TEST SURVEYS ON STEREOSCOPIC PLOTTING MACHINE TOPOGRAPHY

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FOREWORD

IT IS OFTEN NECESSARY TO SACRIFICE ACCURACY SOMEWHAT IN ORDER TO KEEP COSTS FROM BECOMING EXCESSIVELY HIGH WHEN MAPPING REGIONS DIFFICULT OF ACCESS ON THE GROUND, PARTICULARLY WOODED AREAS OF CONSIDERABLE RELIEF. AERIAL PHOTOGRAPHS AND STEREOSCOPIC PLOTTING MACHINES UNDOUBTEDLY GIVE GREATER ACCURACY AND COMPLETENESS OF DETAIL AT LOWER COSTS, AS REPORTED SEVERAL TIMES IN THIS PUBLICATION. YET THERE HAVE BEEN CASES OF UNSATISFACTORY ACCURACY WHEN PHOTOGRAPHS HAVE BEEN COMPILED BY INEXPERIENCED PERSONNEL UNDER PRESSURE FOR PRODUCTION.

THE NEED FOR STUDIES TO DETERMINE THE ACCURACY ECONOMICALLY PRACTICABLE USING DIFFERENT PHOTO MAPPING METHODS AND OF DEFINITE TESTS ADAPTED TO MAKING CERTAIN THAT SUCH ACCURACY IS MAINTAINED LED TO THE FORMATION THIS SPRING OF THE COMMITTEE ON MAP SPECIFICATIONS AND TESTS OF THE SOCIETY UNDER THE CHAIRMANSHIP OF MR. GEORGE D. WHITMORE. AN APPROPRIATION OF $300,000 HAS JUST BEEN MADE TO THE TENNESSEE VALLEY AUTHORITY TO COMMENCE THE TOPOGRAPHIC MAPPING OF THE VALLEY ON A SCALE OF 1:24,000. THE TWO TRIAL PROJECTS AND THEIR TESTING DESCRIBED IN THE FOLLOWING PAPER WERE EXECUTED THIS SPRING FOR THE AUTHORITY, ONE WITH THE MULTIPLEX AND THE OTHER WITH THE STEREOPLANIGRAPH. THEY FURNISH IDEAL MATERIAL FOR THE COMMITTEE. IT IS HOPED THAT THIS FORTUNATE START, WHEN SUPPLEMENTED BY THE EXPERIENCE AND DISCUSSION OF THE OTHER MEMBERS OF THE COMMITTEE, WILL LEAD TO AN EARLY AND VERY VALUABLE REPORT.

O. S. READING

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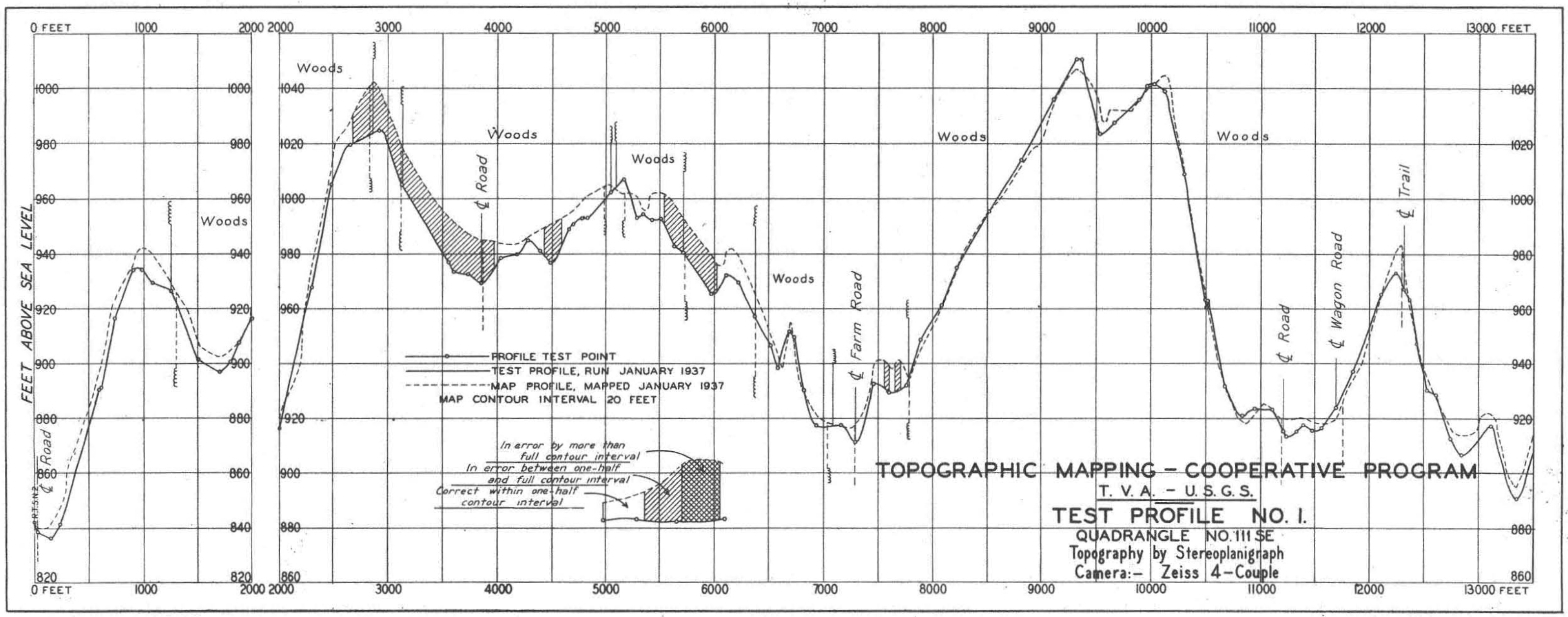
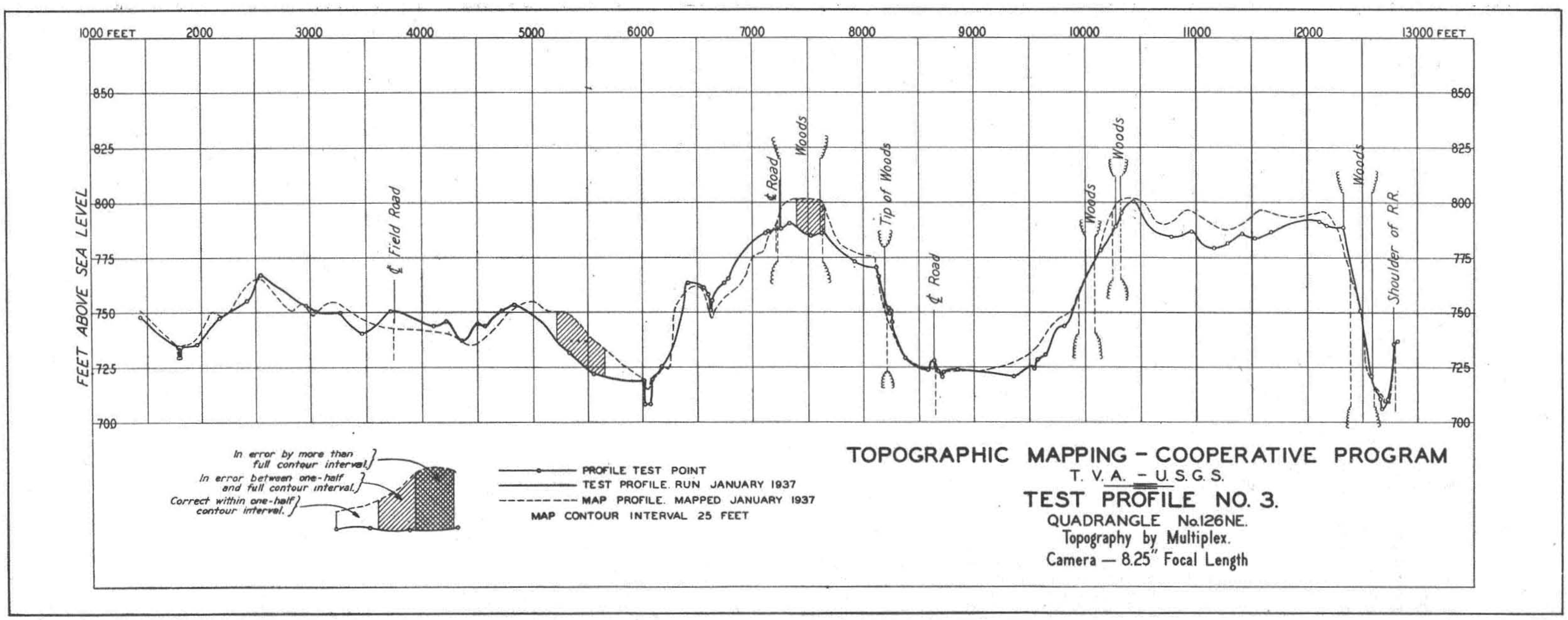
THE TENNESSEE VALLEY AUTHORITY IS BEGINNING THE PREPARATION OF TOPOGRAPHIC BASE MAPS OF THE TENNESSEE RIVER WATERSHED. THE WORK IS TO BE DONE WITH AUTHORITY FUNDS AS A COOPERATIVE PROJECT WITH THE U. S. GEOLOGICAL SURVEY. THE SURVEYING ORGANIZATION OF THE AUTHORITY FURNISHES THE PRECISION AERIAL PHOTOGRAPHS THROUGH CONTRACTS WITH COMMERCIAL FLYING ORGANIZATIONS; EXECUTES ALL CONTROL SURVEYS, THESE BEING PRINCIPALLY THE SO-CALLED SUPPLEMENTAL CONTROL (FOURTH-ORDER COORDINATES AND ELEVATIONS ON IDENTIFIABLE IMAGE POINTS); EXECUTES SUCH TOPOGRAPHY AS IS REQUIRED TO BE DONE BY GROUND SURVEY METHODS; AND FIELD-INSPECTS AND TESTS ALL SHEETS COMPILED BY STEREOSCOPIC METHODS. THE GEOLOGICAL SURVEY IS SUPPLYING STEREOSCOPIC PLOTTING MACHINES WITH A FORCE OF TRAINED OPERATORS THEREFOR, WORKING UNDER THE SUPERVISION OF MR. T. P. PENDLETON, WHO ALSO PREPARED THE SPECIAL SPECIFICATIONS FOR THE HIGH QUALITY, PRECISION PICTURES NECESSARY FOR STEREOSCOPIC PLOTTING MACHINE WORK. THE SURVEY WILL ALSO INK, EDIT, AND REPRODUCE THE MAPS.

DURING THE FISCAL YEAR 1937, AN APPROPRIATION WAS SECURED FROM WHICH RESEARCH AND EXPERIMENTAL WORK WAS CARRIED ON--SPECIFICALLY TO COMPLETE TOPOGRAPHIC MAPS OF CERTAIN AREAS BY STEREOSCOPIC METHODS, TO TEST THE PRECISION OF STEREOSCOPIC CONTOUR MAPS THUS PRODUCED, TO TEST THE PRECISION OF TYPICAL GROUND SURVEY TOPOGRAPHY, TO DETERMINE THE AMOUNT OF GROUND CONTROL NEEDED FOR VARIOUS STEREOSCOPIC PROCESSES, AND TO DETERMINE APPROXIMATE PRODUCTION RATES FOR COST-ESTIMATING PURPOSES. THE GEOLOGICAL SURVEY PURCHASED AND MADE AVAILABLE AT CHATTANOOGA FOR THE TENNESSEE VALLEY WORK A NORMAL-ANGLE ZEISS MULTIPLEX AERO-PROJECTOR, AND ALSO LATER, A WIDE-ANGLE PROJECTOR OF THE SAME MAKE.

THE WORK COMPLETED TO DATE UNDER THIS RESEARCH PROGRAM INCLUDES:

1. MAPPING APPROXIMATELY 240 SQUARE MILES BY NORMAL-ANGLE MULTIPLEX, WITH 8¼" FOCAL LENGTH CAMERA, ALTITUDE ABOUT 9,000 FEET ABOVE THE GROUND, PLOTTING SCALE 1:7,200, FINAL MAP SCALE 1:24,000, 25-FOOT CONTOURS FOR ORDINARY TERRAIN, 50-FOOT CONTOURS IN MOUNTAINS. SIX TEST SURVEYS HAVE BEEN COMPLETED.
2. MAPPING APPROXIMATELY 47 SQUARE MILES BY WIDE-ANGLE MULTIPLEX WITH 6" FOCAL LENGTH CAMERA AT ALTITUDE APPROXIMATELY 12,000 FEET ABOVE GROUND, PLOTTING SCALE 1:10,000, FINAL MAP SCALE 1:24,000, 20-FOOT CONTOURS. TEST


TOPOGRAPHIC MAPPING - COOPERATIVE PROGRAM
T. V. A. - U. S. G. S.
TEST PROFILE NO. I.
QUADRANGLE NO. 111 SE
Topography by Stereoplanigraph
Camera:- Zeiss 4-Couple
PROFILE TEST POINT
TEST PROFILE, RUN JANUARY 1937
MAP PROFILE, MAPPED JANUARY 1937
MAP CONTOUR INTERVAL 20 FEET
In error by more than full contour interval
In error between one-half and full contour interval
Correct within one-half contour interval
FEET ABOVE SEA LEVEL
Woods
℄ Road
℄ Farm Road
℄ Wagon Road
℄ Trail
0 FEET
13000 FEET


TOPOGRAPHIC MAPPING - COOPERATIVE PROGRAM
T. V. A. - U. S. G. S.
TEST PROFILE NO. 3.
QUADRANGLE No.126NE.
Topography by Multiplex.
Camera — 8.25" Focal Length
PROFILE TEST POINT
TEST PROFILE. RUN JANUARY 1937
MAP PROFILE. MAPPED JANUARY 1937
MAP CONTOUR INTERVAL 25 FEET
In error by more than full contour interval
In error between one-half and full contour interval.
Correct within one-half contour interval.
FEET ABOVE SEA LEVEL
℄ Field Road
℄ Road
Woods
Tip of Woods
Shoulder of R.R.
1000 FEET
13000 FEET

	Unit	CONASAUGA QUADRANGLE Multiplex Aero-Projector (Normal) Profile #1	Profile #2	Profile #3	Profile #4	Profile #5	Profile #6	Mean or Total	SODDY ISLAND QUADRANGLE Stereoplanigraph Profile #1	Profile #2	Profile #3	Mean or Total
CONTOUR INTERVAL	Feet	25	25	25	25	25 and 50	25 and 50	25 and 50	20	20	20	20
VERTICAL ACCURACY												
(By Profile Test Points)												
Test points correct within one-half contour interval	Number	143	89	81	66	30	179	588	155	175	295	625
	Per Cent	92.3	96.7	95.3	94.3	93.8	83.3	90.6	93.4	94.1	91.9	92.9
Test points in error between one-half and full contour interval	Number	11	3	4	4	2	36	60	11	11	20	42
	Per Cent	7.1	3.3	4.7	5.7	6.2	16.7	9.2	6.6	5.9	6.2	6.2
Test points in error by more than full contour interval	Number	1	0	0	0	0	0	1	0	0	6	6
	Per Cent	0.6	0	0	0	0	0	0.2	0	0	1.9	0.9
Total	Number	155	92	85	70	32	215	649	166	186	321	673
	Per Cent	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
(By Profile Length)												
Length of profile correct within one-half contour interval	Feet	23,088	11,915	10,671	8,959	8,190	22,980	85,803	20,555	20,347	27,034	67,936
	Per Cent	92.9	92.6	93.9	98.5	98.4	89.5	93.1	90.0	95.9	92.2	92.5
Length of profile in error between one-half and full contour interval	Feet	1,680	955	695	135	135	2,706	6,306	2,285	870	2,095	5,250
	Per Cent	6.7	7.4	6.1	1.5	1.6	10.5	6.8	10.0	4.1	7.1	7.2
Length of profile in error by more than full contour interval	Feet	95	0	0	0	0	0	95	0	0	210	210
	Per Cent	0.4	0	0	0	0	0	0.1	0	0	0.7	0.3
Total	Feet	24,863	12,870	11,366	9,094	8,325	25,686	92,204	22,840	21,217	29,339	73,396
	Per Cent	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average error per test point	Feet	4.8	5.7	5.2	4.7	8.2	12.6	7.7	4.4	4.0	5.4	4.8
Maximum error	Feet	29	16	18	18	30	42	42	18	17	57*	57*
HORIZONTAL ACCURACY												
(Cultural Features, Roads, Etc.)												
Test positions correct within 1/50 inch on final map scale, 1:24,000	Number	14	10	11	5	2	15	57	10	10	3	23
	Per Cent	100.0	100.0	84.6	100.0	100.0	93.8	95.0	90.9	76.9	100.0	85.2
Test positions in error by more than 1/50 inch on final map scale, 1:24,000	Number	0	0	2	0	0	1	3	1	3	0	4
	Per Cent	0	0	15.4	0	0	6.2	5.0	9.1	23.1	0	14.8
Total	Number	14	10	13	5	2	16	60	11	13	3	27
	Per Cent	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average position error on 1:24,000 scale	Inch	0.003	0.007	0.011	0.006	0.000	0.008	0.007	0.010	0.013	0.007	0.011
Maximum position error on 1:24,000 scale	Inch	0.010	0.020	0.030	0.015	0.000	0.022	0.030	0.029	0.028	0.050	0.050

*This error was principally due to a horizontal displacement of approximately 100 feet on the map at the location of a short steep slope.

SURVEYS NOW BEING EXECUTED BUT RESULTS NOT AVAILABLE AT THIS TIME.

3. MAPPING BY CONTRACT 75 SQUARE MILES BY STEREOPLANIGRAPH, PHOTOGRAPHED WITH 4-COUPLE CAMERA, AT ABOUT 14,000 ALTITUDE, PLOTTING SCALE 1:24,000, FINAL MAP SCALE 1:24,000, 20-FOOT CONTOURS. THREE TEST SURVEYS HAVE BEEN COMPLETED.
4. RUNNING TEST SURVEYS OVER PREVIOUSLY-COMPLETED TYPICAL GROUND SURVEY TOPOGRAPHY BY PLANE TABLE ON PLANIMETRIC BASE SHEETS, SCALE 1:24,000, ONE AREA BEING 5-FOOT CONTOURS, ANOTHER AREA BEING 50-FOOT CONTOURS.
5. RUNNING TEST SURVEYS ON GROUND-SURVEY TOPOGRAPHY, EXECUTED BY THE METHOD OF PLOTTING CONTOURS BY PLANE TABLE ON RATIOED PHOTOGRAPHS, THEN PROJECTING THESE CONTOURS TO A PREVIOUSLY PREPARED PLANIMETRIC-MAP BASE COMPILED BY RADIAL LINE INTERSECTION METHOD, MAP SCALE 1:6,000, CONTOUR INTERVALS 5 FEET AND 10 FEET. (IT IS RECOGNIZED, OF COURSE, THAT THIS METHOD CAN BE USED SUCCESSFULLY ONLY ON TERRAIN OF LOW RELIEF, BECAUSE OF THE LARGER DISPLACEMENT OF PHOTOGRAPHIC IMAGES ON TERRAIN OF HIGH RELIEF).

THE PROCEDURE ADOPTED FOR THE TEST SURVEYS IS THE SO-CALLED "TEST PROFILE" METHOD, PROBABLY MORE USED THAN ANY OTHER FOR TOPOGRAPHIC-MAP TESTING PURPOSES. A RANDOM-LINE, TRANSIT-TAPE, FOURTH-ORDER TRAVERSE IS RUN FROM ONE CONTROL SURVEY STATION TO ANOTHER, AND COORDINATES COMPUTED FOR EACH INSTRUMENT STATION. ELEVATIONS OF ALL CHANGES IN GRADE ALONG THE TRAVERSE ARE THEN SECURED, EITHER BY WYE-LEVELING OR BY VERTICAL ANGLES. THE STATIONS OF THE TRAVERSE ARE THEN PLOTTED BY THEIR COORDINATES ON THE MAP SHEET. STRAIGHT LINES CONNECTING THESE INSTRUMENT STATIONS SHOW THE ROUTE OF THE TRAVERSE ON THE MAP. THE DISTANCES TO CONTOUR CROSSINGS ALONG THE TRAVERSE ROUTE ARE THEN SCALED FROM THE MAP SHEET. AT SUMMITS, SADDLES, DEPRESSIONS, SHELVES, ETC., THE MAP ELEVATIONS ARE OBTAINED BY "DOUBLE INTERPOLATION". DISTANCES ARE ALSO SCALED FROM THE NEAREST INSTRUMENT STATION TO ALL ROADS AND RAILROADS CROSSING THE PROFILE. THESE SCALED DISTANCES OF CONTOUR CROSSINGS, INTERPOLATED ELEVATIONS, AND ROAD CROSSINGS ARE THEN PLOTTED AS A PROFILE ON STANDARD PROFILE PAPER, THIS PLOTTING REPRESENTING THE PROFILE TAKEN FROM THE MAP SHEET.

THEN THE SURVEYED PROFILE IS PLOTTED ON THE SAME PROFILE SHEET. IF BOTH PROFILES WERE PERFECT, THEY WOULD FALL ONE ON TOP OF THE OTHER. THIS RARELY HAPPENS, OF COURSE. IN PRACTICE, THE INSTRUMENTALLY-SURVEYED PROFILE IS ASSUMED TO BE CORRECT, ALL DIFFERENCES BETWEEN THE TWO BEING CONSIDERED AS MAP ERRORS. PORTIONS OF TWO TYPICAL TEST PROFILES ARE REPRODUCED ON PAGE 25.

AFTER THE PLOTTING OF BOTH PROFILES IS COMPLETE, A DETAILED ANALYSIS IS MADE, AS INDICATED IN THE SPECIMEN ANALYSES REPRODUCED ON PAGE . THESE INDICATE, MUCH MORE EXACTLY THAN THE PROFILES THEMSELVES, THE PRECISION BEING SECURED IN THE MAP. IT IS EVIDENT THAT THESE RESULTS FOR THE NORMAL-ANGLE MULTIPLEX AND STEREOPLANIGRAPH INDICATE WORK WELL WITHIN THE ACCURACY QUITE GENERALLY ACCEPTED AS STANDARD FOR ENGINEERING OR "STANDARD" TOPOGRAPHIC MAPS. IT IS HOPED THAT ON ALL THE TOPOGRAPHIC MAPS OF THE TENNESSEE VALLEY AREA, 90 PERCENT OF ALL ELEVATIONS WILL BE CORRECT WITHIN ONE-HALF THE CONTOUR INTERVAL AND 90 PERCENT OF THE COORDINATE POSITIONS OF ALL WELL-DEFINED CULTURAL FEATURES WILL BE CORRECT WITHIN 1/50 INCH.

SUCH PRELIMINARY TESTS AS HAVE BEEN MADE ON 20-FOOT CONTOUR MAPS BY THE WIDE-ANGLE MULTIPLEX TEND TO INDICATE THE ACCURACY WILL BE SIMILARLY SATISFACTORY, ONLY DEPENDING UPON FINDING A SUITABLE WIDE-ANGLE CAMERA.

THE TESTS ON GROUND SURVEY TOPOGRAPHY (PLANE TABLE ON PLANIMETRIC BASE SHEET), 1:24,000 SCALE, 5-FOOT CONTOURS ON ONE SHEET, 50-FOOT CONTOURS ON ANOTHER, SHOW RESULTS SOMEWHAT LESS ACCURATE THAN THE STEREOSCOPIC WORK. ON THE OTHER HAND, TESTS ON CERTAIN SPECIAL MAPS BY GROUND SURVEY BY THE RATIOED-PICTURE-PLANIMETRIC-BASE METHOD SHOW RESULTS SOMEWHAT BETTER THAN THE STEREOSCOPIC MAPS.

THE FOREGOING EXPLANATION IS OFFERED ONLY AS A SORT OF PROGRESS REPORT ON THE BASIC TOPOGRAPHIC MAPPING PROGRAM OF THE AUTHORITY. IT WOULD BE UNFAIR AND UNSAFE TO DRAW FINAL CONCLUSIONS FROM THESE RESULTS AS TO THE RELATIVE WORTH OF THE DIFFERENT TOPOGRAPHIC MAPPING PROCEDURES. THE ONLY SAFE CONCLUSION TO BE DRAWN AT THIS TIME IS THAT CERTAIN STEREOSCOPIC PROCESSES, IN THE HANDS OF CAPABLE OPERATORS, AND FOR TERRAIN OF PRONOUNCED RELIEF, WILL PRODUCE MAPS ACCURATE WITHIN THE GENERALLY ACCEPTED STANDARDS.