THE USE OF MODELS IN TEACHING PHOTOGRAMMETRY

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INTRODUCTION

THE QUESTIONS WHICH UNDOUBTEDLY HAVE ARISEN IN THE MINDS OF MOST SURVEYING TEACHERS ARE, HOW MUCH PHOTOGRAMMETRY SHOULD BE TAUGHT AND SHALL I TEACH IT TO UNDERGRADUATE STUDENTS? I KNOW THAT I HAVE GIVEN THE MATTER SERIOUS THOUGHT FOR SEVERAL YEARS.

PHOTOGRAMMETRY HAS UNQUESTIONABLY COME TO STAY, AND WITH THE MANY NEW IMPROVEMENTS IN CAMERA EQUIPMENT, NAVIGATION EQUIPMENT, PHOTOGRAPHIC EQUIPMENT AND PLOTTING INSTRUMENTS, IT WILL REPLACE MANY OF THE OLDER METHODS OF SURVEYING. IT IS MY HONEST BELIEF, THAT NO SURVEY OF ANY GREAT SIZE WILL BE ATTEMPTED IN THE FUTURE WITHOUT THE AID OF THE PHOTOGRAPH. I ALSO BELIEVE THAT WE ARE ONLY SEEING THE BEGINNING OF WHAT PROMISES TO BE OUR MOST IMPORTANT MAPPING TOOL. THEREFORE, WE, AS TEACHERS OF SURVEYING, MUST TRAIN OUR YOUNG MEN TO BE PHOTOGRAMMETRY WISE.

WE, AT RENSSELAER POLYTECHNIC INSTITUTE, FEEL THAT INSTRUCTION IN THIS NEW BRANCH OF SURVEYING SHOULD BE INCLUDED AS A REGULARLY PRESCRIBED COURSE TO ALL CIVIL ENGINEERING STUDENTS, AND FOR SEVERAL YEARS WE HAVE BEEN BUILDING UP THE UNDERGRADUATE COURSE WITH AN OPTIONAL GRADUATE COURSE FOR MORE ADVANCED AND EXPERIMENTAL WORK.

OUR PROBLEM, AS IN MANY OTHER SCHOOLS, HAS BEEN ONE OF EXPENSE AS WE HAD NO LARGE SUM OF MONEY WITH WHICH WE MIGHT PURCHASE EXPENSIVE CAMERA AND PLOTTING EQUIPMENT. WE DID HAVE AN APPROPRIATION TO BUY SOME SMALL EQUIPMENT SUCH AS STEREOSCOPE, STEREO-COMPARAGRAPH, STEREO-COMPARATOR AND A LARGE NUMBER OF SLIDES FOR PROJECTION DURING LECTURES. THE SLIDES ARE A GREAT HELP IN PRESENTING THE THEORY AND MANY PICTURES AND PLATES ARE AVAILABLE FROM WHICH THESE SLIDES CAN BE MADE.

IT IS ALSO POSSIBLE TO HAVE A PHOTOGRAPHIC SURVEY MADE OF THE SCHOOL CAMP AND SURROUNDING TERRITORY AT SMALL COST. WE HAVE USED SUCH SURVEYS AND HAVE COORDINATED THEM WITH OUR REGULAR GROUND SURVEYS.

I BELIEVE THAT AN UNDERGRADUATE COURSE SHOULD INCLUDE ALL OF THE FUNDAMENTAL THEORIES OF PHOTOGRAMMETRY WITH A FEW PRACTICAL PROBLEMS FROM WHICH THE STUDENT CAN ACTUALLY MAKE A MAP AND SEE WHAT LIMITATIONS HE IS WORKING UNDER AND WHAT PRECISION HE CAN EXPECT IN ACTUAL PRACTICE. IN MY OPINION THE UNDERGRADUATE COURSE CAN BE OVERDONE AND THEREFORE SHOULD NOT BE SO STRESSED AS TO MAKE A SPECIALIST OUT OF THE STUDENT IN PHOTOGRAMMETRY.

THE OPPORTUNITIES FOR A SPECIALIST IN THIS FIELD ARE FEW, AND SHOULD HE DESIRE TO MAKE A SPECIALTY OF THIS WORK, HE SHOULD HAVE AN OPPORTUNITY OF PURSUING HIS STUDY IN A GRADUATE OR ADVANCED COURSE. THIS MAY BE PARTICULARLY TRUE AT OUR SCHOOL AS MOST OF OUR UNDERGRADUATE COURSES ARE REGULARLY PRESCRIBED COURSES AND MUST BE TAKEN BY ALL STUDENTS ENTERING A PARTICULAR FIELD. OUR UNDERGRADUATE COURSE IS GIVEN WITH THE PURPOSE OF PRESENTING THE FUNDAMENTAL THEORY AND PRACTICE OF PHOTOGRAMMETRY JUST AS WE PRESENT STADIA, PLANE-TABLE, GEODETIC AND OTHER METHODS OF SURVEYING.

THE COURSE FOLLOWS ALL SURVEYING THEORY, INCLUDING GEODESY WHICH GIVES A STUDENT A GOOD FOUNDATION FOR CONTROL WORK AND OTHER DETAIL PLOTTING OF MAPS. HE ALSO HAS A CHANCE TO COMPARE THE RESULTS OF PHOTOGRAMMETRIC MEASUREMENTS

WITH THOSE WHICH HE HAS MADE ON OTHER SURVEYS BY THE REGULAR GROUND METHODS.

About three years ago experiments were conducted in our department on the possibility of reproducing aerial photographic surveying in the laboratory. The general thought was to build a miniature model of landscape which could be photographed and in turn the resulting photographs used to draw maps. The first suggestion was to build a model on the floor and mount a camera above this and on a movable platform. To accomplish the desired results, the operator of the camera must ride the movable platform which requires a structure of some size. There also are other drawbacks as it is quite difficult to determine the exact altitude, tilt, tip and other elements so important in obtaining a good check on the work. An attempt was also made in having the model move under a fixed camera. This also has its drawbacks as the camera operator must climb to the ceiling and often assume many awkward positions in making the exposures.

It was finally decided to tip the model on its side as shown in Fig. 1. This has many advantages as it permits the camera operator working on the floor where exact measurements can be made. It may not be quite as realistic with the camera axis horizontal but a slight stretch of the imagination will easily change one's viewpoint with the whole set-up rotated through 90 degrees.

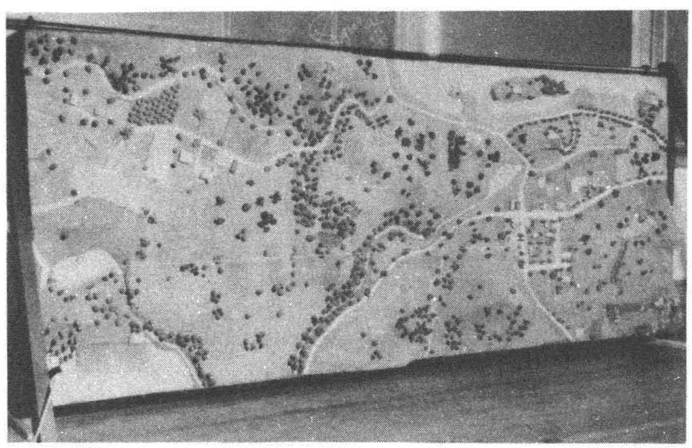


Figure 1

CONSTRUCTION OF THE MODEL

The first step after preliminary investigations was the construction of a model suitable for the laboratory and large enough to enable flight strips to be taken with the resulting overlapped photographs.

A large topographic map was drawn with all of the cultural detail to make a well balanced landscape. If desired, any available topographic map may be used. The map which we made was assumed and made to a scale of 1" equals 40' and is about 4 ft. wide and 12 ft. long.

Next, we procured several sheets of 1/8 inch box board and several large sheets of carbon paper. A sheet of carbon paper was placed on a sheet of boxboard with the map sheet on top of the carbon and the lowest contour was then traced through to the boxboard sheet. The boxboard was next removed and cut along the traced contour by means of a jigsaw and this process used in making a model of each contour level. It is advisable to trace the next higher contour as well as the one to be cut so as to provide a gage for matching the contour models when assembling. Figure 2 shows a small model which illus-

TRATES THE ASSEMBLING OF THE CONTOURS.

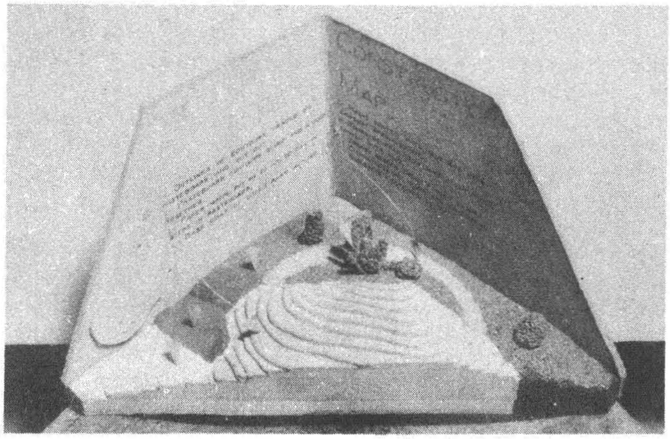


FIGURE 2

PROVISION WAS MADE FOR EXPANSION AND CONTRACTION IN ASSEMBLING THE CONTOUR MODELS BY LEAVING SPACES AT FREQUENT INTERVALS AND EACH SHEET OF BOARD WAS GLUED AND NAILED IN PLACE.

TO ELIMINATE THE STEPS FORMED BY THIS ASSEMBLY, THE ENTIRE MODEL WAS GONE OVER WITH A PAPER PULP MADE FROM NEWSPAPER AND PAPER-HANGERS' PASTE. THIS WAS ALLOWED TO DRY AND THEN COVERED WITH A BASE COAT OF GREEN PAINT MADE FROM SHOW CARD WATER COLOR. THESE COLORS MAY BE PURCHASED IN A GREAT VARIETY OF SHADES. OVER THIS GREEN WAS SPREAD A COATING OF GLUE AND THE PORTIONS WHICH WERE TO REPRESENT GRASS WERE THEN COVERED WITH A COATING OF GREEN SAWDUST. A QUANTITY OF SAWDUST CAN BE EASILY COLORED GREEN BY DIPPING IN GREEN SHOW CARD COLOR AND SPREAD TO DRY ON NEWSPAPER.

CULTIVATED FIELDS WERE MADE WITH TOWELING OR CORDUROY ALSO COLORED WITH SHOW CARD COLOR AND STREAMS AND LAKES WERE PAINTED BLUE WITH THE SAME TYPE OF COLOR. TREES WERE HANDMADE FROM GREEN RUBBER SPONGE MOUNTED ON WIRE, THEN SET IN A SMALL DRILLED HOLE AND HELD IN PLACE WITH GLUE. ROADS WERE CONSTRUCTED OF FINE SAND AND GLUE AND THE BUILDINGS WERE NAILED IN PLACE.

AS MENTIONED, THE MODEL WAS HUNG IN A POSITION AS SHOWN IN FIGURE 1 AND HELD IN PLACE ON A PIPE FRAME. THIS ALLOWS THE MODEL TO SWING ABOUT THE METAL FRAME AND THIS MOVEMENT IS CONTROLLED BY THE ADJUSTING SCREWS AT EACH END OF THE MODEL. (SEE FIGURE 3) TWO SCALES, ONE AT EACH END, ARE PROVIDED TO INDICATE THE NUMBER OF DEGREES OF TILT INTRODUCED IN THE MODEL.

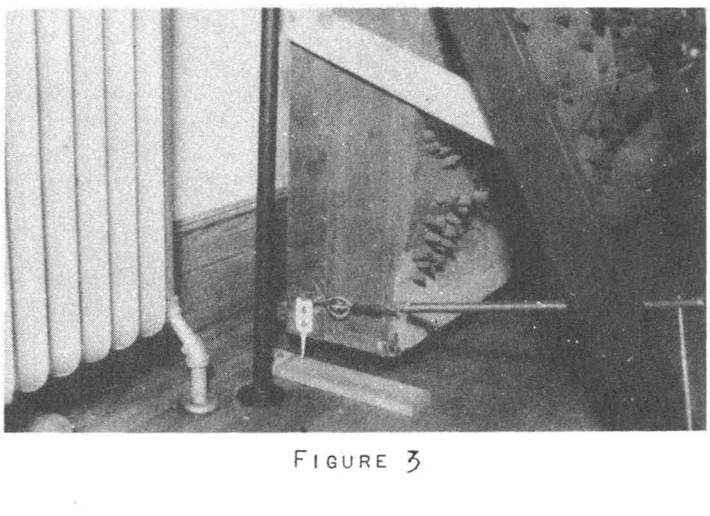


FIGURE 3

CONTROL POINTS

BEFORE ANY EXPERIMENTAL WORK WAS STARTED, THE MODEL WAS SWUNG INTO A HORIZONTAL POSITION AND A GRID OF CONTROL POINTS LAID OUT AND MARKED ON THE MODEL SO THAT ALL CONTROL POINTS WOULD APPEAR ON THE PHOTOGRAPHS.

THE SIZE OF THE GRID SQUARES WAS TAKEN AS 1 FOOT, WHICH ON THE MODEL, IS EQUIVALENT TO 40 FEET.

SECONDARY CONTROL POINTS WERE ALSO MARKED AT HIGH AND LOW POINTS AND THESE POINTS WERE REFERENCED TO THE MAIN GRID SYSTEM BY COORDINATE MEASUREMENTS. NEXT THE ELEVATIONS OF BOTH PRIMARY AND SECONDARY CONTROL POINTS WERE DETERMINED BY ACTUAL LEVELS. A SPECIAL SHORT LEVEL ROD WAS CONSTRUCTED AND A TARGET USED; READINGS BEING TAKEN TO .001 OF A FOOT SO THAT, TO THE SCALE OF THE MODEL, NO ELEVATION WAS MORE THAN 1.0' IN ERROR. THREE SETS OF LEVELS WERE TAKEN AND NO READING WHICH VARIED BY MORE THAN .001 OF A FOOT WAS USED. MOST OF THE READINGS AGREED EXACTLY, WITH THE RESULT THAT MOST ELEVATIONS WERE CORRECT TO 0.5' ON THE MODEL SCALE.

CAMERA STATIONS

HAVING COMPLETED THE CONTROL WORK THE MODEL WAS SWUNG BACK INTO A VERTICAL POSITION AND THE CAMERA STATIONS LOCATED. FOR THESE STATIONS A GRID SYSTEM WAS LAID OUT ON THE FLOOR AND THE STATIONS POINTS MARKED AT ONE FOOT POINTS BY MEANS OF SMALL NAILS DRIVEN IN THE FLOOR AND THE HEADS PAINTED WHITE.

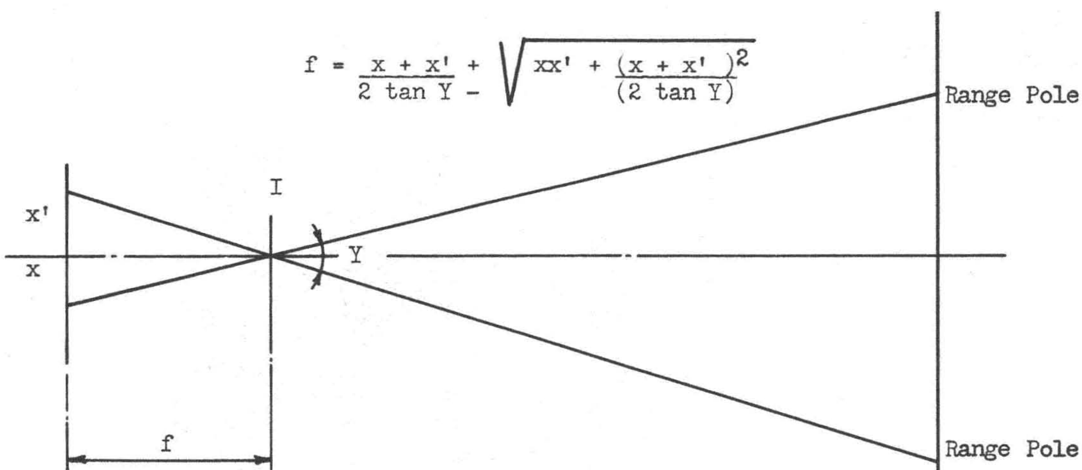
CAMERA EQUIPMENT

EXPERIMENTS WERE MADE WITH VARIOUS CAMERAS INCLUDING THE BOX PIN-HOLE CAMERA. THE PIN-HOLE CAMERA DID NOT GIVE THE DESIRED DETAIL AND IT WAS FINALLY DECIDED TO USE A VOIGHTLANDER AVUS FOCUSING CAMERA WHICH IS ADAPTED FOR FILM PACK, CUT FILM AND GLASS PLATES. GLASS PLATES ARE RECOMMENDED AS THERE IS NO DANGER OF BULGES IN THE FILM WHICH MAY BE INTRODUCED WHEN LOADING CUT FILM.

CALIBRATING THE CAMERA

IT IS NECESSARY TO KNOW THE EXACT FOCAL LENGTH OF THE CAMERA AND THIS MAY BE DONE SUCCESSFULLY BY THE FAMILIAR FIELD METHOD AND THE USE OF THE FORMULA

$$f = \frac{x + x'}{2 \tan Y} \pm \sqrt{xx' + \frac{(x + x')^2}{(2 \tan Y)}}$$



Note: x and x' are measured on the photograph
Angle Y is measured in the field

FIGURE 4

COLLIMATING MARKS

THE COLLIMATING MARKS MUST ALSO BE CAREFULLY DETERMINED AND PROVISION MADE TO REGISTER THEM ON EACH PHOTOGRAPH. ONE METHOD OF DOING THIS IS TO MOUNT THE CAMERA SO THAT THE FRAME HOLDING THE FILM OR PLATE IS IN A HORIZONTAL POSITION. THE CAMERA IN THIS POSITION SHOULD BE SUSPENDED OVER A MIRROR. A GLASS PLATE WITH BLACK LINES DRAWN ON IT SERVES AS AXES OR CROSS LINES FOR SIGHTING THROUGH THE CAMERA TO THE MIRROR BELOW. A HOOD MUST BE PROVIDED AT THE REAR OF THE CAMERA TO PREVENT EXCESS LIGHT FROM SHINING ON THE GLASS PLATE BUT SOME ILLUMINATION MUST BE PROVIDED SO THAT A REFLECTION OF THE BLACK CROSS LINES WILL REFLECT IN THE MIRROR. WITH THE CAMERA HELD IN ITS ORIGINAL POSITION THE GLASS PLATE AT THE BACK OF THE CAMERA IS SHIFTED SLIGHTLY UNTIL THE IMAGE OF THE LINES IN THE MIRROR COINCIDES WITH THE LINES ON THE PLATE. AS THIS POSITION IS HELD, MARKS ARE TRANSFERRED TO THE FRAME OF THE CAMERA WHICH ARE THE COLLIMATING POINTS AND ARE THE POINTS WHERE THE PROJECTIONS SHOULD BE PLACED SO AS TO REGISTER ON EACH NEGATIVE.

REFERRING TO FIGURE 1, IT WILL BE NOTED THAT A HORIZONTAL LINE STRETCHES ACROSS THE PICTURE AND IS HELD IN PLACE AT THE TWO ENDS OF THE MODEL BY TWO MOVABLE ARMS. THIS LINE IS AN ALUMINUM WIRE AND CAN BE ADJUSTED TO COINCIDE WITH THE HORIZONTAL AXIS OF THE CAMERA WHEN IT IS FOCUSSED ON THE MODEL. IN THIS WAY THE HORIZONTAL AXIS OF THE PHOTOGRAPH IS PHOTOGRAPHED AT THE TIME THAT THE PICTURE IS TAKEN. A VERTICAL AXIS IS ALSO PHOTOGRAPHED BY INCLUDING A PLUMB LINE TO COINCIDE WITH THE VERTICAL AXIS OF THE CAMERA.

CAMERA MOUNT

THE CAMERA MOUNT CONSISTS OF AN ADJUSTABLE STAND WITH A CAMERA HOLDER ATTACHED TO A JOHNSON PLANE TABLE LEVELING HEAD. WITH THE CAMERA IN PLACE, THIS STAND CAN BE MOVED TO ANY CAMERA STATION, LEVELED AND AN EXPOSURE TAKEN.

STEREO-COMPARAGRAPH

WE HAVE TAKEN MANY STRIPS OF PICTURES AT VARIOUS ALTITUDES AND HAVE USED THE PICTURES IN THE STEREO-COMPARAGRAPH TO ILLUSTRATE THE PRINCIPLE OF STEREOSCOPIC PLOTTING. WHILE THIS INSTRUMENT IS NOT AS PRECISE AS OTHER PLOTTING INSTRUMENTS, IT HAS A DISTINCT ADVANTAGE IN BEING MUCH CHEAPER. IT, ALSO, IS SIMPLE IN CONSTRUCTION AND MAKES AN EXCELLENT INSTRUMENT FOR TEACHING THE PRINCIPLES OF STEREOSCOPIC PARALLAX AND ITS USE IN DETERMINING ELEVATIONS OF POINTS. THIS INSTRUMENT CONSISTS OF FOUR MAIN PARTS: THE STEREOSCOPE, THE MEASURING SYSTEM, THE DRAWING ATTACHMENT, AND THE ALIGNMENT MECHANISM, WHICH IS NOT INTEGRAL TO THE INSTRUMENT. SEE FIGURE 5.

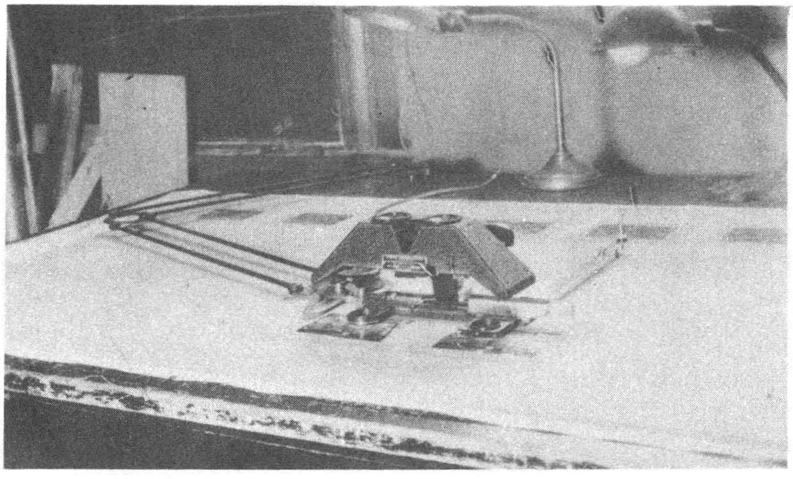


FIGURE 5

The stereoscope is the reflecting type to which has been added a pair of matched lenses for the magnification of the detail of the photographs. This optical arrangement directs the line of sight from the eyes to the matched photographs and accomplishes two objects: one, the stereoscopic observation of the photographs under examination; and two, the stereoscopic fusion of two measuring marks, one on each object glass, for the purpose of determining the displacement of a point.

The measuring system consists of two measuring marks, one in the center of each object lens. The movement of these marks varies with the displacement of the points being investigated and can be controlled and measured by an attached micrometer.

The drawing attachment consists of a special pencil, mounted at the end of a drawing arm which is rigidly connected to the base of the instrument. It is so designed that the pencil will follow the left measuring mark and draw to scale the movement of that point over the photograph. It is with this attachment that contours are drawn directly from the photographs by moving the instrument so that the floating marks trace constant elevations upon the photographs.

The alignment mechanism is a standard type drafting machine. It is so constructed that once the machine is aligned it will stay in that state until changed.

In the operation of this instrument, differences in elevation are represented by differences in parallax, which are measured by the micrometer. A parallax measurement is obtained by bringing the fused image of the two index marks into contact with the stereoscopic model, and noting the reading of the micrometer for each point measured. First the displacement of a bench mark or control point whose elevation is known is obtained. Any other point on the photograph may be picked and the displacement of that point found. From the difference in displacements of these points, the difference in elevation can be found, and thus the elevation of the unknown point can be figured.

If the stereocomparagraph is to be used to plot contours directly, the floating points are brought into fusion so as to rest on a point of known elevation on the stereoscopic model and the micrometer reading noted. If the instrument is now moved so as to keep the floating point in contact with the ground, there will be traced a contour of the elevation of the known point. The difference in parallactic displacement can be figured and a setting now made for the next contour elevation to be drawn, this process being continued until the entire map has been contoured. It is advisable to have several control points to check in on as the work progresses.

It requires a little practice for a man to become expert in the use of this instrument but only a matter of a few hours in most cases. It is interesting to note the reaction of different students. Some can operate the instrument almost immediately while others take several hours and others are unable to operate the instrument due to a defect in vision.

Assuming that we have measured the difference in parallactic displacement of two points and that we desire the difference in elevation of the points, we resort to the following formula and computation:

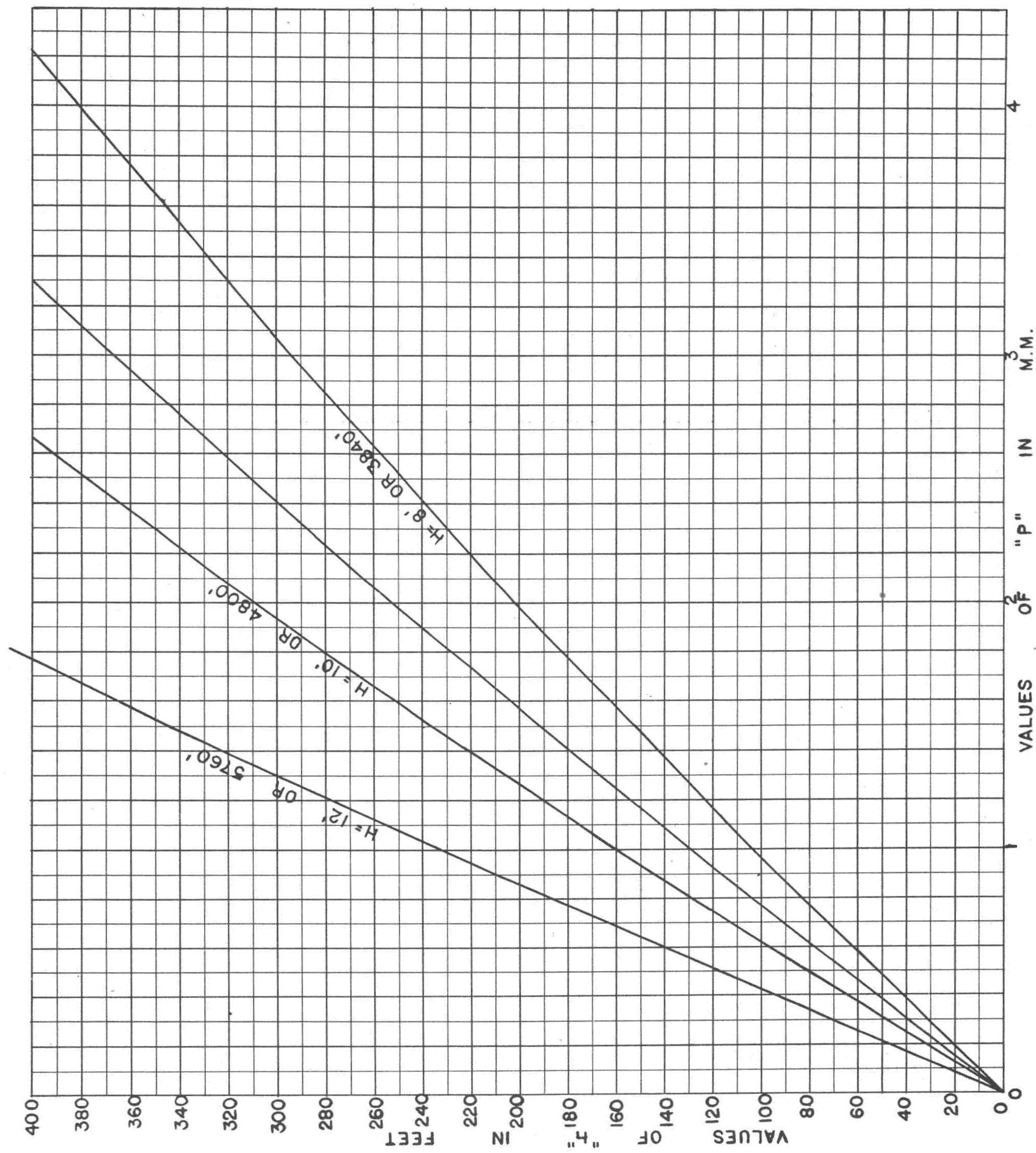
$$h = \frac{dSH}{B + dS}$$

h = difference of elevation
S = scale fraction $\frac{H}{f}$
H = altitude
B = air base
d = difference in parallactic displacement

Example:

d = 0.147"
air base = 2,500'
altitude = 10000'
f = 10"

$$h = \frac{0.147 \times 1000 \times 10000'}{2500 + 0.147 \times 1000} = 554' \text{ Approx.}$$


VALUES OF "H" IN FEET
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
VALUES OF "P" IN M.M.
0
1
2
3
4
H = 8' OR 3840'
H = 10' OR 4800'
H = 12' OR 5760'

For a great number of points this process would be quite long. To speed up the work, a diagram can be constructed from which the difference of elevation can be determined with great rapidity.

CONSTRUCTION OF DIAGRAM

From the formula $h = \frac{dSH}{B + Sd}$ the difference in elevation between two points can be found as shown in the above computation. The formula shows that the difference in elevation involves the displacement (d), the scale fraction (S), the altitude of the camera (H), and the air base (B).

Assuming that "B" remains the same for any one flight strip, the three variables are h, d and H, $S = H/f$ with "f" remaining constant. Under these conditions, a graph can be plotted using "h" and "d" as axes and "H" as the curve. Since the values of "h" are desired in feet and the comparagraph micrometer reads to millimeters, the transformation can be accomplished on the diagram by plotting "h" in feet on the vertical axis against "p" in millimeters on the horizontal axis.

A sample computation for a point on the 8 foot (3840' alt.) graph is as follows:

Camera 8' away from model.

Assume displacement of 0.600 m.m.

$$h = \frac{dSH}{B + Sd}$$

$$h = \frac{0.02361 \times 677 \times 3840}{960 + 677 \times 0.02361}$$

$$h = \frac{61400}{960 + 15.99} = 62.8'$$

Values used in above equation:

$$d = \frac{.6}{25.4} = 0.02361''$$

$$H = 8 \times 12 \times 40 = 3840'$$

$$f = 5.67'' \text{ at } 8'$$

$$S = \frac{3840}{5.67} = 677'$$

$$B = 2 \times 12 \times 40 = 960'$$

Other points were assumed and similar computations made. With these points the curves were plotted and used in determining the difference in elevation between points on the model.

One thing which is quite apparent from the diagram is that small errors in the measurement of parallactic displacement are much more serious for high altitude photographs than at low altitudes. From this it would seem that low flying would be advisable for stereoscopic mapping but there are other things which necessitate higher flights, such as economy in the number of pictures, flying conditions, etc.

RESULTS OF MEASUREMENT MADE ON THE MODEL

In the following pages are the results of a test made by one of our students. Chart No. 1 shows the variation between the elevations of points as determined by the Stereo-Comparagraph and those determined by precise leveling. The plus sign indicates elevations too high and minus too low. These

DETERMINATIONS WERE MADE BY A STUDENT WHO HAD PRACTICED ONLY A FEW HOURS WITH THE INSTRUMENT. THE PHOTOGRAPHS HAD TILT AND TIP WHICH IS QUITE APPARENT FROM THE LARGE AMOUNT OF ERROR AS SHOWN IN CHART NO. 1. THE PHOTOGRAPHS WERE ALSO TAKEN ON CUT FILM WHICH TENDS TO CURL UP AT THE EDGES AND CAUSE ERROR IN DISPLACEMENT. PLATES GIVE BETTER RESULTS AS THEY REMAIN FLAT DURING THE EXPOSURE.

CHART NO. 2 SHOWS THE RESULT FROM THE SAME PAIR OF PHOTOGRAPHS WITH THE TILT AND TIP REMOVED. THE EDGES ARE STILL OUT BUT THE CENTER PORTION CHECKS CLOSELY FOR STEREOSCOPIC MEASURING.

	F	G	H	I	J
1		+5.2	+6.6	-4.4	-28.4
2	-2.5	+28.9	+9.6	-16.5	+19.7
3	-3.5	+23.9		-23.3	-59.4
4	-1.3	+16.6	-19.2	-37.7	-79.2

CHART 1

1		-3.1	-11.4	-4.8	-13.1
2	-50.5	+5.9	-0.4	-8.1	-48.8
3	-49.5	+0.9		-0.3	-31.4
4	-31.3	+7.3	-3.2	-13.0	-34.6

CHART 2

THE METHOD JUST DISCUSSED FURNISHES AN INEXPENSIVE AND ILLUSTRATIVE SCHEME FOR TEACHING THE FUNDAMENTALS OF PHOTOGRAPHIC SURVEYING AND PARTICULARLY THE PRINCIPLES OF STEREOSCOPIC PLOTTING AND THE USE OF FLOATING POINTS IN THE MEASURING OF STEREOSCOPIC PARALLAX. THE INSTRUMENTS USED ARE NOT AS PRECISE AS SOME WHICH ARE IN USE TODAY BUT ARE SIMPLE TO UNDERSTAND AND ALL OPERATIONS ARE OPEN AND EASILY SEEN BY THE OPERATOR. FOR THE STUDENT WITH INITIATIVE AND DESIRE FOR RESEARCH, THE MODEL PHOTOGRAPHS FURNISH A BASIS FOR EXPERIMENTAL WORK. AS A BASIS OF COMPARISON FOR VARIOUS TYPES OF PLOTTING EQUIPMENT, THE LABORATORY SURVEY GIVES A CHECK WITH MUCH LESS TIME AND EXPENSE INVOLVED THAN COULD BE DONE IN ACTUAL PRACTICE.

IT IS MY BELIEF THAT THE WORK JUST DESCRIBED SHOULD BE FOLLOWED WITH INSTRUCTION IN PLOTTING FROM ACTUAL AERIAL PHOTOGRAPHS. THREE AERIAL SURVEYS HAVE BEEN MADE UNDER OUR DIRECTION COVERING APPROXIMATELY 100 SQUARE MILES AND THE PICTURES ON THESE SURVEYS WERE TAKEN IN FLIGHT STRIPS COVERING THE AREAS OVER WHICH WE MAKE OUR GROUND SURVEYS DURING THE SUMMER CAMP PERIODS. THIS MEANS THAT WE HAVE AMPLE CONTROL AND IT IS POSSIBLE TO PLOT MAPS FROM TRANSIT STADIA SURVEY, PLANE-TABLE AND PHOTOGRAPH. A COMPARISON OF THE DIFFERENT METHODS IN THIS WAY SERVES TO ILLUSTRATE THE LIMITATIONS OF THE DIFFERENT METHODS AND THE TIME CONSUMED BY THE VARIOUS SCHEMES.

THE PHOTOGRAPHS TAKEN FROM THESE AERIAL SURVEYS ARE USED TO ILLUSTRATE VARIOUS PLANIMETRIC PLOTTING METHODS, MAINLY THE RADIAL LINE AND TEMPLATE METHODS.

AS INTIMATED BEFORE, IT IS NOT MY BELIEF THAT MANY STUDENTS SHOULD BE ENCOURAGED TO SPECIALIZE IN PHOTOGRAMMETRY ANY MORE THAN A STUDENT SHOULD SPECIALIZE IN PLANE SURVEYING, TOPOGRAPHIC SURVEYING, HYDROGRAPHIC SURVEYING, MINE SURVEYING, GEODETIC SURVEYING BUT AT LEAST ALL CIVIL ENGINEERS SHOULD HAVE INSTRUCTION IN ALL OF THESE BRANCHES. I THINK THAT WE ARE ALL AGREED

THAT A STUDENT CANNOT BE GIVEN A COLLEGE TRAINING TO THE EXTENT THAT HE BE EXPERT IN ANY ONE LINE BUT RATHER, EQUIP HIM WITH A GOOD FOUNDATION WHICH WILL SERVE AS A BASIS UPON WHICH HE CAN BUILD AS HIS EMPLOYMENT REQUIRES.

IN MY OPINION, A TEACHER IN ANY COURSE OF STUDY MUST REALIZE THAT FUNDAMENTALS ARE OF THE GREATEST IMPORTANCE AND SHOULD BE PRESENTED IN THE CLEAREST AND SIMPLEST WAY POSSIBLE. THIS SHOULD BE BORNE IN MIND AS THE PROFESSOR PURSUES HIS INVESTIGATIONS, RESEARCH AND GRADUATE STUDY. TO HIM THE FUNDAMENTALS BECOME MORE AND MORE SIMPLE AND HE MAY BE INCLINED TO SLIGHT THEM TO ALLOW MORE TIME TO TEACH THE MORE ADVANCED WORK WHICH MAY BE SO CLOSE TO HIM AT THE TIME. HE MUST REALIZE THAT WHILE HE IS INCREASING HIS KNOWLEDGE, AS HE SHOULD, THE NEW STUDENT IS ENTERING EACH YEAR WITH THE SAME PREPARATION AND EACH CLASS MUST BE GIVEN THE SAME FUNDAMENTALS. THE PROFESSOR'S ADVANCED KNOWLEDGE SHOULD BE USED IN PLANNING BETTER WAYS AND MEANS OF ACCOMPLISHING THIS RESULT IN KEEPING WITH MODERN THEORY AND PRACTICE.

A PRACTICAL METHOD OF TILT DETERMINATION FOR MULTI-LENS AERIAL PHOTOGRAPHS

BY SIDNEY H. BIRDSEYE, EL SALVADOR-GUATEMALA BOUNDARY COMMISSION.

IN AN ARTICLE PUBLISHED IN THE JANUARY-FEBRUARY 1936 ISSUE OF THE MILITARY ENGINEER, *MR. CHARLES B. MCADAM EXPLAINED IN DETAIL A METHOD USED BY THE U. S. GEOLOGICAL SURVEY AND TENNESSEE VALLEY AUTHORITY TO DETERMINE TILT IN FIVE-LENS COMPOSITE AERIAL PHOTOGRAPHS. MCADAM MADE NO CLAIM FOR MATHEMATICAL ACCURACY BUT STATED THAT EXPERIENCE IN PLOTTING 6,000 COMPOSITE PHOTOGRAPHS INDICATED DEFINITELY THAT THE USE OF THE METHOD GAVE BETTER RESULTS THAN WERE OBTAINED WHEN THE TILT OF THE PHOTOGRAPHS WAS IGNORED.

IT IS GENERALLY RECOGNIZED THAT CERTAIN ERRORS EXIST IN RADIAL LINE GRAPHIC TRIANGULATION DUE TO THE FACT THAT THE TILTED PHOTOGRAPHS ARE NOT ORDINARILY TRANSFORMED TO THE HORIZONTAL BEFORE USE. WHEN USING THE PHOTOGRAPHS IN THIS MANNER THE DRAFTSMAN ATTEMPTS TO FIT TO POINTS PLOTTED ON THE HORIZONTAL MAP PLANE A DISTORTED SYSTEM OF RADIAL LINES FROM THE PRINCIPAL POINT AS ORIGIN AS PORTRAYED ON THE TILTED PLANE OF THE AERIAL PHOTOGRAPH. WHEN THE RELIEF OF THE TERRAIN IS LOW AND THE DEGREE OF TILT IS SMALL, THIS CAN BE ACCOMPLISHED WITH SUFFICIENT ACCURACY FOR MUCH MAP WORK BUT WHEN EITHER TILT OR RELIEF BECOMES LARGE THEN THE METHOD IS INACCURATE AND WILL NOT GIVE SATISFACTORY RESULTS. THE USE OF A SUBSTITUTE POINT AS THE ORIGIN OF THE RADIAL LINES IN PLACE OF THE PRINCIPAL POINT WILL ELIMINATE SOME OF THE ERROR IN THE DIRECTION LINES IF THE ORIGIN SELECTED APPROXIMATES THE POSITION OF THE ISOCENTER OF THE PHOTOGRAPH. THIS PROCEDURE WILL MATERIALLY IMPROVE THE ACCURACY OF THE MAP WHEN IT IS NECESSARY TO USE HIGHLY TILTED PHOTOGRAPHS, ALTHOUGH WHEN THE UTMOST ACCURACY IS DESIRED IT IS ESSENTIAL THAT THE PHOTOGRAPHS BE TRANSFORMED TO THE HORIZONTAL PLANE BEFORE USE.

DURING 1935-36, THE GUATEMALA-HONDURAS BOUNDARY COMMISSION PREPARED PLANIMETRIC MAPS OF SOME 3,000 SQUARE MILES FROM FOUR-LENS AERIAL PHOTOGRAPHS MADE WITH THE BAGLEY TYPE T-2 CAMERA. THE GREATER PART OF THE AREA MAPPED WAS MADE UP OF ROUGH MOUNTAINS COVERED, IN MANY SECTIONS, WITH HEAVY TROPICAL GROWTHS WHERE FEW DEFINITE POINTS FOR RADIAL LINE INTERSECTION COULD BE FOUND. CONSIDERABLE DIFFICULTY WAS CAUSED BY THIS CONDITION, AS WELL AS INSUFFICIENT CON-

* PRACTICAL TILT CORRECTIONS OF FIVE LENS AERIAL PHOTOGRAPHS BY CHARLES B. MCADAM. REPRINT FROM THE MILITARY ENGINEER, JAN.-FEB. 1936 SENT TO MEMBERS WITH NEWS NOTES FOR JAN.-FEB.-MARCH, 1936.