*Latest Advances in Automatic Mapping**

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ABSTRACT: *This paper is principally concerned with presenting the latest results obtained with the automatic equipment currently under development by Geodesy, Intelligence and Mapping Research and Development Agency (GIMRADA). Slides of the outputs are highlighted as well as the accuracies obtained. System descriptions are kept to a minimum. Principal items are the Automatic Map Compilation System, the Digital Automatic Map Compilation System, the Automatic Stereomapping Instrument, and the Automatic Point Marking, Measuring and Recording Instrument.*

AUTOMATIC POINT MARKING, MEASURING AND RECORDING INSTRUMENT (FIGURE 1)

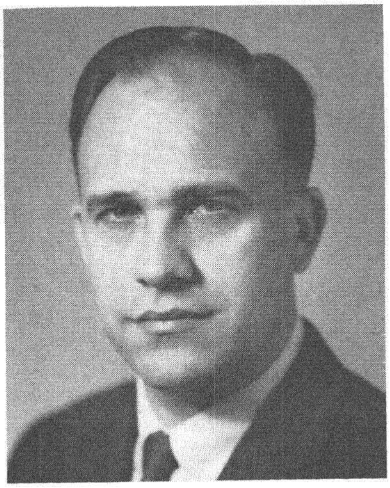
THIS instrument is under contract with the Link Division of General Precision, Inc. The electronic scanning and correlating portions were built by Librascope Division. It was named the Automatic Point Marking, Measuring and Recording Instrument because this is exactly the function that it performs. Its principal purpose is to establish, mark and measure pass-points and control points on a series of photographs for analytical triangulation control extension. It was expected that I would be able to report that everything was performing perfectly at this meeting. Tests that were performed for this status report, however, revealed some necessary minor but essential redesign. It is now expected that the redesign will be completed by the end of April and that testing can be resumed in May 1963.

AIR-BEARING COMPARATOR TABLE (FIGURE 2)

The air-bearing comparator table with its negligible friction and stiction (starting or break-away friction) makes possible automatic positioning, marking and measuring to within a few microns.

GRID POINTS RECORDED (FIGURE 3)

This figure shows the grid points that were read. The plate used is calibrated so that the grid intersections are known to within ½ micron.



EDWARD R. DEMETER

ACCURACY CALCULATIONS (FIGURE 4)

This figure shows the basic calculations and how the accuracy was computed in terms of maximum error and root mean square error or standard deviation. Accuracy along the x-y axis area was found to be reasonable. The maximum error was 10 microns and the root mean square error was 2.9 microns in x and 5.3 microns in y. The corners, however, showed errors in excess of 20 microns. Investigation revealed that a twisting movement was affecting the frame supporting the optical train. The twist movement is induced by the heavy air-bearing table as it extends to its

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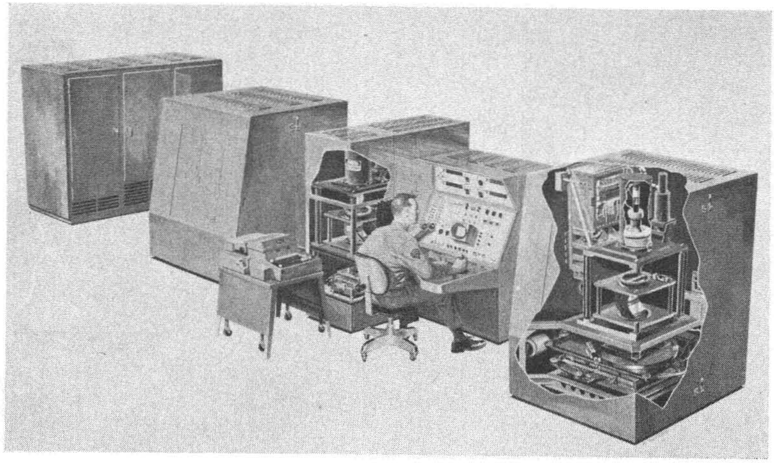

FIG. 1

corner positions. The frame has been redesigned and is presently being fabricated.

POINT MARK (FIGURE 5)

This illustration shows the mark that is recorded on the diapositive, identifying it permanently for future use in compilation. Dies are available for making marks with solid centers of 50 and 75 microns and dies with center circles of 50, 75, 100, 200 and 500 microns. Marking accuracy has been tested on a very limited basis because of other activity in debugging the system. However, preliminary results indicate a maximum error of less than 8 microns and a root mean square error less than 2 microns.

Correlation or automatic positioning accuracy was tested and found to be unsatisfactory. The system is suffering from interference or crosstalk between low signal wires and large signal wires that are housed in the same electrical conduit. The cabling is being rewired to eliminate this condition.

AUTOMATIC STEREOMAPPING INSTRUMENT (FIGURE 6)

The Automatic Stereomapping Instrument was built under contract with Ramo-Wooldridge, Inc. It consists of automatic scanning equipment attached to a Kelsh type stereoplotter. Its input is conventional photography and its output is topographic map data in

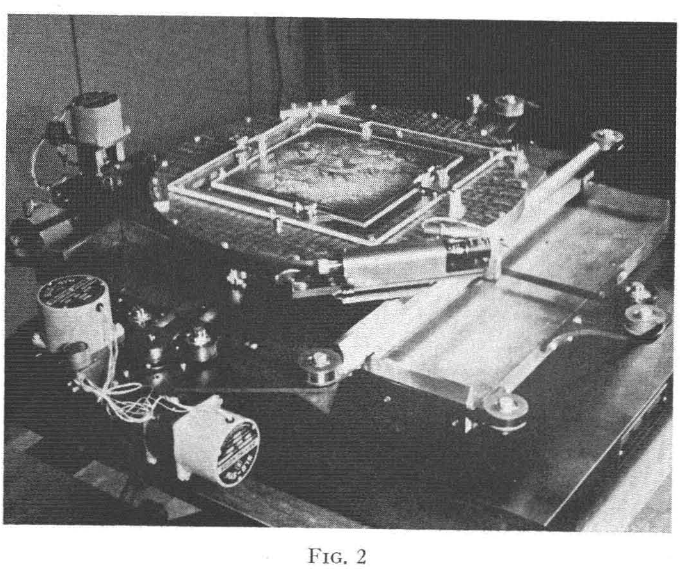

FIG. 2

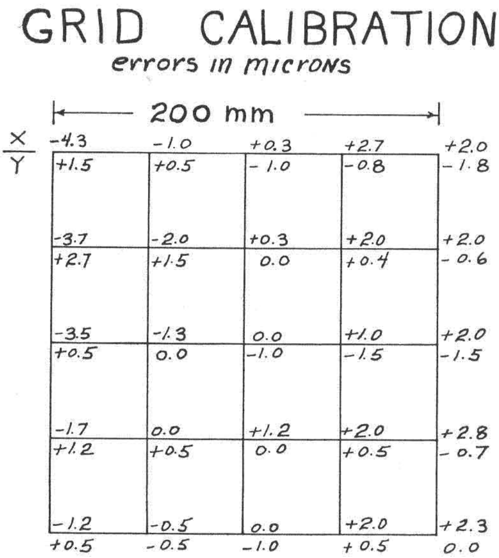

FIG. 3

the form of an orthophoto manuscript and a contour manuscript. Although the orthophoto manuscript can be annotated and used directly as a map, a conventional topographic map is obtained by extracting the planimetric detail from the orthophoto by overlay tracing.

ACCURACY CALCULATION

$$X_i = X_1, X_2, \cdots X_{25} \quad Y_i = Y_1, Y_2, \cdots Y_{25} \quad \text{Significant Digits}$$

$$\overline{X} = \frac{\Sigma X_i}{N} = \text{Mean} \qquad \overline{Y} = \frac{\Sigma Y_i}{N} = \text{Mean}$$

$$dx = X_i - \overline{X} \qquad dy = Y_i - \overline{Y}$$

$$dx' = dx, \quad dy' = dy \quad \text{after rotation and Grid error corection}$$

$$\text{Maximum error} = \text{Maximum } dx' \text{ or } dy'$$

$$\text{R.M.S.E.} \quad \nabla X = \sqrt{\frac{\Sigma_{i=1}^{N} (dx')^2}{N}}$$

$$\nabla Y = \sqrt{\frac{\Sigma_{i=1}^{N} (dy')^2}{N}}$$

FIG. 4

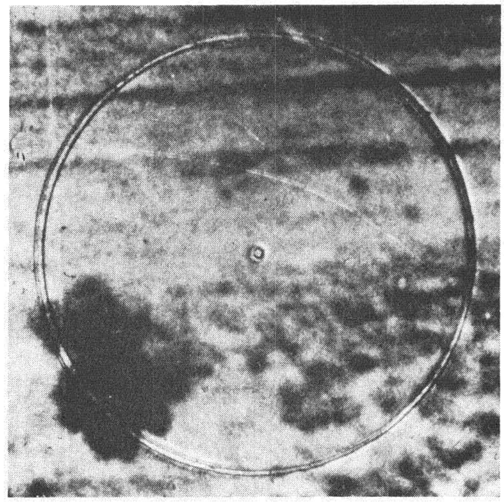

FIG. 5

TEST PHOTO AND ORTHOPHOTO, MODEL 177-178 (FIGURE 7)

This is a comparison between the original photo and the orthophoto output. The apparent band half-way through the orthophoto was caused by a shift in the intensity level of the orthophoto printer.

CONTOUR COMPARISON AND LINE-DROP OUTPUT, MODEL 177–178 (FIGURE 8)

This is a comparison of the manually drawn contours and the contours obtained from the line-drop output on the right. The dashed lines show discrepancies with those compiled on a Wild A-7. The photography scale is 1:20,000 and the model contains 500 feet of relief. The compilation time was two hours including eight manual interventions at points of no correlation. The "*C*" factor obtained is entirely dependent upon how much of the poorly contoured area is excluded and compiled manually. If the bad areas are excluded, the *C* factor is about 500. If the entire area is considered with no manual compilation, the *C* factor computation drops to 200.

TEST PHOTO AND ORTHOPHOTO, MODEL 27-28 (FIGURE 9)

This is a comparison between the original photo and the orthophoto output. The automatic brightness or video gain control sensitivity was adjusted to high and resulted in erasing the shadow area of the hills. It provides excellent correlation and good contouring but degrades the orthophoto. A compromise balance, therefore, must be selected.

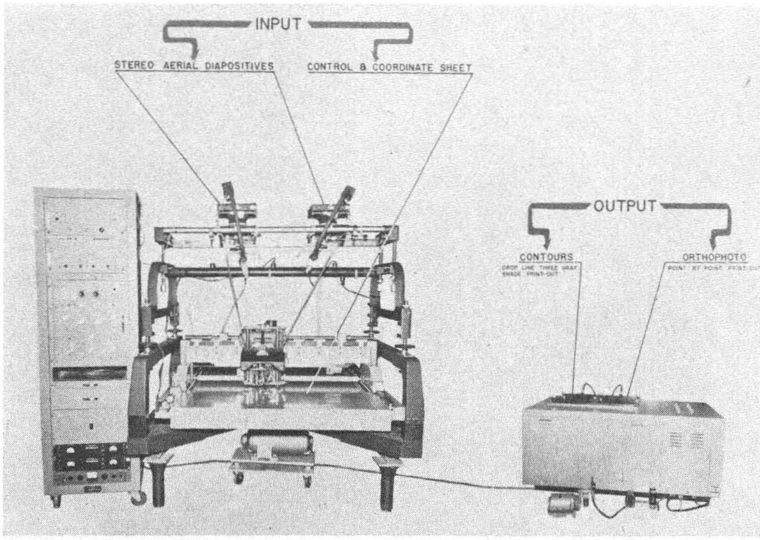
INPUT
STEREO AERIAL DIAPOSITIVES
CONTROL & COORDINATE SHEET
OUTPUT
CONTOURS
ORTHOPHOTO

FIG. 6

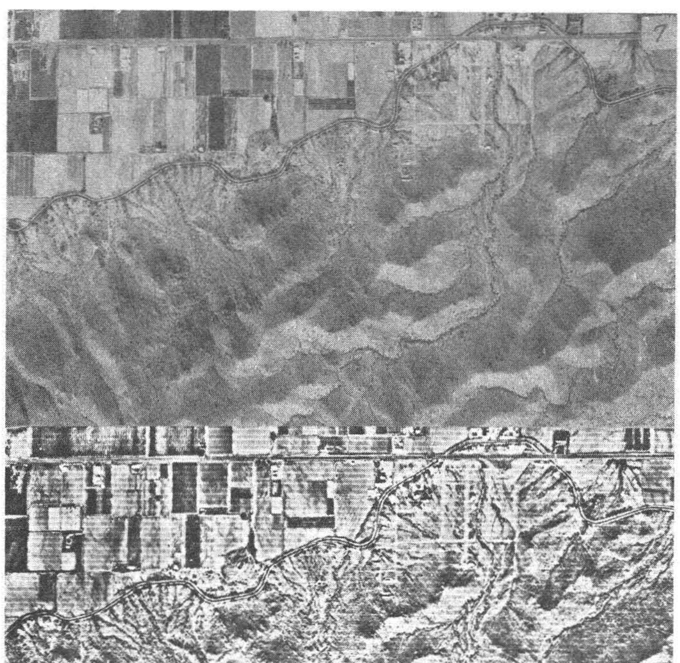

FIG. 7

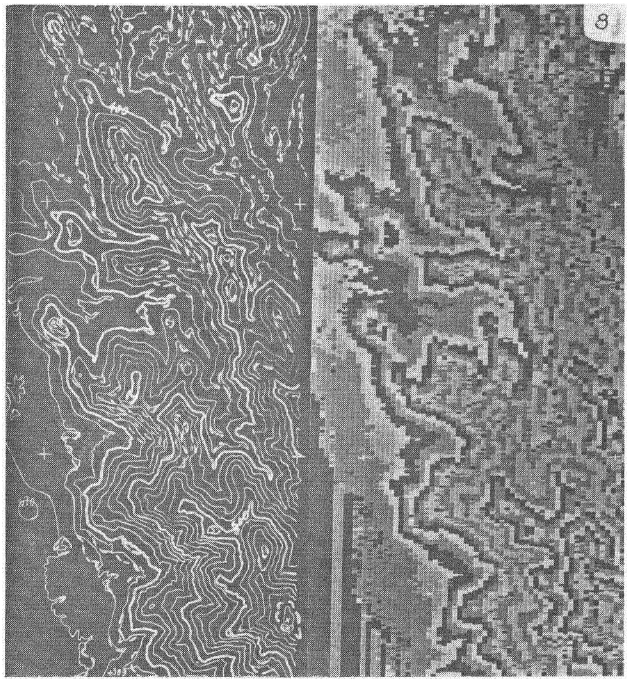

FIG. 8

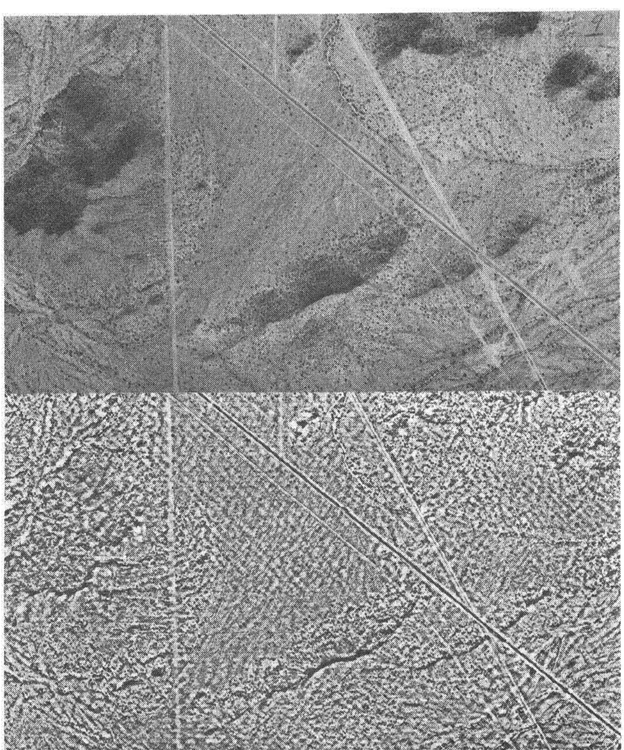

FIG. 9

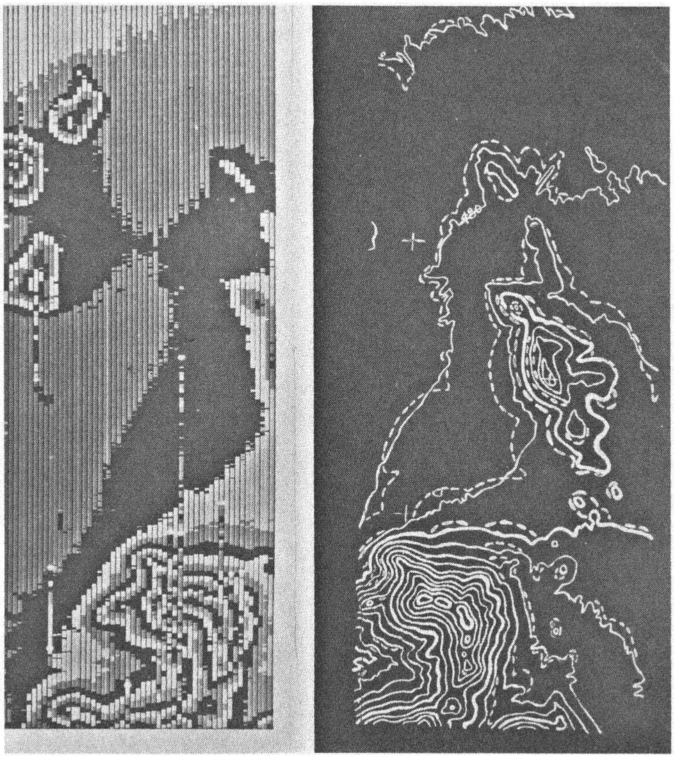

FIG. 10

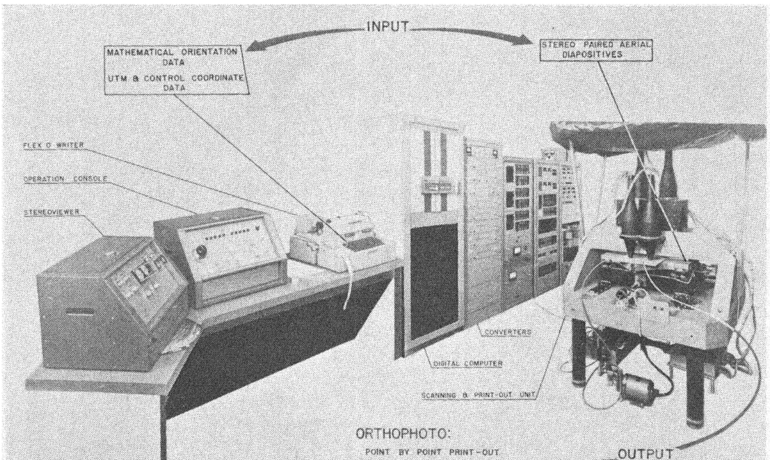
INPUT
MATHEMATICAL ORIENTATION DATA
UTM & CONTROL COORDINATE DATA
STEREO PAIRED AERIAL DIAPOSITIVES
FLEX O WRITER
OPERATION CONSOLE
STEREOVIEWER
CONVERTERS
DIGITAL COMPUTER
SCANNING & PRINT-OUT UNIT
ORTHOPHOTO:
POINT BY POINT PRINT-OUT
CONTOUR:
DROP-LINE, THREE GRAY SHADE PRINT-OUT
OUTPUT

FIG. 11

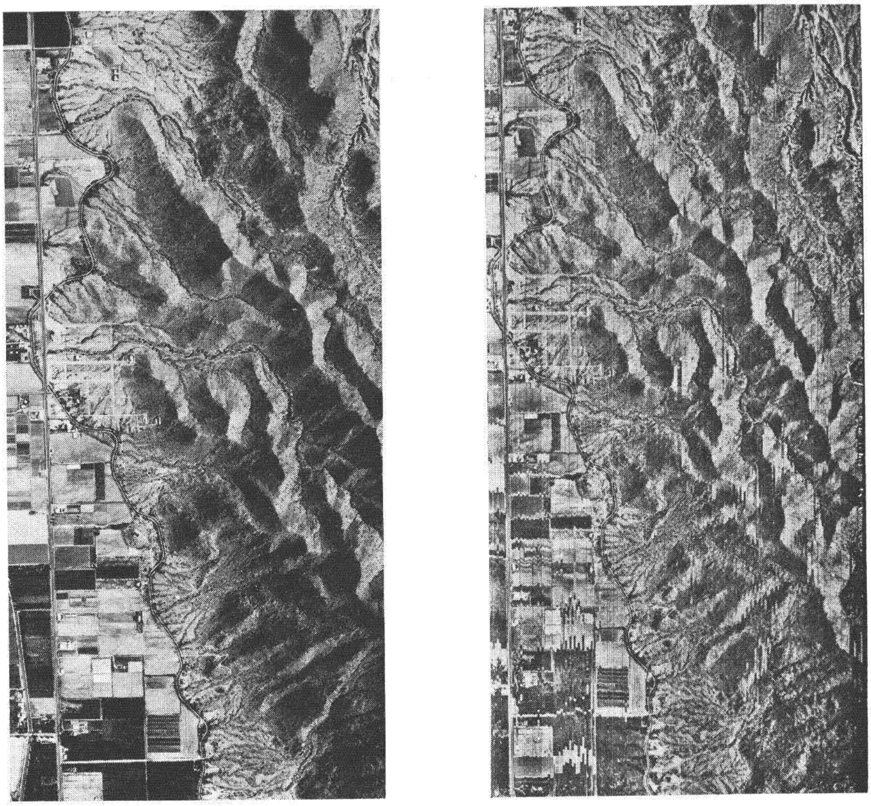

FIG. 12

CONTOUR COMPARISON AND LINE DROP OUTPUT, MODEL 27-28 (FIGURE 10)

This is a comparison similar to the previous compilation for Model 177-178. The compilation time was one hour and ten minutes including four manual interventions. The C factor for the entire area was computed to be 300. If the bad areas are removed from consideration, the C factor increases to 600. The C factors are based upon meeting National Map Accuracy Standards.

The present system possesses a y-tilting capability to approximate the slope in the x-direction. Incorporation of electronic x-tilt circuitry, now undergoing in-house fabrication, is expected to increase system capability in profiling steep areas, thus providing higher output accuracies, greater C factors and a shortening of compilation time per model.

AUTOMATIC MAP COMPILATION INSTRUMENT (FIGURE 11)

This Automatic Map Compilation Instrument was built by Ramo-Wooldridge. It is a continuation of basic concepts for an Automatic Map Compilation System pioneered by Paul Rosenberg Associates of Mount Vernon, New York. The description of this instrument in a paper by Dr. Bertram of Ramo-Wooldridge has been covered in PHOTOGRAMMETRIC ENGINEERING (Volume XXIX, No. 4, July 1963). It uses photography of 9×9 inch format and outputs an orthophoto and contour manuscript similar to the Stereomapping Instrument. It differs considerably, however, in the versatility of input, speed of compilation and accuracy or C factor that ultimately may be achieved. The present instrument, however, is an exploratory research model and does not meet the full potential of this type of system.

TEST PHOTO AND ORTHOPHOTO, MODEL 177-178 (FIGURE 12)

This is a comparison between the original photo and the orthophoto output. The resolution of the orthophoto when referred to the original diapositive plane is 16 lines per millimeter.

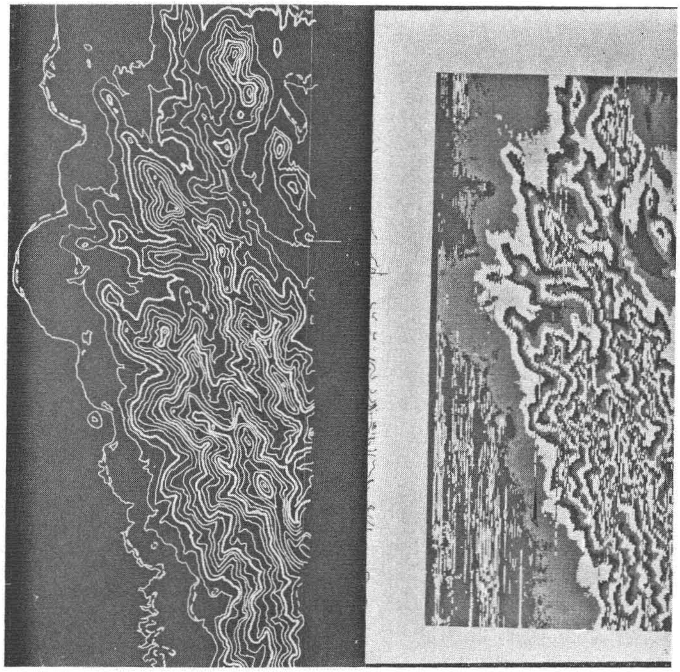

FIG. 13

CONTOUR COMPARISON AND LINE-DROP OUTPUT, MODEL 177-178 (FIGURE 13)

The manually drawn Wild-7 contours (dashed) and the line-drop compiled contours are compared. The area contains slopes up to 72 degrees. The automatic map compilation time for the orthophoto and line-drop manuscript was one hour and fifty minutes. This included more than twenty stops requiring manual intervention which consumed approximately 15 seconds per stop. The computed *C* factor meeting National Map Accuracy Standards is based upon a best fit since the contractor has had considerable difficulty in obtaining the automatic printing of the grid coordinates on the output manuscripts. No allowances were made for horizontal shift, an adjustment if made would produce a higher *C* factor in the steep areas. The best fit *C* factor was computed to be 547 in the difficult high relief areas and 1400 in the normal medium relief and flat areas. If considered as a whole the *C* factor is 974.

TEST PHOTO AND ORTHOPHOTO, MODEL 180-181 (FIGURE 14)

This is a comparison between another original photo and the orthophoto output. The model contains slopes up to 33 degrees.

CONTOUR COMPARISON AND LINE-DROP OUTPUT, MODEL 180-181 (FIGURE 15)

This model was compiled in one hour and twenty minutes with only three manual interventions of approximately 15 seconds each. The *C* factor based upon a best fit was computed to be 680 in the difficult high relief areas, 850 in the medium relief or uniform slope areas, and 1270 in the flat areas. If considered as a whole, the *C* factor is 1000.

The final instrument to be delivered by the contractor will output continuous line contours and approach speeds of forty-five minutes per model. It is expected that the resolution of the orthophoto will be increased considerably and the *C* factor improved to better than 1500.

DIGITAL AUTOMATIC MAP COMPILATION SYSTEM (FIGURE 16)

The Digital Mapping System is being developed by IBM in Kingston, New York. It is different in that it converts the pictorial data into digital form before the mapping process begins and converts it back to a pictorial form only after the process is completed. However, it is similar in that it also outputs an orthophoto manuscript and a contour manuscript as do the other systems. The principal ad-

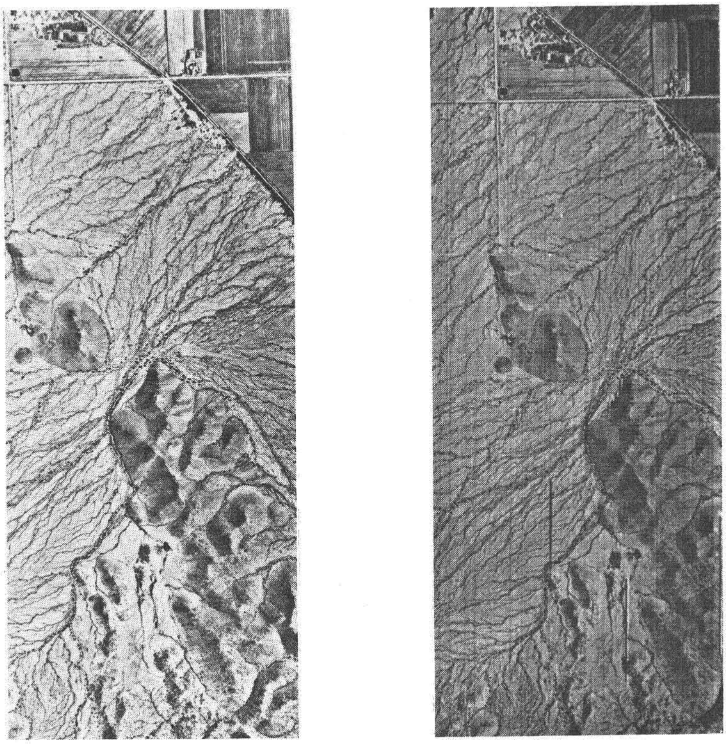

FIG. 14

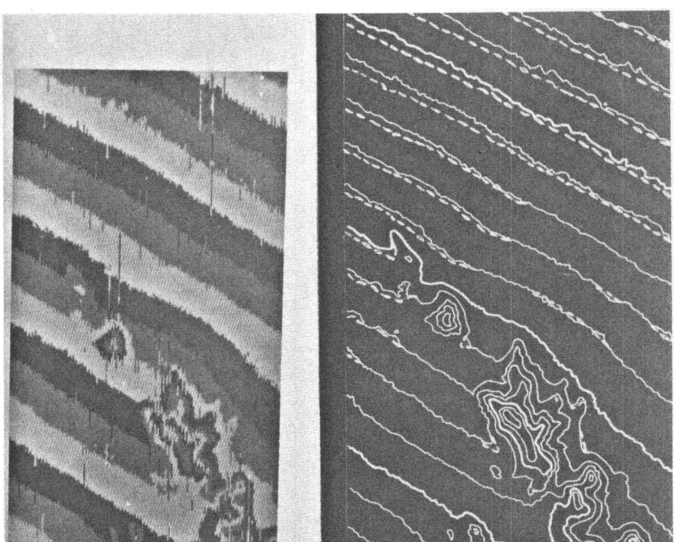

FIG. 15

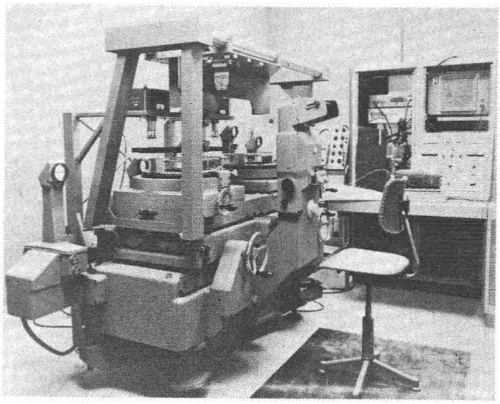

Fig. 16

vantages of the system, high accuracy, speed, resolution and flexibility, are theoretical and have yet to be achieved in practice. The system promises to be the most versatile and accurate of the automatic mapping equipment under present development. Since it is the most sophisticated system and the one most recently placed under development, it has a long way to go before achieving competitive status with the other instruments. A contract is in progress in which IBM is exploring this concept, using a laboratory arrangement of a scanning system mounted on a Wild STK-1 stereocomparator for digitizing the photographic data and printing the orthophoto and contour manuscripts. An IBM 7090 computer is used on a rental basis for processing the data. The objective of the contract is to develop electrically refined equipment and a computer program sufficient to produce the required outputs meeting minimum mapping accuracy standards.

Orthophoto, Model 177-178 (Figure 17)

This is one of the orthophoto manuscripts that were printed. The horizontal accuracy of the orthophoto appears to meet National Map Accuracy Standards; however, exhaustive tests have not been made because of deficiencies in the contour output. It is expected that completely satisfactory outputs will be achieved before this fall.

The present speed per model is not indicative of what can be finally achieved; however, for the curious it is reported that with this laboratory set-up it requires approximately 8 hours.

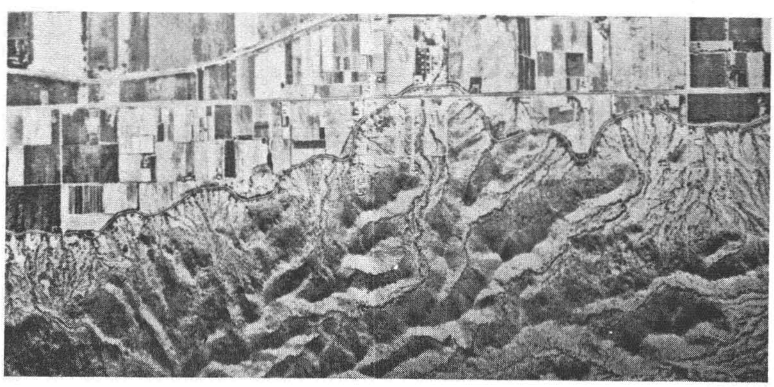

Fig. 17