the line of orientation until you get good relief effect. Be sure the micrometer is about the center of its scale when you fasten the right photo. Now pick out points of known elevation on the two sides of the flight and make the same adjustment as with the Abrams. Note that although the right dot can be moved for y parallax there is no means of measuring this motion. Distance between common points is about 6.20" with this machine.

Measuring elevations. After the photographs have been finially set and you have good stereo vision begin to practice measuring elevations. As suggested above you can best do this at first by blinking from one eye to the other and thus locating both dots on corresponding mark in each photo.

Parallax equation

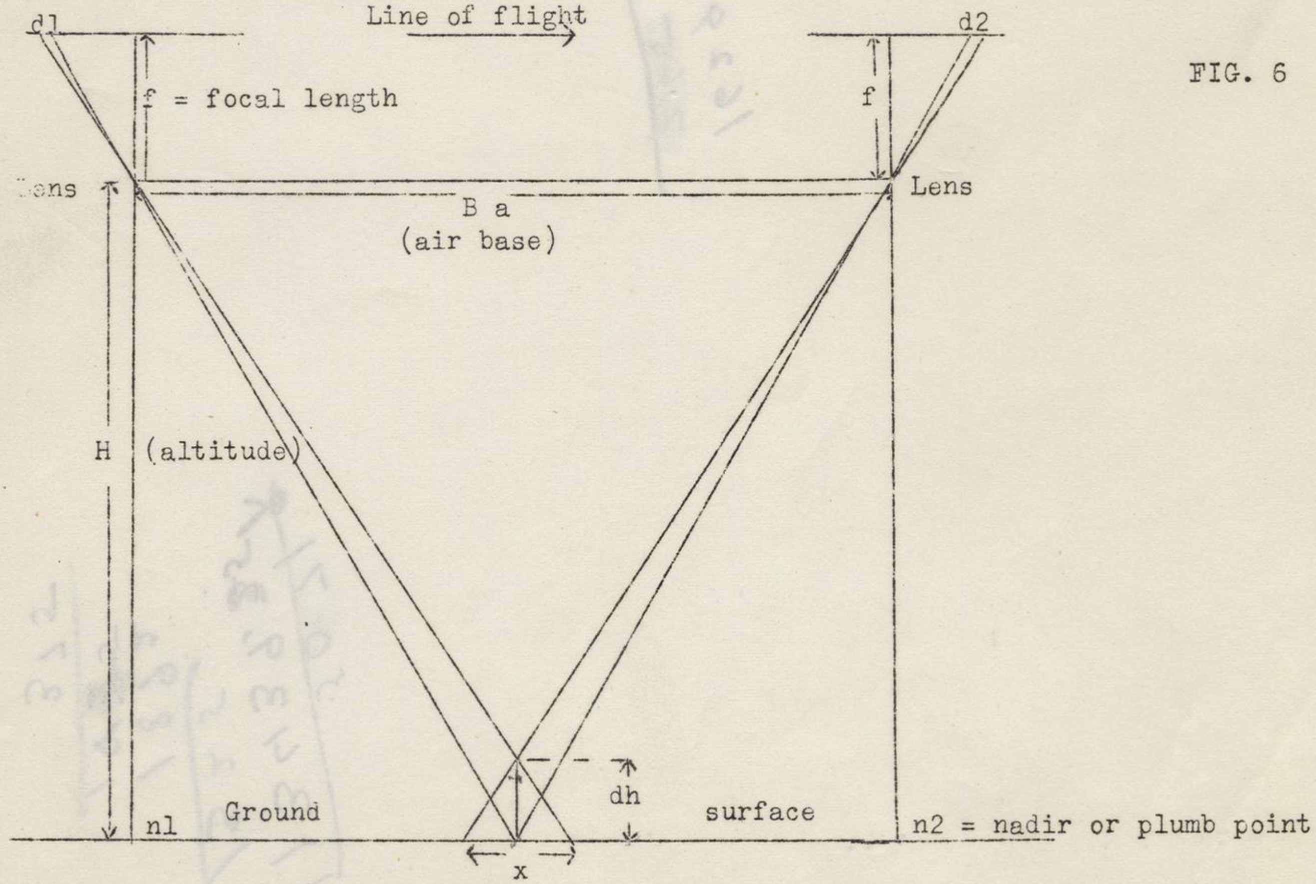


FIG. 6

See next page for derivation of formulas. It is here assumed that flight was exactly level, that axis of camera was exactly vertical in both photos, and that dh is small compared to H. On the two photographs Ba is represented by b, the map or photo base which is commonly assumed to be the distance between one principal point and the next. This distance is shown on both members of the stereo pair of photographs.

1629
2.65

2.65) 13439.25 (5071
1325
1892
1855
375

difference in parallax = $d_1 + d_2 = dp$

scale ratio = f/H = focal length/altitude

dp : x :: f : H, by scale ratio, whence x = dp.H/f (strictly speaking (H-dh) but dh is so small it may commonly be neglected)

also
dh : x :: H : Ba, by similar triangles, whence x = dh.Ba/H

equating to eliminate x,

dp.H/f = dh.B/H, hence dh = $dp.H^2/f.Ba$

but b on photo = Ba . scale ratio or:Ba.f/H

hence by substitution dh = dp.H/b

next substitute for H its value g.f/p where g = a ground distance, and p its length in the photo and f = focal length

Measure p on photos, also b usually in ",

hence dh = dp.g.f/b.p

Assume dp = 1 mm., g = 5280 ft., and f = 8.25 in.
In order to balance different units of measurement either p or b must be in mm.
To change mm to inches multiply by 25.4

Hence $dh' = dp^{mm}\ f''\ g' \ /\ b''.p^{mm}$ <u>or $dh' - 1715/b''.p''$</u>

(This derivation is required of all students.)

<u>Finding the altitude</u>. Even if you had the altitude at which the photographs were supposed to have been taken it may not be correct, for it was based on barometric determination. Most of these photographs were taken with the K-3B camera which had a focal length of 8¼ inches. The scale of the photographs is expressed thus:

$$\text{Scale} = \frac{\text{focal length}}{\text{altitude}} = \frac{\text{photo distance}}{\text{ground distance}} = \frac{f}{H} = \frac{p}{g}$$

Note that these ratios demand that both terms be in the same units.
Solve for altitude and:

$$H\ (\text{feet}) = \frac{\text{ground distance (ft)}\ .\ f(\text{in})}{\text{photo distance (in)}} = \frac{g.f}{p}$$

Note that we can use two different units because there is only one term of each above and below the line so that the correction factor cancels.
We could equally well use millimeters for both focal length and photo distance.
Example: f= 8¼ in.; g = 5280 ft., and p = 3.1 in.
Substituting these values above altitude, H = 14000 ft.
Study your photos in comparison with a map on which known horizontal distances are shown and compute flying altitude for each. The scale of the two photos may not be exactly the same.

1 inch = 25.40 mm. 1 mm. = .0394 in.

<u>Computation of differences of elevation</u>. The formula demonstrated above relates difference in parallax on the photographs to difference of elevation, altitude, and map base. The latter is the average distance between principal points of a pair of photos. It may be expressed either in inches or millimeters. We can also solve the formula for difference in elevation for unit difference in parallax.

$$\text{difference of parallax} = \frac{\text{diff. in elev. . map base}}{\text{altitude}} \qquad dp = \frac{dh.b}{H} \quad (1)$$

Solving for dh,

$$dh = \frac{dp.H}{b} \quad (2)\text{. Substitute for H,} \quad H = \frac{g.f}{p} \text{ then } dh = \frac{dp.g.f}{b.p} \quad (3)$$

6280
6.825
2.65

$$\text{If } dp = 1^{mm},\ g = 5280',\ f = 8.25'' \text{ then} \quad dh = \frac{1715}{b''.p''} \quad (4)$$

2.65

(This form gives either feet per inch of parallax or feet per millimeter. Taking H = 14000 feet, and b = 2.5 inches the result of (3) is 5600 feet per inch or 220 feet per millimeter. Note that again different units may be used provided that the conversion factors cancel out. Check these computations for your particular pair of photos. You can measure b in millimeters if desired. Next you must realize that altitude, H, is that above the particular spot on the photo which you are measuring. For instance if there were a 500 foot hill in the photo described above H would be reduced to 13500 feet changing the results to 5400 feet/in and 213 ft/mm respectively. Although there are tables which may be used to compensate for this in TM 5-230 a simpler solution is to figure the value of dh for the average H over the photo. This may be used to determine differences of elevation such as heighth of hills above known low places. Using (4) if b = 2.5" and p = 3.1" then dh = 222 ft/mm. or 5650 ft/in. Compute dh for your photos. You can also get results by measuring a known difference of elevation on the photo.

Note that measurements uphill register on the Abrams machine by motion of the pointer in the + direction. On the Fairchild instrument the readings on the scale increase with elevation, that is increase toward the left. Compare this with what causes hilltops to appear closer under the stereoscope (FIG. 3). When you measure you may have to use the y motion to make dots coincide. This is a result of tilt (see later). Tilt results in change of scale of the photos so that corresponding points are displaced in relative distance from the line of flight or line of orientation. In the Abrams instrument use the motion of right dot only. Left dot is moved only when first setting up the photos. Study the scale on the Fairchild machine. Whole millimeters are marked on lower side of line except for those which are numbered where line is carried across. Half millimeters are marked on upper side. Since the micrometer head reads only to 50 and measures hundredths of millimeters you must add 50. to its reading whenever a half point is passed. Continue practice on reading spot elevations. Base your parallax difference on elevations on roads, etc., on low ground not too far away on the photo. If you try to measure over long horizontal distances the effect of even slight tilt will make results inaccurate. On the home-made instrument parallax is measured in thousandths of inches; divisions on side are 25/1000", on head of drum 1/1000".

<u>Drawing the map</u>. Each of the machines is provided with some kind of pencil. See that yours is sharp and not too hard. If you can obtain only faint lines go over them with a softer pencil. Colored pencils (provided when possible) are good - Use a sheet of bond paper which shows a watermark when held to light. If drawing board is rough put a sheet of poorer paper below. Fasten down in position so you can map the area common to the two photographs remembering that you have to reverse the photos with all but the Fairchild. In tracing roads, streams and boundaries of dense timber use left hand dot only. Locate dwellings which at most farms are close the road and more or less concealed by shade trees.

for this. Use blue for streams, red for roads and houses, and green for timber.

Do not map all farm buildings. You will have trouble in following some streams because of trees, also in telling what portions of some streams are now part of the actual channel. Dot all uncertain parts. Show streams which do not carry water all the time by dash-dot lines. Last locate spot elevations. Compare with the old topo. sheets! All students will make a map based on common area of one pair of photos.

Contouring. The choice of two methods of drawing contours is possible. All books of directions advise setting the distance apart of the dots to that for a given level and then tracing around the contour. This involves finding the difference, dp, of parallax for a given contour interval. Tilt of the photos makes it necessary to shift the setting for different parts of the map in a very complex manner. Keeping the fused dots together is also difficult at first. After practice they should appear to just touch the surface while looking at the topography and not concentrating on the dots. You can always make the dots blend if you look too hard at them alone. The other method is to measure spot elevations and then sketch the contours from them checking with the stereoscope. Combination of the two methods is suggested. Try to trace the 100 foot contours first. Blink from one eye to another to see that dots rest on same ground point. Change reading in different points of map in response to spot elevation data. Then fill in 50 foot contours between by sketching. Compare your results with the old map which was sketched from the ground! Last locate section corners using the old map as a guide. From these locate the lines about $\frac{1}{4}$ mile apart which subdivide the sections into 40 acre tracts. Draw all those on your paper making section lines solid black and the other lines dotted black. Also draw a line exactly a mile long according to the scale you found. Your map may be presented either (a) in pencil on original paper or (b) traced in ink on tracing paper. If the latter also hand in your sketch. First maps cover only the area seen on both photographs of the pair. Contour interval , 50 feet. Roads may be left as single lines but make branch roads dotted. Show also all dwellings (not barns), streams and swamps as far as possible.

FOR 4 CREDIT STUDENTS

Problem 16a

Material: Aside from that for problem 16, you need 10 sheets of tracing paper 7" x 9" plus a sheet of tracing paper about 18" x 18".

Introduction: 4 credit students will do Problem 16a, map of 10 vertical photos located in two flights, a portion at least of which must be contoured and all completed to show roads, dwellings, streams, woodland, swamps, section and forty lines. The tracing paper about 7 x 9 inches will be required for the radial line plot and larger sheet for final map. First, make the radial line tracings taking lines from principal point of each photo to all section corners, other principal points, and to such points common to the two flights as necessary. Draw fine accurate lines and mark the picture locations definitely although lines should extend half an inch beyond each. Mark photo number in same position as on original. Next lay these tracings over one another to get true locations by intersections. Make lines between principal points coincide. Assume that N-S township lines are straight. Apply same criteria to accuracy of location as with planetable. When you have a satisfactory adjustment, disregarding the apparent locations on photo, tape or staple your assembly together. Then lay it over the master sheet and prick through the revised locations. Remove overlay and mark each prick point with cross for section corner, circle for principal points and other locations. Place photo number at each principal point.

Draw in the section lines on master tracing. Next subdivide each section into 40's using solid lines for sections and dotted for subdivisions. You now have an accurate framework to which sketches and tracings of each photo may be fitted. Last use the stereocomparagraph to make a contour sketch of not less than common area of two stereopairs one in each flight. Adjust contours between the two flights as seems best. Do as much contouring as time permits; if you cannot contour more than minimum finish rest of area as a flat map. Submit your sketches and overlay with the final map. This may be completed either in pencil or ink. Use green crayon for woodland.

Effect of tilt on vertical aerial photographs.

Introduction. As noted above, few photographs taken from planes and intended to be true verticals are such in fact. Efforts to control verticality by levels, views of horizon, gyroscopes, etc., have failed although it may prove practicable to indicate the plumb point by a spot of light regulated by a gyroscope. Fortunately the angle of tilt is rarely over 3 degrees from vertical and can safely be neglected for radial line construction unless the topography is very rugged with high relief. A tilted photo has the same perspective as a very low oblique as explained in Problem 17. Note diagrams on following page. These show that the side which is tilted below the position of an equivalent vertical picture includes a smaller area than it should and is expanded; the converse is true on the other side, that toward which the principal point is displaced from the plumb or nadir point. Midway between the locations of these two points is a line where the equivalent vertical photo intersects the actual picture. Only along this line which is perpendicular to the principal line is scale true.

Fig. 7A See next page

Distortion of a square when tilted along a diagonal line.
True shape borken line; shape in photo shown as solid line

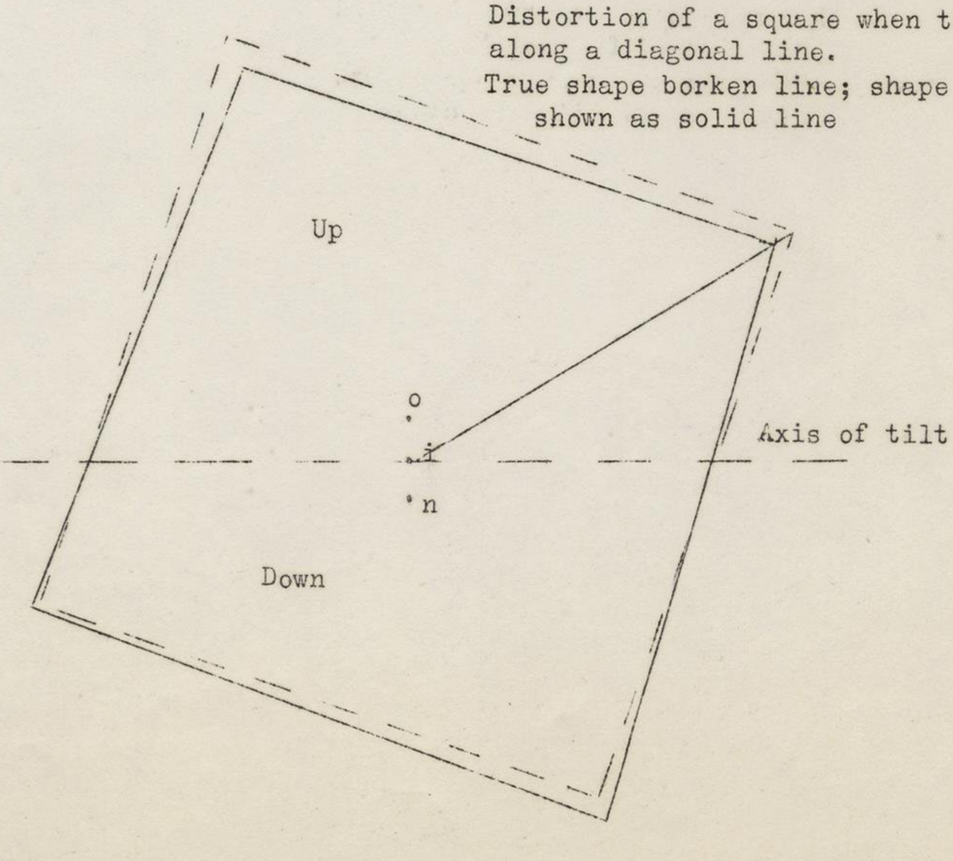
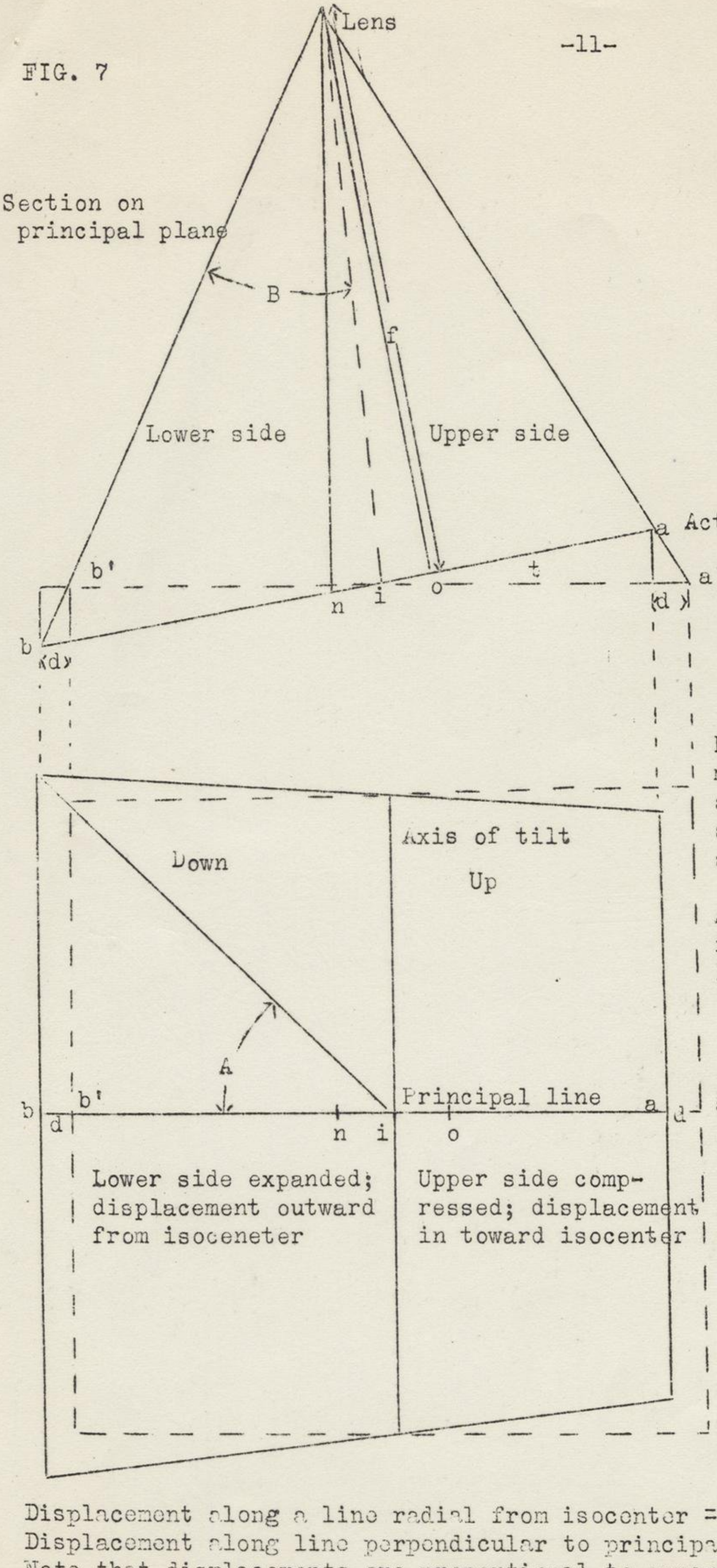


FIG. 7

Geometry of a tilted photo
O = principal point
n = nadir or plumb point
i = isocenter or center of distortion
d = displacement
t = angle of tilt
f = focal length
B = angle between line to a point and line to isocenter



Note that the tilted photograph makes a rectangle on the ground appear too big on lower or down side and the converse on upper side (here to right).

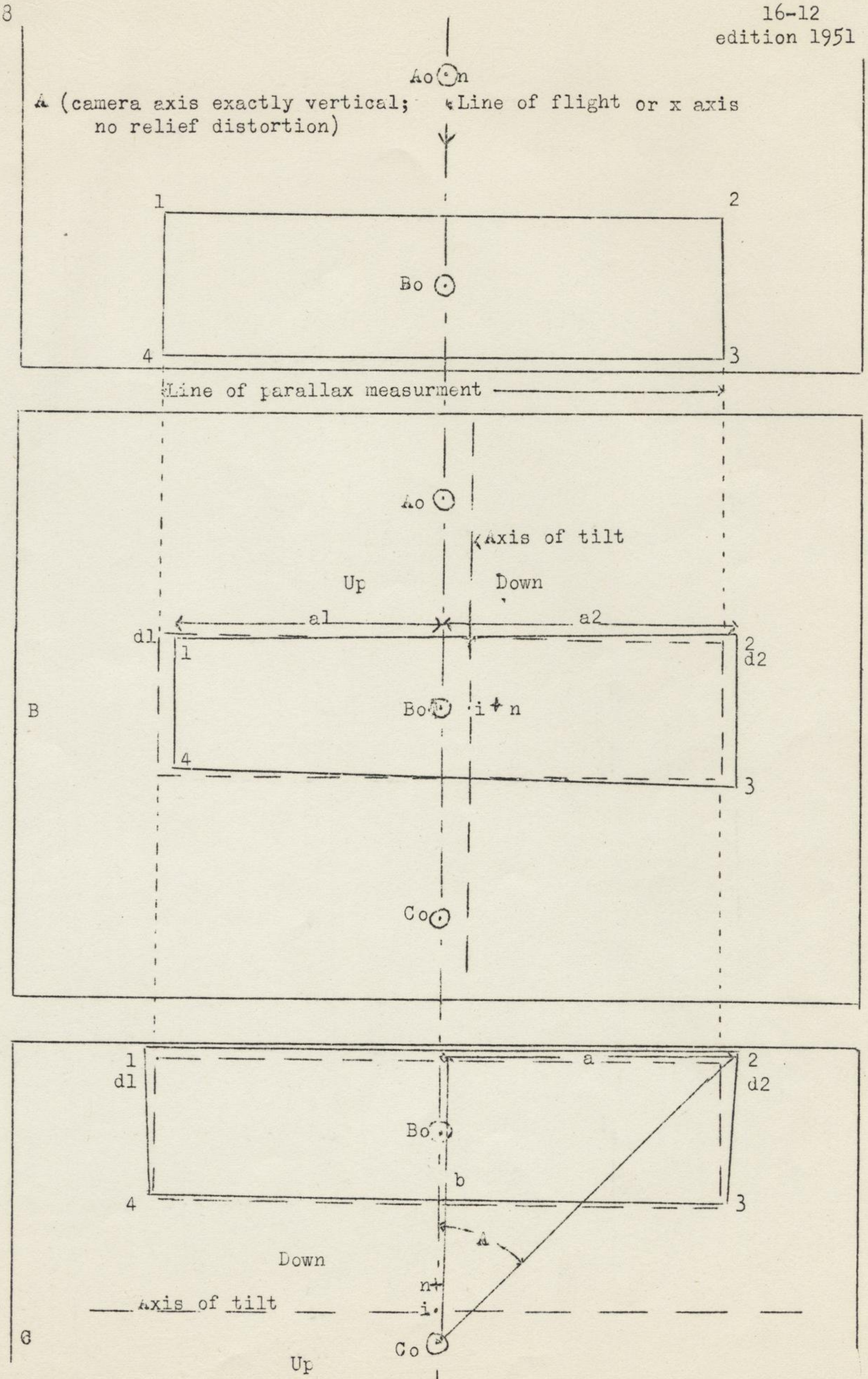
A = angle between a radial line from isocenter and the principal line.

Derivation: (required for 4 credit students)
Vertical displacement of point is ia (or ib) sin t
Horizontal displacement = vert. displacement tan B Since tan B = ia (or ib) / f then
$d = ia^2 (\text{or } ib^2) \sin t / f$ and
$\sin t = d.f/(ia^2)$ whence distance no = f sin t = $d.f^2/(ia^2)$

See Fig. 7A on last page for effect of distortion when axis of tilt is diagronal to sides of a square.

Displacement along a line radial from isocenter = d/cos A
Displacement along line perpendicular to principal line = d tan A
Note that displacements are proportional to square of distance from axis of tilt but are along lines radial from isocenter. Displacements due to relief are radial from plumb (nadir) point. Therefore, there is no single place on a photograph from which both tilt and relief can be corrected. Fortunately, error due to this fact is small in most cases when the tilt does not exceed 3 degrees. In country with high relief, measured in thousands of feet, it is necessary to find the plumb or nadir point for radial line construction. Note carefully the distortion of a sq. due to tilt. If axis of tilt diagonal, square is "skewed".

FIG. 8



See next page for explaination

Figure 8 shows results of tilt of camera axis in successive photographs. A, B, C. Centers (principal points) are designated Ao, Bo, Co. It is assumed that A is exactly vertical with the plumb or nadir point coincident with Ao. The rectangle 1, 2, 3, 4 is correctly shown. Centers of adjacent photos are shown in every case. When set up for stereoscopic examination these are aligned along the line of flight or x axis which is horizontal in the stereoscope. Distances perpendicular to the line of flight are called along the y axis. Photo B is assumed to be tilted along an axis parallel to the line of flight. As explained in Fig. 7 the rectangle is then distorted into the shape shown by solid lines (its true shape is shown by broken lines). n = nadir point, i = isocenter or intersection of axis of tilt with a plane passing through both camera axis and plumb line. Note that points 1, 2, 3, 4 are displaced along lines which radiate from i (see Fig. 7). Distance of 1 in y direction from line of flight is a1, of 2 = a2 Displacement of 1 from a line through 1 in A is d1 and of 2 = d2 both measured in y direction. Such measurements are made with y dial on Abrams instrument; the Fairchild has no graduations on its y motion. Photo C is assumed to be tilted along a direction perpendicular to the x axis (along y axis). Distortion is shown by same method. Displacements from lines parallel line of flight, d1 and d2, are measured in same way. y distance of 2 from line of flight = a and x distance of 2 from Co = b. Angle A is determined by its tangent a/b. Note than tilt is demonstrated when you have to use to y motion to put dots on corresponding points in two photos. Cases of tilt along axes in other directions than those shown by be resolved into components along x and y axes. Displacements due to relief are assumed to be absent.

Correction of parallax errors due to tilt. When a pair of overlapping photos is set up for steroscopic examination the average value of dh must be found first. Known elevations should be present along both sides of the common area and nearly opposite one another. Elevations of 1, 2, 3, 4 should be known. Dots are set on 1 and 1 in photo B; the effect of difference of elevation of 1 and 2 is computed; the x dial is reset and checked on 2 in A and 2 in B. Photo B is then loosened and turned until this distance checks. (Abrams method). This adjustment will (unless the error was due only to faulty determination of centers) serve only to correct readings in a relatively narrow area between the two correction points, i. e. an area extending in the y direction. A different photo position would be needed for points 3 and 4. Hence it is well to use tape on right photo. Error due to the component of tilt on y axis is not affected by this method.

Measurment of relative tilt. Fig. 7 shows how it is possible to compute the displacement of the nadir point in both x and y directions with proper signs. In Fig. 8 displacement left (below) line of flight is - and above (or right) is +. Displacement of n above or left of principal point is - and below or right is +. Photo B shows a + displacement in y direction. Such a displacement is called Dy and is equal to $f \cdot \sin t$ Since $\sin t = d \cdot f/a^2$ it remains only to find a. This must be the average of the two a's on B because we do not know the position of the axis of tilt. This average value corresponds to ia or ib of Fig. 7 and hence $d = (d1 + d2)/2$. By substitution $On = f^2(d1+ d2) / 2a^2$ Note that since both d1 and d2 are to right in B of Fig. 8 a positive value will attach to result. If the displacements had been the other way the result would be - indicating a nadir point below (left of) the x axis. In photo C the tilt is along a transverse axis; d1 and d2 are both measured along the y axis as before but one is - and the other is +. In this case we must use the average of d1 -d2 multiplied by the tangent of the angle A that is by a/b. Now to obtain this average value for d we must recall that the displacements are opposite in sign and that we must therefore use their algebraic difference. Thus $d = (d_1 - d_2)a/2b$. Substituting and cancelling a above and below the line it appears that $Dx = f^2(d_1 - d_2)/2ab$. In the case shown the algebraic sum of the y displacements is negative and the nadir point is displaced to the left or backward on the line of flight. In this manner the x and y displacement components may be found and thus the relative relation to the photo at the left (earlier in the series). But since we have no knowledge of the tilt of that photograph the solution remains relative until the missing data is supplied. Then relative tilts may be carried forward by algebraic differences. This method is described by Van Camp in "Manual of Photogrammetry," pp. 290-302. Possibly we could make a true drawing of an area based on a ground survey. corrected to relief distortion,and platted to photo scalle

The following method is adapted from one by BAGLEY, pp. 180-192, modified to use a rectangle (or square) formed by one or more sections of land. Because most aerial photographs were taken by flying along a N-S section line it would be best to use a pair of adjacent sections east and west of the line flight. It is essential to have the principal point well inside the area used. True dimensions and directions of the sides should be checked by a ground survey with planetable or otherwise. Elevations of each corner must also be known. Also focal length of camera in inches. Steps in construction follow.

(1) Locate both on map and photograph the principal point using radial line construction with former.

(2) Find the average scale of the photograph from a section line near the principal point and compute elevation, H, by usual method. $H = g.f/p$, where g is a ground distance in feet and p the same on photo in inches.

(3) Compute displacement d of all corners to each plane passing through elevation of the lowest corner. $d = h.R/H$, where h = difference in feet elevation of point considered above lowest corner, and R its distance from principal point in inches. Move the high points in toward the principal point as the isocenter is as yet unknown. See Fig. 5

(4) Scale, in inches, the four sides of the quadrilateral as shown on corrected photograph (notediagram); also distance of each corner from the principal point. Also obtain corresponding ground distance in feet from map and field data. See Fig. 9

(5) Revise the figure for altitude H = (L^o) from the fact that $L^o:A^o::$ f:ao' whence $L^{o\prime}$ = f".A o' / ad" approximately. Use mean value from four solutions.

(6) The four triangles embracing lines from L (position of plane) to each corner of the figure can now be drawn to map scale (preferably larger than photo scale). Include corresponding lines in the photograph. Remember that plane of photo is normal to line (L^o) to principal point. It will now be noted that since f is the same in all triangles the lines representing the plane of the photograph will not be parallel to the ground. See Fig. 10

(7) Now we have the data to construct triangles for each of the four exterior sides of the pyramid making the ground line straight. It is not normal to line $L^{o\prime}$. See Fig. 11

(8) The next step is to pass vertical planes through each apex of these triangles. The intersection of these planes with the outside of the pyramid are normal to the ground line and each will pass through the line (Ln) from L to the nadir point. See Fig. 11

(9) Next use the map and draw on it lines normal to each side at proper distances from each corner as shown on base of each triangle. These lines should all intersect at the nadir point, n. See Fig. 12

(10) Transfer this nadir point to the photograph by tracing paper solution of the three point problem. Location of isocenter and axis of tilt are now known. Angle of tilt, t, may be computed since tan t = n'o'/f.

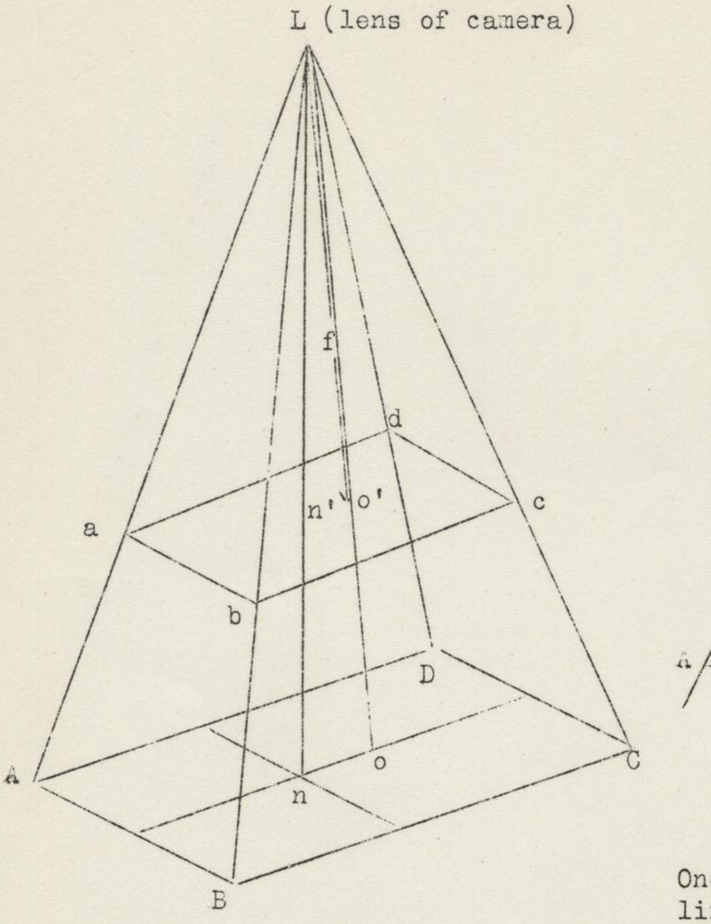


Fig. 9

Pyramid over two adjacent sections of land including the principal point. abcd = tilted photograph ABCD = map on scale larger than that of photo. Because the ground or map distances are horizontal the photodistances must be first corrected for differences of elevation. o = principal point on ground, o' = principal point of photo on line normal to plane of photograph.
n = nadir or plumb point on ground and
n' = nadir point on photograph.

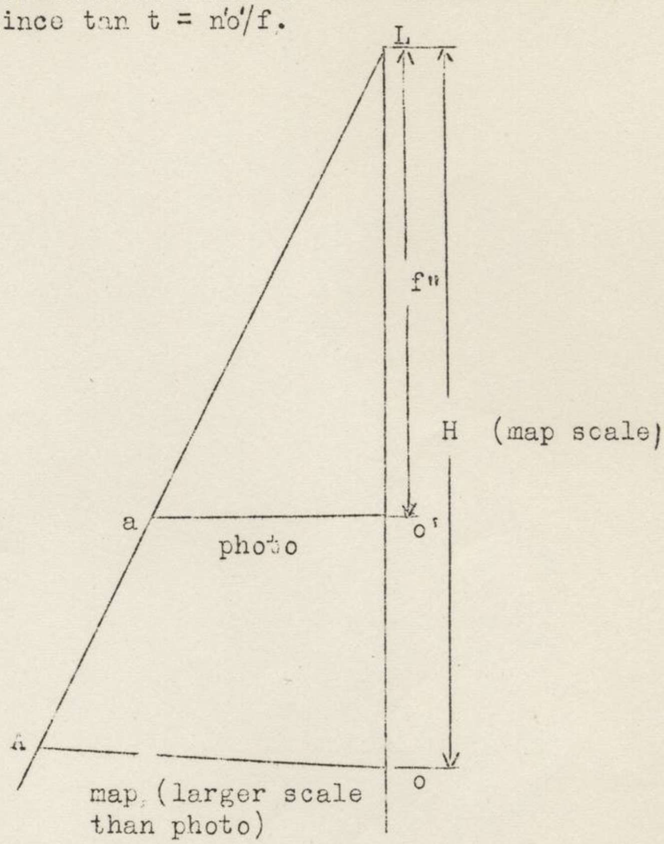


Fig. 10

One of a series of four triangles from line Lo out to each of the four corners of the area on the ground. f = focal length of camera H = altitude of plane at map scale. In order to fit it the true ground distances at map scale it is necessary to make them inclined which indicates tilt of the photograph Construction must include all of the four triangles.

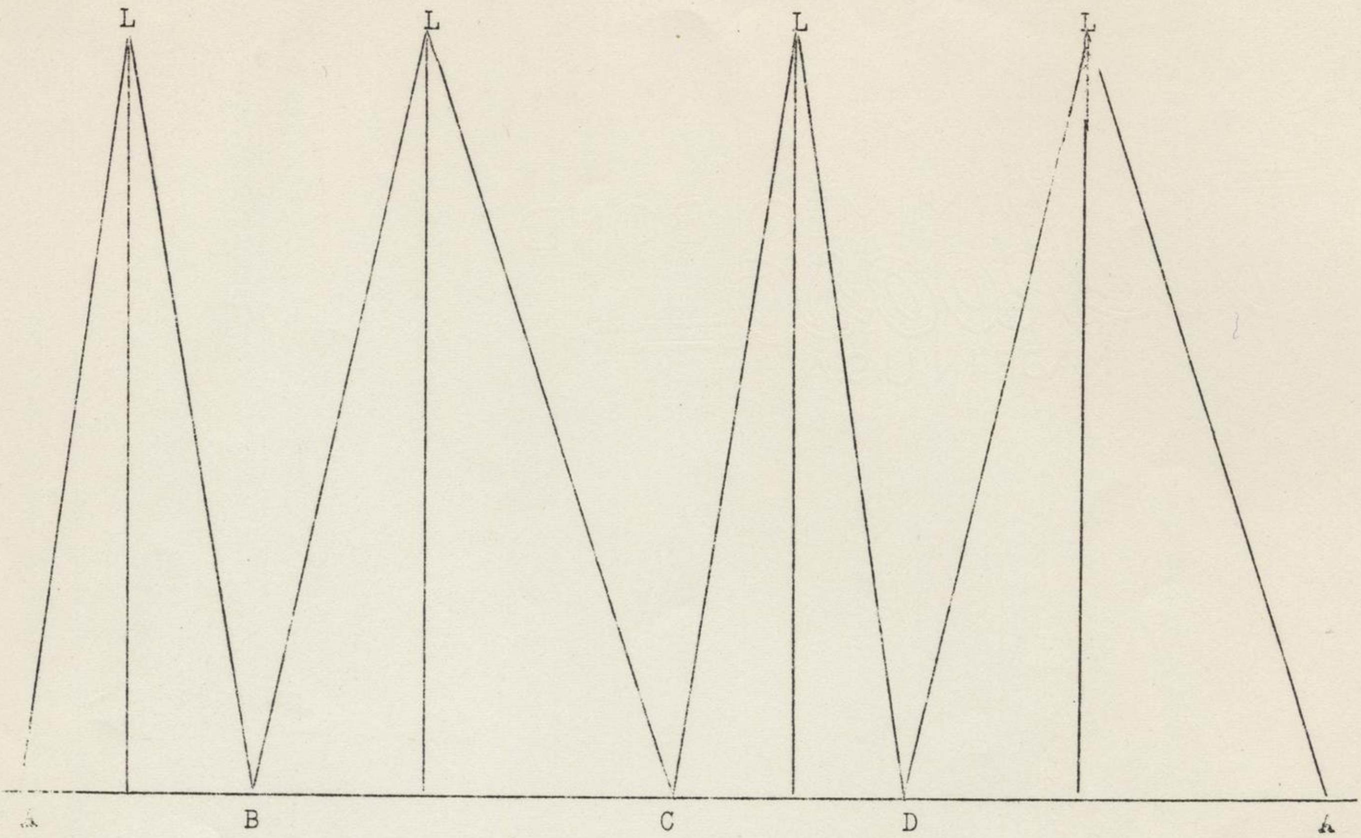


Fig. 11
Four sides of the pyramid spread out with base or ground level as a straight line. Sies of the triangles scaled from four construction figures like Fig. 10 The lines normal to the base line through the apex of each trinagle at L are the intersections of vertical planes with the sides of the pyramid of Fig. 9 Each of these planes must pass through the plumb line below the lens position and hence the nadir point on the map. These planes are not shown on Fig. 9 except where they intersect the ground or map plane.

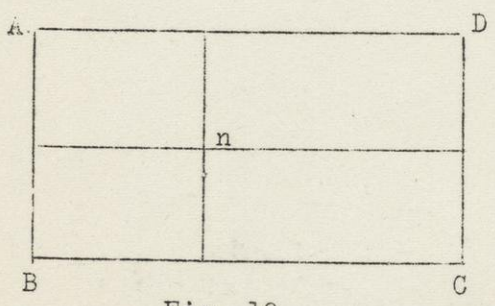


Fig. 12
Map to scale of the area shown in Fig. 9 showing how the nadir point n is located by the interestion of vertical planes through L This position may be then transferred to the photograph by the tracing paper solution of the three point peoblem, here actually four points.

This lengthy solution is justified only for photographs at start and end of a flight and then generally in rather rough country. Location of the nadir point aids in drawing radial lines. It does not aid in tilt correction where displacements are radial from the isocenter.

Rihn's method, "Manual of photogrammetry", 1944, pp. 274-289.

Introduction. Rihn's method is based upon three points, preferably surrounding the principal point, whose elevations and true distances apart in a horizontal plane have been determined by a ground survey. It is first necessary to find the location of each point in a plane at level of the lowest of them. Find the principal point. Measure distance to each control point. Compute displacement by formula d = (diff. elev.) x (radial photo distance)/(elevation of plane). A point 200 feet above datum and 100 mm. from principal point is displaced with photos taken at 14000 feet (200 x 100)/14000 = 1.43 mm. outward. Therefore the location to be used in correcting tilt must be moved by this amount toward the principal point since the isocenter is as yet unknown.

Method.

(1) Select the three points. (2) Set datum plane at lowest of them.
(3) Compute elevation of plane from scale = focal length / elevation.
(4) Compute displacements. (5) Locate position of each point in datum plane.
(6) Measure in inches or mm. length of each side of triangle = P.
(7) Find the actual length of each side in feet or meters = G.
(8) Calculate scale of each side from formula S = P/B. The different scales of each side are shown as Sh, Sm and Sl as ratios.

A, B, D = the three control points
y = plumb or nadir point
i = isocenter
O = principal point

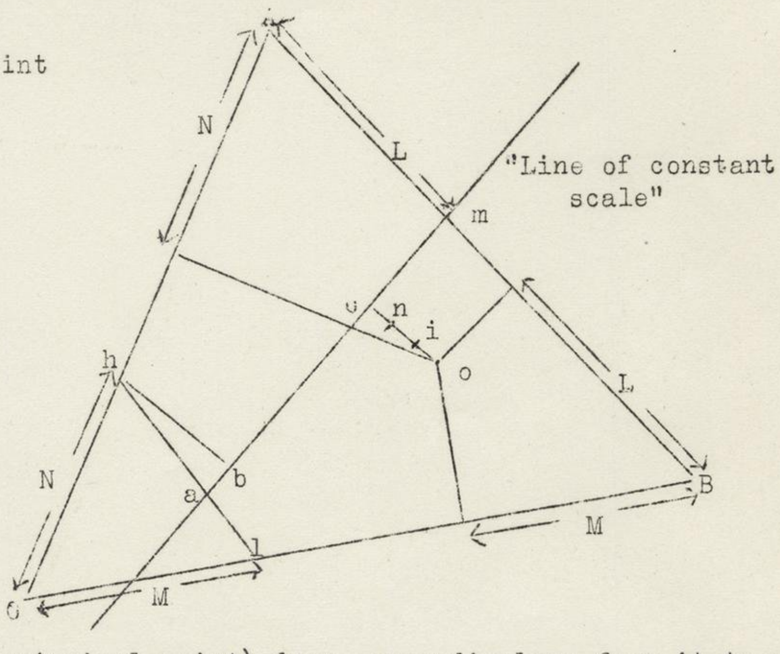


FIG. 13

(9) After finding O (principal point) drop perpendiculars from it to all sides of the triangle. Measure distances L, M, N. Now lay off the same distances from the opposite corners of each side of the triangle. These will give "scale points" h, m, l. If the perpendicular falls on an extension of the side of triangle then lay off an extension at other end. In every case the midpoint of the datum line is midway between the foot of the perpendicular and the "scale point".
(10) Find a point "a" on line hl from formula ha = hl(Sh-Sm)/(Sh-Sl) where S with subscripts refers to the scale at the three "scale points".
(11) Draw ma, the "line of constant scale", and drop a perpendicular oc to ma from the principal point and another from either h or l whichever is longer.
(12) Compute rate of change in scale, dS from formula dS = (Sh-Sm)/hb.
(13) Find the scale at o from S_o = Sm + (oc)(dS) when o is on same side of ma as h or S_o = Sm - (oc)(dS) when o is on same side of ma as l.
(14) Find the angle of tilt, t, from formula $\sin t = \frac{f.dS}{S_o}$ where f = focal length.

(15) The plumb or nadir point, n, is on the line oc on the side of o toward the higher scale cn = f.tan t and oi = f tan(t/2) which places it almost half way between n and o.

(16) If the tilt proves large repeat all steps substituting n for o in Step 5. Then Si = So ±(oi)(dS) in Step 14 and H = f/(Si) in Step 3. In Step 4 d = (h.R)(f±x sin t)/(H.f) + on nadir point side, - on principal point side, and x = perpendicular distance from image point to axis of tilt. If h is less than 150 feet omit this correction.

Example of a computation:

Point	Elevation	h, ft.	R, in.	d, in.
A	692	171	3.90	.05
B	809	288	2.91	.06
D	521	0	--	.00

h = elevation above datum
R = distance from principal pt. before correction
d = correction for relief

Line	G, ft.	P, in.	S = P/G	Scale Line
AB	9574	6.21	648.65	Sn
BD	8894	5.74	645.42	Sl
DA	10398	6.80	653.98	Sh

hl = 2.78" hence al = (2.78) (323)/(8.56) = 1.05"
hb = 1.42" (scaled)
dS = (653.98 - 648.65)/1.42 = 3.75 per inch
oa = 0.52"
So = 648.65 - (0.52 x 3.75) = 646.70
sin t = (8.27 x 3.75)/646.32 = .04796 t = 2 45'
on = 8.27 x 0.04798 = 0.397 in.
oi = 0.20"

Summary. A common way to allow for errors in parallax measurement due to tilt is to draw a graph of error as described in T. M. 5-230, pp. 253-254 and Bagley, pp. 198-199. This method of changing the set of the points for error in parallax is applicable only when following contours. It has often been observed that the more known elevations the more complex the graph, which seems to indicate that distortion of the photograph in developing and printing is an important item. The only real answer to the tilt problem lies in the use of one of the plotting machines such as the "multipler" projection method where the position of the photograph is shifted until it satisfies the ground control. For less expensive machines the best answer lies in the Abrams method plus limitation of the area used to the center of each photograph. This greatly reduces errors but obviously the more known elevations there are the better. Elevation differences should always be measured from known elevations as close to the point concerned as possible. No computations of absolute or relative tilt will be required in Problem 16a but you must understand the principles involved in order to answer questions in the final examination. See specifications for final map given at start of Problem 16a. Be sure you include scale and nadir point.

GEOLOGY 11
MAPPING
Problem 17, edition 1943 (old17 now combined with 18)

Object: To draw a map form oblique aerial photographs

Material: Hard pencil, eraser, scale, magnifier, triangles, tracing paper, one or more photographs, maps of area shown giving control data, white paper

Method: Photographs may be taken from the air with the axis of the camera tilted. If the tilt is not far from vertical the phtos are called "low obliques"; if the angle is not far from horizontal they are "high obliques". Note that the reference is to vertical and not to horizontal in this. Low obliques can be changed to verticals by use of a special printer. This is regular practice with multilens camers which take both verticals and obliques at the same time. High obliques cannot be treated thus but are often used in reconnaisance mapping because less flying is needed to cover a given area and the requirements for flying are not so exacting.

Geometry of aerial photos. The transformation of aerial photographs into maps is a problem in solid geometry. Study the following closely as several published papers contain errors. Every photograph is a record of horizontal and vertical angles which could have been determined if an alidade and planetable had been at the place of exposure. From a given spot in space all points having the same horizontal angle (equal to a single ray on planetable) lie in same vertical plane. All objects which have same vertical angle lie on surface of a cone whose apex is at point of observation. Try this with a telescopic alidade. As you sight at points along one ray you move the telescope up and down in a vertical plane. If you set it to say 10 degrees above the horizon and roatate it to different directions from the planetable you have described the surface of a cone. The three diagrams of Fig. 1 show the differences between pictures taken with axis of camera horizontal, with it vertical, and with it inclined at an angle between these two extremes.

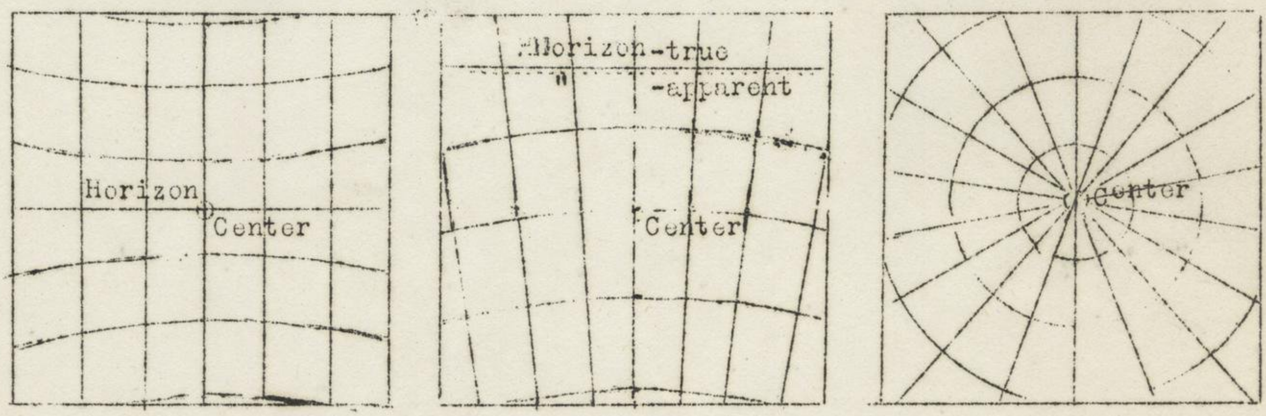


FIG.1

Lines of equal angles in horizontal photo See Problem 15. | Lines of equal angles in oblique photo | Lines of equal angles in vertical photo See Problem 16

Note that the oblique is transitional between the other two extremes. The ground included is shaped like a triangle with one end cut off.

It is highly desirable that the horizon show in an oblique but this is not always possible because of weather conditions or topography. The line on the level of the plane is called the true horizon. It is found above the apparent horizon at an angle in minutes almost exactly equal to the square root of the elevation of the plane in feet. Center of picture is found in same way as with verticals. In practice the camera may also be rotated sideways around its axis but this has no effect on geometry of photo.

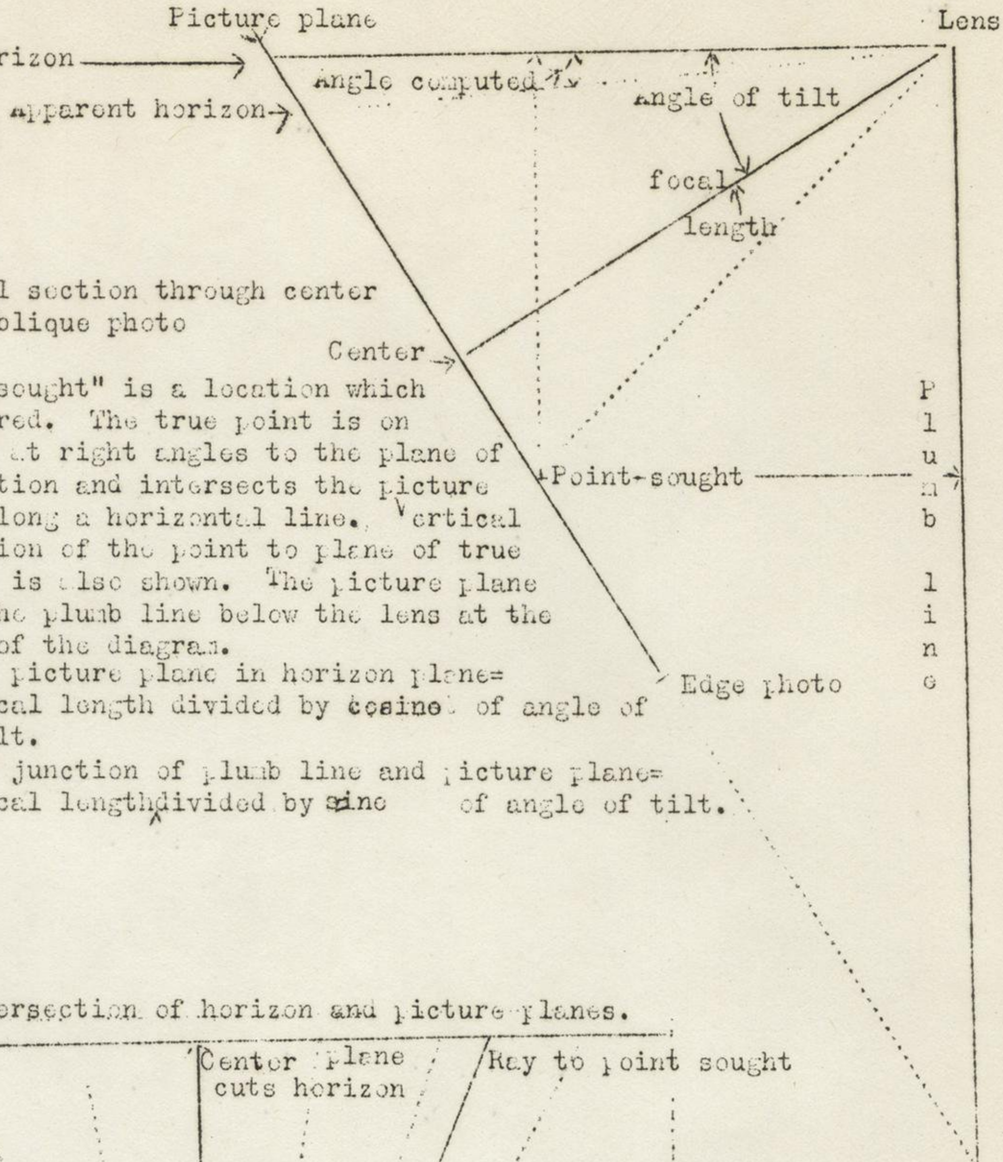


FIG. 2

Vertical section through center of an oblique photo

"Point sought" is a location which is desired. The true point is on a plane at right angles to the plane of the section and intersects the picture plane along a horizontal line. Vertical projection of the point to plane of true horizon is also shown. The picture plane meets the plumb line below the lens at the bottom of the diagram.

Lens to picture plane in horizon plane= focal length divided by cosine of angle of tilt.

Lens to junction of plumb line and picture plane= focal length divided by sine of angle of tilt.

FIG. 3

Intersection of horizon and picture planes.

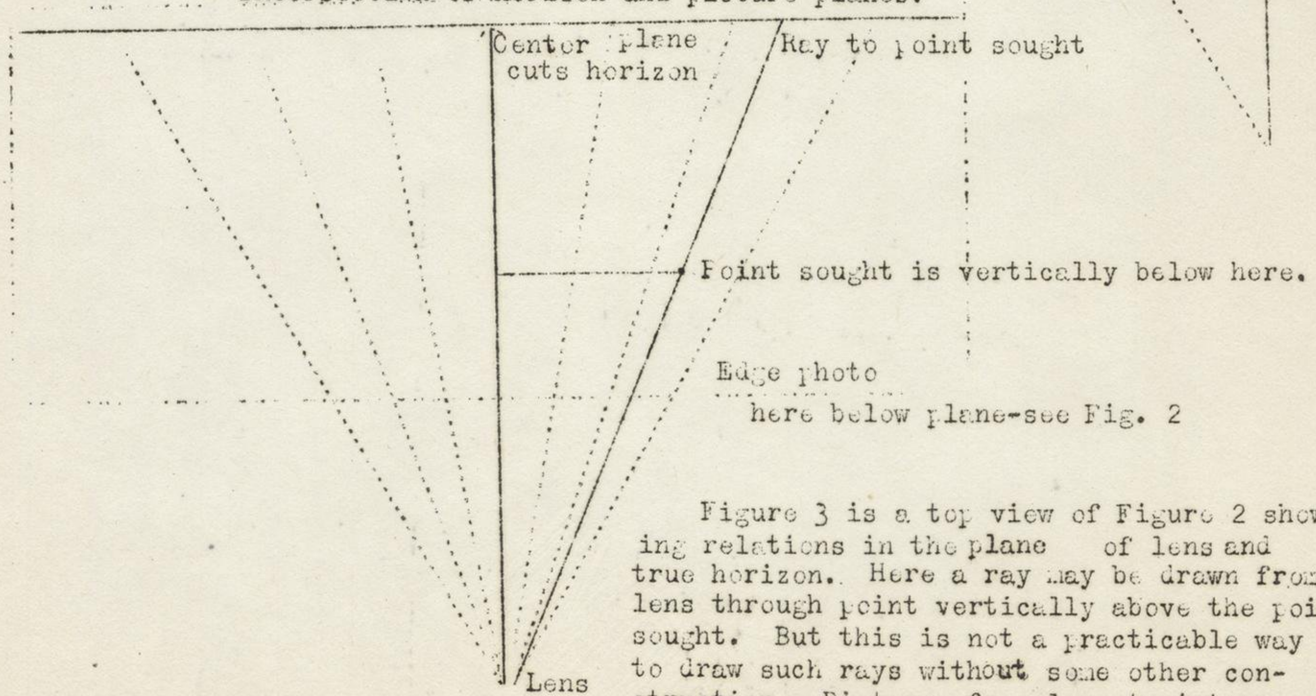


Figure 3 is a top view of Figure 2 showing relations in the plane of lens and true horizon. Here a ray may be drawn from lens through point vertically above the point sought. But this is not a practicable way to draw such rays without some other construction. Distance from lens to intersection of true horizon and picture plane = focal length divided by cosine of angle of tilt. Note that true angle of depression to point sought may be found from this diagram combined with Fig. 2 as explained later.

The following principles must first be understood. (1) As a reference point is required for angles those measured on the map will be taken from the intersection of a vertical plane through the lens and center of the photo with the plane of lens and horizon, (2) All horizontal angles to be shown on a map must be measured either in the horizon plane or a horizontal plane parallel to it, (3) The vertical angle from lens to point sought must be measured in a vertical plane passing through both of those points. It is evident that we cannot choose a point in the plane of the photo and use it to draw map rays to points shown if such points are at different angles below the horizon. The following diagram shows some of the principles.

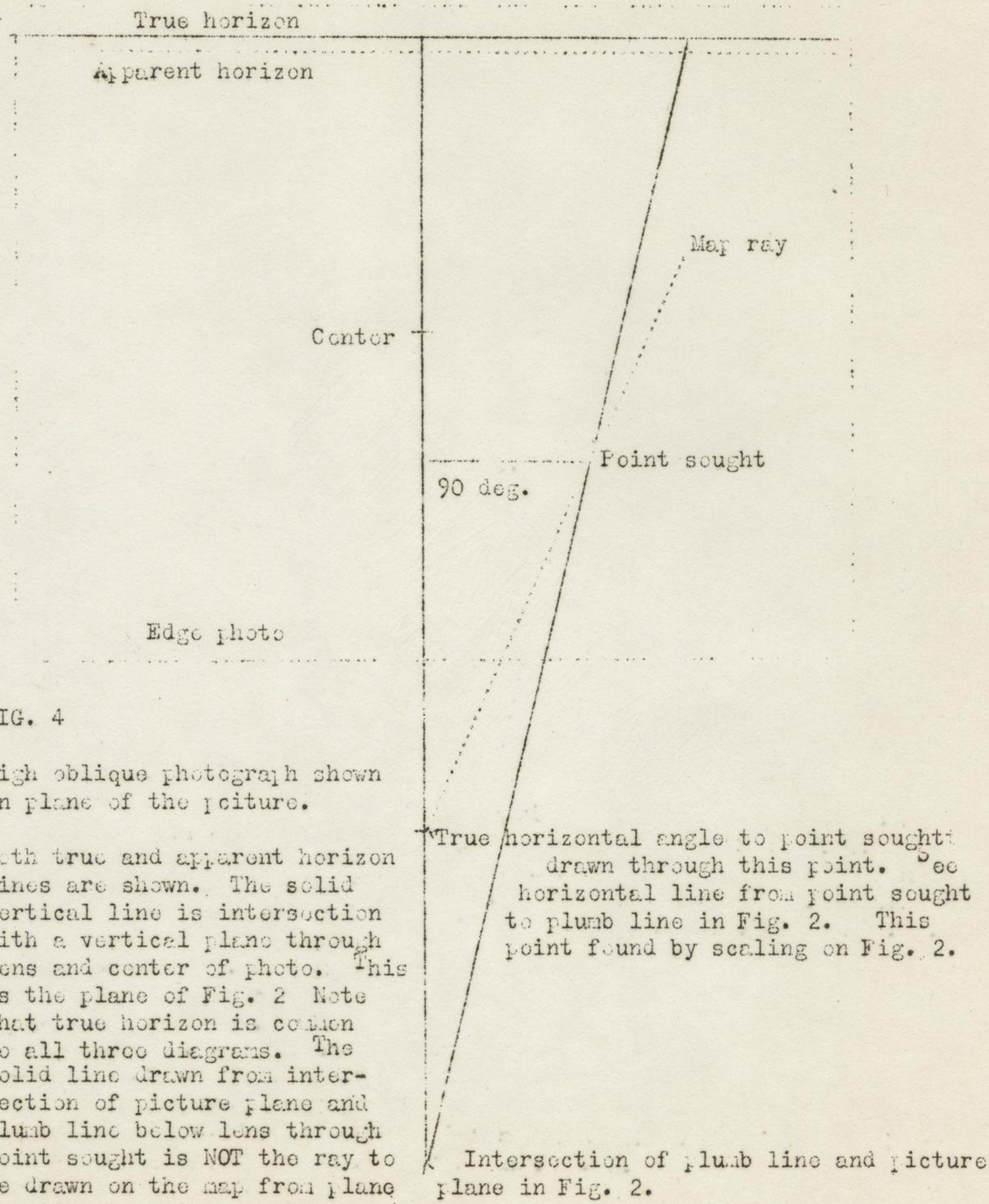


FIG. 4

High oblique photograph shown in plane of the picture.

Both true and apparent horizon lines are shown. The solid vertical line is intersection with a vertical plane through lens and center of photo. This is the plane of Fig. 2 Note that true horizon is common to all three diagrams. The solid line drawn from intersection of picture plane and plumb line below lens through point sought is NOT the ray to be drawn on the map from plane location to point sought.

Although the solid ray above is not correct for a map ray the true angle away from center line of photo can be found by transfering the distance between the two rays on the true horizon line to Fig. 3

However, this solution is not always possible. The lower the angle of tilt below the horizon plane the longer becomes the vertical line through center of photo to intersection with plumb line below lens. This distance would be infinity with a picture taken with horizontal axis. A better solution is to figure out the distance from point sought in the photo plane to place from which true horizontal angle may be drawn to get a map ray. First the point sought may be connected with center line by a line parllel to the horizon. Then Fig. 2 can be used to scale the correct radius for this particular point as done in Fig. 4. Crone's graphical solution is much easier and is explained below.

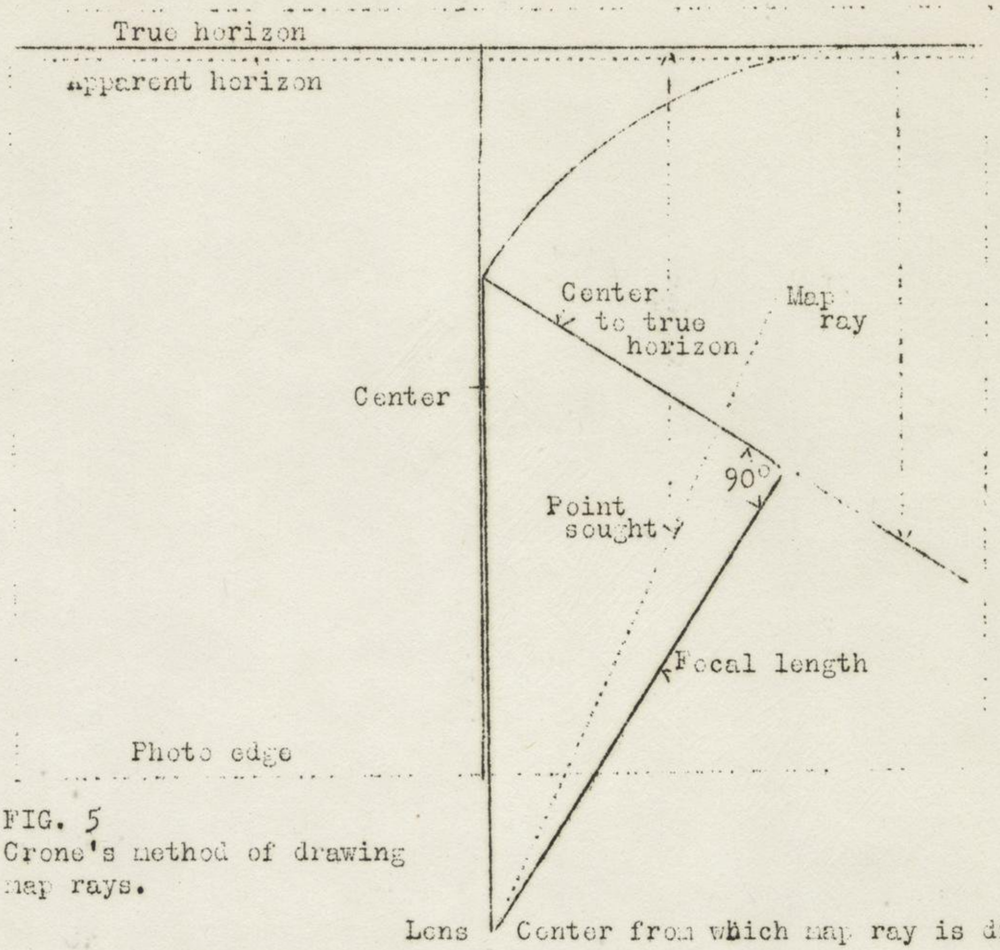


FIG. 5
Crone's method of drawing map rays.

Crone's graphical solution. Crone's method invloves drawing a right triangle; one side (here at right) is equal to focal length; the side at right angles (here upper right) equals distance of photo center from true horizon; third side equals distance of horizon line from lens as in Fig. 2. Note this is the same triangle as above camera axis (focal length) in Fig. 2. This triangle should be laid out on tracing celluloid. The top side may be extended when necessary. Lay the triangle so that the long side is along the line showing intersection with picture plane of a vertical plane through center, that is the line on which Fig. 2 is drawn. Next scale distance in picture plane of point sought from true horizon. Strike a n arc whose center lies on the upper side of triangle(here extended) and passes both through center line of photo and just touches true horizon. The apex of the triangle is now in proper place to draw a map ray through point sought.

Other solutions. Other solutions of this problem have been used which include both graphical and mecanical methods. Several plotting instruments have been devised which somewhat resemble telescopic alidades.

With the instruments the picture is set up in proper relation to map, that is tilted just as taken. (See Fig.2) Then sights are taken on it with a telescope or other similar device. The machine either measures angles in degrees or plats rays on the drawing board.

Locating position of plane. The map position of the plane at instant the photograph was taken may be found as soon as three rays to objects whose map locations are already known can be drawn. These can be platted on tracing paper and the sheet of paper shifted until each ray passes through the known location. Point from which rays were drawn can then be pricked through onto the map and is the point vertically below the plane. Once this location has been found rays to unknown points can be drawn. When other pictures give rays to the same points locations are secured by intersection just as in Problem 15 or with a planetable.

Vertical angles. In order to find elevation of the plane (any record furnished by the photographer was based on aneroid readings) we must measure the vertical angles to points of known elevation whose location is also known on the map. The angle must be found in the vertical plane passing through lens and point sought. No quick and easy solution seems to have been published. It is necessary to draw both Figs. 2 and 3. Then the distance from lens to a point vertically above the point sought and the vertical distance of point sought below horizon plane can be found. Knowing these two sides of a right triangle the angle sought can be found graphically as in Fig. 6

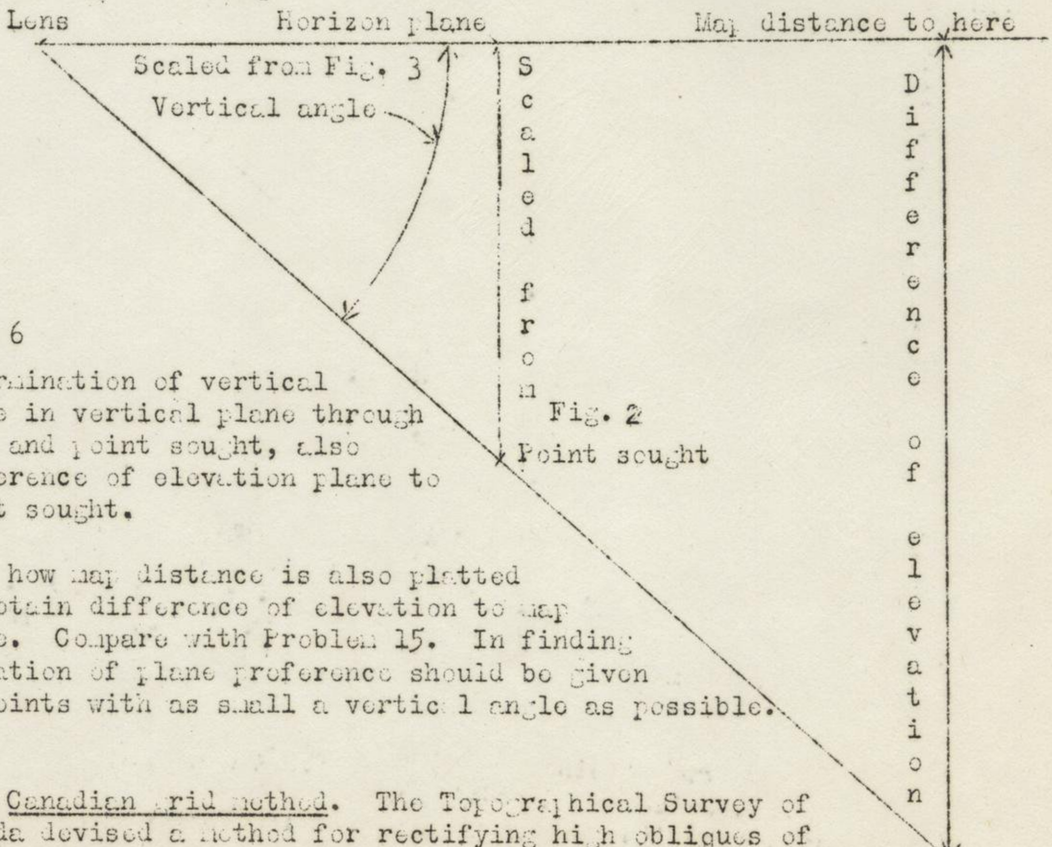


FIG. 6

Determination of vertical angle in vertical plane through lens and point sought, also difference of elevation plane to point sought.

Note how map distance is also platted to obtain difference of elevation to map scale. Compare with Problem 15. In finding elevation of plane preference should be given to points with as small a vertical angle as possible.

Canadian grid method. The Topographical Survey of Canada devised a method for rectifying high obliques of nearly flat country which depends upon the ordinary principles of perspective. In Fig. 7 the elevation of the plane is shown to map scale but the picture plane is shown at actual focal length distance in front of lens position. Picture plane is extended to meet the ground. Along line of intersection with ground picture and map scales are the same. Axis of camera is also prolonged to meet the ground. Equal intervals on ground are laid out to map scale both beyond and back from place where

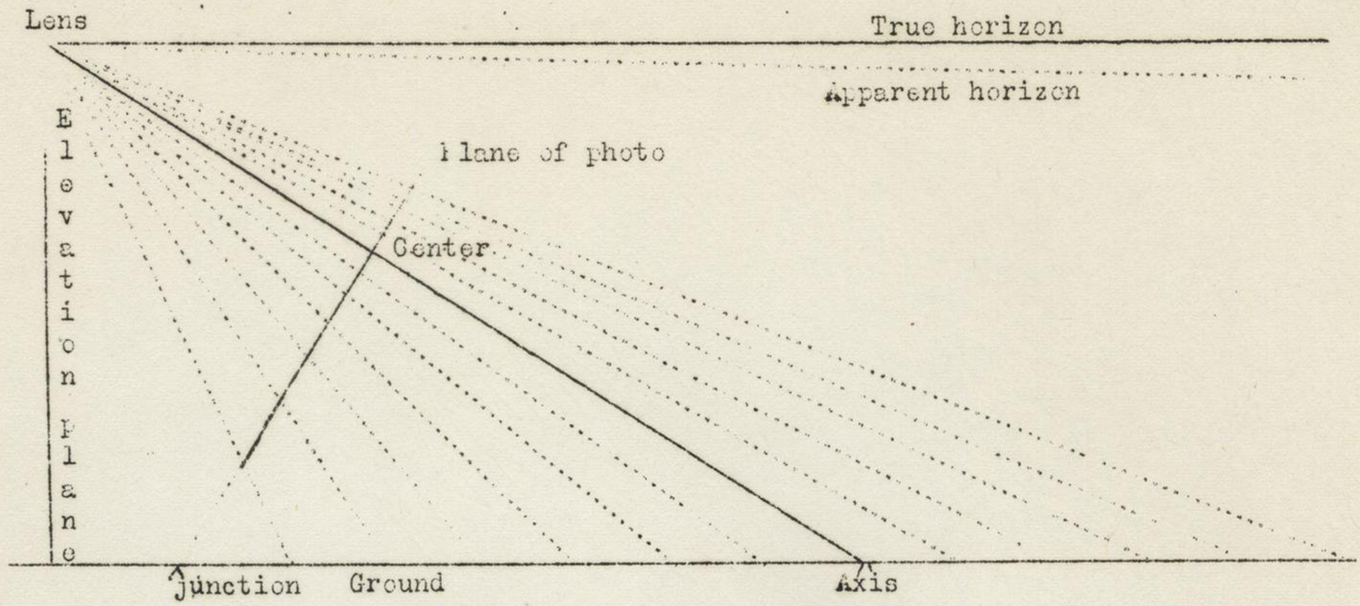
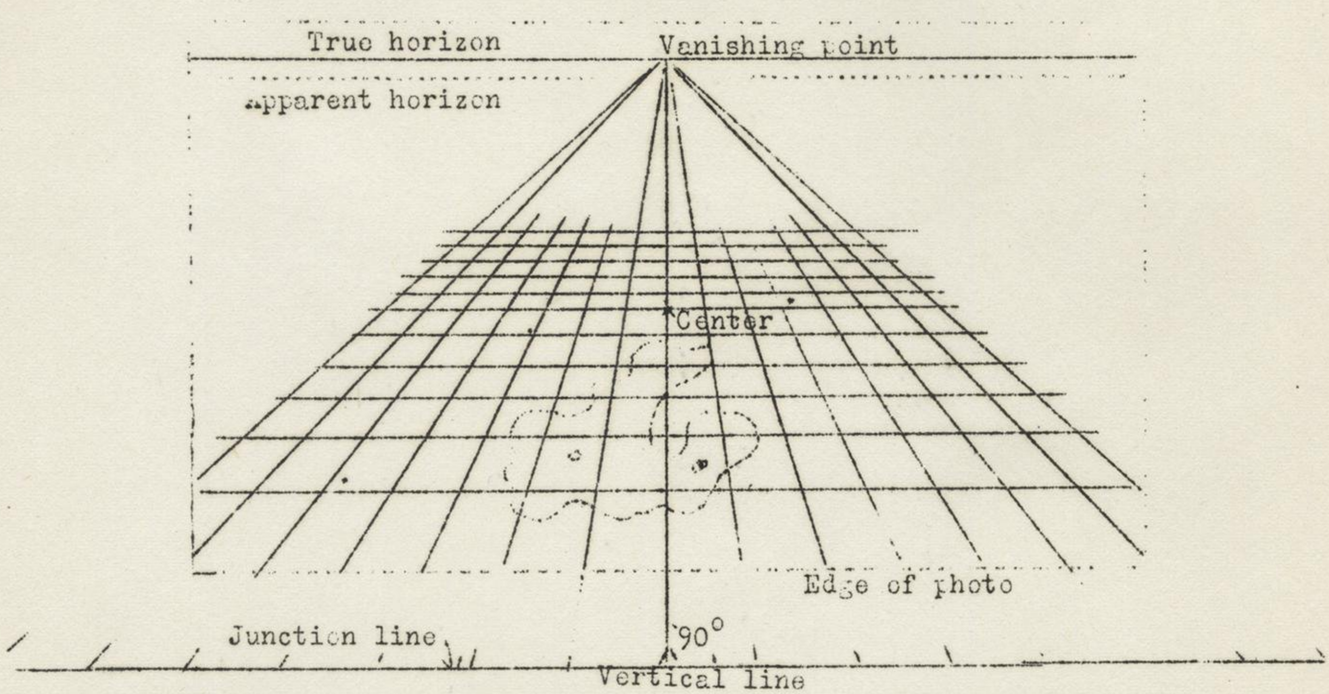


FIG. 7 Vertical section through axis of camera



FIG? 8 Construction of perspective grid in plane of photo.

the axis of the camera intersects the level of the ground (fig. 7). Next connect each of these points to the lens position as shown by dotted lines. In Fig. 8 the plane of the photograph is shown. The line marked "junction" in fig. 7 is drawn and intervals equal to those shown on the ground in Fig. 7 are laid off on both sides of the vertical line through the center of the photo. The intervals determined above are than laid off on this line. Lines parallel to the true horizon are drawn through these points. Then lines from the points on the junction line are extended to onverge at a <u>vanishing point</u> at the intersection of the vertical line and the true horizon. Each figure formed by crossing of these lines corresponds to a square on the ground. To lay out this figure we must have both focal length of camera and alitude at time picture was taken. It is best, however, to check the grid and see if it shows known points on the ground in correct relation. Such known or control points are shown by dots above. Draw the squares one inch to a side and then sketch true outline of lake.

line of lake shown.

<u>U. S. Army method</u>. The U. S. Army manuals describe a method of drawing maps from obliques which involves finding four or more points in the picture whose map locations are known. The diagrams below show how this is made use of. Care should be taken not to draw too many triangles so that they will be confusing. With only four known points the principles of perspective are used and two vanishing points are found. The work has to be done on a sheet of tracing paper considerably larger than the photograph.

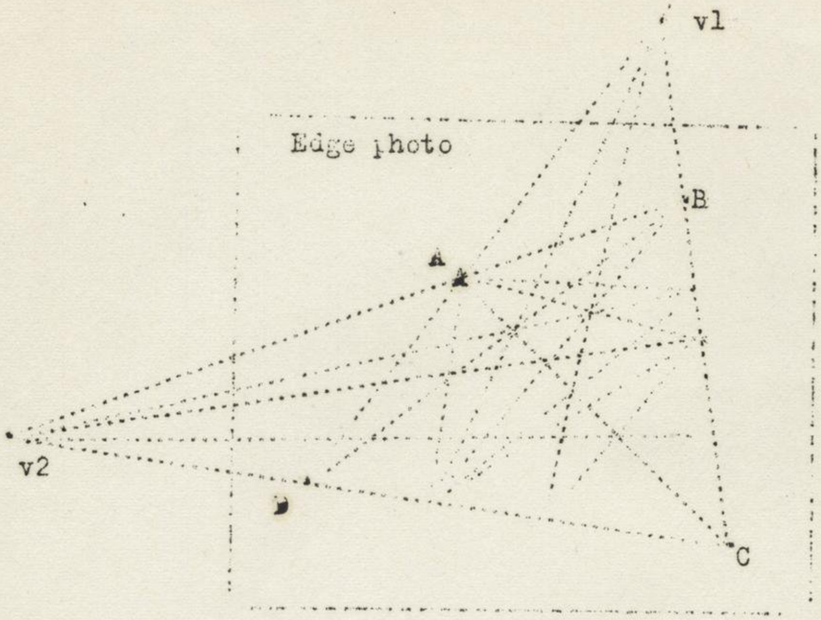
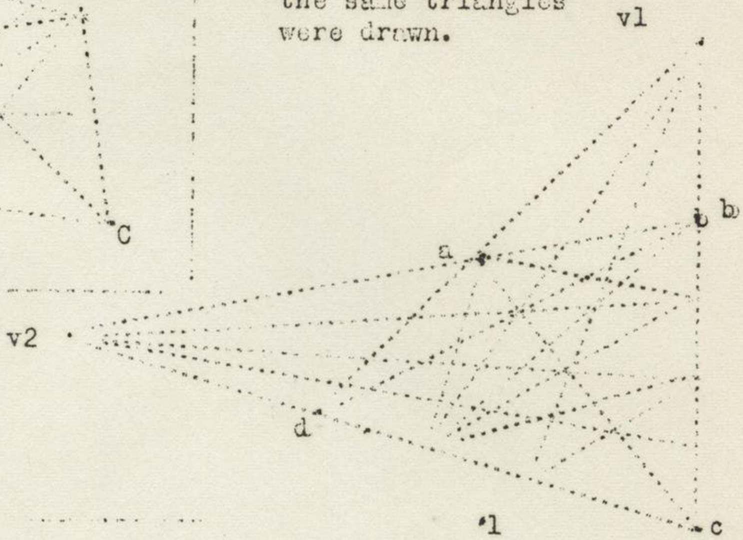
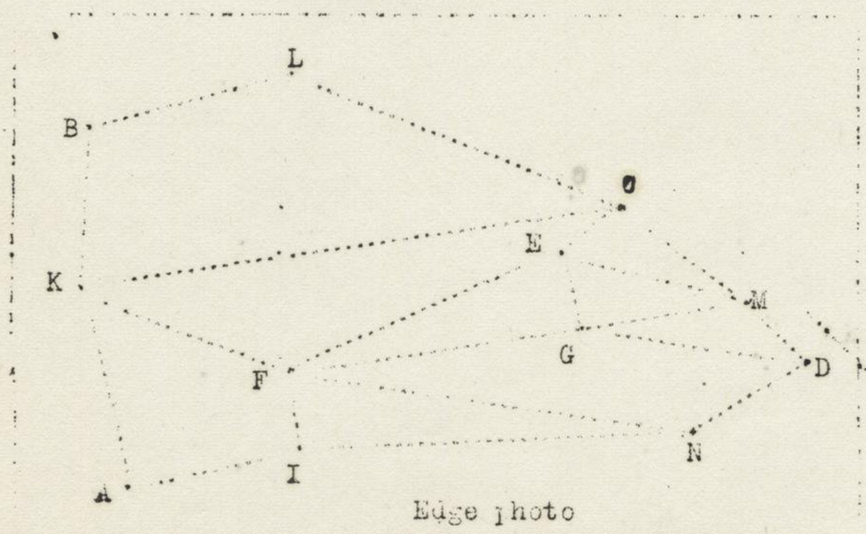


FIG. 8 Army method of drawing map from oblique photo with four known points. Note two vanishing points and how triangles were drawn. The points are shown in correct relation below and the same triangles were drawn.





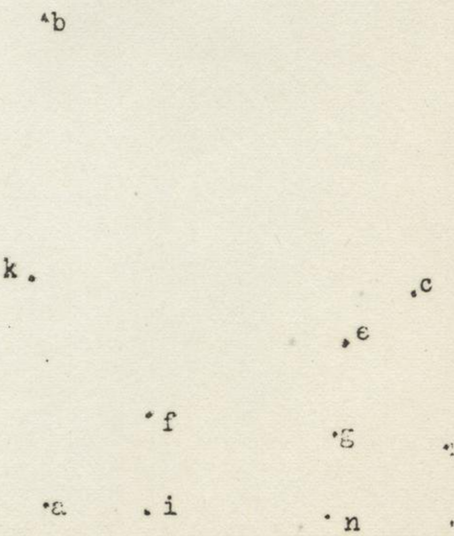
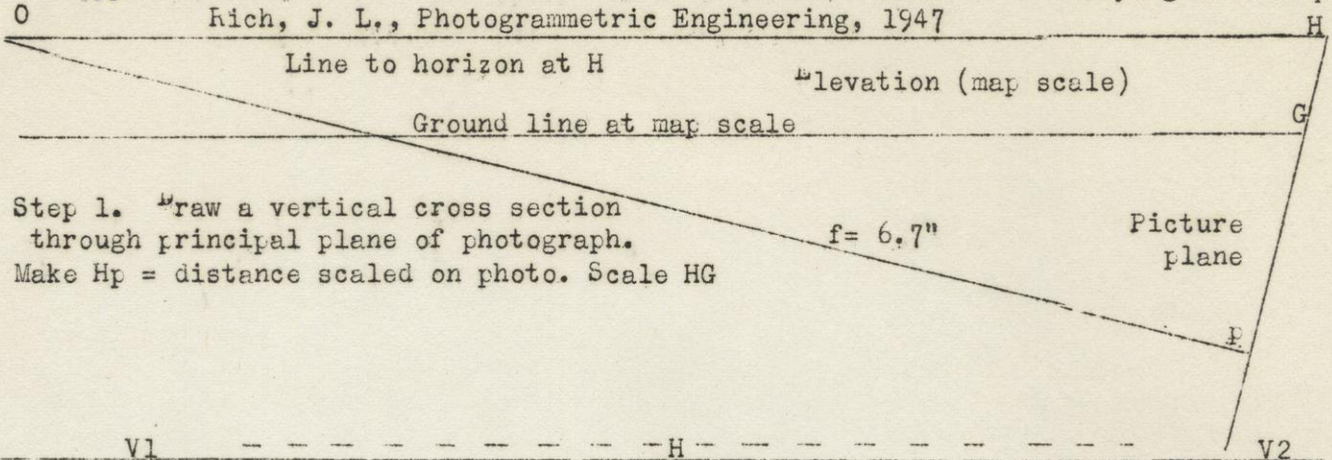


FIG. 9 Army method where more than four known points are present. Draw more triangles on the photo and then draw all the triangles on map shown at right. What kind of country can this method be used for? What advantage over other methods has it?

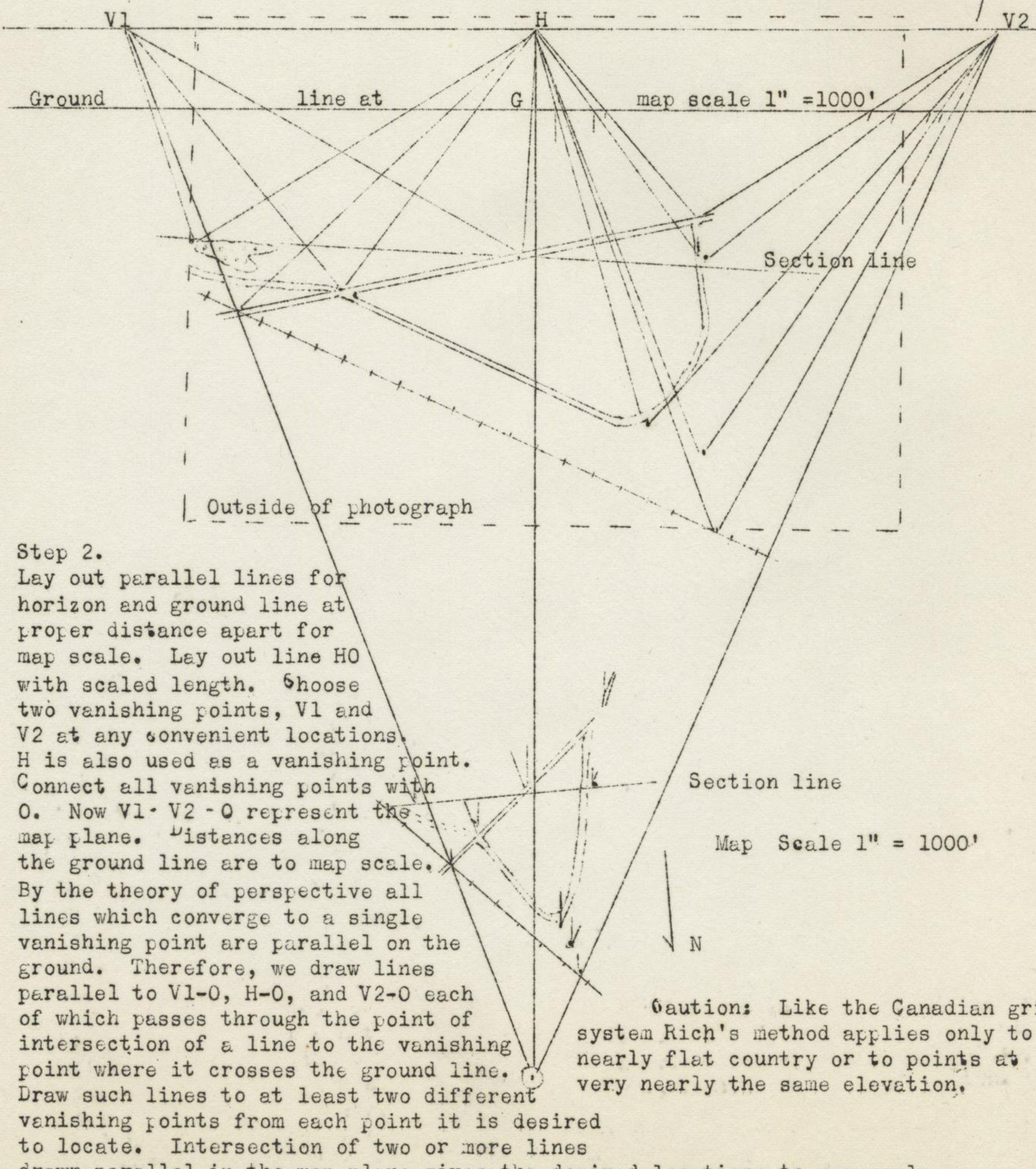
<u>References</u>. See list at end of problem 16. Also Trorey, L. G., Survey by high obliques. The Canadian plotter and Crone's graphical solution: Geographical Journal, vol. 100, pp. 57-64, 1942

Supplement to Problem 17, edition of 1949 Rich's method of rectifying an oblique.

Rich, J. L., Photogrammetric Engineering, 1947



Step 1. Draw a vertical cross section through principal plane of photograph. Make Hp = distance scaled on photo. Scale HG



Step 2.
Lay out parallel lines for horizon and ground line at proper distance apart for map scale. Lay out line HO with scaled length. Choose two vanishing points, V1 and V2 at any convenient locations. H is also used as a vanishing point. Connect all vanishing points with O. Now V1- V2 - O represent the map plane. Distances along the ground line are to map scale. By the theory of perspective all lines which converge to a single vanishing point are parallel on the ground. Therefore, we draw lines parallel to V1-O, H-O, and V2-O each of which passes through the point of intersection of a line to the vanishing point where it crosses the ground line. Draw such lines to at least two different vanishing points from each point it is desired to locate. Intersection of two or more lines drawn parallel in the map plane gives the desired locations to map scale.

Caution: Like the Canadian grid system Rich's method applies only to nearly flat country or to points at very nearly the same elevation.

Supplement to Problem 17, edition, 1950
Proof of Crones method.

The method of getting true map rays from map location of photo where camera axis was inclined can be solved by more than one method as explained before. The fact that displacements on the horizon line or line common to both photograph and map is the one used by the U. S. A. F. The Abrams "Rectoblique Plotter" is a mechanical means of doing this. However, when the angle of depression is low in a high oblique photo the lines from horizon to nadir point are very long and another method is better, i.e. Crones. This method is briefly explained above but is proved and corrected below. In Fig. 13 it is clear that we must obtain on the photo the radius PN' from which to draw true map rays to all points which lie the same distance(in the photo)below the horizon. By projecting this radius to the horizon line HL it is equal to P'L. Attention must then be directed to the triangle HPP' which is here shaded with vertical lines. The distance HP' is the excess over the length of the desired line which is P'L. Fig. 14 is drawn in the plane of the photo. Here are two triangles. One is the same as triangle HCL of Fig. 3 here designated hcl and shaded with horizontal lines. This is in practice made of celluloid or other transparent material. An arc with radius equal to HP of Fig. 13 is drawn with center on prolongation of line hc; this arc is tangent to horizon line and to principal line HN' (drawing in Fig. 5 is incorrect). Next we must superimpose triangle HPP' here shown as hpp' and shaded as before so that it has the same relation as before being simply turned face up. It is then clear that the side hp' cuts off the same amount of the side hl as it does in Fig. 13, and that point p' is on the horizontal line through P. The distance below, PN' is then the same as PN' is Fig. 13 and locates the point on the plumb line from which true maps rays are drawn to all locations on this horizontal line.

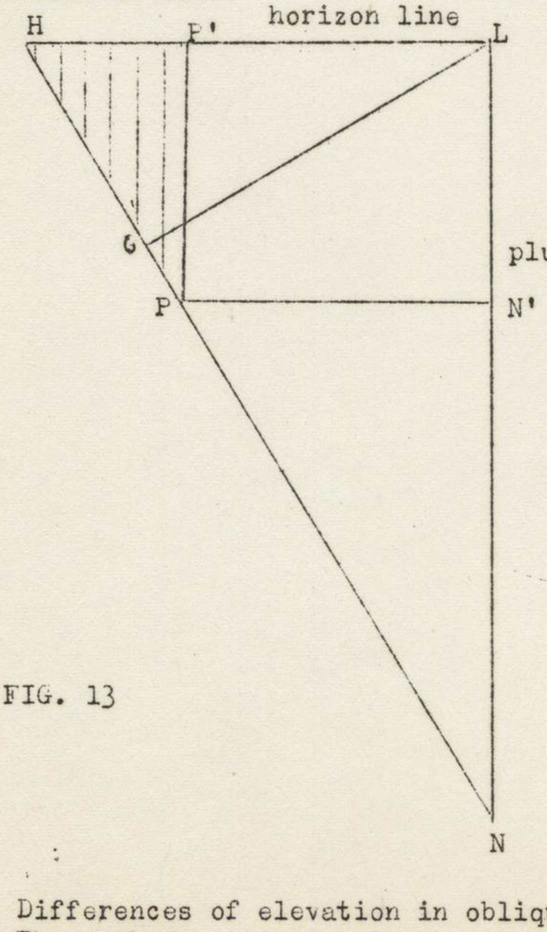


FIG. 13

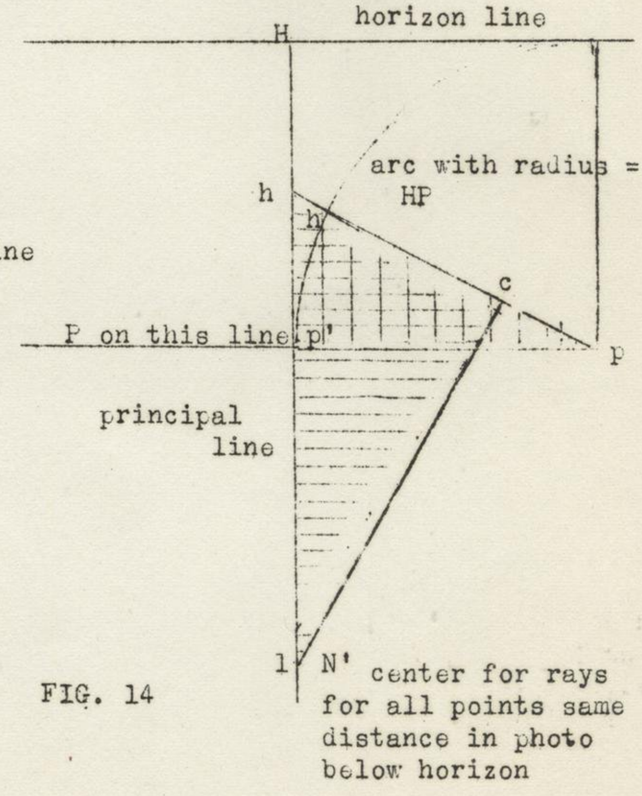


FIG. 14

Differences of elevation in oblique photos by U. S. A. F. method

The method outlined below was used with the obliques taken along with verticals in the "trimetrogon" method used in the southwest Pacific area. It works only when there are overlapping obliques all taken with essentially the same angle of depression. See Fig. 15 on following page.

FIG. 15

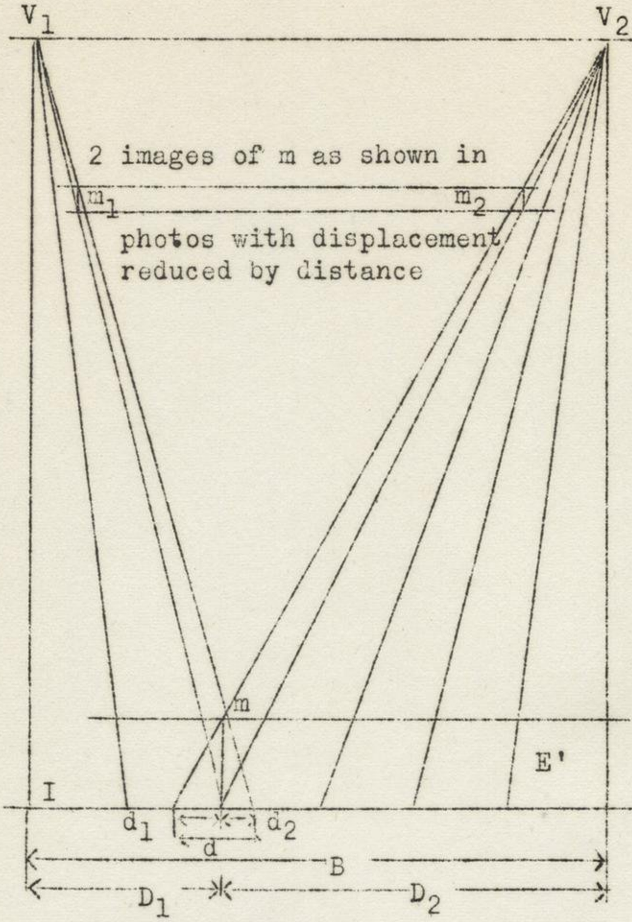
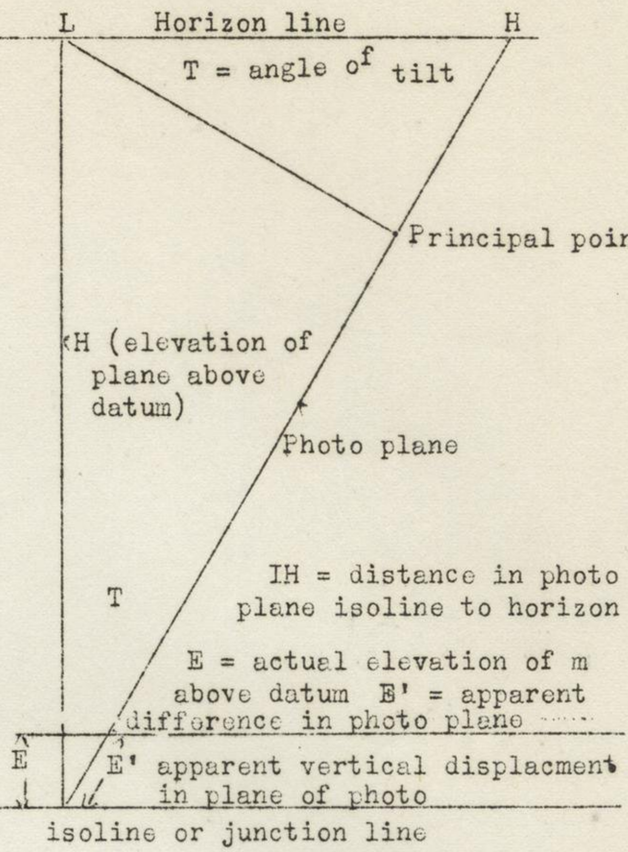


Diagram in photo plane showing converging line to vanishing point of each photograph

FIG. 16

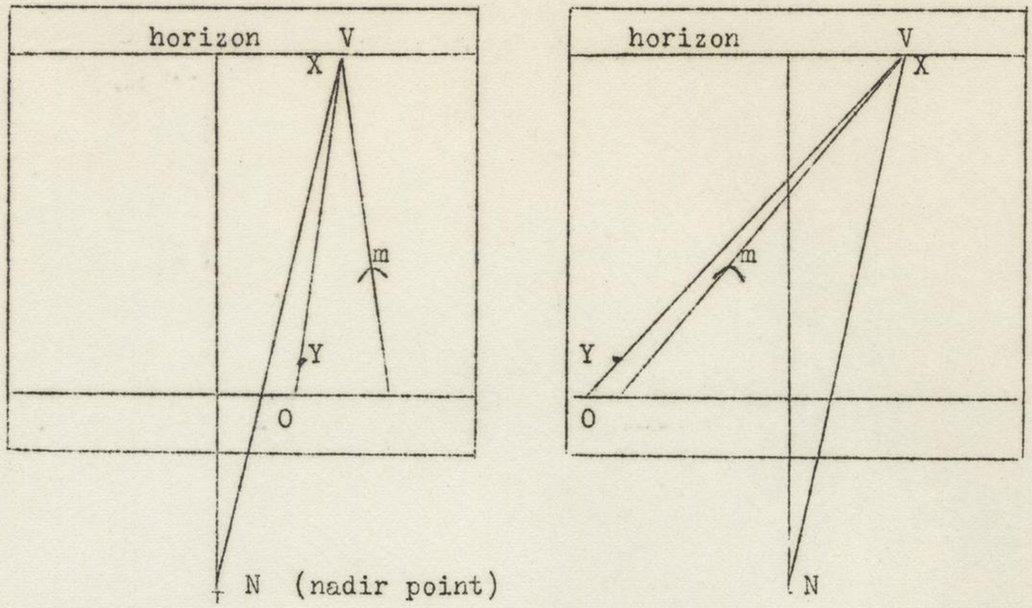


Section on principal plane of one photograph showing relation of E' to E and IH to H (elevation of plane above datum).

Let m be a point whose elevation is E feet above datum plane. Base of perspective line in Fig. 15 is the isoline or ground line where photo is equal to map scale. Note that although perspective lines show only one position for m the position on isoline indicate an apparent or parallax displacment of m here denoted as d. This is the sum of $d_1 + d_2$ total distance of the air base, B is the sum of $D_1 + D_2$ Note that B is equal to V_1V_2 Now $d_1 = E' (D_1 + d_1)/IH$ and $d_2 = E' (D_2 + d_2)/IH$ Hence $d = E' (B + d)/ IH$ Also $E = E' \cos T$ and $H = IH \cos T$ Hence $E' : IH :: d : (d + B)$ and $E/H = d/(d + B)$ The right hand expression of the first proportion is proved by similar triangles. Solving the second proportion where cos T has been cancelled out gives the result that $E = H \cdot d / (B + d)$

For practical application refer to Fig. 17. Here a datum plane was established by a point Y of known elevation which is near principal plane of one photo.

A well marked point X near to the horizon and visible in both photos is then selected and a ray to it through Y is drawn. As extended to the isoline this ray intersects at O which is the base point for all measurments. Similar rays are drawn to the same vanishing point on the true horizon which pass through m and through the plumb or nadir point N. Both are extened to the isoline. Next the same rays are drawn to the same vanishing point on the adjacent photo. The principles of perspective demonstrate that these rays are essentially parallel on the map to those of the first photo. Using an inch scale measurments are taken from the intersection of the base line through X and Y to intersections of the other rays on the isoline. In this the reading of O is taken as equal to 10.00 inches. B, the air base is equal to the distance from the transferred



base line at O in right photo and the line from nadir point, N to same vanishing point, V in right photo. d is the difference in readings of rays in each photo to the point sought, m. H is the difference of sea level altitude of plane and that of the base point Y. If m is lower than Y then the formula given above is changed to B-d. B and d are given in inches, H and E in feet. This method is very briefly described in a publication by Base Map Plant No. 1, G. H. Q, AFPAC, 1945.

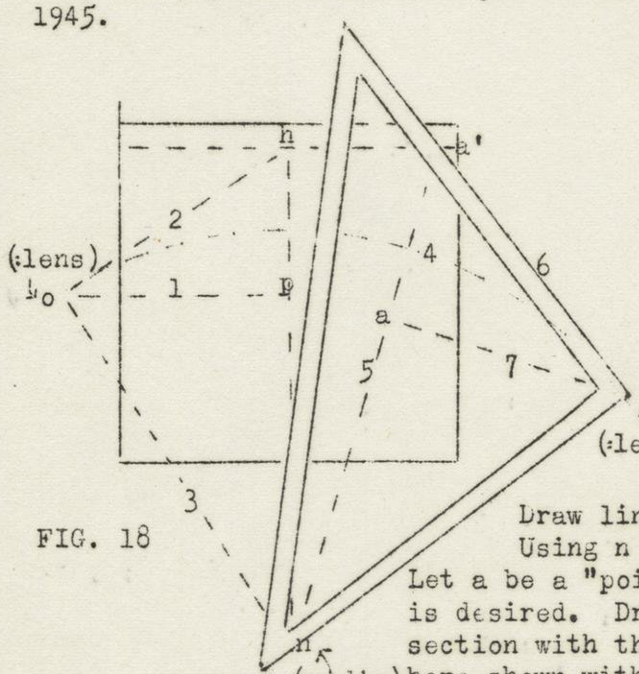


FIG. 18

H. T. U. Smith's method of obtaining true vertical angles from oblique photos, from Photogrammetric Engineering, 1946 In Fig. 18 the plane of an oblique photo is shown with the construction lines dotted.

Draw line nh through principal point p. Draw line 1 from p to o, the location of the lens as shown by tilting the vertical plane through the principal point down into the photo plane. op is then equal to the focal length of the camera, f. Draw line 3 from n to o making a right angle at o. Using n as a center strike arc 4 through point o". Let a be a "point sought" for which the angle of depression is desired. Draw line 5 from n through a to its intersection with the horizon at a' Take a right triangle 6 here shown with the double solid linesand pass its sides through both a' and n and place its corner on line 4. This determines point o" which is the same in space as o but is here turned into the photo plane. In other words the triangle na'o" is a representation of a vertical plane through lens point O and point sought a. The line o" a (line 7) is then drawn and the desired vertical angle a o"a' can easily be measured with a protractor. Smith suggests that the right angle and protractor be combined. To find elevation of a on the map its horizontal distance from the map location of the photo must be found by other methods. Compare with method shown in Fig. 6. Smith's method works best with photographs where focal length is short and angle of tilt is considerable.

End of Problem 17.

GEOLOGY 11

MAPPING

Problem 18, edition, 1939

Object: determination of length of pace.

Material: Notebook, pencil.

Method: The base chosen for determining length of individual pace starts at an elm tree back of the high chimney of Radio Hall; this tree is marked with white paint: "X 11". Follow marks "11" in white paint to north end of south tower of ski slide and thence through woods and brush across the abandoned drive down the hill to lake, through woods on west side to old lake drive at a gray stone, thence along on lake side to tree on north side of drive just at end of a little point which is north of the "Dorms". It is also marked "X 11". Be sure you know where the ends of the line are. The length is 2610 feet. Make at least one round trip over the line. Compute length of pace to hundredths of feet. Count paces, or strides.

GEOLOGY 11
Mapping
Problem 19, edition, 1941

not used often

Object: Compass traverse and sketch map.

Material: Brunton compass, sheet of cross section paper on board or notebook with cross section paper, scale of your paces for 1 inch = 500 feet, protractor, hard pencil, eraser.

Method: The Brunton compass is the great friend of the geologist. In all regions which are devoid of local magnetic attraction geologists use it to keep track of where they are. Unmapped roads, trails, as well as geological contacts, and other features can be traversed. Bearings can be taken to definite points from several locations which when platted on the map serve the same purpose as planetable sights for intersection or resection. The two and three point problems can be solved with the compass. In addition to these functions it serves to measure dip and strike and will in a pinch serve as a hand level. Other compasses are better for surveying but the Brunton is the standby of American geologists.

The area to be surrounded by a traverse is from Muir Knoll west to the longitude of the Observatory, north to Lake Mendota, and no farther south than the walk on the north side of Bascom Hall. Start at any point on this circuit where you think you are away from pipes, tunnels, and other metal objects which cause local attraction. Traverse the area by sighting in the mirror ahead at some definite point like a tree. Take care to hold the compass level so that the needle swings free. Get the line on the mirror in the center of image of the slit in the vane which is kept upright. See that declination of 4 degrees east is properly set off before starting. Use screw driver in large screw on side to do this. After sighting a forward station pace toward it; it may be undesirable to go clear to the point. If so stop in line with it; then sight back on your course to see if there is any local attraction. If there is, the two bearings will not differ by 180 degrees as they should. For instance if you read first N. 50 W. looking back on the same line you should reas S. 50 E. If these do not check you can still make a map. Plat line with protractor and scale distance found by pacing. Then sight ahead and repeat process until point of beginning is reached. Show clearly the error of closure. If no magnetic attraction were feared, how could you vary this routine to save time? Do not try to traverse all the small bends of the lake shore but cut across on straight lines. Keep the map platted as you go. Include on it a sketch of (a) lake shore, (b) roads, (c) trails as single dotted line (d) buildings, approximate outline only. Remember that the map is small scale so that care is needed in drawing. To insure correctness of platting keep notes in one corner of the sheet as follows. Mos compasses we have are graduated in azimuth (0-360 deg). As your protractor is graduated only to 180 degrees, make proper computation to plat.

Sta. occupied	Sta. sighted	Bearing*	Paces

* or azimuth

Then if there is any large error you can check your platting. Remember that errors of interhanging north and south or east and west or of reading the scale in the wrong direction are more common than slight errors. Do not wait for needle to come to a stop but hold compass reasonably steady and then note the extremes of the swing and average them. This is an exercise in field mapping and not in drafting.
HAND IN MAP IMMEDIATELY ON RETURN FROM FIELD. No work will be accepted under any other conditions so do not stay out over the regular time without permission in advance. CAUTION: To get on point hold arms against the body and level compass; then swing on your feet without removing arms until line of sight is on mark.
DO NOT FOREGET A NORTH POINT, SCALE, AND YOUR NAME.

DO NOT LEAVE YOUR COMPASS UNATTENDED! Hand in <u>personally</u> and see it is checked in.

not used

GEOLOGY 11
MAPPING
Problem 20

Object: Plane table topographic map of part of campus

Material: Light plane table, open sight alidade, sheet of paper, field scale showing your paces for 1 inch = 500 feet, hard pencil well sharpened, either hand level, Abney level, or Brunton compass, eraser.

Method: The area to be mapped lies west from Muir Knoll (Ski slide), south of Lake Mendota, north of walk from Bascom Hall to Observatory, and east of a north-south line somewhere near the Observatory depending on time available.

First prepare a field pace scale from the universal pace scale you have. In this case take every other division for this map will be on scale 1 inch = 500 feet. If desired you may also copy the 1 degree slope scale previously prepared also making divisions twice as large. If you copy the contour space scales DO NOT CHANGE THEM for the contour interval here is to be 10 feet instead of the 20 used at Devils Lake. Copy these scales in pencil and paste them onto base of an alidade. PUT YOUR NAME ON THIS so that you can get same one again.

Now run a traverse around the outside of the area starting at any desired location. Use every station method checking oriientation with both compass and backsight. DO NOT FORGET TO BLOCK NEEDLE WHEN NOT IN USE, also do not forget which is the north end. Be sure to use a sharp hard pencil-automatic or self-sharpening pencils will not do. Mark station locations with neat triangle around a dot. Close the traverse and adjust any error. Look out for mixing paces and strides. We will use PACES (every step). Check with inch scale to see if you are all right. That is figure the distance between two stations in feet by your pacing and check to see that you have laid off the right distance. Each year nearly half the class gets balled up on this simple thing!

While you are making the traverse locate buildings, roads, and other landmarks either by pacing to them or by intersections. Some of these landmarks may be outside the area to be mapped but will be useful for 2 and 3 point locations later. Make buildings solid black, roads two solid lines. Do not forget the lake shore.

Now proceed to get elevations of at least 20 key points in the area. Start at U. S. G. S. Bench Mark (Elev 861) just south of main entrance of Bascom Hall. It is cemented into wall several feet from ground. Use hand level or one of the other instruments set to 0. Get height of your eye with a level rod in office. Obtain elevations to nearest foot and mark them on the map. Begin figure immediately after (write figs E-W) point it applies to. Make locations of points in any convenient way- paced traverse, three point, two point with compass orientation, already located points.

Last sketch 10 foot contours. Try to visualize each contour by looking at where it runs on the ground. While sketching you must know the location of the table every time you stop to draw. Do not attempt either to draw contours of ground more than 150 feet away or that you cannot see at the time. Practice using the contour space scales to obtain proper spacing of contours on even slopes. Try to differentiate physiographic features. That is show the postglacial lake cliff and ravines in it as distinct from the uneroded glacial topography. Do not try to hurry at first for more haste means less speed if quality of result is considered.

The finished map need not be inked but must show true and magnetic north, SCALE, contour interval, and name of surveyor.

Problem 21

Object: Use of telescopic alidade and plane table.

Material: Large plane table with paper furnished, telescopic alidade, Cox stadia computer, stadia rod, hard pencil well sharpened, eraser.

Method: Two students must work together with this problem. Turns should be taken in reading the instrument and in holding the rod. Find the elevation of the water surface of Lake Mendota from the known elevation of Bascom Hall Bench Mark 961.3 above sea level. The bench mark is to the left of the entrance to the center of the building; it is a brass plate about 3 inches in diameter cemented into the side of one of the columns about 4 feet from the ground.

CAUTIONS: Do not try to set the table over the bench mark either here or elsewhere. Set up where you can see both bench mark and lake. Do not set up table on pavement or on travelled walk or road. See that it is firm. Never leave it with the alidade on it. Carry alidade in its case when not in use. DO NOT LEAVE GO OF ALIDADE UNTIL TABLE HAS BEEN LEVELED WITH BULLS EYE LEVEL AND CLAMPED WITH UPPER SCREW. Check adjustments before starting. COMPUTE NOTES IN FIELD AT ONCE and hand in work immediately on return.

Draw a line on the table to represent magnetic north; lay the side of the base of the alidade on this line and use the compass to orient the table. Clamp with bottom nut beneath the table. Make a mark for the location of the Bench Mark. Sight it with edge of alidade through this location. Read distance with stadia placing wires so that one falls on a divided foot. Study the rod to see how it is marked; the fifth and tenth feet are the only ones which are subdivided. Use stadia computer to get true horizontal distance and lay this off to get location of table or station. Use no note book but lay off the following form of notes in one corner of the map. This form is for measurments of differences of elevations with vertical angles; this requires the use of the Cox stadia computer.

Locations		Distance		Angles		Diff. elevation			Elevation	
Sta.	Rod.	B.S.	F.S.	Oblique	Diff.	Comp. diff.	Rod cor.	Net diff.	Sta.	Rod.

The oblique angle is that read with the vernier when bubble on index is level and telescope is pointed so that middle wire falls on an even foot, for instance on top of rod. Record what this reading of middle wire was in column for "Rod correction". Be sure that it was the middle wire by recording a "M" before the figure. If angle is small try for a level telescope reading and if such can be obtained record upper wire reading with a "U" and lower wire reading (if such be only one that falls on rod) with a "L". Remember that in such cases the angle difference column must carry a 0 and the computed difference column the value of a HALF INTERVAL. Practice the STEP METHOD of reading if possible.

Also make a duplicate set of notes using the BEAMAN ARC method. Notes as follows:

Locations		Full interval		Arc		Diff. elevation			Elevation	
Sta.	Rod.	B.S.	F. S.	Read.	Rem.	Product	Rod. Cor.	Net diff.	Sta.	Rod.

Do not confuse the two methods. Recall that bubble on index must be leveled and then telescope set to an exact division on the Beaman arc scale before reading of middle wire on rod can be taken. You cannot choose a point on the rod as with angles.

The two systems of notes must check and errors of over a foot or two be corrected.

CONTOUR MAPS

General. Relief may be shown on a map by various methods of shading or by contours. The latter method is almost universally used in this country, although in certain places it fails to show all the features. "Hachures" may be used for steep slopes which are not indicated clearly by the contour lines. Although the general theory of contours is simple the following formal propositions are useful.

(1) A contour line is a line which passes along the surface of the ground through all points which have the same elevation above a certain datum.

(2) Contour lines represent the lines of intersection with the surface of the ground of a plane at a definite elevation above datum.

(3) The vertical distance between successive planes is known as the "contour interval" or "vertical interval" (V.I.).

(4) The less the contour interval the greater the detail of elevations and depressions that can be shown; the size of the contour interval is also affected by the scale of the map since a small interval might make too closely spaced lines.

(5) The land on one side of a contour line is higher than the elevation of that line; the land on the other side is lower. If you should walk along a contour the ground on your left hand, for instance, is lower and on your right hand is higher than the elevation of the contour.

(6) Contour lines never intersect or cross one another.

(7) An even slope is shown by evenly spaced contours; a sloping plane surface by straight contours; a cliff by coincident contours.

(8) Every contour must either close upon itself within the map or pass off the area mapped at two points or a multiple of two.

(9) When a contour closes upon itself the area enclosed by it is either a hill or an inclosed depression; in the first case the exact height of the top of the hill is often indicated; in the second case a pond or marsh is often present. In the case of small depressions a special type of contour line called a depression contour is frequently used to avoid confusion with hill tops.

(10) Maximum and minimum ridge and valley contours always go in pairs; that is, no single lower contour line can intervene between two higher ones and no single higher contour line between two lower ones. Violation of this proposition is a very common error of beginners.

(11) In crossing a valley contours bend toward the source of the stream.

(12) It is advisable to make every fifth contour line heavier than the intermediate ones. The elevations of these heavy lines are shown in a break in the line, not to the side. In very flat country it is necessary to number every line unless the exact elevations of intermediate points are sufficient to tell what the elevation of each contour is.

In addition to the formal propositions the relation between contour lines and the origin of the topography should be understood. The key to all topography is the drainage system. The location, direction, and elevation of points along streams must always be determined. The topography developed by stream erosion depends upon the length of time streams have been at work and on the materials they have worked upon. Certain areas, such as the more recent glacial drift, floodplains, sand dunes, areas of recent vulcanism, etc., have not had any stream pattern developed on them; some of these types are still being built up. Everywhere else stream lines are the control lines of the topography. Second in importance to drainage lines are divides between drainage basins or, in the case of very young stream valleys, the limits of the eroded valleys. Normal streams developed in material of uniform resistance increase in grade toward their source while big rivers generally have a grade of only a few inches to the mile. In material of uniform resistance to erosion mature streams develop valleys with intervening ridges of uniform slope, rounded at the top. Where layers of rock of varying hardness occur the resistant formations make steep slopes or cliffs while the weaker ones make gentle slopes. It is therefore of great importance that the topographer understand something of the geology of the country. Of two maps with the same limit of mathematical error, one made by a topographer who understands geology is "alive" and full of meaning, while a map made without this knowledge is "dead" or "wooden" in appearance.

Methods of locating contours. The original method of locating contours, or "curves of equal elevation", was to trace every contour with a level; this is sometimes done at the present day in country where the relief is low or extreme accuracy is demanded. It is evident, however, that such a procedure would make topographic maps entirely too expensive. The method of interpolation of contour lines between points of known location and elevation was then adopted. Such points should be so placed that they define the borders of plane surfaces; within these plane areas contour lines are equally spaced. Spacing of contours may also be obtained by measurements of the angle of slope of the ground and the use of contour spacing scales for each degree of slope.

Control Points. The number of points whose position and elevation are needed to locate contours depends upon (1) the purpose for which the map is to be used, (2) its scale, (3) its contour interval, (4) the nature of the topography, and (5) the forest or brush cover. If the elementary principles outlined above are noted, it will be seen that one must locate and determine the elevation of all summits, saddles, low places, and changes in degree of slope. In the case of erosion topography, this means the location and elevation of points along ridge tops and drainage lines. In country where the slopes are nowhere uniform it is sometimes preferable to traverse typical cross sections of hills and valleys or to divide the country into a series of squares and determine the elevation of each corner. This method is often necessary in country which is heavily forested or has no definite system to its features. In erosion topography it is most economical to traverse the ridge tops and valley bottoms even in dense forest. The selection of the lower limit in size of valleys which must be traversed depends upon (a) the scale of the map, and (b) its contour interval. In country like forested terminal moraine the method of small squares is preferable since the features follow no law or system. If great detail is needed the position and elevation of points within the squares can be obtained.

Sketching. The exact position of the contour lines after all control points are located is done by sketching. In this work persons vary greatly in natural ability to see the location of an imaginary horizontal line on the ground and to transfer this line onto paper. It is the doing of this work once for all in the field that gives the plane table its great advantage over other methods. It is obvious, however, that in heavily forested country there is no advantage in the use of the plane table. Traverses with compass and aneroid are far more economical unless such accuracy is required that it pays to brush out lines for the use of the stadia. The U.S. Geol. Survey uses a tape and small plame table in brush but it is doubtful if the accuracy obtained is sufficiently greater than that of a paced survey to pay for the increased cost. One should never attempt to sketch contours in timber or brush farther than he can actually see the ground. If the map scale is small and the topographic features devoid of small details which are to be shown, then contours may be interpolated between points where the ground was actually observed. In open country one should never attempt to sketch contours which lie far above or far below the level of observation. The effect of perspective gives rise to serious errors in these cases, so that table locations on the highest summits or in valley bottoms are of little value for sketching. Sketching stations should be chosen at intermediate elevations; their locations may often be made by methods not sufficiently accurate for use in the work of obtaining control points. Never attempt to sketch the reverse side of a hill which you cannot see at all. Above all, do not attempt any sketching of contours except in the immediate vicinity of the table until you have outlined the drainage system and obtained sufficient control points. Viewed from below, a ridge generally appears much wider on top than it actually is. Old U.S.G.S. maps are filled with errors due to sketching from too great distances. This often led the topographers to connect portions of different streams because they had not first followed out the drainage pattern. Treat each interstream ridge as a unit bounded by the valleys on either side and work out the topography unit by unit instead of haphazard. Don't assume that there is no break in slope or concealed valley or knoll in a bit of woods just because the tree tops are of uniform height. Do not get all points on ridge tops only by intersections from below. You must climb hills and go into brush if your map is to be any better than a wild sketch. Such a rough sketch is all right for some purposes and may look better than a real map from the point where it was made, but it cannot be correct. The technique of sketching is very hard to describe; it must be learned by practice. Many approximate methods of location, such as measuring distance from vertical angles to points of known elevation, spacing of contours with slope scale on hills whose profile can be seen, etc., are valuable helps. On very steep uniform slopes do not attempt to draw all the contours in the field; draw only the top and bottom contours and possibly every fifth or heavy contour.

Generalization. As it is impossible to represent all of the smaller features of an area on a map some choice must be made as to what to show and what to omit or generalize. In this choice (a) the scale, (b) the contour interval, and (c) the purpose of the map are factors. The U.S.G.S. has steadily increased the amount of detail shown to far beyond what was once thought possible. Features whose presence is of geological importance or which are diagnostic of the origin of the topography should have preference over mere accidents, like big bowlders on a talus slope. Do not choose a scale for the field map so large that much of the detail cannot be shown on the reduced map used for publication, but, on the other hand, do not use so small a scale that measuring, sketching, erasing, and drawing becomes very laborious. The scales used by the U.S.G.S. for field work are too small for beginners. Above all, do not seek to excuse errors due to insufficient travel over the area, by blaming them to generalization.

Outline of field work. In all mapping of more than a few townships it is necessary to have better "control" over horizontal and vertical locations than can be obtained with the plane table alone. The measurements of location by triangulation (trigonometric survey), primary traverse, or primary leveling all belong to the field of the engineer. This kind of work is seldom done by a geologist. In an area of more than about 15 miles square the effect of the curvature of the earth becomes apparent. A map of such an area made by plane table intersections would be on Mercator projection and the scale would differ in different parts. The matter of map projections to keep the scale the same in all parts of the map by changing directions will not be here taken up.

For small areas, sufficient "control" can be obtained by either intersections from a base line with plane table and telescopic alidade or by traversing around the area and along roads with the stadia. The purpose for which the map is made, its size, scale, etc., will determine the number of points within the area whose position and elevation must be determined in this way. When this work, called "secondary control", is all done and the horizontal and vertical errors of closure adjusted, the filling in of contours may be begun. In case the area is open and considerable accuracy is required, the remaining points needed to locate contours may be determined by stadia. Table locations for this work may be made by compass orientation using either traverse with turning points or resection from points already determined and both methods where possible. In many cases, particularly where several men are working on the area, it is better to transfer the points and elevations determined by the telescopic alidade to sheets on small traverse tables. These can be used for paced surveys and locations by resection; elevations being secured by vertical angles, hand level, or aneroid. In very dense brush note book compass traverses using the aneroid are more economical than the plane table. In areas of magnetic attraction the dial compass should be used. In some cases, as in very complex topography, two men would be an advantage since one could obtain locations and elevations off the line of traverse leaving the other to keep track of locations alone, thus following the well known methods of geological work in the Lake Superior District. The aneroid readings can be reduced at the end of the day by one of the methods outlined before and the corrected locations and elevations transferred to the final map for use in interpolating contours. Tentative contours and slope measurements should, however, be shown on the field sketch. In areas where squares are preferable to ridge and valley traverses, the size of the squares so as to insure that all the area has been seen, depends upon the nature of the topographic features as well as upon the forest and brush conditions. On erosion features in hard rocks, or in ground moraine much larger squares are possible than in a complex terminal moraine or much dissected topography. The squares are best traversed in step-like form, that is, north one square, east one, north again, so that two sides of each square have been previously traversed affording two checks on previously adjusted work. Unless squares less than 1/10 mile on a side are used, every stream and lake shore must be either traversed or located by intersections. The method of squares is slower than traversing of definite features, but that method is applicable only in erosion topography.

Conclusion. Don't try to sketch what you can't see. Don't be in too much of a hurry to begin drawing contours. You can extend contours up or down a slope whose angle is known but it is better to simply record the angle on the map and fill in contours later after elevations are all secured. Draw contours at changes in slope first; the others can often be left until the map is inked in. Don't be afraid to climb hills but don't use extreme summits for sketching. Don't try to sketch distant features. Go through woods along ridges and drainage lines if in erosion topography, otherwise in system of squares. Many important geological features are found in woods. In drawing contours every line worth drawing is worth drawing definitely; avoid scratchy, faint lines. An eraser is a necessary part of your equipment but by being careful to draw only what you are sure of, you can minimize errors due to repeated erasures. If you leave a line of traverse for an outlook take the table with you; you may get a much better sketching station and besides, something might happen to your map while you are away. Avoid unnecessary intersection and other lines; keep careful record of these lines where they are numerous. Keep them around the edges of the sheet to that they can be extended into area being worked on when needed. Keep the map clean. Sometimes a sheet of wrapping paper with a hole over the place being worked on is a very good way, but in high winds it is apt to give trouble. It is best to ink in the map from day to day instead of at the end of a job. If the map is to be photographed use only black ink. Be sure you use the right kind of paper. If you are mapping geology show outcrops and boundaries by usual symbols. If you are preparing a map for a geologist exact elevations marked on the map near outcrops are often of great value. Exact elevations of bodies of water, hill tops, road intersections, land corners, sags, and saddles in divides are all important to geologist. Exact location and elevation of springs may also be valuable.

Geographic nomenclature. The names of all geographic features should be shown on a finished map. Great care should be taken to find the names actually used by the inhabitants of the region; you are not called upon to criticise their choice. Never make up names of your own unless you are certain that no name has ever been previously applied to the feature. Avoid duplications of names elsewhere and under no circumstances name a feature after a living person (unless possibly someone of great eminence); avoid long and clumsy names and such terms as "Little", "North Branch," etc., in naming forks of rivers.

Finishing the map. Plane table maps should be inked in as soon as possible after the completion of the field work, if possible in the evenings and on rainy days. Waterproof inks should be used. If the map is to be photographed it is best to use only black, but if it is to be traced or engraved, then the three colors used on U.S.G.S. maps may be employed with geologic data in a fourth color. Blue is difficult to photograph.

Reproduction of map. Maps may be reproduced by photography in several ways. The photostat gives white lines on a dark background. Zinc cuts are made for printing on paper. In case the size of the photographed map is to be very much smaller than that of the original, great care must be taken to avoid narrow spaces and sharp angles between lines which might blur in printing. Cut out parts of lines where necessary. This is especially the case in zinc cuts. Maps can also be reproduced by tracing. Information is readily transferred from one map to another of the same scale by tracing on tracing paper in pencil. Then lay the tracing on the other map with a sheet of carbon paper beneath and then trace with hard sharp pencil or steel point. Tracings used for blue or black line prints must be made wholly in black. It is best to use only the dull side of tracing cloth especially if the map is to be photographed. Erasures may be made with razor blade or ordinary eraser. Remember that both tracings and blue prints for publication are made by photographing onto metal or stone plates. The lines are then cut in with a steel tool. Separate plates have to be made for each color. Copy for zinc cuts, must be all in black. To make cuts from colored maps have them first photographed with proper color filter on a panchromatic plate.

General hints on drafting maps. Systematize your work -- for instance do all roads, then all water features, then all water features, then all contours, etc. Never draw freehand any line, however short, which is intended to be a straight line. Use proper instruments and measurements to construct right angles, parallel lines, or circles, however small. Contour, swivel, or Paysant pens can be used for some curved lines; they insure evenness of width. Use guide lines for all lettering. Do erasing slowly; never try to hurry. Wherever possible place all lettering parallel to bottom of map. Where lettering cannot be horizontal incline it so that it can be read from the east side of the map. Balance the size of letters to importance of places named. Follow a U.S.G.S. map for styles but avoid fancy lettering. Plan your lettering so that it will not obscure important details on the map. Place your title in lower left hand corner if possible. The words "map of" are often unnecessary. Give name of organization you are working for, date, name of chief of party, names of instrument men, graphic and at least one other form of scale, magnetic and true meridians. Fancy borders are generally not needed. Remember that all of your work including field notes is the property of your employer. All your work must be in such form that anyone else can "take over" at any time. No one is infallable; check all your work and if possible, have someone else also check it.

Use slanting letters for names of bodies of water and for public works like railroads and vertical letters for all other features. Section numbers can be either placed in center of each section or on large scale maps put in the corner of every section so that there are four numbers around every section corner. Corners which were actually found from either a monument of some kind or from fence corners should be marked with proper symbol and distinguished from corners whose position is simply inferred. heck carfully to see that you did not violate any of the rules for contouring.

THE UNITED STATES SYSTEM OF PUBLIC LAND SURVEYS

Introduction. The public lands of the United States extended west from the east line of Ohio, north of the Ohio River, and west of the Mississippi River with the exception that Mississippi, Alabama, Louisiana, and Florida were also included; large parts of Texas and California, as well as smaller areas in other states, were privately owned at the time these regions were acquired and were therefore excluded from the survey. According to law the public lands were to be divided into tracts six miles square, known as "Townships", with north-south and east-west boundaries. These were to be subdivided into 36 sections each a mile square. The system of surveys is important to geologists because (a) it affords a means of describing points where notes were made in a manner such that anyone could find them, (b) in examining private lands their boundaries must be found, (c) land divisions must be found in order to show them on new maps, and (d) land divisions are an immense help in finding ones location on a map.

Baselines and meridians. Surveys were started from many initial points. sometimes several in the same state. A true east-west line was run through the initial point and called the "Base Line". A true north-south line was run through the same point and called the "Principal Meridian." Every six miles on the base line township corners were established. "Range Lines" were run true north from each of these for from 24 to 60 miles. Points six miles distant from one another on these were joined by east-west lines called "Township Lines", thus forming townships. On account of the curvature of the earth townships thus surveyed became narrower and narrower the farther north they were of the base line. This reduction below the legal size was compensated for by running new "Standard Parallels" either every 24 (or every 60) miles on which new full-sized townships were started to the north. Such lines were also called "Correction Lines". Ends of the lines south of the correction lines were called "Closing corners" while corners for the full townships to the north were called "Standard Corners."

Numbering of townships. East-west rows of townships are called "Tiers". Townships in the first tier north of a base line are each called "Township 1 North. The next tier is T. 2 N. and so on. North-south rows are called "ranges" and townships in the first row east of a principal meridian are called R. 1 E., in the next row (or range) R. 2 E., and so on. In some cases townships are numbered south of base lines and west from meridians. In Wisconsin there is only one base line, the south line of the state, and only one principal meridian, the fourth. All townships are therefore N. but there are both E. and W. ranges. The complete description of a township would read: Township 48 North, Range 6E, 5th Principal Meridian, or usually abbreviated T. 48N, R. 6E, 5th P.M., or more briefly, 48-6E. See Fig. 1.

Sections. Townships were divided into 36 sections numbered as in Fig. 2. A few of the older surveys used a different system. Section lines are supposed to be parallel to the south and east boundaries of the township and work was supposed to proceed from the southeast corner toward the north-west. The Sections were intended to be exactly 5280 feet (80 chains) from north to south with the exception of the north row of each township in which all of the error in subdivision was concentrated. East and west the maximum discrepancy in a section was supposed not to be over 33 feet (50 links), except that all discrepancies, as well as the effect of convergance of the range lines, were concentrated into the westermost row of sections in each township. As a matter of practice few section lines are straight lines for more than one mile and few are exactly north-south or east-west. In some of the older surveys, as in southern Wisconsin, no attempt was made to join section lines to the corners laid out on the north township line and as a result every township line shows slight offsets between the corners for the township to the south and those for the township to the north, although the township lines themselves run straight through. None of either the west or the north sections of a township are squares. A given section would be described as Section 21, Township 47 North, Range 19 East, 4th P. M. or more commonly Sec. 21, T. 47 N., R. 79E., 4th P. M., or still more briefly, 21, 47-19E. In the last method the designation Section and North have been omitted where no ambiguity is caused thereby.

Subdivision of sections. The government surveyers placed "quarter posts" at half mile intervals on the section and township lines; lines connecting these divided the normal sections into quarters of 160 acres. The points of intersection of the two "quarter lines" in the centers of the sections were not marked but were left to later surveyors. A quarter section would be described as the northwest quarter of section 5, usually abbreviated to NW 1/4, Sec. 5. or simply NW 5. In the north and west rows of sections the quarter posts were set a half mile from the south and east boundaries respectively, thus throwing all deficiency or excess into the marginal quarter sections on the north and west sides of townships. Elsewhere in the townships the quarter posts on the east-west lines were set exactly midway between the adjacent section corners. Later, settlers wished smaller farms than 160 acres and the quarter sections were divided into quarter-quarters or "40's", the others in these sections being full size. The fractional areas on the north and west sides of these sections were called "lots" by the Land Office and numbered in each section in general from east to west and from north to south. Geologists generally do not recognize lots in recording locations but treat all sections as though they had been completely subdivided into 40's. See Fig. 3.

Meandering. The borders of bodies of water were supposed to have been "meandered" by lines run at angles along their irregularities but apparently when this was done at all it was very crudely executed and few "meander posts" can now be found. The odd-sized tracts were called "lots" and numbered as shown on the original plats which should always be consulted. For descriptive purposes pay no attention to these lots. Adjacent to bodies of water which interrupted the usual routine of surveying there are many descrepancies in the land survey.

Corners. In spite of elaborate rules and regulations for the marking of corners with stones, pits, mounds of earth, etc. few seem to have been thus permanently established. Generally a square wood stake was set; such stakes were marked in various ways but few original corner stakes can now be found. Corners were also "witnessed" by taking the bearing and distance to several trees which were blazed and marked "B. T." generally with the number of the section, township, and range also indicated. Most such trees have long since gone but later surveyors have sometimes made new ones. Where corners fell in lakes, streams, etc. "witness corners" were also established on the lines as far as they could be run. Many later surveyors have set iron stakes, dressed stones, or piles of stones often around stakes. Most lines were blazed and later surveyors have reblazed them. Such blazes are generally found at the same height on both sides of trees on or near to the lines and can thus be distinguished from nat ral scars. Care should be taken not to be deceived by corners set by unauthorized and incompetent surveyors; government and county surveyors are alone authorized to reestablish lost corners. Correct corner descriptions can generally be obtained from county surveyors. Original plats are on file at government land offices, and in many states at the capitol. County surveyors also have copies and some "plat books" are also reliable. Roads are commonly laid out along section, quarter, and 40 lines and county maps are therefore a guide to locating land lines and corners. Farm boundaries are generally fenced in a more permanent manner than are lines within the property since the latter are more often changed. "Line fences" are also a guide to finding land lines; farm lines are shown on many county maps. In vertical aerial photographs line fences are easily seen, also differences in time of cutting in the forest and less commonly areas along fences cleared to prevent trees from falling onto fences and breaking them. These should not be confused with clearing along electric "high lines". In asking questions remember than many people miscall 40 acre tract corners 1/8th posts instead of 1/16th posts.

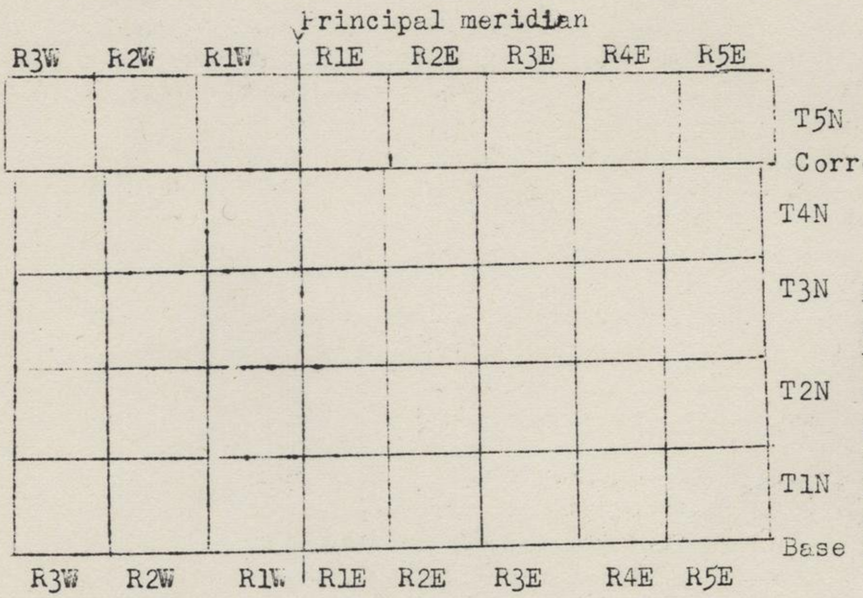


Fig. 1
Base line, principal meridian, and townships. On many maps the township and range numbers are given opposite middle points. of each township and range.; on large scale maps it is better to place them on respective sides of lines.

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Fig. 2
Numbering of sections in a township. On north and west sides the sections are not of regular shape with western ones generally narrow. North row may be either large or s mall.

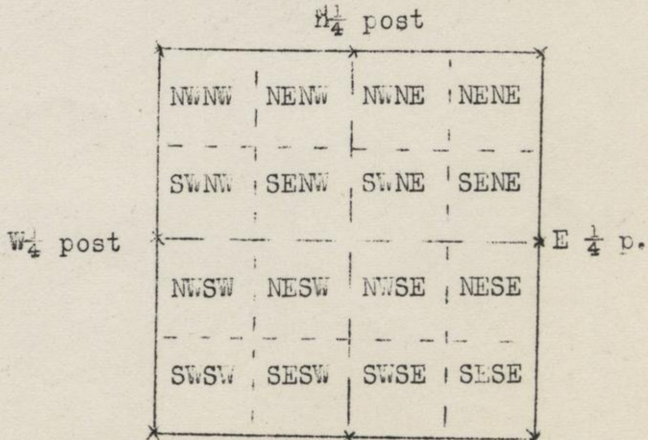


Fig. 3
Subdivisions of a section into 40 acre tracts or 40's Only the section and ¼ posts (corners) were set by original survey. 40 posts are often called "1/8th"

MAPPING

Review questions, 4 credits   Use diagrams in explaining derivations

(1) Derive formula for difference of elevation on vertical photographs in relation to parallax difference; give both forms, dp and dh.

(2) Derive formula for elevation of plane when taking verticals at given scale.

(3) Combine formulas for difference of elevation per unit of difference of parallax and for elevation of plane.

(4) Describe the essential steps in preparing vertical photographs for use in stereocomparagraph (contour finder).

(5) Outline the steps in computing the required information about vertical photographs necessary to their use in stereocomparagraph.

(6) Explain theory of radial line adjustment of vertical photographs, and steps in setting up a radial line plot using tracings.

(7) Explain radial line plot by slotted templet (or equivalent) method.

(8) Derive the formula for horizontal displacement of a point in vertical photograph due to slight tilt of camera axis. Explain fully.

(9) Explain why there must be a "y" motion to one of the marks in a stereo-comparator and which mark it should be on, right or left.

(10) Explain how the movement of the "y" motion can be used to find relative tilt of a "vertical" pair of photographs. General principle only.

(11) Derive formulas for finding relative tilt of "vertical" photographs from measurments in Y (transverse direction).

(12) Describe general principles of several different types of machines for drawing contours from vertical photographs.

(13) Derive formula for horizontal displacement of a point on a vertical photograph due to difference of eleavtion; explain fully.

(14) How is distortion in vertical photographs due to relief adjusted?

(15) How is distortion in vertical photographs due to slight tilt adjusted?

(16) Explain relations of relief distortion to tilt distortion.

(17) How are tilt and relief distortions minimized.

(18) Under what circumstances is is desirable to find the plumb or nadir point in vertical photographs?

(19) Describe several methods of transferring photo detail to map.

(20) Define briefly: principal point, principal plane, plumb point, nadir point, isocenter, axis of tilt, vanishing point, perspective, true horizon, apparent horizon, mosaic, anaglyph, equivalent vertical, focal length, comparagraph, planimetric, pseudostereoscopic, air base, photo base, map base, scale ratio, high oblique, low oblique, rectification

(21) Diagram the relation of an oblique photograph to the land which it shows.

(22) Explain the Canadian grid system of mapping from obliques, including the required data.

(23) Explain principles of Rich's method of mapping from oblique photographs.

(24) Explain geometry of finding true map directions to points in an oblique photograph of an area with considerable relief.

(25) Explain the U. S. Air Force method of finding true map directions from oblique photos.

(26) Explain Crone's method of finding true directions to points in oblique photographs. When is this method better than that of question 25?

(27) Compare the advantages and disadvantages of mapping from obliques and from vertical photographs.

(28) Describe a system of combining obliques and verticals for rapid mapping.

(29) Describe methods of making mosaics.

(30) Compare advantages and disadvantages of mosaics compared with maps.

(31) Explain desirability of ground surveys in connection with mapping from aerial photographs, including determinations needed.

(32) What methods might be used for ground control including their relation to scale of final map?

(33) If you could not obtain any ground control of your own where could you find information to be used instead?

(34) What are most essential points on vertical photos for having elevations determined by ground survey?
(35) If you have no information on type of camera used in taking certain vertical photographs what information must you have in order to find differences of elevation on them?
(36) Explain methods of drawing contours with the stereocomparagraph.
(37) What is a "camera lucida" and of what value is in in use of photographs?
(38) Describe the two types of instruments called "sketchmaster".
(39) How may oblique photographs be changed to verticals by photography?
(40) Describe several types of stereoscopes and compare advantages and disadvantages.
(41) How may stereo vision be obtained without any instrument?
(42) Describe the cause of stereovision and some visual defects and habits which may prevent its use.
(43) How can stereoscopic vision be used with oblique and ground photographs?
(44) Describe Abram's method of correction for slight tilt of "vertical" photographs.
(45) Explain with diagram the direction of displacement of objects due to slight tilt of a "vertical" photograph.
(46) Explain the "multiplex" method of mapping with vertical photographs.
(47) Compare advantages and disadvantages of use of elaborate machines for mapping from aerial photographs.
(48) Explain a method of correcting for slight tilt in "vertical"photos.
X(49) Describe methods used to overcome aerial haze in taking aerial photographs. red or yellow
(50) Whay are most bodies of water black in prints of aerial photos?
(51) How can you distinguish sandy from clay soil in aerial photos?
(52) How can you locate on a previously made map a point shown only on a new verti cal photograph?
(53) How can you find the position on the map of the plumb point of an oblique phtograph?
(54) Under what conditions do aerial photos display bed rock geology best?
(55) Even if aerial photographs do not show geologic boundaries directly how may they be an aid in geologic mapping?
(56) What difficulties occur in mapping a sandy coast?
(57) How could you measure map distances with ground stereoscopic photos?
(58) Explain why the photo or map base, b, on vertical photos is not in every case the same in adjacent photographs (more than one reason.)
(59) What is effect of difference of elevation on value of dh or "multiplying factor" with vertical photographs.
(60) What effect has relief on scale of vertical photographs?
(61) What are two necessary conditions to make a"vertical" photograph a true map of area it represents?
(62) If you have no information on true directions on the ground what data on a vertical photograph serve to approximate them?
(63) Be prepared to solve problems on map scales and photo scales.
(64) What is meant by "junction" or "ground" line in oblique photos?
(65) Explain two ways in which slight tilt of a "vertical" photograph may be detected.
(66) Explain principle on which amount of tilt of a "vertical" photograph can be measured by scale differences.
(67) From what point can radial lines be drawn to correct BOTH relief and tilt distortion of a "vertical" photograph at once? Explain.
(68) Be prepared to work problems in computing values of dh and dp for vertical photographs given either the parallax formula or a known difference of elevation.

"0"

(69) Prove basis for Crones method of obtaining true map directions in oblique aerial phtographs using geometric constructions.

(70) Derive formula for obtaining difference of elevation in a pair of high oblique aerial photographs.

(71) Under what conditions of topography may perspective methods of rectification of oblique photos be used?

(72) Explain how radial line adjustments may be made with high oblique photographs.

(73) How can raidal line construction with high obliques be combined with that from verticals of same area?

(74) Show with diagrams how vertical and horizontal angles are recorded in vertical, horizontal, and oblique photographs.

(75) Show the distortion of a rectangle in true vertical, low oblique, high oblique, and horizontal photographs.

(76) Show with diagrams Smith's method of obtaing true vertical angles in high oblique photographs.

(77) Explain with diagrams how effect of tilt in near vertical photographs may be resolved into two components.

(78) Explain effect of each component of tilt on parallax determinations.

(79) Comment of validity of the Abrams method of correction for slight tilt of near vertical photographs.

(80) Explain a pracitcal method of correction for slight tilt of near vertical photographs.

(81) Lay out a plan for the aerial survey of a township using vertical photographs and expaing necessary ground surveys.

(82) Lay out a plan for a ground survey of a township using ground photographs for the contouring.

(83) Lay out plan for aerial survey of a township using oblique photos and explain the preliminary ground determinations needed.

(84) Explain in principle only the ground determinations needed for a trimetregon survey of a route.

(85) Explain theoretical basis of the "alidade" type of devices to obtain true directions on oblique aerial photographs.

(86) How may map location of plane (plumb point) be obtained from an oblique photograph?

(87) Explain value of the determination in (86) in completing a map.

(88) Compare radial line method with plane table survey on ground indicating its advantages and disadvantages.

(89) List three common causes of distortion of intended vertical photographs.

Tilt - relief Photography - poor lens Printing etc.

(90) Explain how each three types of distortion may be corrected. (see 89)

(91) Explain why it is harder to fit raidal line construction of one flight to an adjacent flight than it is to adjust one flight only.

(92) What determines scale of radial line plot if no ground control exists?

(93) What is advantage of slotted templet assembly over tracing paper method for radial line plot?

(94) Define briefly: isoline, junction line, horizon line, vanishing point, relief distortion, tilt distortion, center of photo, Crone's method, Rich's method, angle of tilt. X motion, Y. motion, Y displacement.

(95) Account for the better apparent stereo depth of lens stereoscopes compared with mirror stereoscopes.

(96) Which are more accurately determined in vertical aerial photographs, distances or directions? Why?

(97) Apply your conclusion of 96 to oblique phtographs.

GEOLOGY 11
MAPPING

Review questions — Second half final exam (3 credits)

(1) Compute how far apart contours of given interval are on different map scales and different slopes. Tangent 1 deg. = 0.0175.
(2) State effect on (a) horizontal closure, (b) vertical closure on point of beginning, and (c) map scale of an error in stadia constant of telescopic alidade.
(3) State effect as in (2) of failure to compute true horizontal distance in telescopic alidade plane table traverse.
(4) What effect on elevations has omission of table height above ground in a telescopic alidade traverse run with backsight orientation?
(5) Under what conditions must you use backsight orientation with telescopic alidade?
(6) A traverse was run with telescopic alidade and compass orientation through a doubtful area; at end the point of beginning could be seen. Do what?
(7) In preceeding question it was found that sight did not check. Give two alternative procedures to correct this error.
(8) State caution in seeking corners along west and north sides of township.
(9) Where can you find correct information on size of sections?
(10) Describe methods of obtaining true horizontal distance with paced traverse and ground is such that ordinary pacing is either impossible or inaccurate. Actual field practicability is considered, also different types of instruments, such as opensight alidade and planetable, Brunton compass and sketch board, etc.
(11) Compare different methods of using Brunton compass for direction including type of ground or slope in which each is used.
(12) Compare advantages and disadvantages of Brunton and prismatic compasses.
(13) On some township lines you find two sets of corners except at the corners of the township. Explain why.
(14) In case traverse with telescopic alidade shows that a section of land is not the shape it is supposed to be, suggest check lines to prove which is right.
(15) Be familiar with different near-obsolete units of land measurements, chains, rods, acres used for distance, etc. coverting each into feet.
(16) Be prepared to compute difference of elevation from telescopic alidade readings with different conditions and stadia factors given; include angle, Beaman, and level telescope systems.
(17) Explain methods of measuring distance with telescopic alidade when only one horizontal wire is available.
(18) Compare different systems of obtaining differences of elevation with telescopic alidade considering which allow you to choose point where middle wire is placed on rod.
(19) Explain methods of working with telescopic alidade which could be used if you could not adjust it or one of the levels is missing.
(20) Explain how to use Brunton compass to measure slopes and how you will use slope data for contouring.
(21) Explain how you could use Brunton compass to obtain differences of elevation using more than one method.
(22) In running telescopic alidade traverse you catch sight at a station of a distant point already located on your table; it is too far away to visit. Do what to check directions and elevations? Show computations.
(23) On setting up to start a branch telescopic alidade traverse should you set up over an old station, have rod held at a former station or have rod held at a former turning point, set up on old turning point? Explain possible error.
(24) Explain fully why an index level was added to the first telescopic alidades.

(25) Explain different ways of correcting readings of the barometer when working alone; consider case of long interval between visits to known elevations.

(26) Compare results obtained in field with hand level with those you obtained with barometer.

(27) Explain computations of map distances on different maps scales and transformation of map scales into fractions and vice versa.

(28) Explain the distortion of a vertical aerial photograph due to relief of region shown, considering not only displacement of points but also change in shape of straight lines on ground.

(29) How obtain factor to measure difference of elevation on vertical aerial photograph if you have no information on type of camera used.

(30) Under what two conditions is a vertical aerial photograph a correct map of the ground?

(31) What steps must you take to find the scale of a vertical aerial photograph?

(32) Compare advantages and disadvantages of Beaman and vertical angle systems of the telescopic alidade.

(33) Explain why algebraic signs of backsights and foresights with telescopic alidade follow different rule.

(34) Explain advantage of making sideshots with telescopic alidade.

(35) What kinds of surface features should be carefully located with telescopic alidade if you are to complete your map from aerial photographs?

(36) Explain advantage to planetable or compass survey of location of a prominent although inaccessible point like top of windmill; include elevation as well as location determination.

(37) Explain why you should obtain elevation of surface of a body of standing water or slow-flowing stream.

(38) Explain effect on compass needle of different types of local attraction, such as R.R. track, joints in rails, reinforced concrete, end of fence, north-pointing fence corner, buried iron pipe, etc.

(39) Explain effect on accuracy of elevation determination of high and low vertical angles.

(40) How can you find true north; explain general principle of two different methods using Polaris.

(41) Why in finding true north from Polaris must you know approximate latitude?

(42) Which way do you move south end of observation line on Polaris to obtain a true north line? Diagram.

(43) Explain use of survey of a railroad in making an accurate map.

(44) Explain steps in checking stadia constant of telescopic alidade including different types of this instrument.

(45) Explain the rules in regard to contouring which must always be remembered in field drawing of a map.

(46) Explain two ways in which you can find the time on a given day that Polaris is true north?

(47) Be prepared to transform true to magnetic azimuth and vice versa; also azimuth to bearings and vice versa.

(48) Compare advantages and disadvantages of azimuth system versus bearing system.

(49) How can you use vertical angles as an aid in obtaining horizontal distance?

(50) How do you distinguish between Beaman and angles scales of telescopic alidade?

(51) Explain possible error in using for straight checks with barometer of (a) level of a cold body of water along with (b) points on open ground away from water.

(52) What would be effect on difference of elevation of confusing Beaman and angle systems on telescopic alidade?

(53) How do you detect areas of local magnetic attraction due to unknown cause?

(54) What might be cause of apparent agreement between Beaman and angle systems of measuring elevations with telescopic alidade when results were actually in error?
(55) In an intersection survey why is so much stress laid on sights along the faces of the bluffs?
(56) What is limiting factor in accuracy of elevations obtained from the intersection survey?
(57) Compare accuracy of level and angle shots with telescopic alidade?
(58) Why and where might engineers level be superior to telescopic alidade for elevation determination?
(59) Why is permissible error in closure not directly proportioned to distance covered by survey but increases at a lesser rate?
(60) Be prepared to compute radius of railroad or highway curves of different degrees of curvature.
(61) Describe how you lay out railroad or highway curves on a map.
(62) What is meant on map by term "B. M."? by the small triangles with dot in center? by letters on such marks "T. Tr."? Describe marks you would expect to find at these points when visited?
(63) What are advantages and disadvantages of different ways of expressing scale of a map?
(64) State bare minimum of information necessary in legend of a map.
(65) How can you change scale of a map in absence of any special apparatus?
(66) If a map is to be reproduced by blueprint (or black line print) what colors of ink are allowable?
(67) What color must be avoided if a map is to be reproduced by ordinary photography?
(68) What types of checking may be done to determine accuracy of a given topographic map?
(69) Why is "tracing paper solution" of three point problem useful mainly in office?
(70) Explain how the U. S. Land survey was supposed to be laid out.
(71) Define, baseline, correction line, meridian, meander corner, township, section as used by U. S. Land Survey.
(72) Be prepared to compute notes taken with telescopic alidade (any system).
(73) Compute notes taken with engineers level or hand level and rod.
(74) What is limiting factor of accuracy in using hand level?
(75) What is limiting factor in accuracy with barometer?
(76) Describe two ways in which paced distance may easily be laid out on map.
(77) What is limiting factor of accuracy in pacing?
(78) Why is it necessary to set flags to sight on in intersection work?
(79) Describe steps in finding a land corner in unfenced region.
(80) Why are results with large telescopic alidade commonly better than with small or explorers model?
(81) Why are foot numbers commonly omitted on stadia rods?
(82) Explain two major "personal security rules" when working with a party.
(83) Under what circumstances should telescopic alidade be kept in its case during moves and when not?
(84) Explain reason for precautions during leveling plane table with telescopic alidade and when setting up on rocks.
(85) Why is Brunton compass better for following land lines than is prismatic?
(86) Give precautions in carrying telescopic alidade in its case when traveling by car.
(87) When it happens that you cannot see enough of the rod to span the smallest interval in your alidade and you cannot have rod moved suggest what method to obtain true distance.
(88) Outline procedure used to check accuracy of the stadia constant.
(89) Under what circumstances could you find a "neutral point" where the compass needle will not stand still?

Review, 2nd half

(90) Under normal circumstances does motion of compass needle indicate local attraction?

(91) Although the f + c constant with telescopic alidade is less than 1 foot could its omission cause an appreciable error in a long traverse?

(92) It is commonly said that the allowable error in surveying is proportioned to the square root of distance covered. Explain qualitatively.

(93) Explain two important reasons why geologists must be familiar with the U. S. Land Survey of area in which they are working.

(94) Why is it better to follow land lines when sun is out?

(95) What limits methods used for long sights with telescopic alidade when rod can be seen only through a narrow lane between trees?

(96) Plan how you could carry out a "two base" barometric survey by cooperation between several parties.

(97) Outline best method of using barometer when you are always close to straight checks.

(98) Outline a method whereby two observers, each with a barometer, could carry correct elevation over a considerable distance from nearest known elevation.

(99) You desire to check the magnetic declination for use with a hand compass and have no astronomic tables. Outline practical method.

(100) Describe effect on compass of (a) another compass close by it (b) of a north-south fence, (c) of a vertical iron rod in ground, (d) of a break between rails of railroad, (e) of a buried iron pipe not at the ends, (f) of a concrete bridge or culvert.

Review questions, first half final exam (Use Diagrams)

1. Full interval reading = 5.0 ft. Beaman arc = 56. Middle wire at 8.0 ft. Difference of elevation? (Stadia constant 101) Up or down.
2. If above is a backsight on point with elevation 1000, table elevation = ?
3. If above were a foresight with table elevation of 1000, rod elevation = ?
4. Rule for sighs with backsights.
5. Rule for signs with foresights.
6. Rule for signs of rod reading.
7. When other than middle wire is read how make correction to middle wire?
8. Full interval = 10 ft. Angle scale = 31-08 (factor = 2.00%)
   35-46 (factor = 10.00%) middle wire 10.0
   Difference of elevation? Up or down? Stadia constant = 100
9. If a backsight from elevation 850, table elevation?
10. If a foresight from table elevation 900, rod elevation?
11. Why keep alidade cases on hinge side?
12. Why hold onto alidade until table is levelled and clamped?
13. How use the compass on base of alidade when on table?
14. Describe principle of drum method.
15. Describe basic idea of step method.
16. Whey is there an "f + c" constant? How applied? When can it be omitted?
17. Describe briefly 5 methods of getting difference of elevation with tel. alidade
18. Full interval = 8.0 ft. Stadia constant = 100. Lower wire read 12.0 Difference of elevation, up or down from table?
19. Full interval = 12.00 Stadia constant = 100. Upper wire read 1.0 Difference of elevation up or down from table.
20. List essential steps that must be taken before starting work with tel. alidade Omit details.
21. Explain in full each of above steps.
22. When elevations are obtained by intersection and vertical angles instead of with rod, how compute difference of elevation? Why?
23. When you enter area of local magnetic attraction how run traverse with p. table and tel. alidade?
24. Whenever you catch sight of a previously located point in course of tel. alidade survey do what? What two things will be accomplished thus?
25. What is a sideshot and what taken for?
26. How are sideshots computed and what danger of error with them?
27. If you are going to use aerial photographs to complete your map what kinds of points should you locate on your planetable sheet?
28. If you pass a body of standing water in your area so what? (tel. ali. survey)
29. What caution must be taken in handling striding level whenever instrument is placed in its case?
30. Why cannot tel. alidade be used in rainy weather? Two reasons.
31. You are issued a planetable which has a built-in compass and are to use the tel. alidade. Do what first?
32. Caution in tel. alidade instrument man carrying a compass?
33. Why do engineers have to defer computations to night? Advantage in doing them at once?
34. Suggest methods of checking differences of elevation in field?
35. When is steel tape measurement desirable? With planetable?
36. Cautions in use of steel tape. Three kinds.
37. How is slope compensated in use of steel tape? Two methods.
38. Could you use tel. Alidade for a Polaris observation? Explain.
39. Explain how without any tables or other aids you could obtain true north from Polaris using methods suitable for any hour. For culmination?

40. Define: culmination, elongation, meridian, zenith, hour angle.
41. What effect does latitude have on direction to vertical plane through Polaris? Explain.
42. Describe two methods of indicating directions.
43. Define: azimuth, quadrant, bearing, true, magnetic as applied to directions.
44. In running a compass traverse could you use every-other station method and under what circumstances.
45. If local attraction occurs or is suspected can you still run compass traverse and how?
46. How is Polaris located in sky and how can you tell its position in orbit Give two methods of latter.
47. If a line of known true direction is obtained by sight on Polaris how can be corrected to a true N-S line?
48. How can you tell when you are far enough from a known source of local attraction to get true(correct) reading.
49. Transform some quadrant readings to azimuth and vice versa.
50. Transform some true azimuths to magnetic azimuth and vice versa,
51. What must be done to compass when it is moved to a different latitude? Why?
52. Explain the sundial compass. What must be used with it?
53. Compass foresight = 220; backsight from next station = 30. Explain.
54. Draw diagram of compass circle showing how divided.
55. Draw a diagram showing how to set off a declination of 5 East on Brunton; also 10 West. Show line of sight and needle.
56. Show two methods of getting directions with Brunton.
57. Show how slopes (vertical angles) are found with Brunton.
58. Diagram construction of prismatic compass.
59. Compare advantages and disadvantages of Brunton vs. prismatic compass.
60. Are land divisions of U.S. Land Survey true or magnetic?
61. If your retracing of an old map shows a different declination than was originally used, what is explanation?
62. Explain magnetic pole, declination, deviation, magnetic storm, long term (secular) change.
63. Define township, section, correction line, principal meridian, forty.
64. Diagram subdivision of township into sections.
65. Diagram subdivision of section in 40 acre tracts
66. Diagram where error in surveying etc. is concentrated in township.
67. Explain why correction lines are needed and where error is concentrated.
68. Someone tells you that a certain corner is 40 acres distant; meaning?
69. Define, quarter corner, 40 corner. Why is latter sometimes called 1/8th corner?
70. In following lines along west and north boundaries of townships how obtain distance recorded by original surveyors? If sections are subdivided into 40's where is irregularity concentrated?
71. What is meander corner? meander line? chain? link? bearing tree?
72. Explain how original surveyors were supposed to subdivide a township.
73. If you find two sets of section and quarter posts along township lines what is reason?
74. Define; contour, contour interval, vertical interval, depression contour, hachure.
75. What rule applies to position of lower(or higher)land as you travel a contour in one direction.
76. What rule with regard to vertical cliff contours, to contours on divide, to contours crossing a valley, to elevation of contours, to choice of contour i interval.
77. Draw some simple contour diagrams of hill with depression, drumlin, valley, even slope, two-story valley, concave slope, etc.
78. What methods might be used to locate contours (ground survey)
79. Other methods of showing relief. Advantage of contours.

80. Define: tangent, degree of curviture, radius of curve relation of center of curve to tangent, station, including system of recording distances.
81. How can you find value in feet of difference in parallax-two methods.
82. Parallax measures 15 mm. to top of a hill; at a point 500 feet lower the measurement is 12.5 mm. Compute difference in ft. elevation per mm. of parallax
83. Explain purpose and method of radial line system of joining vertical photographs.
84. Two methods of drawing contours from vertical aerials.
85. How find alitude at which photos were taken. Show formula.
86. Derive relation between parallax difference and other quantities.
87. Show how formula for difference of elevation from unit parallax difference was derived.
88. Why is there a motion at right angels to line of flight on one of measuring dots? What does its use demonstrate?
89. Describe process of setting up a stereo pair.
90. Describe processof finding multiplying factor with formula given.
91. Where is it most desirable to have true elevation on a vertical photo?
92. Which dot should be used to trace detail?
93. Describe differences between the three models of stereo instruments used.
94. At what alitude must you fly to take photos at 1;20000 with a camera of 6 in. focal lenght?
95. A mile on photo measure 3.0 in. Find scale as fraction. Also number of feet to one inch.
96. When and why is true horizontal distance used with plane table?
97. When is horizontal distance correct on vertical photos?
98. How can you correct for error due to differences of elevation using vertical photos?
99. If you used an erroneous stadia factor with tel. alidade would it affect differences of elevation; exception to this rule?
100. In what direction are contour intervals measured; map distances?

Geology 11

Review questions, six weeks   Use diagrams

(1) Telescopic alidade: define apparent distance
(2) Define slant distance with tel. alidade, and give relation to apparent dist.
(3) Show how appare nt distance is corrected to true horizontal distance.
(4) Which, sla nt or horizontal distance is shown on a map?
(5) In computing difference of elevation with telescopic alidade which is used, when observation is with stadia rod: slant, apparent, horizontal distance?
(6) Which distance, slant, apparent, horizontal is found when intersection method is used on plane table?
(7) Derive formula for difference of elevation used when distances are by intersection and vertical angle is measured.
(8) Derive formula for vertical difference when stadia rod is used.
(9) Define, stadia, interval, rod correction, half interval, rod intercept.
(10) Define angle scale
(11) Define, Beaman arc
(12) How can you tell Beaman arc from angle scale on telescopic alidade?
(13) Explain basic principle of Beama n arc.
(14) Make sketch showing how you read vernier; on which scale is it?
(15) What is the drum?
(16) Explain basic idea of the drum.
(17) How is the drum used to measure distance (more than one way).
(18) How is the drum used to measure difference of elevation? Show computation.
(19) What is prupose of the striding level?
(20) Draw a diagram of essential parts of telescopic alidade.
(21) Show why and how the striding level of tel. alidade is adjusted.
(22) Show why and how the line of sight of tel. alidade is adjusted.
(23) Why is there a control or index level on telescopic alidade?
(24) Explain why and how the indèx or control level is adjusted on tel. alidade.
(25) How would you work if there were no control or index level on alidade?
(26) How do you read the vernier on Beama n arc? Explain.
(27) What would you do if the striding level of tel. alidade is not broken but cannot be adjusted?
(28) Why is it a good idea to lay down a telescopic alidade with hinge down?
(29) Could you measure distance if there were only one horizontal wire in tel. alidade? Explain method.
(30) Define full, interval, half interval, quarter interval, rod reading.
(31) Explain more than one way to find distance when not enough of the rod is seen to span a half interval. (No quarter interval on instrument).
(32) Explain level shot. What is its advantage?
(33) Show by a diagram how you find difference of elevation with telescopic alidade when leveled and middle wire does not strike rod.
(34) Derive the formula for the "f + c" correction to stadia distances.
(35) Explain why the f + c correction can often be omitted.
(36) When a nd why is plumb bob needed with plane table?
(37) What are major advantages of plane table?
(38) What are some of the most important objections to use of plane table?
(39) In what kind of terrain can you survey by plane table intersections?
(40) In what kind of terrane would you survey by plane table traverse?
(41) Explain difference between intersection and resection.
(42) Compare advantages and disadvantages of two methods of traversing.
(43) Explain two methods of plane table traverse.
(44) Define orientation, station, turning point, resection, intersection.
(45) Explain two ways to orient plane table.
(46) What is purpose of "three point problem", of "two point problem."
(47) Explain solution of one case of wone method of solution of three point problem (method suitable for use in field).
(48) Describle solution of "two point problem".
(49) Explain foresight, backsight, side shot
(50) Explain advantages of telescopic alidade over opensight.

(51) What is major cause of error with planetable?
(52) Explain rule governing reliability of intersections with plane table.
(53) Should any shots be made which do not conform to rule of minimum angle of intersection? Why?
(54) In what kind of country is use of planetable not advised? In what kind of country does it work best?
(55) Define "base line."
(56) Caution in use of planetables with leveling head.
(57) Why does use of planetable appeal more to geologists than to engineers?
(58) You want to measure distance across water with plane table and cannot see a readily recognizable point on other shore to intersect. Do what? (Water can be crossed). Stadia rod cannot be used.
(59) Define "stadia constant."
(60) Full interval at 1000 feet, true distance = 10.2 ft. Stadia constant =?
(61) Why is a lateral adjustment needed for striding level?
(62) What is limiting factor in accuracy of stadia distance?
(63) Why is full interval reading the most accurate?
(64) Diagram essential parts of hand level.
(65) What limits accuracy of non-telescopic hand level? Assume it to be adjusted.
(66) Step needed before use of hand level for any purpose. Explain.
(67) How is hand level used when working alone?
(68) Terrane in which hand level cannot be used working alone.
(69) Do what after adjusting before using hand level alone.
(70) Show method with form of notes for use of level with assistant.
(71) Why choose hand level instead of barometer?
(72) Why choose hand level over telescopic alidade?
(73) Suggest a method of finding a level line for adjustment of hand level on telescopic alidade.
(74) When prefer barometer to hand level?
(75) General principle of barometer.
(76) Give limiting factor of accuracy of barometer; explain.
(77) Explain a practicable method of compensating for weather when working alone.
(78) Explain use of stationary barometer.
(79) Explain two base method of compensation; show computations.
(80) Explain basic principle of Lahees method of use of barometer.
(81) Explain effect of a thunderstorm on barometer.
(82) When and why use a thermometer along with barometer?
(83) Major advantage of barometer over other instruments.
(84) Define straight check; how used for correction of barometer readings.
(85) Define cross check; how used for correction of barometer readings.
(86) Describe a practicable method of correction of barometer readings when straight checks can be found only at start and finish and you work alone.
(87) Could you use a barometer as an aid in finding horizontal distance? Explain.
(88) Give three ways of describing scale of a map.
(89) Scale 1/20000, 1 in = ? ft.
(90) Scale 1/20000, how many inches = 1 mile.
(91) Scale 1 in = 2000 ft. Give fractional scale.
(92) Define "vertical photo".
(93) Define "low oblique photo".
(94) Define "high oblique photo".
(95) Define "principal point" of photo.
(96) Define "nadir" or "plumb point".
(97) Define "parallax".
(98) Explain cause of stereo vision.
(99) Explain several physical defects which may prevent stereovision.
(100) Explain in general terminology displacement of points in vertical photo due to differences of elevation.

GEOLOGY 11

MAPPING

PERSONAL DIRECTIONS--DEVILS LAKE FIELD TRIP

General. Unless prevented by heavy snow the trip will start on Saturday morning. Date of return will be fixed by weather, not later than the following Sunday afternoon. (eight days total)

Equipment. Each student must provide:

(a) Clothing suitable for work in brush and mud at temperatures down to freezing; some include thin gloves which you can wear while using instruments. Footgear are very important. Use either well-oiled boots with composition soles if possible or lumberjacks rubbers with leather tops. HOBNAILS ARE NOT DESIRABLE for they slip on the smooth rocks. A water-proof coat or a slicker, a cap or soft brim hat (on account of the alidade), and a belt are essentials. Take a change of clothes for it almost certain that you will get wet in April. Lighter shoes or slippers for house wear are good.

(b) Bedding for temperatures considerably below freezing; this means not less than three (3) HEAVY blankets, not quilts unless filled with wool. Mattresses are furnished to everyone!

(c) Watch, for use with aneroid barometer and in order to get in on time.

(d) Small drafting instruments such as a ruling pen, lettering pen, bottle of India ink, triangles, at least two hard pencils (4 to 9 H), scale with decimal divisions of inches, protractor, etc.

(e) Pocket notebook, not over 4 inches wide; a few sheets of cross section paper. THIS NOTEBOOK WILL BE INSPECTED AT END OF TRIP. If you copy partners notes label them COPY. Do not use too soft a pencil when writing in this book.

(f) Copies of Problems 1, 8, 9, 10, 11, 12, 13, and 18; Solar ephemeris.

(g) Small knapsack; this is very important as a safeguard against loss of small instruments as well as for your lunches, unless you have a parka or hunting coat.

(h) Flashlight is handy at times.

(i) Field glasses are handy; a talley register is good, also a slide rule, but these are not essential.

ORGANIZATION. Direct management of the house and table is placed in charge of the Cook. Students will be assigned to K.P. in turn. Note schedule of appointments. These are to help washing dishes, setting table, putting up lunches, etc. Firemen will attend to stoves and provide all fuel. Sweepers are responsible for cleanliness of all quarters. INSPECTION FOR CLEANLINESS of quarters and dishes will be made without notice! Keep beds made up properly. Dishes must be rinsed free of soap; soap has been known to kill a horse! Firemen are volunteers for the trip and normally exempt from K. P.

PERSONAL DIRECTIONS

Complaints. As nothing undermines the morale of a party faster than complaints all such are strictly forbidden in public. Any complaints about food, service, etc. must be made to the Chief Growler IN PRIVATE. The Growler will make his report when called upon and complaints will then be investigated. Every effort is made to make the trip as pleasant as possible but it is not a pleasure trip and in this season of the year it is inevitable that there will be some hardships. Violators of the above rule will be put on K. P. ahead of and in addition to their regular turn.

PERSONAL DIRECTIONS CONT'D.

Personal supplies. Personal supplies can be ordered through the Cook who will appreciate advance payment.

Hours. Rising hour (unless changed for special reason) 5:45 A. M. Dinner at dark. No lunch will be served at camp but those working near the camp can park lunches there and come in to eat them. Evenings are devoted to study and work on inking maps, adjusting aneroid readings, checking notes, looking up information for next day, etc., etc. Work will be permitted in the study hall until midnight

sleep. Work is permitted on Sunday. Discipline must be maintained to safeguard the rights of all. Do not leave the work area without advance notice to the Chief of Party or stay out beyond reasonable hours (dark). Any violation of rules involving delay and trouble to others is a serious offense just the same as a violation of any University or Park rules. SEE END OF DIRECTIONS

Care of instruments. Please observe all cautions literally. Remember that telescopic alidades and all instruments for that matter, are VERY EXPENSIVE. Do not jump fences or off cliffs. Check up your instruments whenever you go through a fence and whenever you leave a point you worked at. Follow definite lines so that if you leave or drop something you will know exactly where to look for it. Accidents do not "just happen" but are the result of failing to consider the risks. A. B. C. = always be careful! Better be safe than sorry. The dishes etc. are property of the Instructor not the University. Please be careful of them and do not include silver in the garbage! You are personally responsible for loss or damage in excess of normal wear and tear of any and all supplies charged to you or your party. Credit is withheld until such charges are paid to the Bursar.

Personal Safety. Be careful on the rocks especially if there is snow. Remember that Northwestern trains run on the left hand track; KEEP OFF TRACKS WHEN A TRAIN IS PASSING! Do not stray from your area; leave it only when absolutely necessary. There is no excuse for getting lost when you have instruments. Trust your compass and use your location maps. Do not take shortcuts across talus and cliffs for they take longer than to follow trails and roads. The greatest danger you are exposed to is that when alone you might slip and injure a leg or foot so that you could not walk. To guard against this event carry matches and if incured make every effort to light a smudge in daylight or a fire at night. Be particularly careful to not stay out after dark alone. Ordinarily you should never get out of contact with your party. Do not leave for field without proper equipment including clothing suitable for weather. A. B. C. Do NOT carry pencils etc. in bootlegs. Women students must not work alone or leave immediate vicinity of the building after dark without proper guard. NEVER fail to keep an appointed meeting place; do not go looking for the others.

Fire warning. April is in the Spring Fire Season in the woods. The dry leaves make the danger very great except during and just after rains or snows. Fires are particularly hard to fight at the Lake on account of the rocks. Let's not start one. Please be careful with stubs and matches both in woods and in the house. Cigarette stubs do start fires, propaganda to the contrary notwithstanding! Break your match and step on stubs on hard ground. A. B. C. Use empty tin cans on the tables. Don't throw any stubs or matches on the floor.

Health. If it is warm when the trip starts do not be misled into thinking that summer has come. Some bad weather is almost certain. Avoid wet feet and chills. Change wet clothes and shoes IMMEDIATELY on return to camp. Try to keep as well washed as at home. Shaving may be omitted. The menu is selected to offset any trouble due to sudden change in habits. In general you should feel

PERSONAL DIRECTIONS CONT'D.

better than at home! Never drink from streams. Learn to avoid drinking any liquid during the day and you will suffer less from thirst. Help keep the dishes clean — it pays! Apply to Chief of Party or Cook for first aid as soon as possible after any injury.

Park rules. The rules of the State Park forbid starting fires (Unless you are seriously injured), cutting live timber, and bringing intoxicants or firearms into the park. Please obey these rules.

Private property. In many places you will have to trespass on private property but the district has been selected to keep you out of such as far as possible. Please do not break any fences or leave any gates open. It is best not to work on Sunday near houses or on main roads. Avoid contact with natives as far as possible as most of them like to talk too much and will delay you. Avoid grain.

Mail. Have your mail sent care of F. T. Thwaites, Geology Camp, General Delivery, Baraboo and the Cook will get it if possible. There is a telephone at the assistant superintendent's home near the lake.

Transportation. The University is not responsible for any student cars or for accidents incurred in use of them. Take 12-13 to junction with 159. Turn right (east) onto that and follow it to junction with 123. Go a short distance to right on that and then leave concrete to follow gravel road to right (south) up the bluff. Follow that to sign indicating route (east) to south end of lake. Follow Park road around south end of lake to Camp Devils Lake. Avoid the Skihi shortcut. If possible, gasoline, RR or bus fares will be paid out of the deposit fund. File claims for such expenses with Treasurer. No return fare will be allowed if student is dismissed for misconduct. Park along road opposite office.

Cost. Expenses may run to $[illegible].00. Deposit must be paid in full before [illegible] [illegible] for the [illegible] . Living costs of Instructor, pay and keep of cook, and rent of house, are paid out of this fund. Any surplus will be refunded together with a group photograph (if possible) at earliest possible date. Unclaimed refunds will be applied to next years class. Owners of dishes etc. get nothing for them except any left-overs at end of trip.

Grades Students who complete the required field work in a manner which is merely "satisfactory" will automatically receive grade of C. Higher grades are given as rewards for ACCURACY of work, interest, resourcefulness, dependability, etc. Lower grades are result of CARELESSNESS including loss of equipment through violation of rules, neglect of opportunities to work, unreasonable neglect in reading and following instructions, slowness in grasping ideas, etc.

Conclusion. Success is up to your initiative and gumption. When in doubt try to figure out SOME WAY to get the desired result. Get locations from map and not from natives. Check over equipment when starting and returning to camp. Remember cost of replacing losses falls on you. Beginners are not expected to be perfect but are expected to learn. CARRY ON! Let's try to better the record of the previous classes! LET'S GO! Making your deposit constitutes a pledge to observe both above and any new rules which may become necessary. Failure to sign-out for town leave or for air photos etc. taken from study hall, staying out later than is reasonable, or causing any disturbance in quarters are serious offenses. Chief of each party must sign all members in on board as soon as he reaches camp. All accidents must be reported promptly.

F. T. Thwaites, Chief of Party

GEOLOGY 11
MAPPING
Directions for field work at Devils Lake
edition 1941

Introduction. Field work at Devils Lake will be divided into three phases: One day in testing the alidades and doing an intersection survey; a shortpractice traversi . The following three or four days in three man parties with the telescopic alidade. (Each party will have 1/2 square mile to survey per person); two or three days doing contouring.

Testing the telescopic alidades.

Material. Large plane table, sheet of mounted paper, telescopic alidade, adjusting pin and screw driver, note book, hard pencil sharpened to chisel point on one end, eraser, magnifying glass. One party will have tape line (steel), plumb bob, marking pins, wood stakes, hatchet or axe.

Method: Each party will work together except as some members will be detached for measuring lines and setting flags. Go to the level open ground east of camp. There measure off a line about 1000 feet long, . Set up table so that center of instrument when placed on it will be about 1 foot back from zero point of your test line. This will compensate for the constant which is usually neglected in practical work. Note how your large table is levelled. There are two wing nuts below the table. Of those the upper is for levelling and the lower for orienting. Place some grease or vaseline on threads of screw which serves to attach the board, otherwise you will have trouble in removing it. Do not place paper on table until you can do so in a warm place or it will buckle when heated. To level the table first loosen both nuts. Note which way you should turn the nuts. Place alidade on it. HOLDING THE ALIDADE with one hand level the table and clamp the upper nut. CAUTION: NEVEL LEAVE GO-OF THE ALIDADE UNTIL THE UPPER NUT IS TIGHT for otherwise a sudden jerk will cause it to slip off and such falls do not agree with any instrument. Never set up the table on rocks without piling stones not less than 4 inches in diameter around the legs. Remember that you have big boots on and sooner or later will strike a tripod leg with one of them. SAFETY FIRST; it is better to walk around rocks than to pay for repairs. After leveling the table it can be oriented to any desired position and then clamped with LOWER nut. After leveling the table it will now be unnecessary to orient it for all you will have to do is to read the rod on mark. Record results in notebook. Change places at instrument so that every man of the party will make observations. Then compare with what you should have obtained . The conclusions may be stated in either of two ways: (a) as the number, say 101, by which you will multiply each full interval reading to get true distance, or (b) the percent you have to add or subtract from 100 x full interval to get real distance. READINGS AND COMPUTATIONS MUST ALSO INCLUDE HALF AND QUARTER INTERVALS, both upper and lower separately. Make sure that instrument is always same way up by keeping FOCUSING SCREW AT RIGHT. After all computations have been tabulated in notebook proceed to test the drum adjustment. find out what the drum actually reads when wire is swung over 1 foot per 100 foot Repeat determination being sure that clamp screw on telescope axis is tight and that spring is pressing on lever correctly. Make all readings by turning TO RIGHT. Each member of party should make his own tests. Last check all other adjustments of the alidade making sure that everything is tight when finished. DO NOT THINK, HOWEVER? THAT THIS ADJUSTMENT IS PERMANENT. Check adjustment of wires every day, and of bubbles whenever you have a chance during course of work.

Intersection survey.

General. The remainder of the first day will be devoted to a survey by intersections from a base line measuring elevations by means of vertical angles. The base line will be measured with steel tape. It will be located on the flat west of camp as far to the south as is possible. From the base we must be able to see all the stations on East Bluff to the north but need not be able to see those on South Bluff. Do not use the testing base line!

Setting signals.

Material: Red and white cloth in sizes not less than 3 feet each way, location map, string, hatchet if possible, field glasses if possible.

Method: Read over the instructions and get verbal directions as well. So far as possible each man will be responsible for only one station. Be sure you understand fully the requirements as the setting of the stations determines the success of the survey. The stations which are to be marked must be so placed that a plane table can be set up either under, over, or just by the side of the flag in a safe position to work. Marking must be good enough to see with naked eye and good enough to see even if snow falls. With exceptions only as given verbally BE SURE THAT EVERY STATION ON EACH BLUFF IS INTERVISIBLE. That is from each station you MUST BE ABLE TO SEE ITS NEIGHBORS along the face of the bluff. Unless this is so you will never be able to get accurate results. Visibility must be from level at which table will be set about three feet from the ground; kneel down to see if this is done. Never locate so that next station can be seen only through trees and brush; the line of sight must be open. Do not locate a station on a tree for same reason. Use the engineers tripods where there are such . In general it is best to use flags on vertical poles stuck into cracks of the rock. Tripods may also be made of three dead branches tied together at the top. Flags may be draped over tops of these. You will undoubtedly find remains of former signals but do not depend on their location being correct.
Stations on East Bluff are : at southwest corner ;this is called EAST BLUFF.

East of the trail near to a large square stone on the edge must be seen from EAST BLUFF way; this is SOUTHEAST. East of Deer Gap and above the quarry on a ledge which can easily be seen from Southeast but not from other East Bluff Stations; DEER GAP.
Stations on South Bluff are: on the talus above camp not far from the top but so located as to be able to see the engineers tripod far to the east; this is TALUS.

The engineers tripod at the farthest east part of South Bluff which can be seen from camp; this is SOUTHBLUFF. On top of some talus about ¼ mile farther east but not visible from South Bluff; this is RUM RUN . Other stations may be set on West Bluff if there is time. In this work please AVOID CUTTING ANY LIVE TREES. Rum Run cannot be seen from South Bluff.

Survey by planetable intersections and vertical angles.

Material: large plane table, sheet of mounted paper, telescopic alidade, adjusting pin, note book, 6 H pencil sharpened to chisel point on one end, magnifying glass, eraser; if party is to measure base line, steel tape, plumb bob, marking pins, stakes, flags, axe or hatchet. Field glasses are very helpful. Rod will be used once by each party.

Method: It is first necessary to locate the base line. WEST BASE should be located roughly between Talus and East Bluff in the open field .

EAST BASE must be located as far east and as far south as possible, near to the woods east of the tracks. ALL STATIONS on East Bluff (except the Deer Gap station) MUST BE SEEN FROM BOTH ENDS OF THE BASE. It is not necessary to see any South Bluff Stations. During the time that some men are out setting flags two will measure the base one way and (if possible) another two measure the other way. Keep careful count of number of tape lengths as an error in this means one of 100 feet. Keep tape always on the line and keep it as near level as possible using the plumb bob on the end off the ground. Look for the correct 0 on the tape

If it is necessary to measure across the railroad DO NOT ALLOW THE TAPE TO TOUCH THE RAILS for these are electrically charged and to touch them interferes with the train signals. Also look out for trains while tape is on the right of way. Trains may be heard at some distance.

After the base line has been measured find the elevation of one end of it by use of stadia rod held on the railroad benchmark on the top of the second of northern cement base of the signal bridge on the west side of the track, that is the one nearest the old depot. Its Elevation is 991.8 To do this it is best to set up the table about midway between the bench mark and the base line station. The rod will not be needed after this is done. To do this is is not necessary to mark any lines on the table but they may be put in if desired.

To start the map first choose a suitable place for it on the sheet remembering about how big it will be. See problem 13. Scale 1 inch = 500 feet. On this small scale it is possible for more than one party to set their tables at a station but a similar off center position must be used at both ends of the base if this is done. First set up and level the table as described above remembering the caution about not leaving go of the alidade until the table is clamped. Draw a long line parallel to one edge of the table and lay the alidade on it. Release the needle and orient the table. Do not fail to do this at every station hereafter as a check on backsights. With table oriented select position to plat the baseline station you are on. Mark very neatly with usual triangle outside the dot. Sight the other end of the base and draw line. Measure length of the base on this very accurately using the scale on the base of the alidade which is divided into 50ths of inches. Plat other end of line. If your table is off center allow for this in sighting. Keep pencil sharp with sandpaper on bottom of table. Now line in all stations that you can see drawing lines with chisel pointed pencil the full length of the alidade. This is done in order to facilitate laying the alidade on the line again for a backsight. Read vertical angles with middle wire on top of each flag. Remember to CENTER THE CONTROL LEVEL FOR EVERY SHOT. Record notes in following form but NEVER use signs for degrees and minutes. Instead separate them by a dash and enter a 0 before the figure when the minutes are less than 10. Look out for the false 0 point on the index. Look out for big errors like this and the small ones like vibration of the table will take care of themselves. One of the party should read and the other record and then check by reading himself. Change places to divide time evenly.

Sta. Oc.	Sta std.	Dist.	Angle		Comp. diff.	Elevation					
			Oblique	Diff.		Sta. occupied			Sta. sighted		
						gr.	H. I.	inst.	Gr.	H. F.	F

Note change from Problem 13 in that column for height of instrument above.

Column F is for elevation of top of flag.

Do not forget to indicate on lines what stations they are to. Some bad errors have arisen from disregard of this. Keep stations in abbreviated form in notes.

Field glasses are an immense help in picking up stations. After shooting all stations which can be seen from one end of the base go to the other end and set up. If off center make proper allowance in orienting by backsight. Check with compass. DO NOT FORGET TO BLOCK THE COMPASS WHEN THROUGH OR TO SEE THAT STRIDING LEVEL IS FIRMLY ON ITS POST. Measure height of flags with pocket tape or other convenient instrument. If need be you can use the scale on the alidade. The nearest foot is enough. Now you will have intersections on most of the East Bluff stations. Put neat squares around their locations. Of them choose the one with best intersections and go to it. Trail up bluff is marked with sign at the bottom. Use it in preference to direct climbing. Take table apart for convenience if desired. Be sure to carry alidade in its case. After a rough climb check adjustments at first station. Set up on station chosen and change the square to a triangle to show that it has been occupied. If you set up on rocks do not forget the cautions to be observed. Alidades are not intended for rock breakers! DO NOT FORGET WHAT THE CONTROL LEVEL IS FOR or to check its adjustment. It gets out of adjustment from striking the side of the case in carrying. Do not forget that you MUST sight the other stations on the bluff along its face. This is of vital importance and cannot be neglected. If you cannot see them from location on table try another place on table and transfer line by drawing one parallel to it through map location of station occupied. Another trick is to have your companion go to the other station and wave a flag on a stick until you can see the spot. Now you will be able to get shots to the South Bluff stations. Keep on going to new stations each of which has previously been well located. A plan of movements is essential to avoid piling up a cumulative error. Make all possible check sights. Always use the sights from the base for orientation whenever possible. Think over the intersections you will get and how they will strengthen the accuracy of the map. Do not forget that in some places resection is just as accurate as intersection and use this fact to save having to go to some stations. It is better to let some stations go than to get to them so late in the day that you would have to descend the talus in the dark for that is very dangerous both to you and to your instruments. BEFORE LEAVING ANY STATION CHECK YOUR ORIENTATION BY RESIGHTING THE FIRST SHOT. Look out for readings of other than middle wire.

In the evening first [illegible] what you did. trick [illegible] very small dots for station locations, lines between stations except inside the squares or triangles. Erase other lines and temporary notes putting names on final locations of stations for later inking. Also ink the line for magnetic north which was used for compass orientation. Now scale distances between stations (except the base which should be shown as measured with the tape). Use either the alidade or a good scale divided into 50ths or 100ths of inches. Use lens for extra accuracy. Record these in proper columns of notes. Study Problem 13.

multiply the distance by the natural tangent of the vertical angle. Tangent table is provided.

Record sign of differences of elevation recalling that most of them are foresights. Apply these readings to elevations of instrument to get elevations of flags at stations sighted. Fill out all the columns except that for H. F. where you did not visit the station. For these stations you can only give the elevation of the flag. You will undoubtedly find that readings to the same station from different places do not all check. The chief cause of this is error in scaling the distance. Remember that steep angles cause the greatest errors from this reason. Another error is to read the wrong wire.

In three wire instruments this causes an error of 17 minutes. In four or five wire instruments the error is 8½ minutes. Reading the false ℄ on the index causes an error of 29 minutes. Other errors are due to incorrect counting of the divisions on the arc (not the vernier on the index). Check all computations. Disregard results which differ widely from others. If the work has been well done, particularly the intersections and scaling, the differences in elevation obtained from different souces should not differ by more than 5 feet. Before putting down on the map the elevation of a station weigh the probable accuracy of the different observations. Give preference to low vertical angles. Also consider the probable accuracy of the elevation of the station from which each sight was taken. For instance an error between the two ends of the base line would affect all shots from one end of the base. When finished clean up the map and ink in the ground elevations of all stations which you have determined and also place the flag elevations of stations sighted but not occupied. These are distinguished by squares instead of triangles. Remember the rule that all lettering should be read from bottom (south) or east. Make lettering parallel to south side of map whereever possible. Give elevations to nearest foot only. See new directions for final map.

Traverse with plane table and telescopic alidade.

Material: large plane table, telescopic alidade, stadia table, adjusting pin, note book, magnifying glass, hard pencil, stadia rod, field glasses if possible.

Method: You will have to make a traverse through the areas assigned to your party for mapping. Keep the same alidade you had on the first day. Check all adjustments first. Use same sheet as on previous day. Obtain information on nearest bench mark and its elevation. Check over the location of your party's area from the location map. Go to the bench mark and prepare to start a traverse to the area. Do not set up table over the bench mark. NEVER SET UP ON PAVEMENT or travelled part of a main road. Remember cautions about leveling. Your traverse will normally be made by the Every Other Station method using compass orientation. Look out for local attraction from fences, reenforced concrete, steel culverts, etc. Choose station locations so as to get long shots where needed. Mark stations (table locations) with triangle around a dot and turning points and other rod points with square around a dot. Set up table and take a backsight to the bench mark. Continue with foresight to turning point. Then go beyond and repeat the process until you reach the area. See form of notes on next page. When you reach the area try to determine as many elevations and locations of features within it as is possible. Traverses need not always follow roads. In April it is possible to run through a large part of the woods. Mark turning points so you can find them again. Red rags are best in the woods and small piles of stones along the sides of roads. Choose central locations for stations in the area from which you can get several sideshots to recognizable points. Make separate columns for these in your notes. The purpose of this survey is to help you locate contours in your area. Plan it carefully. Three or four days are allowed for this kind of work. NEVER GO AWAY FROM YOUR TABLE WITH THE ALIDADE ON IT. That is the time the wind will blow it over or a cow nose it. Whenever possible let sunlight fall on face of rod. Hold best end up under conditions of each shot: black against sky, white against woods. Plan your traverse to close back on point of beginning. Scale: 1 inch = 1000 ft.

Care in planning station and rod locations will make sights longer and progress more rapid but do not take so many shortcuts as to make you miss the points of which you will need elevations. KEEP TWO SETS OF NOTES, one by the Beaman system and the other by the angle system. Make Beaman readings first, then move the middle wire using slow motion screw until it hits 10 feet or top of rod, whichever you prefer, then wave rodman on or to lay down rod as case may be and read angle. COMPUTE NET DIFFERENCES IMMEDIATELY. Then compare results of two methods. If they do not agree within a foot or so repeat readings. Change places as rodman and instrument man whenever that seems desirable but be sure to show when in notes and make times equal. Elevations need not be computed in field only net differences. Failure to have these up to date is a demerit. Keep notes neatly and use eraser if you have to change a reading. Avoid soft pencil. Try for level shots whenever possible remembering rules for reading other than middle wire. Upper wire readings are + angles, lower wire - angles. Computed difference is HALF INTERVAL. Other rules same. Do not confuse with step method which uses full interval. DO NOT FORGET TO CENTER THE CONTROL LEVEL FOR EVERY SHOT. Review your copies of Problems 11 and 12 to make certain that you know just what each column is for. Sketch in roads, streams, lake shore, etc. as you pass them. LOCATE CORNERS both on outside and inside of sections. Get their elevations if possible. If you compute elevations in field sketch contours whenever you have time. Do not forget elevations of road corners.

In the evening after your notes have been inspected see that they are copied correctly in notebooks of all members of the party. Show when instrument man changed. Then check all computations. When agreement is reached ink in your survey showing section and subdivision lines, main fences, stations and turning points with elevations of ground at latter to nearest foot (with 0.5 foot take even foot.), lakes and streams, roads, etc. Give elevation of lake. Show names of party, scale, and north point. ALL LETTERING MUST BE READABLE FROM SOUTH OR EAST SIDE OF THE MAP.

In case you need to survey a railroad use the Every Station Method orienting the table by backsights. Mark stations with sheet of paper on a twig or have rodman hold rod on them. Put mark directly under location of point on table not under center of tripod. After having set up in same way over what otherwise would have been a turning point use the rod to measure the height of the table above the ground. Enter this in Rod Correction column treating it as a backsight with + sign. Enter a 0 in distance column and in angle column in the angle notes and 50 in Beaman arc column. Then use rules as usual.

Notes for Beaman arc

Locations		Full interval		Arc	Diff. elevation			Elevation	
Sta.	T.P.	B. S.	F. S.		Comp. diff.	Rod cor.	Net diff.	Sta.	T. P.

Notes for angle system

Locations		Interval		Angles		Diff. elevation			Elevation	
Sta.	T. P.	B. S.	F. S.	Oblique	Diff.	Comp. diff.	Rod cor.	Net diff	Sta.	T. P.

There is no mystery about an alidade and no need to take a half a day to make a single sight as some have done. Read over directions the night before starting and ASK QUESTIONS THEN. Be sure you understand notes. Use letters for stations and numbers for turning points. Extra shots are SIDE SHOTS; add special columns for them in appropriate places. Watch to see what wire you read every time. Note the Quarter Interval wires in some instruments.

These who have not had sufficient previous experience must do over a practice traverse near camp until both vertical and horizontal closure is satisfactory. Do this problem on your wrapping paper cover sheet.

At first do not try reading other than middle wire !

Topography. Each member of the party will be responsible for a topographic and outcrop map of approximately 1/2 square mile. While he instrument man with the alidade he will work mainly on his personal area and should therefore have not only some known elevation points but a start on accurate contours. Naturally the telescopic alidade will be used mainly in the more open parts of the area and along roads and trails. In April it is possible also to go through the woods wherever there is not too much brush. In the foregoing note forms there is no column for SIDE SHOTS. Add one at right. Side shots are foresights taken to points like fence corners, lakes, culverts over streams, crests of hills or ridges to obtain data for locating what is to be shown on your final map. As far as possible the rodman should mark those points where there is nothing by which the spot can be later recognized. "Bull rags" on trees - or sticks stuck in ground are good. The computor of the party is to keep the figuring of all notes up to date and report the results to the instrument man. This job requires work and is not an opportunity to catch up on sleep!

Boundaries. Your next problem will be to tell where each man's area begins and ends. In general you should be able to locate either one corner of one of the areas or some landmark which is a known direction and distance from such a corner. Locate this with a rod reading. Next use your location map to lay out tentatively the outline of the areas. Study this map to see the dimensions of the sections and their subdivisions as given by the U. S. Land Survey. When resurveyed these may not all check exactly but large errors should not be expected. In laying this out on the table remember the DECLINATION of 4 degrees EAST. In case you cannot find a corner DO NOT HOLD UP WORK looking blindly for it but go ahead with the map and when someone can later show you the corner then locate it. You cannot find corners with certainty unless you follow tge lines which lead to them. Most corners are marked by intersection of fenses. Others have a stake in center of a pile of stones, a pile of stones without any stake, or rarely an iron stake. In trying to follow fences do not be misled because some are strung irregularly from tree to tree. Remember that fence wires attract your compass so sight parallel to fences not right alongside them. Many property lines which are not fences are blazed. Look for old healed blazes which can be distinguished from accidental scars by being on both sides of a tree at same elevation from ground. Some of the State Park corners have cement posts with signs on them; at other places there are small "Wild Life Refuge" signs. Fences on property lines are commonly more substantial than are the more or less temporary fences within farms. It will in most areas be uneconomical to try to traverse all of the outside with the telescopic alidade. Run lines to some of the corners and across the more open parts of the area. While doing this do not neglect to map what topography you can, using a 20 foot interval. Get all you can done in way of locating roads, trails, houses, and rock outcrops while you have the telescopic alidade with you. (To finish the area you will have to split up and each work alone in the more densely wooded parts of the areas.) You will probably strike interior as well as exterior corners. Do not neglect to identify them by scaling with alidade base. It may at times be desirable to detach the computor of the party to scout around alone and hunt for corners. To do this he must have a compass and if possible a barometer. Take these instruments along although not called for above. The scout must calculate how many paces to $\frac{1}{4}$ mile. When he starts on a line he will pace to this distance and then mark the spot and circle until he either finds a corner of his personal area or decides there is none. In latter case he may want to carry on another $\frac{1}{4}$ mile and look for the next. Remember that most of the bluffs is held by prairie farmers in small 10 or 20 acre woodlots so expect to find other boundaries than those of 40's. Note "timber boundaries" shown by different ages of cutting. Many of these are blazed. The scout should keep notes--see sample. In general he will endeavor to thus learn his personal area.

Completing the topography, etc.

Material: Sketching board or plane table, sheet of paper, Brunton, hard pencil, note book, eraser, aneroid barometer, watch. Field glasses and talley register desirable and a hand level is useful

Method: In order to finish the topographic and outcrop map of your square mile it will now be necessary to break up the party of three . One of the party will keep a section of the sheet already made with the large planetable but the others must transfer the data on their areas to other sheets. In transfering sheet to another table DO NOT FORGET THE MAGNETIC DECLINATION!!! Make copies with thin paper and carbon paper using hard pencil. On reaching the field you will start at a point already fixed on the map and run out the land lines not previously traversed. It is easier to do this with the compass than with a planetable. Be sure your compass has the declination set off correctly. Check by sighting along a line which is known to be north and south such as the one fixed by observing Polaris. Remember that in laying out lines on the planetable you should make the distances between corners what they are supposed to be (use scale of feet) not what your pacing makes it. Directions may, however, be made what the compass makes them. It is well to figure the number of paces for ¼ mile; this will make it easier to know when to expect a corner. Some lines on rough ground cannot be paced and must be measured by intersection, resection, vertical angle, or by detouring. You will probably want to run some common lines with one or more neighbors.

While you are traversing the exterior of your area read the barometer. Be sure to set this at camp. Try to visit all known elevations you can during the day. At them read and compute the error for later use in making a curve. Keep times to nearest five minutes. As we do not have thermometers and the probable temperature will not be far from that to which the instruments are set no attempt will be made to compensate for temperature. See Problem 1.

Form of notes for aneroid

Location	Time	Reading	Correction	Elevation

Mark ~~straight~~ straight checks with circle and cross checks with cross and line leading to the other reading or readings at same place. Remember how the slope scale can be used to get straight checks. Try it whenever you can see a place of known elevation at a known distance. Although it is true that aneroid readings cannot be fully corrected until the end of the day <u>do not hold up the drawing of contours</u> to wait for this. Estimate the correction from that at the last straight check and draw tentative contours which may be corrected later if need be. Do not forget to map outcrops, roads, trails, buildings and fences if on lines. Show all land corners you have found. Use the level whenever you need it either to level up important hills or to sight to known elevations. Get height of your eye above the ground. On the first day try to go around the outside of the area first. DRAW NO COUNTOURS EXCEPT OF THE GROUND YOU ARE LOOKING AT. Delay means losing the main advantage of this kind of mapping. Contour spacing scales can be used. Keep moving to new locations when drawing contours. Keep looking back at what you have done and erase if you do not think it is right. Practice make perfect. Remember that the true test of accuracy in contouring is to make the map so that anyone can locate himself on it from the features shown without having to measure distances. Try to work in as many small details as you can. Most beginners generalize altogether too much. There has not to date been any wholly accurate map of the bluffs so try for this ideal. Try to see as much as possible of your area.

Use of aerial photographs. Aerial photographs are an aid of immeasurable value for they show features not found on maps and enable one to get a view of the ground from above. Please do not mark them, please do not take them into the field without special permission which will be granted only if you have means to protect them from folding and soiling. Make a tracing of trails, roads, timber boundaries, etc., in your area to put in your notebook. Follow methods of Problem 16 to make this a real map, 1:20,000, in evenings; ink in and add elevations you have determined. Use stereoscope to sketch 20 foot contours of features in your area which show out well. Much detail can be worked in if your eyes are good and you use a sharp pencil. Check form of contours by tracing directly from photograph [illegible] If you have a rainy or snowy day you can enlarge this aerial map ~~onto your~~ field. scale of 1:12,000. Use system of squares, say by subdividing the forties into 10 acre patches. Show timber boundaries. Some outcrops can be loacted fromthe air. Note, however, that there are changes due to logging since the pictures were taken, also new roads and trails not shown on them. Try to work in all practicable detail and make proper corrections to present conditions when your data is checked in field.

Remember that the drainage is the key to the topography, so be sure to get it outlined first. Do not sketch contours too far away; traverse to the new location or walk there and then locate yourself. Do not guess; try to be as precise and detailed as you can be. Your scale will permit of showing features 20 feet across and 20 feet high. Use two or three point methods of location, if necessary.

DO NOT FORGET THE ROCK OUTCROPS but do not map talus and broken rock. Obtain dips by getting your eye into plane of beds and then holding Brunton compass or Abney up so it lines in with edge of bed. Then center bubble and read dip. Record on map. Get strike by sighting a level line on a bed and then orienting table and shooting it in. See symbols in outline for abbreviations. (Non-geology students may omit.)

Above remarks apply mainly to the open part of your area. Parts will be so densely covered with vegetation that even in April you will not be able to see very far. Either take notebook and compass only or table top and compass. With this traverse N-S and E-W lines through the wooded part of the area so that you will be assured that you have not missed anything of importance in the way of topography and outcrops. Unless the topography is of very large features (coarse texture) you should go through the area at least every 1/8 mile, otherwise every ¼ mile both North and South and East and West. Boundaries of lots are shown by blazed lines and boundaries between different ages of cutting. Do not forget to traverse in all important logging roads closing such traverses on corners or points previously surveyed. Use protractor if you use compass and keep a record of courses run in your notebook. Use Brunton to measure slope of ground so that you can fill in contours later. Read barometer as usual keeping notes as before. You can secure frequent cross checks if you traverse in a system of checkerboard, that is first North, then West, then North, and so on, for instance. This will bring you to corners previously determined at more or less regular intervals. Make side trips whenever possible to secure straight checks. Indicate positions of aneroid readings on map as before. Also map drainage and if possible draw tentative contours as far as you can see from the line leaving them dotted. Indicate slopes with usual slope symbol with number of degrees given at apex of triangle. At night adjust aneroid readihgs and transfer corrected elevations to map sheet. You can then finish the contours between lines of traverse. Some have followed the method of devoting the first two days to securing and adjusting elevations and the third day to sketching contours in the field. This seems to be a good plan. No maps will be accepted unless the CONTOURS ARE ALL DRAWN BEFORE LEAVING DEVILS LAKE. Every map must be submitted for inspection every time you return from the field. If yourmap is not satisfactorily completed, return must be made to Devils Lake to finish it at a later date, at your own expense.

Edition of 1941

After the return to Madison you have the option of either (a) inking in the map sheet, or (b) tracing the map on tracing cloth or paper. In latter case, a sheet the size of this page, $8\frac{1}{2}$ x 11, can be used. All of a party may combine their maps into one. Colored inks will not be insisted upon. If they are used, contours should be either red, orange, or brown, water features blue, man-made features (culture) black. Follow U. S. G. S. style except to make section lines solid. Fences need not be shown except where very few. Do not attempt fancy lettering but make everything readable from either south or east sides of map. Do not forget your name, the scale, true and magnetic north. Your work will not be complete until all other plane table sheets you have worked on are also inked in and completed as per directions. This work will complete the course for 3 credits, but be sure to inquire if all work is done. This course cannot make you a skilled surveyor, but should teach the uses and the limitations of the different instruments commonly used by geologists. Blueprints of tracings will be accepted.

Amendments to Devils Lake Directions, 1952

Testing Alidades. First make normal adjustments of the alidade indoors. Set two stakes about 200 to 300 feet apart on the open area west of the railroad tracks. Set up the instrument midway between the stakes and use the rod to find the difference of elevation of their tops. Set up alongside one of the stakes and measure carefully elevation of axis of telescope above the top of the stake below. Use rod to do this. Then compute what you should read when rod is held on top of other stake. If it fails to check adjust horizontal wires. Do not change the bubble of level. Then follow old directions. Measure baselines for stadia check and for intersection baseline with steel tape always on ground except across railroad tracks. Since East Base is much higher than West Base determine average slope of the more steeply inclined part of the base and use a table of cosines to find true horizontal distance of this portion. It is absolutely necessary for more than one party to measure the base. Some may prefer to hold tape level and use plumb bob. Check one another. Check zero and 100 foot points on tape. The most common error is to make the line 100 feet too long. If a pin is dropped at initial point then the rear man has in his hand the correct number of pins for tape lengths NOT counting the last pin in the ground. (Low's method is to not use a pin at start and then count the one in ground at last full tape length; this is not advised.) Never count a pin for the fractional length of tape at the end. Remember how engineers always count number of tape lengths (hundreds of feet) and record for a mile 52 + 80. Example: at 1000 feet you will have used all 11 pins and the rear man will hold 10 in his hand. Record, pass these forward, and start new. At 1900 feet the rear man will hold 9 pins. If the end stake is 70 feet farther then the total distance is 1970 feet. Hence the pin in the ground at 1900 feet is NOT counted nor is a pin counted at 1970 feet. The check or testing line should be about 1000 feet long. The intersection baseline is in a different place and as long as possible. Get advice on location of ends of this line.

Trial Traverse. Use a small sheet of paper fastened to planetable sheet with masking tape. Letter neatly and hand in without inking. A good place to run this trial traverse is just east of camp along the quarry railroad and the road north of the camp, and back through the camp's area. Look out for local attraction of rails, air line, and well casing. (Well is near water tank) Do not set up close to any of these hazards. Use scale of 1 inch = 500 feet. Keep notes in corner of the sheet of paper showing both vertical and horizontal errors of closure. Be sure this is checked before leaving for your area in the field. Every party has a chief who, in absence of any instructor, is to decide all points of dispute.

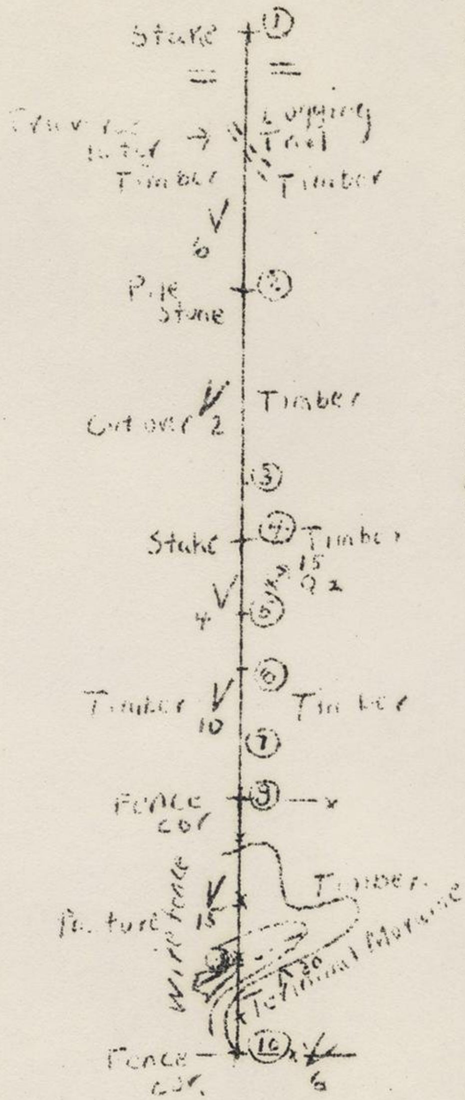
Intersection Survey. Only one sheet of mounted paper can be supplied to each party. For the intersection survey use scale of 1 inch to 500 feet. Do not ink on the planetable sheet. After measuring distances, trace the entire problem carefully onto a piece of tracing paper and ink this. In the notes add a column for tangent of vertical angle. Use the tangent table. Your party map must give scale, exact location of stations, lines sighted, and ground elevations of each station to nearest foot, as well as names of party and date. Last erase your pencil marks on the mounted paper, and clean it up ready for the traverse survey of your area.

Traverse Survey.

Use scale of 1 inch = 1000 feet. Be sure to get directions as to where to start and how to find your particular area. Add to form for notes a column for stadia (conversion) factor as obtained from stadia table (either mimeographed or in back of Low). All notes should show full interval rod intercept, corrected by proper stadia constant if necessary. The f + c constant is generally negligable. Do not multiply by stadia constant (stadia interval factor) except for platting (when corrected to horizontal distance) on planetable sheet. Do not place horizontal distance in the notes. Do not forget to show if half or quarter interval was actually read. Follow Low and give half interval reading as 2 x 8.3, quarter interval as 4 x 11.0 etc. in column with other readings. Multiply when you compute. Do computations at once and systematically. Keep column for computation of elevations. This portion only can be deferred until night. All instruments with Beaman arc must keep duplicate set of notes, one in each system. All instruments without the Beaman arc must keep two independent sets of notes reading a different point on the rod in each. In such instruments the level reading (with striding level centered) should be placed below each oblique angle reading when telescope is pointed to rod. Remember that subtraction of degrees and minutes of angles involves carrying of 60 -(60 minutes in a degree)- instead of the usual 10 of ordinary subtraction. Even if you have had some surveying experience avoid very long shots, use of drum, and readings of other than middle wire until thoroughly familiar with both instrument and computation. Keep rodman within shouting distance at all time. Until you have complete confidence keep rodman on his place (he can lay down the rod unless asked to put it up again) until net differences of two note systems check within a reasonable degree of error, say not over 5 feet vertical at any time. Reread whenever you find a disagreement of greater magnitude. Otherwise never alter the notes. Get all data you possibly can onto your planetable sheet; it helps later.

Field Maps. Some will use planetable top, others sketch boards. Not every party can get a barometer. Use scale same as traverse, 1 inch to 1000 feet. Do not enlarge. Make copy from planetable sheet with tracing paper and prick through control points, or you can use carbon paper tracing with sharp pencil point. Instead of using a "pacing scale" make a small table of feet for every 10 of your paces up to 90 in your notebook or in border of the map. You can then find number of feet for any number of paces by simple addition of hundreds (decimal point moved one place to right), tens, and single paces (decimal point moved one place to left). Plat the paced distances with your engineers scale. Plat compass directions with protractor. When following lines have one man do pacing, other leveling, sketching, compass work, etc. Change places on the separate areas so each man draws his own contours. The odd man detached from a three man telescopic party will be sent out with one of the men from the party in an adjoining area. Do not go out alone - for one thing there are not enough instruments. Remember that road and highway hills are contoured just the same as natural features. Areas drained by culverts are shown as depressions. Permanent streams do not have grass in bottom. Note underground streams in many places which flow only in wet weather. Your final map should show all features which would aid a stranger to find his location on that map. DO NOT TAKE OUT ANY AIR PHOTOS MARKED "OFFICE USE ONLY" OR "RESTRICTED OFFICE ONLY" We must have a full set always available.

Sample of notes for notebook traverse in dense timber or brush
Scale 1" = 1000'



Keep this sketch in book using pace scale to lay out distances; if you prefer, however, this may be put on the table using top only in work of this kind. If possible make these paces the ideal or 2000 to the mile but if this is too hard to figure record your own paces but state which. Note slope and outcrop symbols, as well as form lines or tentative contours
Anaroid corrections cannot be made until night

Monday, April 13, 1931 Observer ------ Aneroid No.----

Location	Time	Barometer	Correction	Elevation	Remarks
Devils Lake	7:00	960	0	960 . o	
1 NW. cor Sec. 25, 11-6E	8:15	1315	0	1315	Wood stake
2 ½ m S.	8:25	1385	-5	1380	Pile of stones
3 900 p. S	8:45	1470	-10	1460	Change in slope
4 ¼ corner	9;00	1485	-15	1470	Wood stake, blazed trees
5 1150 p. S	9;35	1385	-20	1365	Outcrop quartzite, strike 285, dip 15
6 1300 p. S	10:00	1295	-30	1265	Change in sl
7 1400 p. S	10:35	1200	-40	1160	Edge flat
8 1/16 cor.	11:05	1150	-50	1100	Fence E., S.
9 1850 p. S	11: 35	1100	-55	1045	Ravine, edge mine
10 SW cor. 25	12:00	1015	-60	955	

CONVENTIONAL SIGNS

CULTURE (black)

Building School house Church Camp Public road in good condition
Road in poor condition or private Trail not open to wheeled vehicles - - - -
Railroad, single track Railroad, double track RR, temporary
Tunnel State line County line Civil township line
U. S. township line Section line, where subdivision lines are shown
City limits Reservation or state park line Land corners found +
Traingulation station Boundary monument Well, non-flowing o
Well, flowing, in rock Well, flowing in drift Exploration drill hole
Oil wells-drilling Oil well Gas well Gas and oil well Dry hole
Dam Cemetery Bench mark x BM Lighthouse Quarry Dump
Shaft Pit in drift Road cut Fence, barbed wire —x—x—x
Timber boundary

Section line, where subdivision lines are shown----- Subdivision lines-----

RELIEF (if colors are used, brown)

Elevation of definite point 793 Cliff Slope, gentle Slope, steep
Undulation, gently Undulating, roughly Sags and knobs, gentle
Sags and knobs, pronounced Flat Plain, pitted Sand or wash
Sand dunes Contours, numbered 800 Make every fifth contour heavy and number it as shown.

WATER (if colors are used, blue)

Stream, permanent Stream, intermittent Ditch Spring
Marsh, fresh Marsh, salt Tidal flat Lake, intermittent
Glacier or make blue contours on the ice Lakes may be left open

GEOLOGICAL

Outcrop of sedimentary rock, horizontal or unknown dip dip known
Outcrop of igneous rock Outcrop of gneiss or schist Bowlders or talus
Gravel pit G Clay pit Cl
D=drift S=sand T=till cg=conglomerate dl=dolomite ls=limestone
sl=slate ct=chert qz;quartzite sh=shale ss=sandstone Bt=basalt
Dr=diorite Gn=gneiss St=schist Db=diabase Ga=gabbro Gr=granite
Po=porphyry Tr=trap

SOILS

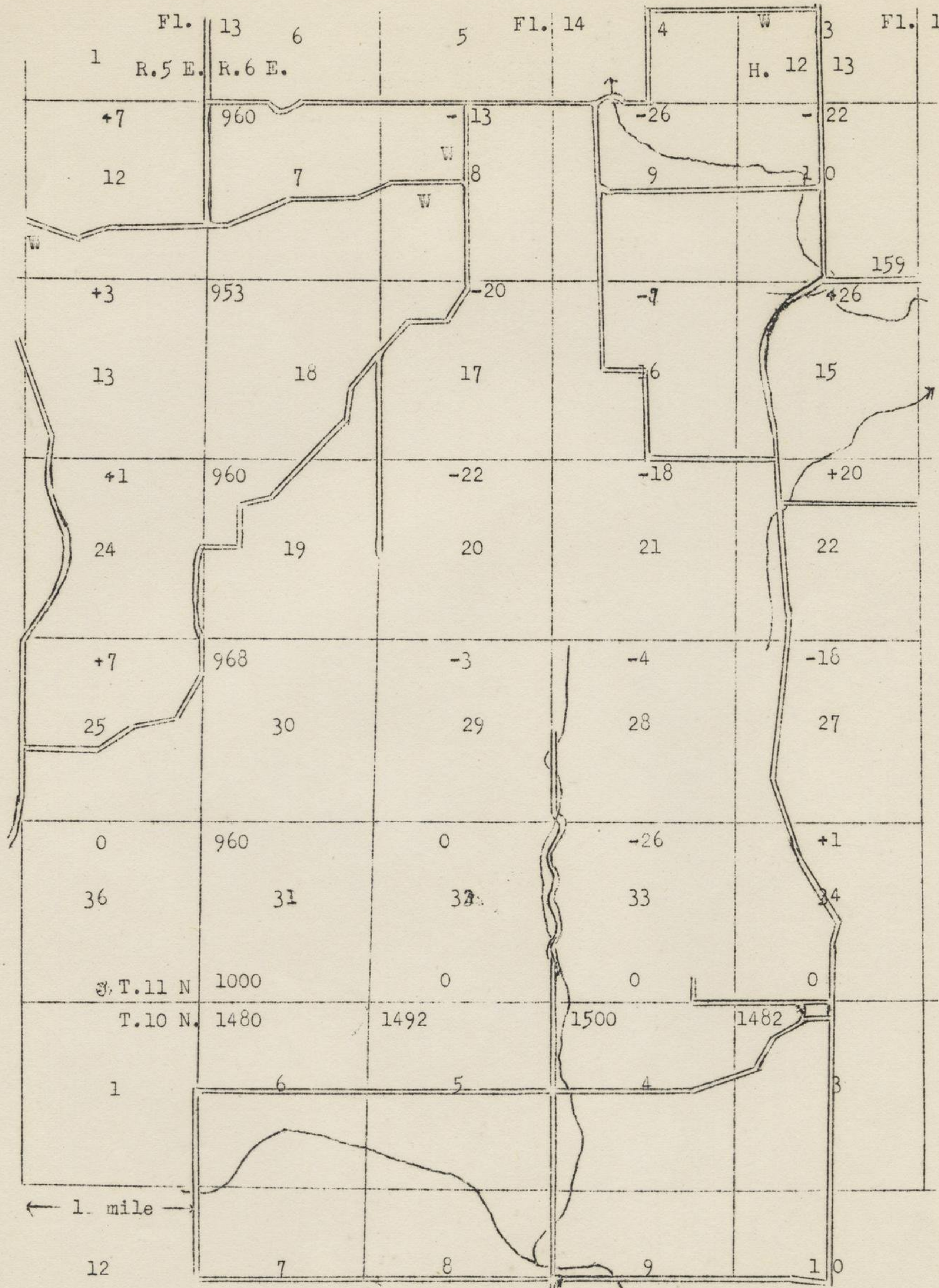
cl-l = clay loam sdy-l = sandy loam lt cl-l = light clay loam

TEXTURES AND STRUCTURES

amg = amygdaloidal gns = gneissic por = porphyritic sch = schistose
str = stratified tkb = thick bedded tnb = thin bedded xb = cross bedded
xin = crystalline xin-c = coarsely crystalline xin=f = finely crystalline

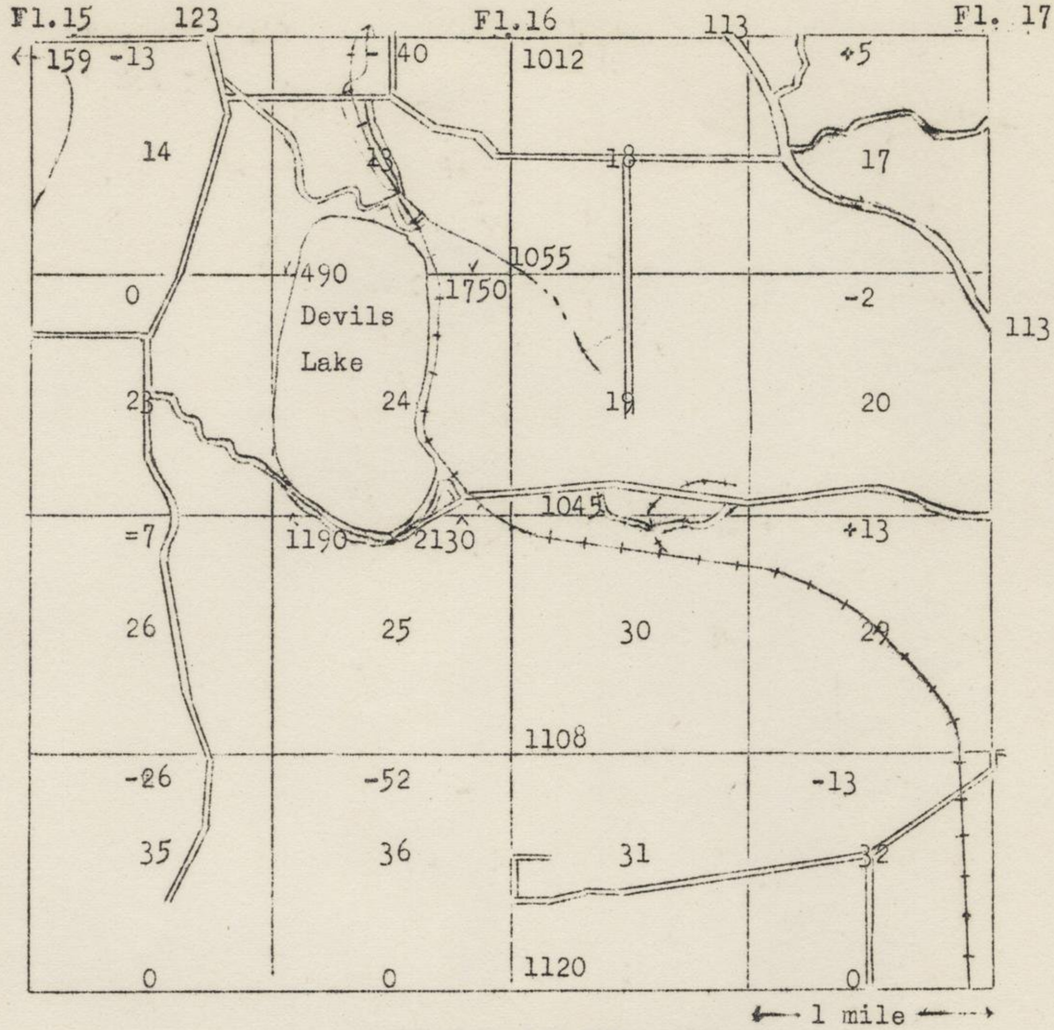
COLORS

bf = buff bk = black br = brown bu = blue dk = dark dr = drab
gn = green gy = gray lt = light rd = red wh = white yl = yellow



FAR WESTERN LOCATION MAP, 1951

Departure of east-west section lines from normal + or - in feet. Note odd lengths of 40's on W and N. sides of townships. Closing corners on township line (E-W) not shown. On Highway 12-13 in NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 15, T. 11 N., R. 6 E. U. S. C. and G. survey B. M. M109 NE end of east base of railing $\frac{1}{2}$ ft. above pavement B. M. = 984.4 Other B. M. on highway were removed during reconstruction but level of pavement may be used. U. S. G. S. B. M. W. $\frac{1}{4}$ post 9-10-6=848.3

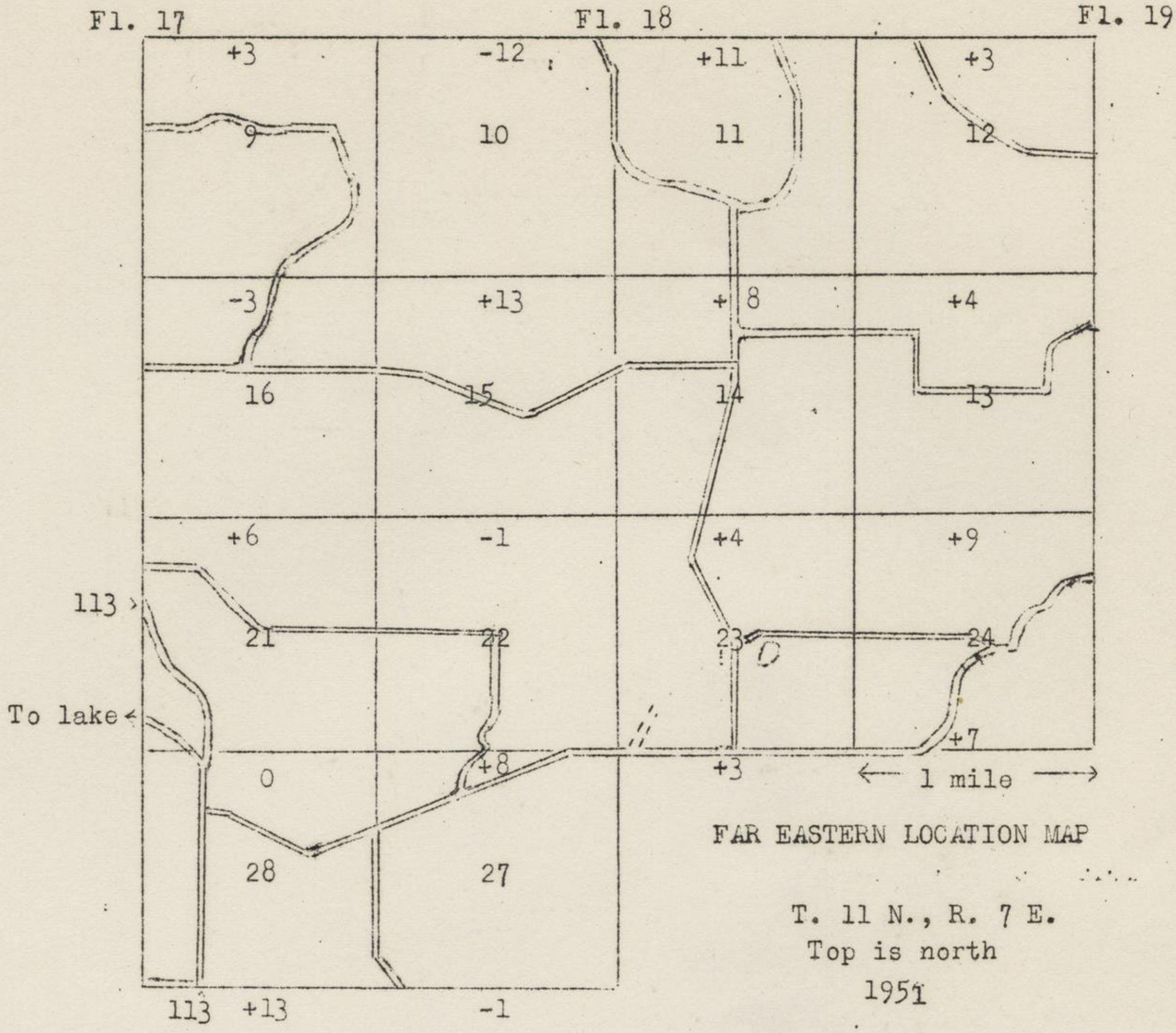


CENTRAL LOCATION MAP

T. 11 N., Rs. 6 and 7 E.

Excess or deficiency of E-W section lines shown in feet + or -
E-W width of western 40's shown in feet S. township line normal lengths.
Railway is double track
See far estern map for elevations on track
Top of map is north
Logging trails not shown Park boundary not shown.
Flight numbers of air photography shown at top.
Lengths of lines to meander corners shown in feet.
See Far Eastern Location map for list of elevations
All north-south lines are normal unless noted.

1951



FAR EASTERN LOCATION MAP

T. 11 N., R. 7 E.
Top is north
1951

Elevations on U. S. 12 S$\frac{1}{4}$ p. 34-11-6E = 870.2 NW 27 (Paul Zantow farm entrance) =1233.5 NE$\frac{1}{4}$NW$\frac{1}{4}$ 27 (entrance to Myrtie Zantow garage) = 1192.0

U. S. C. and G. Survey B. M. K109 on concrete culvert 22' E. of center old pavement, 2' below road, 18' N. of side road near S. line 27 + 1055.2 removed

U. S. C. and G. S. B. M. L109 on concrete culvert SE corner of headwall, 18' E center of pavement and same level NW$\frac{1}{4}$ 22 = 1096.4 (removed)

C. and NW Ry. B. M. topfoundation of signal tower N line 24-11-6E. = 971.9
" top foundation signal tower N line 25-11-6E = 991.8
" base of rail under signal about 100' E W. line 29-11-7E = 954.0
" base of rail at former signal bridge NE$\frac{1}{4}$SE$\frac{1}{4}$ 29-11-7E =906.0
" top of W. coping of bridge over town road, about 580' S of N. line 32-11-7E = 884.7

C and G. Survey B. M.s have metal plate with number but no elevation.
Railroad B Ms are not marked; locations approximate.

Triangulation station under tower of Radio Station WMCF assumed to be 1620 elev.

Flight numbers of air photography shown at top.

Departure of east-west section lines from normal shown in feet + or -

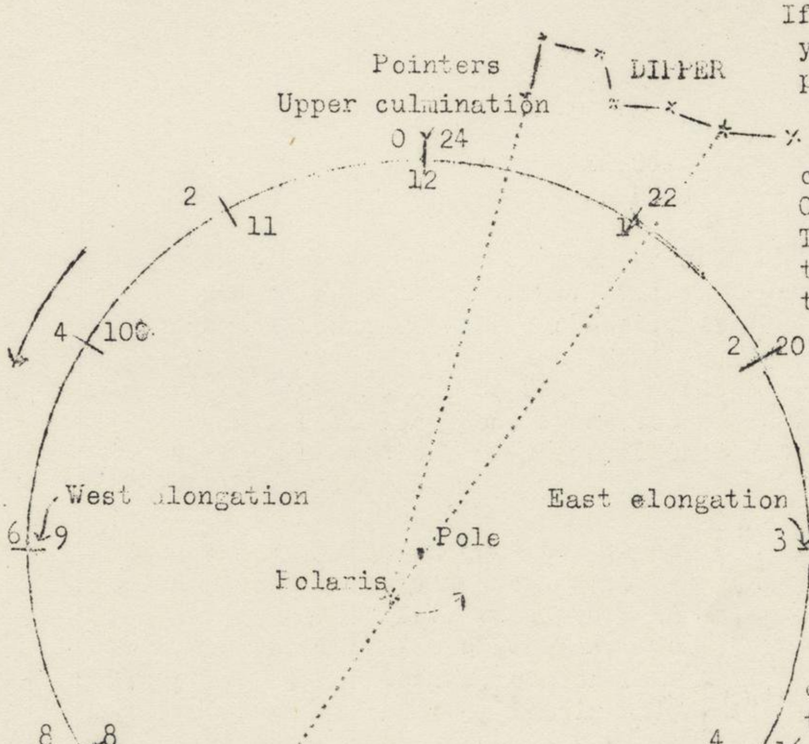
GEOLOGY 11
MAPPING

Determination of true north from Polaris   Edition of 1943

Based on Spaulding, G. R., Training manual in topography, map reading and reconnaisance, U. S. War Dept., 1917

Material: Strong twine or fish line about 30 ft. long, weight, two stakes several feet long, one stake less than 2 feet long with cross bar nailed to to top, 2 needles, axe, two flash lights, pocket tape, scale divided into tenths of inches.

Method: Study the diagram to see how Polaris is found from the pointers of the dipper. Polaris is not exactly on the projection of the earth's axis but roughly a degree off. It appears to an observer to revolve in a small orbit in a counterclockwise direction. Compare with direction of motion of sun. Study Fig. 1 for definitions of four different positions in this orbit. At two of these the star is directly north (on the medidian). Polaris is found at an angle above the northern horizon (Fig. 2) approximately equal to the latitude of the point of observation(at both elongations it is exactly equal). Study Fig. 2 to see why we must know the latitude of a locality with more and more exactitude as we go north, also why no accurate observation of Polaris for direction is possible in the far north.



If you timed a revolution of Polaris you would discover that it is completed in 23 hrs. 56 min of earth time or "mean solar time". The "hour angles" given outside the circle represent hours after Upper Culmination in "siderial time". The difference between this star time and our earth time is due to the fact that the earth goes around the sun every year. We do not have to compute the difference between the two kinds of time because it is too small to make a material difference in any one day with observations to be used only with the hand compass. But it is worth noting that Polaris comes to the same position about 4 minutes earlier every day. You can look up the exact times of each position in the ephemeris making corrections for both days since the one given and for longitude. Where we live the latter is not important for compass observations. When you do not have a table you can still get time of culmination very closely by watching to see when one of the dotted lines to second star from left of both Dipper and Cassiopeia are on vertical line below Polaris. The Dipper line passes this position about 8 minutes before Upper Culmination and the Cassiopeia line about 9 minutes before Lower Culmination. But this does not always occur during the hours of darkness or may be at an inconvenient hour. Spauldings method is to imagine that the time is shown on a celestial clock with Polaris at the center and with the lines to Cassiopeia and the Dipper as hands (both hour hands). The hours of this clock run in the contrary direction to the hour angles and each represents two siderial hours. You can make a clock face out of cardboard with a hole at the center. Then hold this up at right angles to the line to Polaris and read the "clock time" by holding out a string or ruler until it touches the proper star. Near the twoculmingations time must be estimated within about 15 minutes but near the elongations such accuracy is not needed.

Study Fig. 2 to see why as latitude increases the divergance of the planes from zenith through the elongations increases at the surface of the earth or

FIG. 2

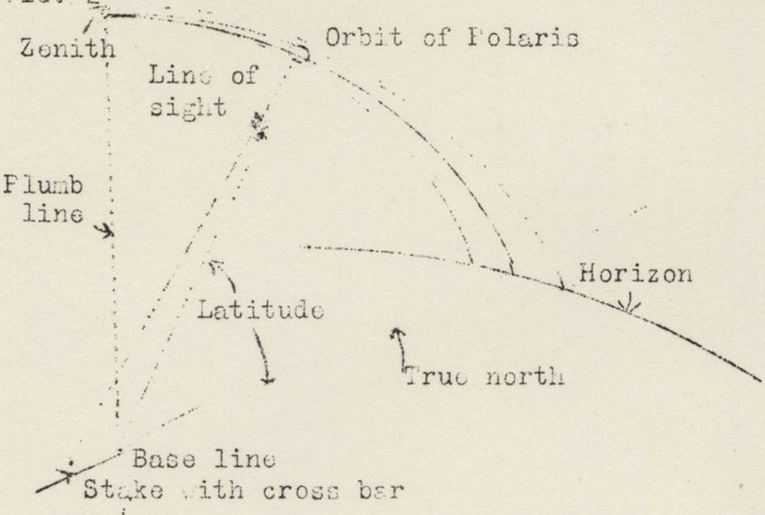
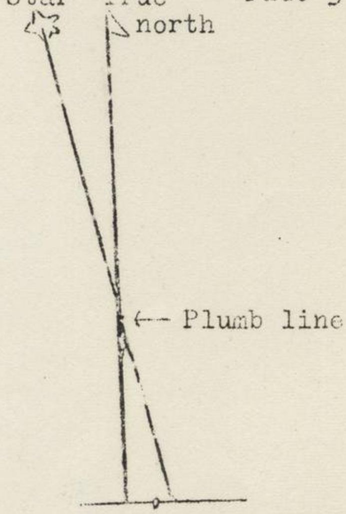


FIG. 3



Stake with cross bar at south end base line
Make offset in same direction as star is from true north.

horizon plane. This is like opening a door by inserting a given object farther and farther.

The following table is for 10 deg. north latitude and gives the horizontal or horizon angle of Polaris in both minutes and offset in inces per foot of baseline for both hour angles after Upper Culmination and for "clock" time.

Star west of north					Star east of north				
	"Clock"					"Clock"			
HA	Cass	Dip	'	" per ft.	HA	Cass	Dip	'	" per ft.
U.C 0	12	6	0	0	12	6	12	0	0
1	11:30	5:30	16	.056	13	5:30	11:30	16	.056
2	11	5	31	.108	14	5	11	31	.108
3	10:30	4:30	44	.155	15	4:30	10:30	44	.155
4	10	4	53	.185	16	4	10	53	.185
6	9	3	61	.213	18	3	9	61	.213
8	8	2	53	.185	20	2	8	53	.185
9	7:30	1:30	44	.155	21	1:30	7:30	44	.155
10	7	1	31	.108	22	1	7	31	.108
11	6:30	12:30	16	.056	23	12:30	6:30	16	.056
L.C. 12	6	12	0	0	24	12	6	0	0

Latitude	Factor
0-20	1.0
20-31	1.1
31-38	1.2
38-43	1.3
43-48	1.4
48-51	1.5
51-54	1.6
54-56	1.7
56-58	1.8
58-60	1.9
61	2.0
62	2.1
63	2.2
64	2.25
65	2.3
66	2.4
67	2.5
68	2.6
69	2.7
70	2.85
71	3.0

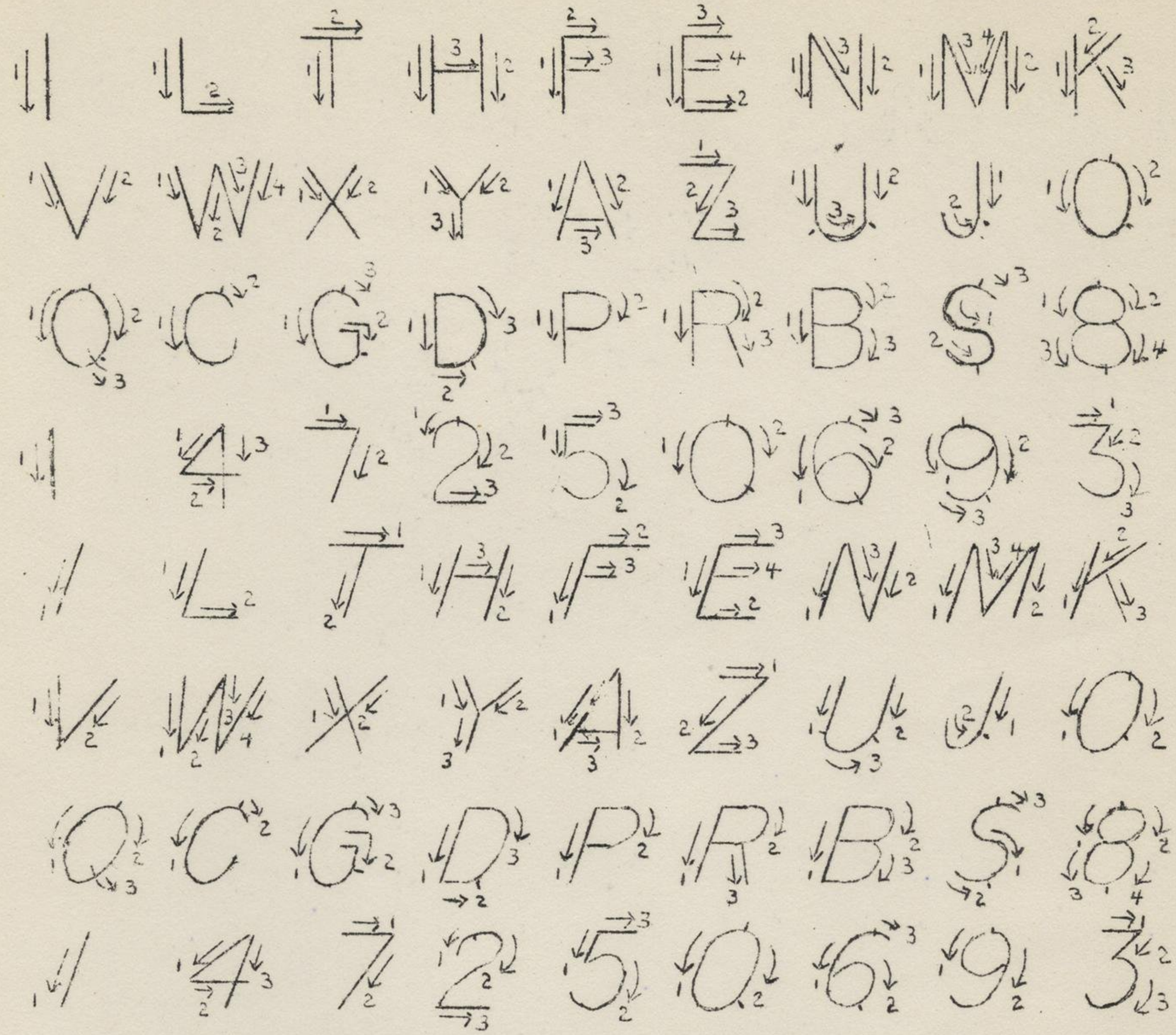
Routine of observation. Prepare stakes, etc. before dark and if possible select the point for the plumb line and place it. If a tree it should be as large as possible and the line hang from a stout limb where the view to north is reasonably free of obstructions. Ground to the north must be nearly level. Line can generally be thrown over and so tied at one end that it can easily be pulled down when through. Place weight on the free end. If disturbed by a slight wind the weight can be placed in a pail of water. Choose a time for observation as near as possible to an elongation. After you go to the location after dark find Polaris. Then estimate "clock" time. An observer on the ground will then line in the plumb line and star. A flashlight on the line but turned away from the eyes of the observer will make this possible. Place needle. Then compute offset in inches by multiplying the 10 degree value by the latitude factor. Measure base line in feet. Multiply offset by this.. Set second needle on cross bar in proper direction from first needle. See Fig. 3. Now use two flashlights to set the large stakes from 100 to 300 feet apart along the line of second needle and plumb line. Remove plumb line. Next day find local declination by reading compass on this line. (Line must be removed far enough from sources of local attraction.)

Example of computation by use of ephemeris.

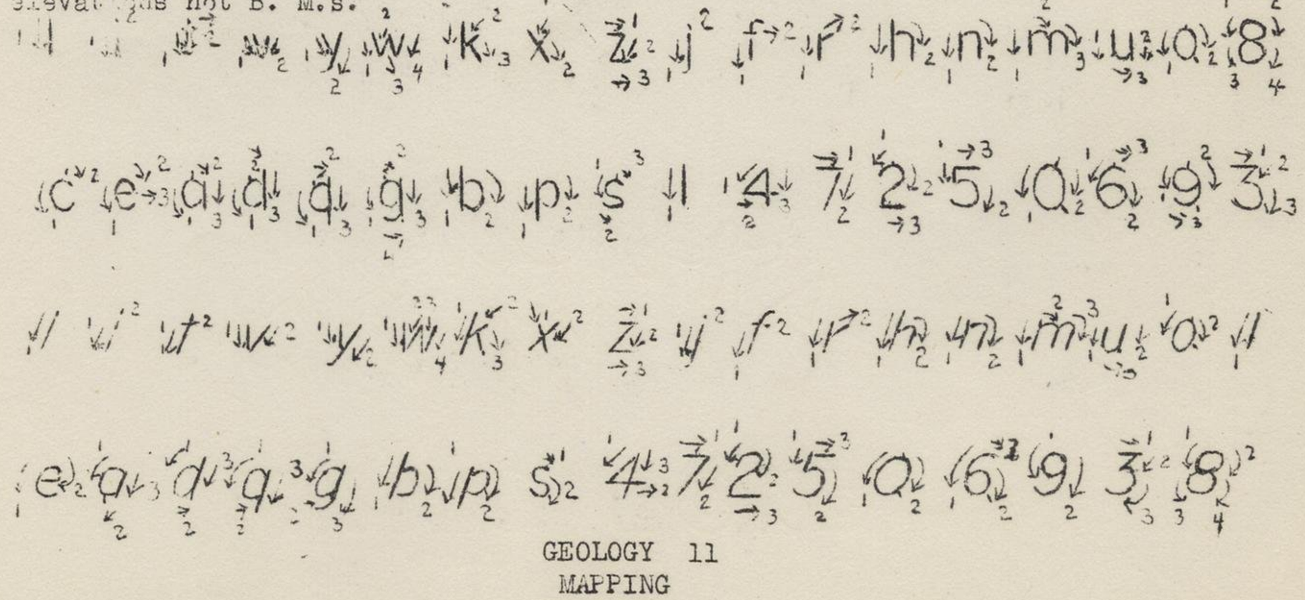
Madison, March 17, 1942 Time 10 P.M. C.W.T. = 9 P.M. C.S.T. = 9:02 P.M. Local mean solar time. (correction for longitude).

Upper culmination Greenwich March 15, 1942	2h 13 m P.M.
Subtract change, 2 days, 3.93 min per day	8
Upper culmination Greenwich March 17	2h 05m P.M.
Correct to Long. 90 W. subtract 1 m	1
Upper culmination Madison March 17	2h 04m P.M.
Time of observation L. M. S. T.	9h 02m P.M.
Elapsed time since Upper Culmination	6h 58m solar time
Change to siderial time add 7 x .16m	1
Hour angle in siderial time (star west of north)	6h 59m

From table Polaris 1 deg. 18 Min. W of north at 7 hours in lat. 42
" 1 deg. 21 Min. " " " " " " in lat. 44
Polaris 1 deg. 20 min. West of North at Madison (43 deg.)
Tangent 1-20 = .0233 Multiply by 12 to reduce to inches = 0.2796 offset in inches per foot of baseline. Multiply by length of baseline and make offset to west of first needle.



Use slanting letters for bodies of water, public works; slanting numbers for elevations not B. M.s.



GEOLOGY 11
MAPPING

Freehand lettering after Orth and Maclin. See also T. M. 5-230, sec. IV
Arrows show direction of strokes; numbers show their order. Draw guide lines; lower case letters extend 2/3 heigth above and below lines. Practice makes perfect.