WHAT CANADA IS DOING WITH THE AID OF CAMERA AND AEROPLANE

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IN ORDER to understand the progress of photogrammetry in Canada, it is necessary to take into account the character of the topography and the distribution of population which are factors that have influenced the trend this science has taken. Canada is a young country and still is in the development stage. Its area is somewhat larger than that of the United States but only a relatively small part of it is well populated. Of the balance much is sparsely settled and the larger part is altogether unsettled or has very isolated settlements.

By examination of the map of Canada you will see that there are no railways or roads in the more northerly parts of the country. Travel in the past has been largely by canoes and this has been possible only in the short season of open water. This condition is changing and regular air routes are being opened up. Supplementing these routes, transportation into nearly any part of the country is effected by aircraft. We are rapidly becoming independent of the tedious pioneer means of transportation.

The distribution of population, however, is a poor indication of the potentialities of the country. Because large areas are virtually unexplored, it should not be assumed that the resources are all embraced within the settled parts. The vast, sparsely settled or unsettled regions contain resources which scarcely have been tapped, the extent of which it is difficult to estimate. Sufficient is known, however, to permit of considerable optimism. Opinion varies from extravagant prophecy to optimistic conservative estimate. All that can be reasonably certain is that there is hope for a period of prosperity.

The prosperity of Canada is closely associated with the development of the natural resources. Many of the centers of population are dependent for their basic activity upon developments often hundreds of miles away. These developments are increasing more and more in newly explored country often difficult of access. Canada is very fortunate that the era of flying has come at this time. It is most opportune. Developments which were impractical before the recent advance in flying now are economical propositions. Travel and transportation have been revolutionized and the north is coming into its own.

The problems confronting photogrammetry to a very large extent are those affecting a pioneer country. While the settled districts present problems for the photogrammetrist, the primary objective of photogrammetry is to be of a maximum of assistance in the discovery and development of new resources. For this reason the endeavor has been to concentrate on methods suitable for the accomplishment of this objective and which will push back the frontier as rapidly as possible.

Of the natural resources which require the assistance of photogrammetry, mining and forestry are outstanding. Agriculture, power development, transportation, public works—all present problems—and investigations are carried out in these connections, but the former to a greater and greater extent are depending upon air photography for assistance in development. During the business recession of recent years, mining and forestry contributed materially toward mitigating the severity of the depression and it is safe to say that their ability to expand under these difficult conditions was rendered much easier by improvements in air mapping and transportation.

The application of photogrammetry in Canada has developed along lines peculiar to that country. Study has been directed more toward meeting the main objective of developing our country than along purely scientific experimentation. I do not mean to say that the latter phase has been neglected. That is not the case. I do mean that even the research in this science has as its major purpose the improvement in procedure and in instruments particularly applicable to the main problems.

The larger part of the unexplored areas lies within the Canadian Shield, an area of Precambrian rocks covering over two million square miles surrounding Hudson Bay. As you may know, the southerly part of the Shield contains the great mineral belts of Ontario, Quebec, and Manitoba, and similar mineral fields may await discovery in the vast northern region. In fact, one such field has already been opened up at Great Bear Lake where deposits of radium and silver have been found and another at Lake Athabasca and Great Slave Lake where important discoveries of gold have recently been made.

Another part of the unexplored country lies in the Cordilleran belt of British Columbia. This too has great mineral possibilities and maps are urgently required for effective prospecting.

Canada is also well endowed with a wide range of marketable timber. About one-third of the country is forest-covered. It, as you know, stands high among the lumber producers of the world and its contribution to the pulpwood situation is well known. I mention these facts in order to emphasize the enormity of the problem with which photogrammetry is confronted in assisting the development of mining and forestry.

By ground travel it has been economically possible to penetrate effectively only the more accessible parts of the country. I use the term effectively in order to qualify this statement so as to give due credit to the explorers who have made such valuable contributions to the knowledge of our country. But even these valuable explorations could only follow natural travel routes and extend back from them a very limited distance. It is true that each exploratory trip made it that much easier to penetrate further but this process would have required an unpredictable time to produce maps which could be classed even as high as reconnaissance.

With the advent of flying these restrictions have largely been removed. The element of travel time has been reduced to a relatively minor factor, permitting of a much larger part of the available working season being devoted to effective exploration. In contrast with the weeks which formerly were spent in travelling to many fields of work, travel time is now measured in hours. The result has been that country which would not have been prospected for years is being made as accessible as that just beyond the frontier.

Ground Photogrammetry

On account of the extensive mountainous areas, photogrammetry has played an important part in Canadian mapping practice for over fifty years. The ground photographic method as developed by Laussedat in Europe found its most extensive application in Canada, chiefly in the mountainous areas of British Columbia, Yukon Territory, and the western part of Alberta. Its first application was in 1886 when it was employed to map a strip of country along the main line of the Canadian Pacific Railway through the mountains of British Columbia. The results were a complete justification of the use of this method rather than that of plane table intersection, and it has since been firmly established as a standard Canadian mapping practice. During the last field season

more than 12,000 square miles were mapped in this way, the very large part of which was at a scale of 1 inch to 4 miles. This, as you will see, is in keeping with the objective of providing quick reconnaissance so that preliminary investigations may be carried out with the aid of the topographic information of commensurate accuracy.

During the last five years, considerable attention has been directed toward overcoming the handicap imposed upon ground photographic mapping by prevailing weather conditions. Rain and smoke have been a great hindrance to effective photography, and the field season, under the best conditions none too long, was considerably curtailed as a consequence. Infra-red plates have replaced orthochromatic and panchromatic which were in use formerly. This has resulted in a very appreciable reduction in the amount of time lost due to rain, and has greatly improved the definition of features and increased the distance at which detail can be obtained.

Attention is being directed also toward simplification of the camera. The one in general use is somewhat cumbersome. Experiments are being made with the object of reducing the weight and of obviating some of the operations now associated with the procedure of the camera station. These have followed the line of combining the camera and transit, and as a result it has been possible to do away with the camera sketches which otherwise were considered essential.

The office equipment also is being modified. Study along this line is in connection with the elimination of picture traces by a greater use of direction rays. It is hoped to avoid the confusion of disfiguring lines which are necessary when picture traces are used.

Air Photogrammetry

In Canada, air photographic mapping is divided into two spheres of work: the flying and photographic operation, and the reduction of photographic information to map form. While there is a close liaison between the two operations it should be understood that insofar as government work is concerned, the former lies within the province of the Royal Canadian Air Force. This Service carries out the flying and photography on request from other Services and also provides air transportation for surveyors engaged in making astronomical observations for control in the areas which it is photographing. This work is in the nature of a by-product of R.C.A.F. training activities and was originally initiated in 1921 with the Air Board of Canada and continued in 1923 when the work of the Air Board was absorbed by the Department of National Defence.

Insofar as air transportation is concerned, the R.C.A.F. feels that this work belongs to commercial companies and every precaution is taken to keep out of this field. Where these companies have equipment, suitable for carrying out air photographic operations in keeping with the requirements of the mapping authorities, contracts are sometimes let for such work as may more conveniently be handled in this manner.

To insure that flying operations are co-ordinated and duplication avoided, the Interdepartmental Committee on Air Surveys and Base Maps has as one of its functions the consideration and recommendation of the requests which are of most pressing necessity and which can be carried out within the appropriation for this purpose. It also acts in conjunction with the Topographical Survey, Department of Mines and Resources, in preparing flying instructions.

All negatives taken by the R.C.A.F. remain in the possession of that Service and are stored in fireproof vaults especially equipped with apparatus designed to minimize the damage which might be caused by fire. Prints from these negatives are supplied at fixed charge on order by the Air Photographic Library.

Research

For the greater co-ordination of mapping activity and in order to encourage research work for survey purposes, the Associate Committee on Survey Research of the National Research Council has been established. It consists of officers representing the Department of Mines and Resources, the Department of National Defence and the National Research Council. The work of the Committee between meetings is maintained by a small executive. The detailed research projects are under the guidance of special sub-committees. At the present time these are four in number but there is considerable flexibility in that regard and the number may be increased when the necessity for doing so arises.

The sub-committees are set up as follows: (a) Photographic Aircraft and Cameras (b) Mapping Methods (c) Photographic Technique (d) Survey Instruments. Details of the various activities and accomplishments of the Committee are contained in the Annual Report of the National Research Council under "Committees."

Aircraft

After consideration of the various types of planes available on the market, the R.C.A.F. has selected for their photographic operations the Northrop Delta to which can be fitted wheels, floats or skis, as best suited for the area in which operations are to be carried out. There will be available for this season's program nine photographic aircraft comprised of Northrop Deltas, Fairchild Super 71 and Bellanca cabin aircraft, all equipped with floats. It is expected that the Bellanca will be replaced by Northrop Deltas when they become worn out.

With the exception of one project area under consideration for photography, no flying fields exist in areas to be mapped. This condition has existed in the past and, as a consequence, the use of wheel landing gear has been impractical. There are, however, abundant bodies of water of suitable size upon which to land with floats, so this is logical landing gear. The sole exception as far as present operations are concerned is in the Drought Area in the southern portion of Saskatchewan. In this area no water bodies of suitable size exist and wheels are used.

At the conclusion of the war, the old free-nose flying boats were used in Canada for photography. They had a very limited range of photographic flight at an altitude of 5,000 feet. The limit of this range did not exceed 225 miles which was a serious handicap to effective mapping. The change to cabin aircraft, equipped with floats, allowed for a considerably longer duration of flight with greatly improved performance. The altitude adopted for oblique photography is 8,000 feet and the spacing of parallel flight lines has been increased from six to eight miles. The change of aircraft necessitated an alteration in the camera mounting. Where formerly photography was from the cockpit in the direction of the route, it is now from inside the cabin and is in the general direction of the track of the aircraft.

Cameras

The first air cameras used in pioneer operations were war time productions, one type using plates and another films. The latter, a Kodak Eagle Camera with a "Hawkeye" lens, a suction device for holding the film flat and a focal plane shutter, was fitted with collimating marks and its principal distance determined at the Survey Laboratory. It was probably used for taking the first photographs in Canada seriously intended for map production. One of these cameras is preserved in the Surveys Museum of the National Research Council.

Later, the K3 Fairchild camera was adopted by the R.C.A.F., this camera

being a marked advance on war time instruments. At an early date the focal plane glass plate of these cameras was etched with a cross to register on each photograph the position of the principal point. Due to tolerances in the fit of the magazines and of the component parts of the camera, there was always some uncertainty as to the correct position of the cross, and representations were made to the Fairchild Corporation which resulted in the production of the F3 type camera with the glass plate permanently fixed in the body of the camera and dowels fitted to insure correct registration of the camera parts when assembled. In these cameras the glass plates are interchangeable, as the principal point has been established by a jig with reference to two adjacent and specially ground edges of the plate which fit snugly against bearing surfaces fitted to the camera. F3 cameras have been used whenever possible in all survey operations with the K3 cameras relegated to less important work.

The cameras are calibrated and the shutter speed checked each year after overhaul in the Camera Shop of the R.C.A.F. by the National Research Laboratories. Laboratory methods are used exclusively. The position of the principal point is checked with the aid of a mercury surface and an auto-collimating eyepiece. For measuring the principal distance (and initially for determining lens distortion) a simple apparatus layout has been developed (see *Canadian Journal of Research* 1934, pp. 239–243). This method yields both principal distance and distortion to a high degree of accuracy and includes the effect of the glass plate.

Camera Lenses

Focal lengths of about 8 inches have been most commonly used, with 6 inches, 10 inches, 12 inches and 20 inches available for special applications. The F3 cameras are fitted with Ross Xpress lenses of f/4 aperture. So far no attempt has been made to stop down these lenses in summer but it is possible with the improved photographic materials now becoming available this may be tried.

A seven lens multi-lens camera has been tried only to a limited extent as the use of floats renders it difficult to find the unobstructed field of view required. The present opinion is that the best field for investigation is the wide angle single lens now being developed. The Surveys Research Committee is endeavoring to acquire a Ross Survey lens of f/5 aperture and capable of yielding a good image relatively free from distortion over a field of more than 45 degrees from the axis. It is felt a lens of this type promises to give a useful field of view wide enough for all practical applications in vertical photography without the complications of the multi-lens camera and the difficulties inherent in obtaining rectified prints of desired quality.

Some work has already been done with six-inch Ross f/6 lenses in $7'' \times 9''$ Fairchild cameras and the present consensus is that future cameras should be $9'' \times 9''$ and fitted with a lens of $6''$ focal length. This would result in a minimum of exposures at reasonable photographic scales.

Camera Mounts

In the early work, oblique photographs were taken from free-nose flying boats, a single camera being used, so that the central and the wing photographs were necessarily exposed from different camera stations. Now that faster cabin aeroplanes are used, three fixed cameras are mounted in each machine and are exposed simultaneously by means of one intervalometer. The pictures are thus referred to a single station and are very suitable for use in the High Oblique Plotter, where the camera station can be determined by resection and control carried through series of oblique photographs.

A considerable amount of development work has been carried on with regard to camera supports. The mount just mentioned for oblique photography is a stiff light beam casting of Dow metal with each camera supported from three points. The dihedral and depression angles are set by means of a transit (or preferably three transits) in a location where a distant point is visible as an azimuth reference. Once set, the cameras are dowelled in position and a levelled surface on the casting permits the correct angle of depression to be reproduced in the aircraft. From the calibration constants and the known values of the dihedral and depression angles, it is possible to find the true tilt of one of the cameras if the trim of the aircraft is such that the horizon is not registered for that camera.

Auxiliary Equipment

Instrument records, particularly those of a sensitive altimeter to indicate elevation differences between successive camera stations, are very desirable. The Exposure Recording Altigraph does this automatically with the requisite accuracy. This special altigraph was developed in the National Research Laboratories. It gives an open height scale of 1,000 feet equal to one inch height of chart by limiting the operation of the pen to the strata of height in which photography is to be carried out—say 7,000 to 10,000 feet above sea level. Secondly, it gives an open time scale of $\frac{1}{4}$ inch to one minute over a period of several hours with good accuracy. Thirdly, it records the time of exposure of the air cameras by tapping the electrical trip circuit of the intervalometer. The impulse received operates a hammer by means of an electromagnet and gives the tracing pen a flicker which indicates the instant of exposure on the height trace.

It is possible that future cameras will be fitted with a special recording camera for the purpose of registering instruments but preferably without sacrificing any of the field of the picture proper. For use with existing cameras, a special auxiliary camera is now under development by the National Research Laboratories to photograph a number of aircraft instruments on a single frame of standard moving picture film each time that the air camera shutter is operated. It is hoped to utilize the data so obtained for a more accurate determination of the camera station. A device for registering the true tilt on each photograph would be a valuable one but to the present no original progress has been made in this direction.

Film and Paper

The Topograph Non-shrink film base which shows low shrinkage and distortion is in use. The emulsion is a super-sensitive panchromatic of good keeping qualities and with good sensitivity value toward the long wave lengths of the spectrum. A minus-blue filter is regularly used and it serves to eliminate, from the picture-forming rays, those of shorter wave lengths such as the ultra-violet, violet and most of the blue to which the film is very sensitive. It has been found that the contrast in the tones of air photography is improved greatly by utilizing the longer wave lengths to which the emulsion must be sensitive. The advances in fineness of grain of recent fast emulsions have produced much better pictures in recent years.

A standard double-weight paper exhibiting under test low shrinkage and distortion and which will lie flat under working conditions is used. This should have a surface which readily permits marking with pencil and ink and at the same time give good definition for interpretative work. Experiments are being carried out in respect to paper coated with cellulose for the purpose of minimizing shrinkage and curling tendency.

All paper and film are tested for shrinkage and distortion before being accepted for use by the R.C.A.F. A rectangular co-ordinate measuring instrument, capable of making precise measurements, is used for this purpose and the determination of shrinkage and distortion is effected at critical points.

Research in connection with films and papers is undertaken by the Subcommittee on Photographic Technique of the Associate Committee on Survey Research. Study is being made in regard to emulsions adapted for use by the various services. At the present time, the use of infra-red film among others is under investigation.

The Air Photographic Library

The necessity for a central reference for all air photographic work carried out by the federal government was admitted with the establishment of the Air Photographic Library in 1923. By means of the index and filing system which has been adopted, complete information is readily available regarding any operation, flight, or individual photograph. The library now contains 725,000 individual index prints, an increase of 35,000 during the past year. The extent of its activities may be judged by the turnover. One hundred thousand prints have been sold, loaned or used in the library during the past year. It is interesting to note that of this number only 40,000 were for purely mapping purposes. In oblique plotting, the photograph is not mutilated to any extent and the library copy is used. In vertical plotting, markings disfigure the photograph and consequently it is necessary to obtain extra copies for this work alone. The balance of the use was by geologists, mining companies, power companies, lumbering companies and the many federal and provincial bureaus which are constantly requiring this assistance.

The index and filing system comprises the following: (a) a card index, (b) index maps, (c) filing arrangement. From the card index it is possible to obtain all essential information with regard to the operation number, the individual number of any print, the conditions under which the negative was taken, all camera data, the date of exposure of the film and of receipt by the library and any filing record. The index maps supply information which permits the very close placing of any print in its relation to the ground. It obviates the necessity for examining a number of photographs in order to get the position of one of them. By means of the filing arrangement any one of the 725,000 prints filed in the library may be produced without delay.

The library receives all requests for the purchase of photographs, prepares requisitions for them which the R.C.A.F. fills. A charge of 12 cents each to government bureaus and of 24 cents to private organizations or individuals is made for the 7×9 prints.

A very complete detailed description of the operations of the Air Library can be obtained from *Bulletin No. 62* of the Topographical Survey.

Consulting Assistance

In close association with the Air Library, a staff of technical officers is available to provide assistance of a consulting nature to public bodies, private organizations and individuals. In some cases, this service consists of quite considerable investigation of the problem presented while in others it involves only advice as to available photographic information, depending largely upon the facilities for dealing with the problems possessed by the organization from which the request for assistance originates.

At the present time, a project of major importance which is engaging the

attention of this Service is that in connection with the rehabilitation of the Drought Area in the southern part of Saskatchewan. Assistance in this connection is being supplied to the Department of Agriculture which has this work in hand. It involves a study of the available surface water, of prospective storage basins, of runoff and of sites for dams which may be required so as to create reservoirs. It also calls for a study of soil types and soil classification. Photogrammetry is playing an important part in solving this national problem and is being applied on a large scale.

That the assistance being rendered by this staff is of a very practical nature and is received with confidence is evidenced by the fact that engineering projects have been undertaken largely as a result of the advice received. Its usefulness to the public is shown by the large number of persons who make use of its facilities every day.

Air Mapping Services

All original federal air mapping with the exception of that carried out by the Geographical Section of the General Staff, Department of National Defence, is concentrated in the Topographical Survey, Department of Mines and Resources. The mapping by the Geographical Section is undertaken largely for training purposes and on account of the importance of this from a military standpoint it is considered to be more satisfactory that this work remain under the direct control of the Department of National Defence. However, the efforts of this organization are applied toward productive ends, their mapping being carried out in areas of military importance, thus effecting a very considerable saving in the cost of national mapping.

The Topographical Survey carries out all air mapping for base maps for the other departments of the federal service. In contrast with the particular purpose for which the Geographical Section makes maps, this Survey has the more general function of supplying the requirements of bureaus which deal with natural resources. With the boom in mining, a large percentage of the work is in connection with that industry.

Flying Instructions

In preparing instructions for photography over a map sheet area, all information pertaining to the area is collected and the best available map or sketch to which additional information may be added is utilized for projecting thereon the routes to be followed by the aircraft in obtaining the desired photographs. The lines of flight usually run east and west since the compass is more subject to turning errors when flying in a north and south direction. For oblique photography the flights are spaced about eight miles apart while for vertical they are designed so that one strip overlaps another without intervening gaps. The spacing for the latter is usually $1\frac{1}{4}$ to $1\frac{1}{2}$ miles so as to give an overlap of 40 percent if the flights are flown as projected. Experience has indicated that this tolerance should not be reduced if gaps are to be avoided.

In addition to the stripping flights required to cover the area, north and south cross flights are made at the easterly and westerly limits of the map sheet area and at suitable intervals between these limits.

Flying is carried out at 8,000 feet above the ground for oblique and at 10,000 feet for vertical photography. In the case of vertical flights it becomes necessary where the area is particularly hazardous to extend the photographic altitude to 12,000 or even 15,000 feet.

Ground Control

Very little can be added in the matter of ground control. In the unexplored regions, dependence is largely placed upon astronomical observations. In other areas triangulation and traverse are employed. The placing of the control follows the practice described in publications of the Topographical Survey and of the Geographical Section. The importance of adequate and well placed control is well appreciated and is receiving careful attention.

Mapping Methods

In referring to methods, it is assumed that you are acquainted with the practice which has been employed and which has been very completely described in publications. You will, however, no doubt be interested in any changes in the practice which have occurred in recent years.

Oblique photography is still utilized to a considerable extent in mapping the lake and forested country of central and northern Canada, but there have been modifications chiefly in the manner of taking the photographs, as referred to previously, which have resulted in economies. It might be noted that there has been no change in the manner of recording the apparent horizon since the inception of the method in 1922. It still is obtained through the agency of the camera lens and on the same plate as the photograph itself which permits the graphical rectification being applied very simply.

The plotting of the oblique photographs is carried out in much the same manner as formerly described in *Bulletin No. 62*. With the fixed assembly of three cameras, it is not now essential to plot two points in the overlap between the central and wing photographs upon which to hang the plot of the wing photographs, as the three exposures are made from the same air position. The scale of compilation—one inch to one mile—is still employed, the finished map being issued at the four mile scale.

For the graphical rectification of the information shown on the photographs, the original type of glass grid showing a perspective of two systems of parallel lines intersecting normally is still employed. These lines form a system of x and y co-ordinates with origin at the principal point of the grid. The dimensions of the corresponding squares on the compilation sheet remain the same—$\frac{1}{8}$ inch corresponding to $\frac{1}{8}$ mile.

Another form of rectifying grid used for point by point plotting in rough areas is one corresponding to polar co-ordinates. This consists of a perspective of lines radial from the ground plumb point at one degree intervals and of arcs of circles centered at the same point corresponding to bases of cones formed by equi-depression rays from the air position, each differing by one degree of depression. The construction of the grid is described in Breed and Hosmer's, *Higher Surveying* (latest edition).

Vertical photography plays an increasingly important part in the general air mapping situation. During the past year, of the ten aircraft available for photographic operations six were employed on both oblique and vertical, three on vertical mapping alone and one for transportation. This, of course, is not a fair criterion by which to judge the relative extent of country covered by each method as the oblique photography is used only on small scale work and has a much greater coverage than the vertical. In point of area mapped, that by vertical photography covered 21,000 square miles while that by oblique covered 56,500 square miles. To date, air photography has been carried out over 775,000 squares miles since air mapping was started in Canada, of which 213,000 square miles have been by vertical and 562,000 by oblique. To a great extent, vertical

photography has been restricted to the settled or comparatively settled country where the detail has been of an amount which could not readily be obtained from oblique photographs.

The radial line method of plotting is used for vertical work. This is essentially the same as the Arundel Method described in Professional Paper No. 3 of the Air Surveys Committee of the War Office in London.

Plotting Instruments

To meet Canadian conditions, mechanical equipment has been designed and constructed in the National Research Council Laboratories with the objective of improving the speed and accuracy of plotting procedure. None of these machines is intended to compete with the existing universal plotters but are intended for rapid economical use in small scale map production which is the paramount necessity in Canada. Two of these, the Radial Stereo-Plotter* for vertical photographs and the High Oblique Plotter have been described in the *Canadian Journal of Research* and are now in use by the Geographical Section. A third plotter for vertical photographs is now under construction by the National Research Council Laboratory. It embodies improved method of construction over the Radial Stereo-Plotter and a number of refinements have been added. Like the latter, it is mainly intended for carrying forward radial line control.

The High Oblique Plotter, as presently used, is mainly for projecting control, both vertical and horizontal, by means of a flight of oblique photographs on which control is later identified and used with the vertical photographs from which both planimetry and relief may then be plotted.

The Radial Stereo-Plotter is designed to accomplish radial line plotting mechanically under continuous stereoscopic examination. The endeavor is to eliminate tracing and draughting errors and those arising from faulty identification of detail. It is hoped also to speed up the work.

Another interesting development is the Radial Line Positioner for more rapid and accurate placing of the relative position of tracing and photograph when carrying forward radial line control by the usual graphical method. It avoids the small errors inherent in the plotting of strips by manual means and also somewhat increases the speed. It has been described in the October, 1937 issue of the *Canadian Surveyor*.

While waiting for the construction of the Positioner, a simplified plotting board was made which also facilitated the accurate placing of tracing and photograph. It allowed for only one motion, depending upon hand operation for the other movements. It has the advantage of being very low in cost and is a considerable aid in the usual graphical method. Several of these boards are now in use.

The Multiplex Aero-projector is also being used. A twelve projector instrument is now in use by the Geographical Section and tests to date have indicated that this instrument will provide a rapid and economical means of mapping in rough and inaccessible areas, avoiding the heavy work involved when establishing control on the ground.

Some interesting experimental work has been carried out in British Columbia involving a combination of ground and air photography. The former is employed essentially to provide horizontal and vertical control for the plotting of vertical air photographs. The ground photography is carried out in conjunction

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with the triangulation and the number of camera stations is kept at a minimum. In this way, the additional field work involved is very small. The detail is plotted from the air photographs by the radial line method. This combination has the advantage of providing a wealth of minor control so essential for accurate delineation of planimetry and relief.

Bulletin No. 62 indicates that all strip reductions are made on vandyke paper by photography. This practice has been abandoned by the Topographical Survey and now the strip plot as made on Kodatrace is projected optically to the desired scale by the use of a lens in a simple enlarging or reducing apparatus and the projected image traced, in whole or in part, on tracing paper. It is found that this modification allows for better adjustment between strips. For filling in detail from vertical photographs, particularly in the compilation of large scale maps, the Barr and Stroud survey epidiascope has been found most useful.

References

Detailed description of the methods are contained in the following publications:

a. *Standard Mapping Method of the Geographical Section*, General Staff, Department of National Defence.
b. *Bulletin No. 62*, Topographical Survey, Department of Interior.
c. Publication of the Survey Research Committee of the National Research Council of experiments carried out under their auspices.
    1. Report on Petawawa and East Thurlow Island. Experiments in contouring from Air Photographs with minimum control.
    2. East Templeton Experiment No. 1.
d. *Surveying from Air Photographs* by Captain M. Hotine, pp. 98–110 and 152–172, War Office, London, England.
e. *Higher Surveying* by Breed and Hosmer (Latest Edition).
f. Determination of the Distortion in a Number of Camera Lenses, by R. H. Field, Vol. 10, *Canadian Journal of Research*, pp. 239–243.
g. A Plotter for High Oblique Air Photographs—*Canadian Journal of Research.*
h. The Radial Stereo-plotter—*Canadian Journal of Research.*

Other Applications

In this résumé of the situation in Canada, it has been possible only to deal in a very general way with each phase of the work. An attempt has been made to give a rapid picture of aerial activities. No attempt has been made to go into detail or to deal with the peculiar activities of the various Services which make use of photogrammetry. Much interesting work is being carried out with respect to the identification of geological features and formations and for studying physiographic problems. The Forestry Service is developing a technique for identifying tree types and for estimating their height and from this surprisingly accurate estimates of stands of timber are being made. Already over 100,000 square miles of forests have been classified in this way at a much lower cost than by ground surveys.

The Hydrographic Service is making valuable use of air photographs in charting shore lines and in locating submerged features. As referred to previously, the Department of Agriculture is deriving material assistance from air photography in problems connected with the Drought Area. Even in the field of legal surveying, the surveyor in re-establishing lost corners is able to get much evidence which when assembled is very valuable in helping to untangle many a legal mix-up.

Canada is vitally interested in the development of photogrammetry. Her problems are somewhat different from those encountered in older countries where mapping is no longer exploratory. You will see that we are rapidly working toward the time when the whole country will be covered with maps of a reconnaissance nature, and at the same time we are proceeding with the detailed mapping in fields of economic importance. There is much exploratory work ahead of us, however, and the general methods now in use may be expected to prevail for some years to come.

DISCUSSION OF MR. SHEPPARD'S ADDRESS

C. H. Birdseye

The four things that interest me most in Mr. Sheppard's address are:

First: His citations of what Canada has started to do, and will continue to do, in using the airplane in traveling to the unexplored regions, and in using the camera, both from the ground and from the air, to explore the unsettled regions in order to develop their natural resources, particularly the mineral and timber resources. As stated by Mr. Sheppard, Canada led the way in the western continent in ground photogrammetry; in fact, Captain Deville was a contemporary of Colonel Laussedat, and probably the predecessor of most other Europeans, in the development of terrestrial photogrammetry. I am tempted to warn our Alaskan topographers that they must "watch their step" or our Canadian friends will out-distance them in aerial photogrammetric methods used in exploratory and reconnaissance surveys.

Second: His statements that Canadian photogrammetrists are beginning to favor short focal length, wide angle, single lens cameras and a square rather than a rectangular negative. Our president elect has developed a 9×9 inch camera, using a lens of 6-inch focal length covering an angle of sharp definition of about 80 degrees. If we can use a 9-inch cross dimension, I see no reason why we should not use the same forward dimension. Personally, I hope that Dr. Gardner's report on Precision Cameras will substantiate this desire for a wide angle, short focal length camera.

Third: Use of high oblique photographs taken from three fixed cameras in the airplane, and maps plotted from them by means of the High Oblique Plotter. We have reprinted Colonel Burns' article on his Radial Stereo-plotter in our December PHOTOGRAMMETRIC ENGINEERING and I wish we would reprint the article on the High Oblique Plotter. I particularly call the latter to the attention of our Alaskan topographers.

Fourth: His statements on the Air Photographic Library. This was first called to our attention by Mr. Narroway in his lecture to our Society on February 20, 1935, and the success of the Canadian Library and Laboratory is of great interest to us now in connection with the proposed establishment by our National Archives of a similar library and laboratory. I suggest that our members in the aerial photographic industry and in our Army Air Corps consider Mr. Sheppard's remarks on this subject and see if we can not all get together and back the establishment of a similar agency in the United States.

In addition to the above favorable comments, I have noted Mr. Sheppard's statements on the use of *The Topograph Non-Shrink* film base. I am not sure just what type of film this is but assume that it is similar to the Eastman Panatomic Aero Film Topographic. I also assume from his statements that this film is now used generally in Canadian Aerial Surveys and call to his attention the recommendation of our National Bureau of Standards to conduct further research on the possibility of using acetate rather than nitrate film.