

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 CLEAR-EST 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 ISO-CENTER 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.

TROL AND EXCESSIVE TILT. WHERE THE FLIGHT LINES WERE ADJACENT AND PARALLEL TO HIGH MOUNTAIN RANGES, ONE WING PHOTOGRAPH HAD A MUCH LARGER SCALE THAN THE OTHER DUE TO THE STEEP SLOPES OF THE MOUNTAIN SIDES. THE USUAL METHODS OF MAKING THE INTERSECTIONS ON TRACING CLOTH PLACED OVER THE AERIAL PHOTOGRAPHS WERE NOT SUCCESSFUL AS IT WAS FOUND IMPOSSIBLE TO PREVENT EXCESSIVE SWINGS IN AZIMUTH.

AFTER THE COMMISSION OBTAINED PERMISSION TO USE THE NEWLY DEVELOPED "SLOTTED TEMPLATE" METHOD IT WAS FOUND POSSIBLE TO ADJUST MORE OR LESS SIMULTANEOUSLY ALL PHOTOGRAPHS BETWEEN AREAS THAT HAD BEEN WELL CONTROLLED. HOWEVER, THIS METHOD DID NOT ELIMINATE THE TROUBLE CAUSED BY EXCESSIVE TILTS IN MANY OF THE PHOTOGRAPHS. HAD IT BEEN POSSIBLE TO EMPLOY THE McADAM METHOD OF DETERMINING AN ORIGIN FOR THE RADIAL LINES IT IS PROBABLE THAT THE PLOTTING OPERATIONS WOULD HAVE BEEN EASIER AND MORE ACCURATE.

ATTENTION WAS DRAWN TO MR. McADAM'S ARTICLE WHEN MAP COMPILATION WAS STARTED ON THE EL SALVADOR-GUATEMALA BOUNDARY LINE IN SEPTEMBER 1936 AND CONSIDERABLE STUDY WAS GIVEN TO THE APPLICATION OF THIS METHOD TO THE FOUR-LENS CAMERA PHOTOGRAPHS USED ON THIS BOUNDARY. THE METHOD PROVED VERY SATISFACTORY FOR SIDE TILT CORRECTIONS (LIST) BUT DID NOT GIVE THE EXPECTED RESULTS WITH END TILT CORRECTIONS (TIP). THIS MAY HAVE BEEN DUE TO THE FACT THAT THE FOUR-LENS COMPOSITE PHOTOGRAPHS DO NOT HAVE A TRAILING WING PRINT, THUS PREVENTING A CHECK COMPUTATION FOR TIP. THE McADAM METHOD, AS APPLIED TO TIP ANALYSIS IN THIS CASE, INDICATED THAT ALL CORRECTIONS WERE IN ONE DIRECTION WHICH WAS CONSIDERED AN IMPROBABLE CONDITION.

THE LIST ANALYSIS, AS DESCRIBED BY MR. McADAM WAS USED BUT A NEW METHOD DEvised FOR THE TIP ANALYSIS. IN ADDITION, A SIMPLE DEVICE DESIGNED BY SENOR A. G. PRIETO WAS USED WHICH GRAPHICALLY DETERMINES THE CORRECTIONS TO BE APPLIED FOR LIST AND TIP, WITHOUT RECOURSE TO CALCULATIONS OR TABULATIONS, WITH THE EXCEPTION OF ONE DIAGRAM FOR DETERMINATION OF McADAM'S "MEAN BAND" ADJUSTMENT TO THE LIST CORRECTIONS. THE RESULTS OBTAINED FROM THE PRIETO METHOD WERE CONSISTENT IN THAT THE TIP CORRECTIONS VARIED IN DIRECTION, SOME BEING TOWARD THE FORWARD AND SOME TOWARD THE TRAILING EDGE OF THE PHOTOGRAPH. THE LIST CORRECTIONS AGREED WELL WITH THOSE DETERMINED BY THE McADAM METHOD. THE ACTUAL PLOTTING BY THE PRIETO METHOD WAS SATISFACTORY AND VERY LITTLE TROUBLE WAS ENCOUNTERED IN LAYING THE SLOTTED TEMPLATES.

TROUBLE IN DETERMINING THE TIP CORRECTIONS WAS ENCOUNTERED WHERE THE LINE OF FLIGHT OF THE AIRPLANE PASSED OVER A HIGH VOLCANIC PEAK WITH STEEP SLOPING SIDES. DISTORTION DUE TO THIS RELIEF SERIOUSLY AFFECTED THE MEASUREMENTS BETWEEN THOSE PRINCIPAL POINTS WHICH HAPPENED TO FALL ON THESE STEEP SLOPES. IT WAS FOUND NECESSARY TO MAKE CORRECTIONS TO THESE MEASUREMENTS BEFORE THEY COULD BE USED IN THE PRIETO TILT FINDER, INDICATING THAT LARGE DIFFERENCES OF ELEVATION BETWEEN SUCCEEDING EXPOSURE POINTS SERIOUSLY AFFECT THE VALUE OF THE TIP CORRECTION AND MAKE NECESSARY AN ALLOWANCE FOR ITS EFFECT.

AFTER THIS MAP COMPILATION HAD BEEN COMPLETED BY USE OF THE PRIETO METHOD, ATTENTION WAS CALLED TO THE AERIAL PHOTOGRAPH CALCULATOR, INVENTED BY LIEUT.-COL. JAMES W. BAGLEY (U. S. PATENT No. 2,053,019, SEPTEMBER 1, 1936), AND IT BECAME APPARENT THAT THERE WAS SOME SIMILARITY BETWEEN PRIETO'S DEVICE AND THE TILT FINDING PART OF THE AERIAL PHOTOGRAPH CALCULATOR. HOWEVER, USE OF THE DEVICE DOES NOT REQUIRE ANY GROUND CONTROL, AS DOES THE BAGLEY CALCULATOR, AND SR. PRIETO DOES NOT CONTEMPLATE ITS COMMERCIAL MANUFACTURE OR APPLICATION FOR A UNITED STATES PATENT. COL. BAGLEY HAS READ THE FOLLOWING PAPER BY SR. PRIETO AND STATED THAT HE HAD NO OBJECTION TO THE PUBLICATION OF THE ARTICLE BECAUSE OF SOME SIMILARITY BETWEEN THE PRIETO DEVICE AND HIS OWN ELEVATION CALCULATOR.

GREATER ACCURACY COULD HAVE BEEN OBTAINED IN THE GRAPHICAL TRIANGULATION HAD IT BEEN POSSIBLE TO TRANSFORM TO THE HORIZONTAL THE EXCESSIVELY TILTED PHOTOGRAPHS. UNFORTUNATELY, THE COMMISSION DID NOT HAVE THE EQUIPMENT FOR

THIS WORK SO IT WAS NECESSARY TO PROCEED WITHOUT THESE TRANSFORMATIONS. WHILE NO CLAIMS ARE MADE FOR GREATER ACCURACY OF GRAPHICAL TRIANGULATION EXECUTED WITH THE AID OF THE PRIETO TILT FINDER, IT IS BELIEVED THAT THE REDUCTION IN TIME REQUIRED FOR MAKING THE LIST AND TILT ANALYSIS AS COMPARED WITH THE McADAM METHOD IS OF NOTEWORTHY CONSIDERATION.

A DEVICE FOR GRAPHIC DETERMINATION OF TILT IN MULTI-LENS AERIAL PHOTOGRAPHS

By A. G. PRIETO, EL SALVADOR-GUATEMALA BOUNDARY COMMISSION

A TILT FINDING DEVICE IS USED TO DETERMINE THE LIST AND TIP COMPONENTS OF TILTED MULTIPLE-LENS PHOTOGRAPHS USED BY THE EL SALVADOR-GUATEMALA BOUNDARY COMMISSION. IT CONSISTS OF A POINTER ARM AND AN UPPER AND LOWER PLANE PIVOTED TOGETHER SO THAT THE POSITION OF ONE PART TO ANOTHER CAN BE ALTERED AS DESIRED AND THEN FIRMLY CLAMPED TOGETHER. PROVISION IS MADE FOR THE OPERATOR TO SET OFF ON EACH OF THESE PLANES MEASUREMENTS THAT HAVE BEEN TAKEN FROM TWO OVERLAPPING PHOTOGRAPHS AND THUS GRAPHICALLY REPRODUCE THE APPROXIMATE COMPONENTS OF THE TILT THAT EXISTED IN THE AERIAL CAMERA AT THE MOMENT OF EXPOSURE.

THE LINE OI ON THE POINTER ARM (FIG. 1) REPRESENTS ANY IMAGE RAY LINE, AND THIS LINE CAN BE SET ON EITHER OF THE TWO SCALES TO ACCORD WITH MEASUREMENTS THAT ARE MADE ON THE AERIAL PHOTOGRAPHS. A CLAMP IS PROVIDED FOR CLAMPING THE POINTER ARM TO THE UPPER PLANE AS SHOWN IN THE FIGURE. THE UPPER PLANE IS IN THE FORM OF A SEGMENT OF A CIRCLE AND CAN BE ROTATED AROUND THE PIVOT POINT WHICH IS FIXED TO THE LOWER PLANE. THE LINE OP' ON THE UPPER PLANE REPRESENTS THE OPTICAL AXIS OF THE CAMERA. THE SCALE $A'B'$ IS DRAWN ON THIS SAME PLANE NORMAL TO THE LINE OP' AND AT A DISTANCE FROM THE PIVOT POINT EQUAL TO THE PRINCIPAL DISTANCE OF THE CAMERA. IT IS GRADUATED IN MILLIMETERS IN BOTH DIRECTIONS FROM THE POINT P' WHICH INDICATES THE PRINCIPAL POINT OF THE PHOTOGRAPH.

THE LOWER PLANE, TO WHICH THE PIVOT IS FIXED, REPRESENTS THE TILT-FREE POSITION OF THE CAMERA WHILE THE UPPER PLANE CORRESPONDS TO ITS ACTUAL TILTED POSITION AT THE TIME OF EXPOSURE. THE LINE OP ON THE LOWER PLANE CORRESPONDS TO THE VERTICAL FROM THE CAMERA TO THE GROUND SURFACE AND ALSO THE LENS AXIS IN A TILT-FREE POSITION. THE SLIDING, HORIZONTAL SCALE, MN , IS PLACED UNDER THE LOWER PLANE NORMAL TO THE OP LINE AT A DISTANCE FROM THE PIVOT EQUIVALENT TO THE PRINCIPAL DISTANCE OF THE CAMERA. THIS SCALE IS ALSO GRADUATED IN MILLIMETERS IN BOTH DIRECTIONS FROM ITS CENTRAL ZERO POINT AS INDICATED IN FIGURE 1 AND IS SO ARRANGED THAT IT CAN BE MOVED HORIZONTALLY AS NEEDED.

A NEW TILT FINDER MUST BE CONSTRUCTED FOR EACH AERIAL CAMERA AS THE OP AND OP' DISTANCES MUST ALWAYS EQUAL THE PRINCIPAL DISTANCE OF THE CAMERA. IT IS ESSENTIAL THAT CELLULOID, OR SOME OTHER TRANSPARENT MATERIAL, BE USED IN ITS CONSTRUCTION, TO PERMIT SETTING THE POINTER ARM ON BOTH SCALES AND READING THE DISTANCE ON THE $A'B'$ SCALE BETWEEN THE OP AND OP' LINES.

McADAM COMPARES MEASUREMENTS OF DISTANCES MADE ON SUCCESSIVE PHOTOGRAPHS FROM A COMMON IMAGE POINT TO THE OUTER FRAME OF THE A AND C WING PRINTS OF A FIVE-LENS COMPOSITE PHOTOGRAPH. HE GIVES A RELATIVELY SIMPLE FORMULA FOR CALCULATING THE SIDE SWING OF THE CAMERA BETWEEN SUCCESSIVE EXPOSURES AND THIS SWING IS THEN REDUCED BY A FACTOR TO DETERMINE THE RELATIVE LATERAL SHIFT IN POSITION OF THE PRINCIPAL POINTS AGAINST THE GROUND SURFACE. IN THE CASE OF THE NEW TILT FINDER THE IMAGE POINT COMMON TO TWO OVERLAPPING PHOTOGRAPHS