a location acceptable to the majority of interested people; (2) a twelve-month survey season instead of the usual six; (3) a saving of engineering manpower for preparing contract specifications and supervision of construction; (4) the survey dollar stretched over many more miles than it previously covered; (5) already a saving of many miles of high-cost construction and avoidance of difficult areas by being able to "look ahead" through photogrammetry.

Although the equipment represents a considerable monetary investment, there is every reason to believe that in two to four years it will pay for itself in actual cash savings to the U. S. Forest Service. This estimate is based on a double-shift capacity of 150 miles of road design per year at a savings of approximately $300.00 per mile or $45,000 per year. Each operation is directed toward saving time and money and the elimination of interference from adverse weather conditions, limited field season and personnel shortages.

The efforts are only just beginning to materialize into production. The operation has been shifted into second gear—so to speak—with 16 hours of operation per day; there is hope of having seven road surveys completed within the next 6 or 8 months. A standing invitation is given to visit the laboratory to observe the work, discuss procedures and exchange a few ideas. Like topographic mapping, engineering surveys have taken to the air and tedious computations are being comfortably consumed by the electronic computer.

The Forest Service engineers have accepted these new tools and are enthusiastic about their possibilities. It is hoped that they will help others to accept and use these tools successfully.

The operations and procedures described in this paper are in use by the Forest Service, U. S. Department of Agriculture at the Region 4 headquarters of the Forest Service at Ogden, Utah. Dr. Richard E. McArdle is Chief of the Forest Service and Mr. Floyd Iverson is Regional Forester for Region 4. Mr. Arval Anderson is the Assistant Regional Forester in charge of the Division of Engineering and the author is Chief of the Cartographic Section of that Division.

*Mapping of the Ungava Peninsula**

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ABSTRACT: *The mapping of the mineral wealthy Ungava Peninsula of northern Quebec has provided the Topographical Survey of Canada to assess new survey and photogrammetrical techniques on a large practical test. The environment is described with particular emphasis on mapping conditions and the initial planning and surveys are outlined. In the Ungava operation the application of electronic instruments was impressive and included the use of Shoran for geodetic control, radar altimeters for vertical control and horizontal scale, tellurometers for secondary survey control and for establishing scale on selected flights. Experience gained from the Ungava project should reduce the cost of mapping in the northern areas of Canada.*

THE mapping of the Ungava Peninsula of northern Quebec has proved to be one of the most important mapping projects ever undertaken by the Topographical Survey of Canada. The reason is not that the potential mineral wealth of the Penin-

* By permission of the Director, Surveys and Mapping Branch, Department of Mines & Technical Surveys, Ottawa, Can., presented at 24th Annual Meeting of the Society, Hotel Shoreham, Washington, D. C., March 26, 1958.

sula which might be very great, nor the number of square miles involved, but rather because it has given us an opportunity to assess new survey and photogrammetrical techniques on a large practical test. Initially, the job was not planned to be experimental in any way; but through force of circumstances Ungava has, in fact, turned out to be an excellent proving ground. Compilation of the maps is far from being complete, but good progress has been made on the less predictable phases of the job, and the balance of the work should follow the well established pattern of the many other comparable mapping projects we have undertaken.

At the 50th Annual Meeting of the Canadian Institute of Surveying and Photogrammetry, Col. Gerald Fitzgerald gave a most interesting paper entitled, "New Tools for Mapping Arctic Alaska." It was after listening to his description of some of the new photogrammetrical methods used by the United States Geological Survey for mapping the Brooks Range that it occurred to me that the mapping we were then planning for Ungava might provide suitable material for a paper on a large Canadian project. This has proven to be so and I hope that I can do justice to this interesting job in the time available.

The Ungava Peninsula is rugged and treeless and subjected to Arctic weather conditions for about eight months of the year. Although few of the hills can be classed as mountains, they are numerous and rise abruptly several hundred feet. The many lakes and streams are ice free from the end of June to the beginning of October.

Wildlife consists of the thousands of geese which make Ungava their summer home and the scattered remnants of what used to be large caribou herds. Fishing is excellent on the inland lakes and the fisherman can normally count upon landing a five pound speckled trout or arctic char within a few minutes.

The native Eskimos form the larger part of the population. In addition, missionaries, Hudson Bay factors, Royal Canadian Mounted Police officers, Department of Transport wireless operators, northern service officers and nurses form the permanent population of the few scattered settlements along the coastline.

Communications to and in the area are difficult, roads and railroads being non-

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existent. In the summer, travel is by water along the coast or by seaplane if moving inland. By winter, travel is by dog-sled or ski-equipped aeroplane. During the four month navigation season, supplies can be brought from the south via Hudson Strait or from Churchill or Moosonee across Hudson Bay. There is a regular air service from the south into Chimo at the bottom of Ungava Bay, and in the summer there is a flying boat service from Moosonee to the settlements along the east shore of Hudson Bay.

The mapping planned for Ungava Peninsula covered some 14 standard national topographic series maps at 1/250,000 scale with 100 foot contours. The area extends from the 71st Meridian of west longitude westward some 250 miles to the east shore of Hudson Bay and from north latitude 58° northward to Hudson Strait some 300 miles distant. In addition to the 70,000 square miles of small-scale mapping, some 9,000 square miles of 1/50,000 scale maps showing 50 foot contours was required through the known mineralized zone extending from Wakeham Bay in Hudson Strait to Mosquito Bay in Hudson Bay.

Complete map coverage at the reconnaissance scale of 8 miles to the inch was available for planning purposes. These maps were compiled from trimetrogon photography and positions obtained by astronomical fixations. In 1955, the Topographical Survey had established a net of triangulation control between the west shore of Ungava Bay and the 71st Meridian, following this Meridian south to the 58th parallel of latitude. This net, which was used to control a band of 1/50,000 mapping, was tied to the shoran stations which had been established by our Geodetic Survey. Further triangulation control was being extended from the topographical net westward up the Payne River, for the purpose of determining the area and power potentialities of that drainage system for the Quebec Streams Commission.

It was anticipated that the Ungava area would be extremely difficult to photograph, not only because of the short season during which it is free of snow and ice but also because of the cloud and fog conditions encountered when the ice starts melting on Hudson Bay. Since it was probable that there would be more photographic days suitable for intermediate-scale vertical photography than for the small-scale normally requested for northern operations, it was decided to accept 20,000 foot photography despite some loss in mapping efficiency. Other factors favouring this decision were that the Geological Survey indicated a preference for the larger scale photography for its investigations, and it was probable that radar altimeter profiles could be taken simultaneously with the photography at this altitude.

As expected, poor photographic conditions have been encountered and on the completion of the first season's photography in 1955 only 45 per cent was covered of the 72,710 square miles called for in the contract. A further 14,600 square miles were photographed in 1956 and coverage was available for the southern two-thirds by the time our field surveys commenced in 1957. A few more lines were added in 1957 and the area that still remains to be done is approximately 20,000 square miles all of which is in the northern section, the area where mineral occurrences are now being investigated.

Coupled with the contract for air photography was a specification for radar altimeter profiles along each flight line. Thus vertical control was to be obtained by electronic means from the air. For the photographic lines flown with A.P.R. equipped aircraft, profiles and vertical photography would be taken simultaneously.

Field surveys were scheduled to commence in 1956 using helicopters supported by float-equipped Beaver aircraft and the bulkier supplies such as gasoline were shipped during the summer of 1955 to Port Harrison, Povungnituk and Chimo, key bases for the field operations. However, since progress on photography in 1955 was poor, the survey was postponed a year. By 1956 the tempo of the mineral exploration in the area had increased, and it was decided to proceed with the survey control in 1957 even though the photography was far from complete. Fortunately the trimetrogon photos of the area were good and these flights subsequently proved useful in several ways.

The original plan for survey control was to extend a triangulation net around the coastline starting at Hudson Strait from our own work on the 71st Meridian, following the shore westward to Cape Wolstenholme, down Hudson Bay to the 58th parallel, and thence eastward to the 71st Meridian. In addition, two east-west nets were to be run from Hudson Bay to the 71st Meridian at about latitudes 60 degrees and 62 degrees, the whole system to be tied to the four shoran stations in the area. To subdivide this framework to control the east-west mapping photography, it was planned to have several bi-camera flights with simultaneous A.P.R. run in a north-south direction. The total control, approximately two field seasons work for the survey crew, amounted to 1,900 line miles of triangulation plus 1,400 line miles of bi-camera photography, the cost of the latter being approximately $50,000.

However, before this plan was put into effect, it became evident that the Topographical Survey would be equipped with the Tellurometers for the 1957 field season. The plan was therefore modified to take advantage of this new equipment.

From the information that could be gleaned from the sketchy reports available, it seemed that a transit and tellurometer traverse could be run much faster than a triangulation net, provided, of course, the staff could be trained to use the equipment effectively, and these new electronic tools could be depended upon to remain serviceable. With these provisos, investigations indicated that the major problem would be moving camp, since the rate of progress might be two to three times that of previous years. It, therefore, seemed advisable to increase the amount of survey control and cancel the bi-camera lines.

Our survey party arrived at Chimo on the 15th of June but was delayed there owing to the late spring and the slow breakup of the ice on the lakes. Work finally got underway on the 5th of July and, despite the vagaries of the weather, all the field work, including the horizontal and vertical control for 9,000 square miles of 1/50,000 mapping, was completed by the 22nd of August. In 38 working days 2,100 lines miles were traversed and 600 miles of distance measurements taken, the latter being used to provide horizontal scale for selected trimetrogon flights. The average closure on 500 mile survey loops is about 1 in 35,000, much better than we would have obtained by third-order triangulation.

Trigonometric levels were carried on the Tellurometer traverses and tied to common points on the radar altimeter lines, the latter being adjusted to the traverse values. The general agreement between the two systems of levelling has been remarkable, differences being of the order of about 10 to 15 feet. It would seem, therefore, that A.P.R. heights are quite acceptable for this scale of mapping.

Our field parties engaged on major survey operations are usually equipped with uncontrolled mosaics to facilitate traveling and the selection of control points. In the areas not covered by vertical photography, strip mosaics made from the vertical flights of trimetrogon photographs proved to be very useful. The survey party was also provided with a 5×5″ camera with a 5″ cone which was used for photographing control points from a height of about 2,000 feet. This method of identification proved particularly useful for recording control points in the areas not covered by vertical photographs.

The area for which maps are most urgently required lies in the mineralized zone Since vertical photographs of this important area are not yet available, planimetric maps are being compiled from trimetrogon photographs at a scale of 1 inch to 1 mile as temporary map coverage. Some of the field control for the 1/50,000 mapping had been located on the trimet flights and these could, therefore, be well positioned. Several methods of extending control were attempted using the obliques of the trimetrogon flights. Best results were obtained by photo-alidade resections on well identified detail along the control flights, and then computing the plumb point position. This system would seem to be more accurate than the graphical method normally used when compiling from trimetrogon photographs, and may have some application to small-scale mapping.

The photogrammetrical techniques being used on this job are varied but by no means complex. The objective is to provide some form of perimeter control for a number of blocks measuring approximately 50 miles by 50 miles and the major framework of survey control has been previously described. Secondary control is being established photogrammetrically as follows:

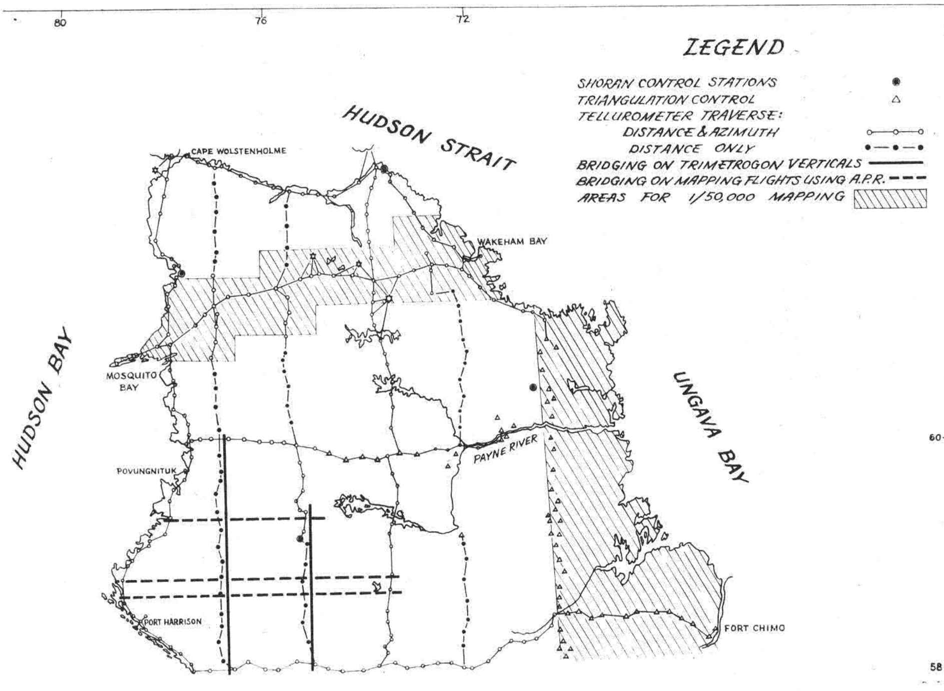
(1) Selected north-south flights of vertical photographs from the trimetrogon photography are bridged on a first-order plotter, and scale corrected according to Tellurometer distance measurements. Although these flights will bow, the over-all distance between any two selected points should be good. The latitude values of points along these north-south flights can therefore be accepted.

(2) Selected east-west mapping flights having A.P.R. information taken at the time of photography are also plotted on a first-order machine between field-control points. Ground clearance for each photo is introduced into the machine and thus the horizontal scale throughout the plot should be uniform. After a small adjustment for over-all scale, the points along these east-west control flights should be accurate in longitude, but are probably displaced in latitude.

(3) The knot points between the north-south control flights and the east-west control flights are adjusted to the stronger latitude and longitude values.

(4) Normal bow corrections are applied to all the control flights based on positions obtained as above.

In some instances it has been necessary to run short bridging flights to establish



start points on the north-south flight. This could have been avoided by locating horizontal control points at each end of these flights. Having established perimeter control for each block, normal slotted templets at photo scale will be laid to this, and should give a satisfactory answer for this scale of mapping.

The final steps in compilation of the small-scale mapping will be the hand contouring of photos under a simple stereoscope using the adjusted A.P.R. values for height control and the transferring of planimetry and contours to the manuscripts with the vertical sketchmaster. In areas of more complex topography it is probable that a third-order plotter will be employed. The multiplex method will be used for both the bridging and topography of the 9,000 square miles of 1/50,000 mapping which we hope to have photographed in 1958.

The application of electronics to the Ungava surveys in some form or other makes an impressive list:

1. Shoran Geodetic Control for Primary Positions
2. Radar Altimeter Values for Vertical Control
3. Radar Altimeter Values for Establishing Horizontal Scale
4. Tellurometer Traverses for Secondary Survey Control
5. Tellurometer Distances for Establishing Scale on Selected Flights

I think you will agree that this Ungava project has given the Topographical Survey an opportunity to test a wide range of field and office mapping methods and equipment. Unusual combinations of electronic measurements, varied requirements and unconventional methods of tying together the whole job has made this one of the most interesting projects we have undertaken. It may be too early to draw conclusions, but we are confident that the results obtained will prove entirely satisfactory. The Ungava job has already provided valuable information which is being used in the planning of future operations, and should help to reduce the cost of mapping in our northern areas.