is best, in drawing the flight curve, to make reasonable allowance for a slower-than-average speed during the climb, and, perhaps, for a greater-than-average speed during the descent (the pilot's air-speed recorder should be useful in this connection).

Having prepared the flight curve, it is a simple procedure to locate along the flight line any point where observations were made or photographs taken. For example, see Figure 2. Photograph 5 was taken at 1.40 P.M. A perpendicular from point 1.40 on the time coordinate to the flight curve and thence a perpendicular dropped to the distance coordinate locates the point along the flight line where Photo 5 was taken. It is not necessary to use the starting point for each of these distance determinations because each control point in succession can be used in a similar way.

By the graphic method here described, adjustments to control are very easily made because it is necessary only to alter the shape of the curve to fit any new control observations. One then scales off the distances easily and automatically from the graph.

An aerial traverse controlled in this way can be surprisingly accurate as to distances, because under ordinary conditions the rate of flight of a plane is very uniform, and with a reasonable amount of control on an ordinary good-weather flight there is no reason why a point should be out of position by much more than a mile, and the error in many instances will be less than that.

ADVANCES IN THE USE OF AIR SURVEY BY MINING GEOLOGISTS

G. W. Rooney and W. S. Levings†*

THE majority of geologists, particularly those in mining, have not kept up-to-date with developments in air survey. It is only since this last war, as they did after the first, that geologists and mining engineers returning from air survey and intelligence work in the Services have sought to promote its increased use in their peacetime tasks. This is evident in the courses for mining and geology students that are beginning to appear in the Universities of the United States, Canada and England. A few mining exploration companies have been using air photographs extensively in the newer unmapped areas as rough guides or maps, but the majority of geologists are still not in possession of a stereoscope or any pertinent facts. Especially the possibilities of detailed mapping at large scales from air photographs in lieu of pace and compass traverses, plane-table and transit surveys, have not been reconsidered in the light of present-day photography and mapping techniques.

It is therefore, up to the few geologists who have used air photographs in their work, to disseminate the information gained in order that further research may be done, and that this economical and practical aid to geological survey be used now in the acceleration of post-war development.

The purpose of this paper is to add to the present published knowledge of what has been done recently. Part I is an account of recent and proposed applications of aerial photography in Canada, where there is a definite need for all types of air survey. Part II is a description of the course of instruction that has

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been started at the Colorado School of Mines on the uses and interpretation of aerial photographs, which is typical of the courses springing up for geology and mining students throughout the world today.

PART I. RECENT AND PROPOSED APPLICATIONS OF AERIAL PHOTOGRAPHY TO GEOLOGY

Aerial survey can assist the prospectors, geologists, mining exploration companies and government geological surveys in Canada to a far greater extent than is generally realized. A fundamental requirement that has been neglected in the past is to secure the correct type of aerial photography to suit the particular geological purpose. The most suitable time of year, filter and photographic scale, to mention only a few of the variables, must be considered. The following remarks apply chiefly to the pre-cambrian shield of Canada, but with a few modifications may apply also to most other regions favorable for geological exploration.

The Aerial Photography Flown for Geological Research Purposes in the Beatty-Munro Area. District of Cochrane

The initiation of air survey programmes now under way throughout the Dominion warrants a more thorough investigation of the types of air photography required by the geologist, as well as the forester and the cartographer. To date, the most comprehensive use of aerial photography has been made by oil companies, timber companies and government mapping agencies. With the recent improvements in the technique of aerial photography and mapping, there is now no reason why the work of the mining geologists and prospectors cannot be aided by this powerful and rapid mapping tool.

An Aerial Survey Advisory Committee associated with the Ontario Research Commission requested Photographic Survey Company Limited, Toronto, to fly an area selected by the Geology Sub-committee, to test the use of aerial photography, particularly with regard to the most suitable season, scales, and filters for geological survey.

The area selected, a part of Beatty and Munro Townships, District of Cochrane, Northern Ontario, was considered to have sufficient outcrops of a typical variety of pre-cambrian Rocks.

Method. Two flight-lines were chosen to cover the most representative parts of the area. Four flights were made on June 16th, 1947, over these two lines by an Anson aeroplane, equipped with two cameras, an Eagle IX with a 6-inch focal length lens and an F.24 camera with a 14-inch lens. Three flights were made at 6,000 feet above the ground, using the 6-inch camera with a different filter for each flight—minus blue, green and red—and giving a photograph scale of 1 inch = 1,000 feet. During one of these flights the 14-inch F.24 camera was used with a yellow filter, producing a photograph scale of 1 inch = 430 feet. A fourth flight was made at 2,400 feet above the ground with the 6-inch camera and a yellow filter, at a scale of 1 inch = 400 feet. A total of 186 photographs were made in the 15 square mile area.

The photographs were examined in the air survey company's office and maps, geological interpretations, mosaics, stereograms and enlargements were made to illustrate the observations at this stage. This photographic material was then taken into the field by G. W. Rooney for a ground check, in company with J. Satterly who mapped the ground in the Beatty-Munro area in 1944 for the Ontario Department of Mines. Field observations were made concerning the interpretation and mapping value of the photographs.

Courtesy of Photographic Survey Co. Ltd., Toronto, Canada

FIG. 1. (a) Summer. (b) Early Spring. Stereograms of exactly the same area in the pre-cambria Shield to show how vegetation masks rock outcrops in summer, as shown in Fig. 1(a), whereas in spring photography, Fig. 1(b), the rock outcrops are completely visible.

Some of the observations made can be seen in the accompanying illustrations. The observations are as follows:

Season for Geological Photography. A very typical example of the right and wrong time of year for photography flown for geologlcal survey purposes is shown in Figure 1. This consists of a stereogram of spring photography mounted for comparison below a stereogram of photography of the same area taken the previous summer.

The main observation is the difference the state of the foliage makes in the study of the rock outcrops. Throughout Northern Canada, the hardwoods or deciduous trees are usually found on the dry, high sites, whereas the softwoods or coniferous trees predominate in the wet, low sites. Consequently, the hardwoods coincide in location with the outcrops as most rock outcrops protrude through the overburden in such a way as to produce an increase in elevation ranging from a slight hump of soil and rock to hills and mountains. In the Beatty-Munro area the rock outcrops produce a change of elevation of only a few feet on the average, with the odd knoll or hill as high as 15 or 20 feet, yet even these slight elevations are sufficient to support deciduous trees and bushes mixed with coniferous.

In the summer photography in Figure 1, the deciduous trees and bushes appear white, and the coniferous trees appear half tone to black. The tree cover is so complete that most of the rock outcrops are masked. Even in relatively open areas the rock is masked by undergrowth. Ground relief alone is not sufficient under the stereoscope to outline the rock outcrop areas, as gravel deposits such as some appearing immediately south of this area produce the same relief and similar tree cover.

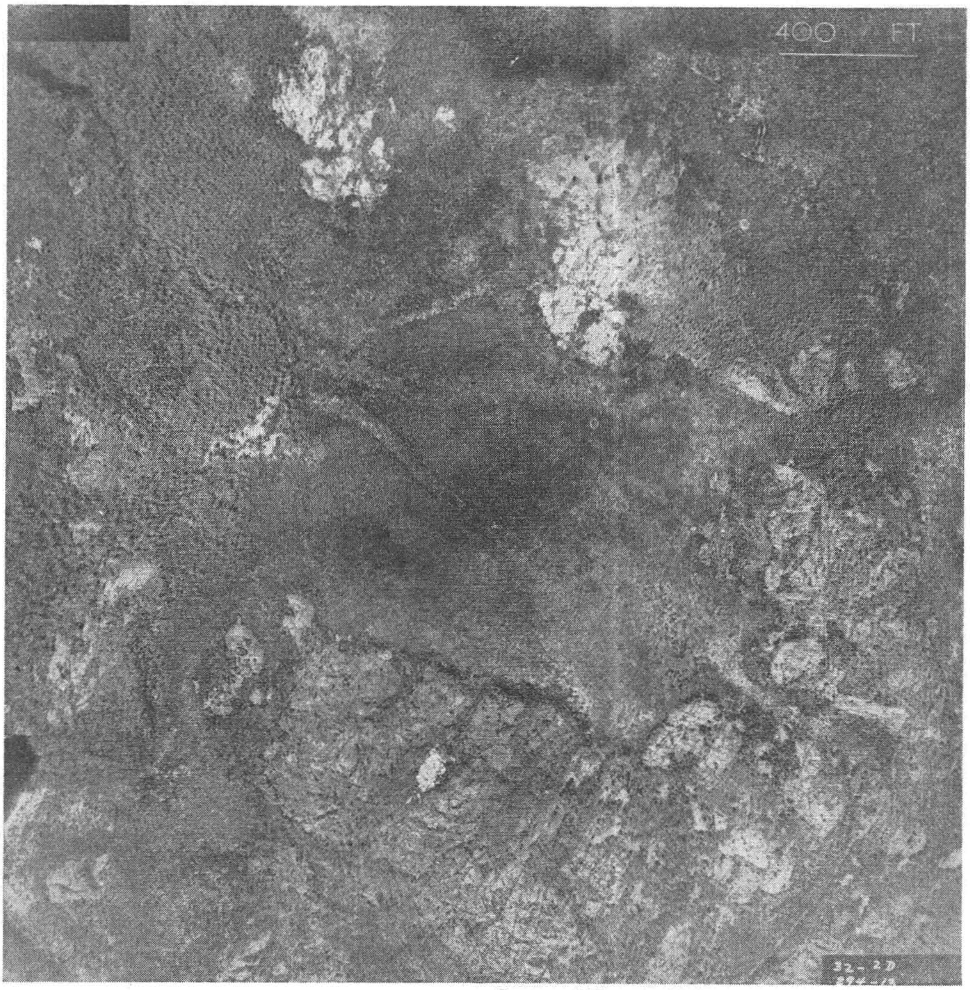
In the spring photography, however, every outcrop can be detected quite readily by its bare, rough appearance and comparatively lighter tone than the trees. Also a differentiation between rock types can be made in this case as, for example, the dikes lying in a north-south direction near the center of the photograph which are quartz diabase and intrude sedimentary and volcanic rocks.

Experiments are being carried out with photography taken in autumn after the leaves have fallen. It is not considered likely that the results will be as good as those of early spring owing to the accumulation of dead vegetation.

The same masking effect by the leaves on the hardwoods has been noticed in most photography made in the pre-cambrian Shield. This is due to the fact that originally this photography was flown for ordinary planimetric mapping or forest surveys and only made available to geologists afterwards. Broad geological features such as major faults are indicated in the summer and autumn photography by linears along lakes and streams, etc., but detailed features such as small outcrops, minor faults, fractures, dikes and contacts in the rock outcrops themselves can only be seen when the rock outcrops are bare of leafy vegetation in the spring.

There is usually about a month in the spring between the time when the snow has disappeared and the leaves begin to appear on the hardwoods—about May in the Porcupine-Kirkland Lake area. This is an inactive period for planes flying forest surveys as they are usually based in the area with only a few tie strips to fly while they wait for the leaves to appear, and they could easily fly the comparatively small areas required by mining surveys during this time.

Filter Effects. Three filters were used in turn on the camera over the same ground. In judging filter effects, care must be taken to eliminate effects due to wrong exposure and poor processing, but if results are judged from an examina-



Courtesy of Photographic Survey Co. Ltd., Toronto, Canada

FIG. 2. A vertical photograph (red filter, contact scale 400 ft. = 1 in.) from the set flown in Beatty and Munro Townships, District of Cochrane, Northern Ontario on June 16, 1947. From a stereoscopic interpretation of this photograph and overlap, the Photogeology Map shown in Fig. 3 was produced.

tion of a good many prints in the roll along the flight line, these erroneous effects can be identified and eliminated.

There were two main observations on the use of filters for geological photography.

(1) The red filter produced photographs with the best resolution of detail in the rock outcrops and it also produced the best contrast between the rock outcrops and the vegetation The minus blue (yellow) filter produced almost as good results as the red, and the green filter produced poor contrasting results.

(2) None of the filters aided in detecting weathering colour not found by the other two filters.

The stereograms made from spring photography in Figure 1 and the photograph in Figure 2 are typical of the photography made with a red filter. Examples of the photography made with various filters cannot be reproduced in a publication such as this to show sufficiently clearly the contrast in definition.

Photographic Scale. From the geologist's point of view, photographic scales should be chosen to suit interpretation needs as well as those of mapping. Obviously, the greater the scale of the photograph the more detailed is the interpretation. Major faulting and other large structural features can be seen on small scale photography covering large areas but for detailed mapping of outcrops, fracture patterns, formations, etc., as in the Beatty-Munro area, large photographic scales are essential.

It is usually necessary to strike a balance in scale depending on the purpose of the coverage. The topographical engineer will welcome 3,000 feet = 1 inch because it reduces his mathematical computations while still giving him all the detail he requires. Such a scale, however, is relatively useless to forestry engineers doing an accurate forest inventory. At 3,000 feet = 1 inch individual trees are lost to detail and the forester is seriously handicapped. The same might be said for a geologist looking for small outcrops.

There is the relief or vertical scale of the photography under the stereoscope to consider as well. Under the stereoscope, photography made with a 14-inch lens has not as much topographical relief as that made with a 6-inch lens and the same horizontal scale. The extra relief effect gained by using the 6-inch lens photography is helpful in that outcrops stand out much more clearly, eroded fault-lines along slight gullies and depressions are more noticeable, and there are more differences in elevation on outcrops to identify on the photographs as landmarks in the field.

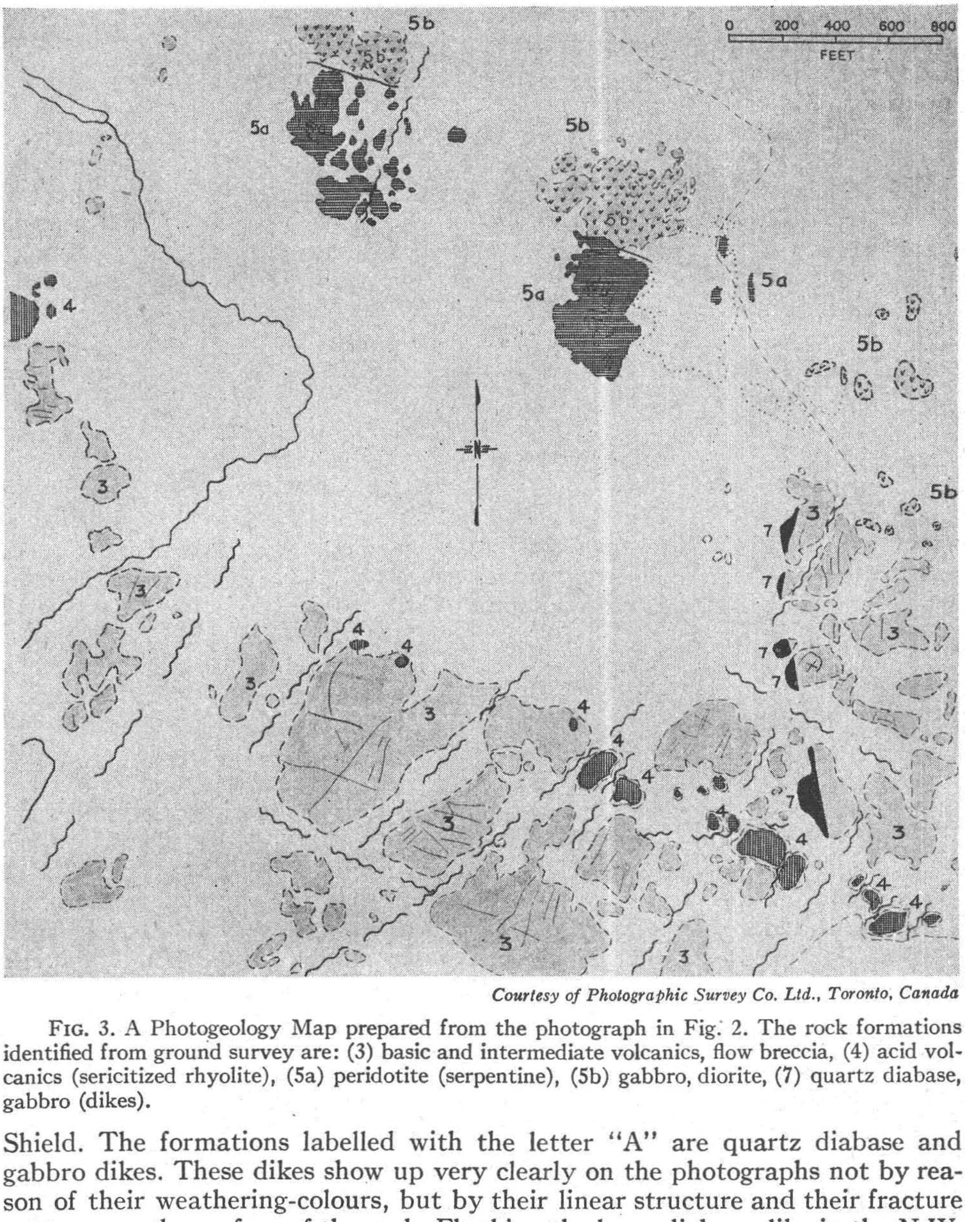
Enlargements have a definite place in a consideration of photographic scales. It is possible to enlarge photographs to $2\frac{1}{2}$ times the contact scale without much change in definition. Beyond this the lack of definition in the photography is a handicap to geological interpretation. The resolution or minimum visible size of objects does not improve with enlargement but remains the same. However, detail is spread out more which is a definite advantage for annotating and mapping.

Mapping and Interpretation. The photogeology maps in Figures 3 and 5 show the amount and kind of geological information that was obtained from the air photographs before going into the field for a ground check. These can be compared with Figure 4 showing the amount of information obtained on the ground by a geological field party in the same area in a summer's work in 1944. The field map covered an area of 18 square miles, but was trimmed to the exact area covered by the photogeology map, 15 square miles, for comparison purposes, and both were reduced for reproduction to the same scale.

The photogeology map at 1,000 feet = 1 inch was made by making a rough laydown of the 1,000 feet = 1 inch photographs (using every alternate print) and placing a very transparent tracing paper "Perfectrace" over it, on which the geographical and geological detail was compiled. This detail was interpreted and transferred by viewing with the stereoscope and the remaining photographs through the tracing paper, producing an uncontrolled map.

The tracing of the photogeology map was placed over the field map and it compared quite favorably. All the outcrops mapped on the ground were found on the photogeology map. The interpretation of the faults on the photogeology map compared closely with those on the field map, as the faults are located similarly in the field—along the linear gullies, scarps and lines of vegetation. In some places displacement of formations by faults can be detected on the photographs.

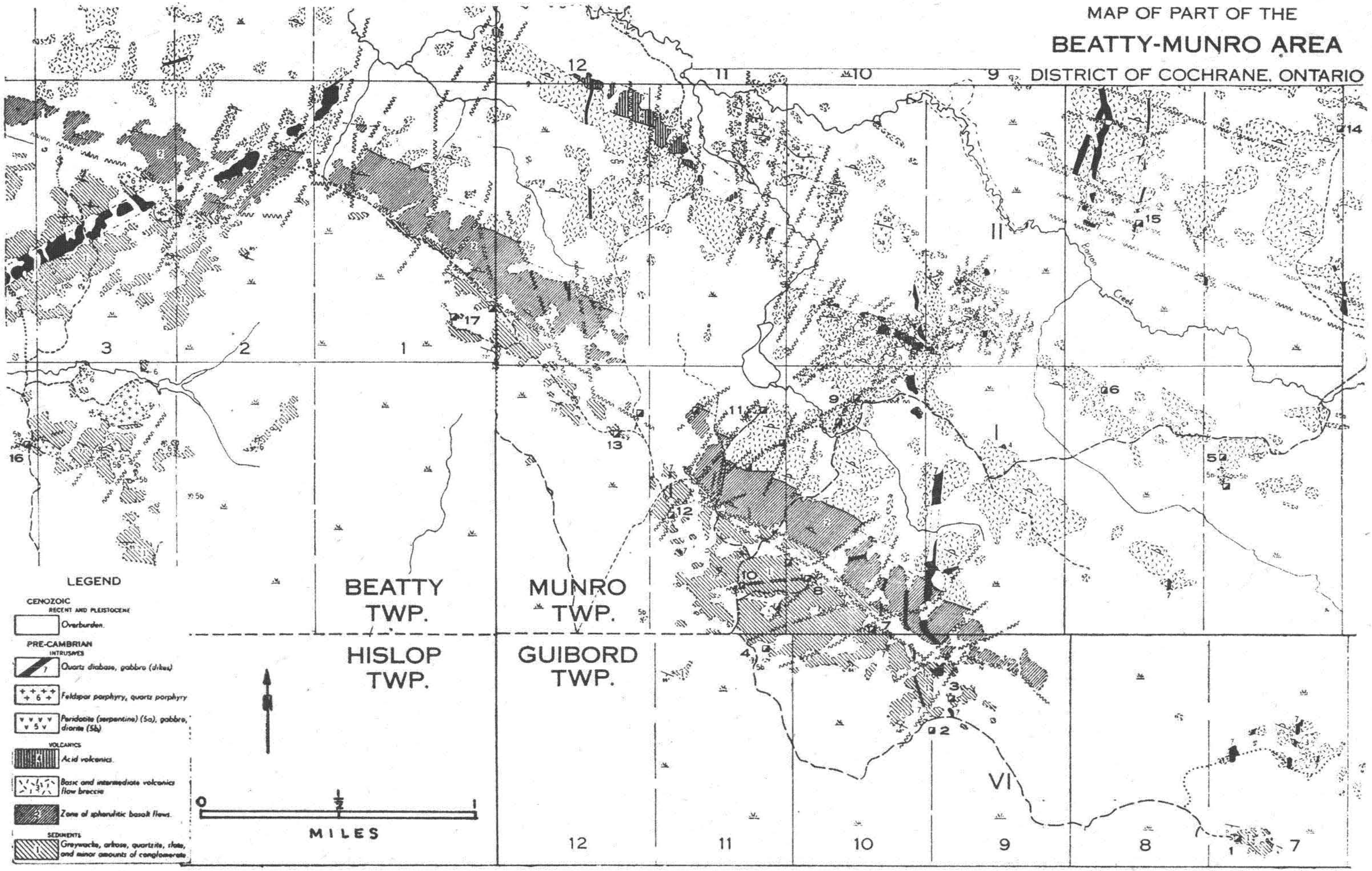
A brief description of formations shown on the photogeology map is necessary here to emphasize how typical they are of the rest of the pre-cambrian



Courtesy of Photographic Survey Co. Ltd., Toronto, Canada

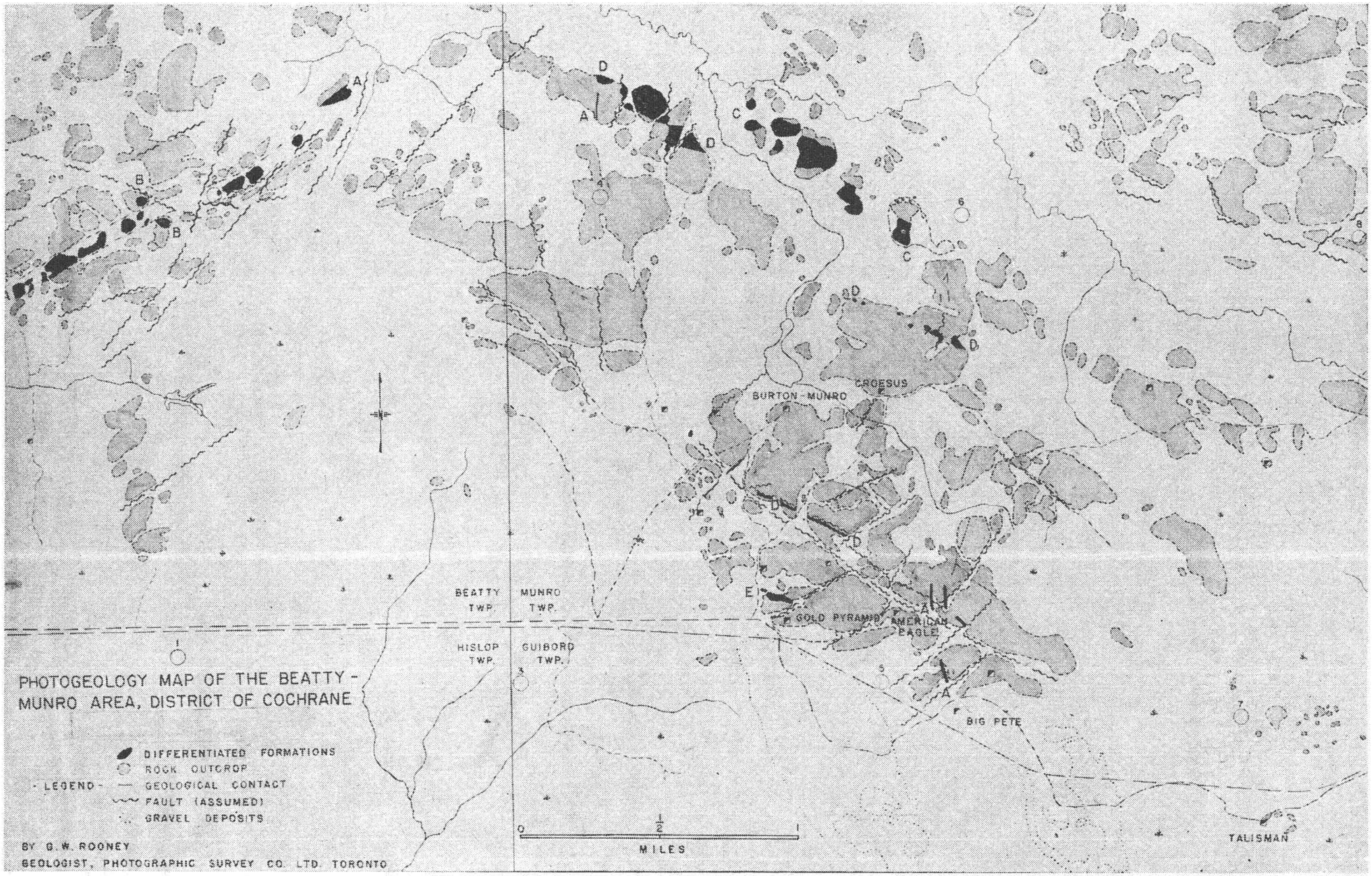
FIG. 3. A Photogeology Map prepared from the photograph in Fig. 2. The rock formations identified from ground survey are: (3) basic and intermediate volcanics, flow breccia, (4) acid volcanics (sericitized rhyolite), (5a) peridotite (serpentine), (5b) gabbro, diorite, (7) quartz diabase, gabbro (dikes).

Shield. The formations labelled with the letter "A" are quartz diabase and gabbro dikes. These dikes show up very clearly on the photographs not by reason of their weathering-colours, but by their linear structure and their fracture patterns on the surface of the rock. Flanking the large diabase dike in the N.W. corner of the sheet are two outcrops marked "B" of quartz porphyry weathering to a lighter colour than the diabase dike. The most north-easterly formation marked "C" is an intrusive band of serpentized peridotite weathered to a whitish colour in contact with rusty-weathering outcrops of diorite and gabbro. The formation marked "D," parallel to the peridotite and just ¼ mile south, is another intrusive, sericitized rhyolite with a yellow weathering-colour appearing almost white in the photographs, in contrast to the adjacent formations of rusty-weathering intermediate to basic volcanics which appear dark toned in the photographs. There is another intrusive of sericitized rhyolite in the form of a narrow dike or sill marked "D" lying in a N.W.–S.E. direction about ¾ of



Courtesy of Photographic Survey Co. Ltd., Toronto, Canada

FIG. 4. Ontario Department of Mines Preliminary Map of Part of the Beatty-Munro Area, District of Cochrane, Northern Ontario, by J. Satterly, 1944. Note: Map has been trimmed to correspond to area shown in Figure 5.



Courtesy of Photographic Survey Co. Ltd., Toronto, Canada

FIG. 5. Photogeology Map made from a stereoscopic interpretation of photographs at a contact scale of 1,000 ft. = 1 in. covering the area shown on the government map (Fig. 4).

a mile further south. This rhyolite band masks the contact between the sediments to the south and the volcanics to the north for part of the way along a large strike-fault. This strike-fault is offset by numerous cross-faults, mostly indicated by their topographic expression (linear troughs). About $\frac{1}{4}$ mile north of this long strike-fault and parallel to it is a linear with a contrast in tone on either side denoting a contact in the volcanics between the zone of spherulitic basalt lava and the intermediate volcanics. (See Fig. 1(b).)

It is possible to go into great detail to describe how all these formations and structures appear on the photographs but it would be quite inadequate without reproducing the original photographs and this could only be done, in magazine form, with a considerable loss of definition.

The photogeology map (Fig. 3) is an example of detailed interpretation and mapping. It was made from an examination of the photograph in Figure 2 at a scale of 400 feet = 1 inch along with the overlapping prints under the stereoscope. The greater amount of detail available from this scale of photography than in the 1,000 feet = 1 inch photographs can be seen by comparing the two maps (Fig. 3 and Fig. 5). The area covered by Figure 3 is one half mile north of the Croesus mine in Figure 5.

The map from the 400 feet = 1 inch photographs has greater detail in the outline of the outcrops; smaller outcrops are shown; fracture patterns and more faults are mapped; contacts are mapped with more precision; an extra diabase dike is mapped.

To sum up the interpretation and mapping value of these photographs in the Beatty-Munro area:

(1) All the rock outcrops could be seen and mapped from the photographs.
(2) Rock formations with yellow to white weathering colours (quartz porphyry, sericitized rhyolite, greywacke, serpentized periodotites) could be differentiated from the rocks weathering to pale rusty or darker colours and their contacts drawn.
(3) Most of the faults located on the ground could be located by their topographical expression on the photographs. Additional faults and extensions of known faults were indicated also.
(4) Small fracture patterns too numerous to map on the ground could be mapped quickly on the photographs.
(5) Much more geological detail was evident, of course, on the 400 feet = 1 inch photography than on the 1,000 feet = 1 inch photography.
(6) Practically none of the above geological detail interpreted from the photography made in spring before the hardwoods were in leaf was visible on the summer photography in the same area.

From the above short account of what can be interpreted from air photographs, it can be seen that geological surveys and mapping programmes could be speeded up considerably by their more extensive use. This would involve using photography flown in May or June before the leaves come on the hardwoods, preliminary interpretation and mapping of outcrops and photogeology before going into the field, and using contact prints or enlargements from a suitable flying scale as base maps in the field. Controlled geology maps could then be made from the annotated prints by means of the slotted templet and sketchmaster methods now in use for planimetric mapping, forest inventory maps, etc.

Suggested scales from experience with air surveys for mining companies, in Canada, for various types of geological mapping programmes are:

(1) Reconnaissance Mapping:
Photography 2,000 feet = 1 inch.
With rough laydown mosaics at 1 mile = 1 inch.
(2) Regional Mapping:
Photography 1,000 feet = 1 inch.
Controlled mapping 1,000 feet = 1 inch.

(3) Mining Property Maps (size of area up to 5 square miles):
Photography 400 feet = 1 inch.
Controlled mapping 200 feet = 1 inch.
Controlled mosaicing 200 feet = 1 inch.
Enlargements to 100 feet = 1 inch for more detailed mapping of ore zones.

Mining property maps may be the most important contribution made by air survey to geological work. The first stage in the development of a mining property should be the preparation of suitable base maps for use in the ensuing geological and geophysical surveys and surface diamond drilling programmes. Air survey can provide accurate detailed maps in a fraction of the time required by ground methods and at a much lower cost if properly planned. A base map can be prepared by air survey, for instance, which will show all topographical detail appearing in the photographs including accurate outlines of rock outcrops, forests, clearings, muskeg, etc. This base map, along with the photographs, will thus provide sufficient reference points for a geologist to tie his geology to when examining the property on the ground without much tedious surveying traverses and line cutting through the bush.

Conclusion. In the past, practically no vertical air photographs have been made in the pre-cambrian Shield, especially at scales of under 1,000 feet = 1 inch, suitable for geological purposes and therefore their use has not been properly considered as an aid to the geologist in the field. With the enormous task of geological mapping, both reconnaissance and detailed, ahead of the geologist in Canada, any improvement in the present field techniques should be welcomed. It is hoped, therefore, that further research will soon be carried out along the following lines:

(1) Fly photography with a red filter at suitable scales in springtime in other areas of the Canadian Shield to confirm that this technique is widely applicable.
(2) Map parts of these areas geologically, at the scales suggested above, using air photographs as base maps.
(3) Compare the cost and time required and quality of these maps with those produced by present methods.

PART II. INSTRUCTION AT THE COLORADO SCHOOL OF MINES

The course of instruction at the Colorado School of Mines on the use and interpretation of aerial photographs requires about 15 weeks to complete and is limited to those senior and graduate students possessing the necessary prerequisites, chief among which is credit in structural geology. Classroom work, consisting of one hour lecture and two hours laboratory per week, is interspersed with several field trips. Successful completion of the course entitles the student to two semester hours of credit and is essential to graduation for students majoring in geological engineering.

From the broad point of view, the objectives of the course comprise basic work involving the characteristics of photographs, fundamentals of stereoscopy, methods of study, and elementary photogrammetry followed by specific applications to the search for mineral deposits.

It is the experience of the writer, extending over a period of three years, that the textbook "Aerial Photographs and Their Applications" by H. T. U. Smith, supplemented by a few government publications mentioned subsequently, is admirably suited to the attainment of the above objectives. Not the least of the commendable features of the book is the inclusion of selected exercises and problems, the solution of which tends to promote clear ideas on the related subject matter.

Regarding the general method of presentation, the first hour of the period is normally spent in explanation and demonstration of illustrative material, the remainder being devoted to the application of principles and, periodically, to the examination of the individual's mastery of the same.

At the outset the aerial photograph of an area is compared and contrasted with the corresponding map. This is facilitated by the development of the principles of perspective from orthographic projections. Thus the student readily becomes aware of the fact that all image displacements on a photograph are those which are inherent in perspective projections. An instructive exercise in emphasizing the relationships between maps and photographs is embodied in the construction by the student of a topographic map of a prominent landscape feature, two photos of which are taken from the ends of a base line defined as to length and elevation.

The scales of vertical aerial photographs are determined by (1) consideration of the lens height, if available, and (2) by comparing distances measured on the photograph with corresponding distances measured either on a map or on the ground in the vicinity of Golden. Due consideration is given to (1) the areas covered by separate prints at various scales, (2) the net area obtained, and (3) the various factors limiting a range of scales in mapping an area under any specified overlap.

Early in the course the student is taught the basic principles of stereoscopy. To attain stereoscopic vision without optical aids he is urged to practice a few minutes daily with a perception acuity chart. Within a relatively brief time, many students are able to fuse stereoscopically the overlapping portion of a pair of 7″ by 9″ prints with ease. The construction of a few simple stereoscopic line diagrams serves a useful purpose in indicating the application of the principles of parallactic displacement to the portrayal of geologic structural relationships.

Stereoscopes of various types are available for student use, but the type most in evidence is the pocket folding, magnifying type. Of incidental interest is the pronounced stereoscopic effect provided by a type of illuminated magnifying glass similar to those furnished in kits supplied to the Army Air Forces for photographic interpretation. Illumination is provided by flashlight batteries or by plugging into a 110-volt circuit. The cut-away model permits the use of scales beneath the lens on maps and photographs. Further, vectographs and anaglyphs have been found effective as aids for first perception of stereoscopic relief.

The dominant theme emphasized in the study of the aerial photographs is the necessity for a logical method of approach involving a study of the broad features first and an analysis of the smaller features second with constant appeal to the probabilities and possibilities suggested by the broad features. Once the student has grasped the basic concept of understanding the associations of features and the relationships of one feature to the whole picture, he will be better prepared to correlate and integrate all the available data.

As a preliminary step towards this end, the student makes a detailed study of a selected group of annotated photographs embracing the identification of all cultural features. His attention is drawn to the basic characteristics of color tone, texture, shape, and size as a basis for logical inferences.

The study of land forms shown on the photographs follows the orthodox order—structure, process, and stage of development. Numerous examples of the various types are shown in mounted stereopairs both vertical and oblique with short descriptions to facilitate understanding in each instance. Selections are made to provide simple illustrations of the features under consideration followed by prints showing similar features under more complex conditions. The point is stressed that many land forms have indices that identify their origin, and in general, the type of material making up the mass.

The masking effect of vegetation in summer and fall photography is compared to the added geological detail visible in photography made in spring before the hardwoods are in leaf in regions of mixed hardwoods and conifers containing scattered rock outcrops. Also the subtle changes in the appearance of rock weathering-color tones and the enhanced definition of detail in photography made with a suitable filter for geological interpretation (i.e. a red filter) as compared to other photographs of the same area made with less suitable filters (i.e. a green filter) are studied.

The attempt to identify various types of soils as indicative of the bedrock lithology is based on the criteria of land form, drainage pattern, type of erosion, and color tone. In this regard, the government publication entitled "The Origin, Distribution, and Air-Photo Identification of United States Soils"[1] has been found very helpful. Appendix B of this publication contains 63 aerial photographs, many of which are excellent stereopairs, illustrating the airphoto techniques for identifying soils and incidentally various types of land forms.

Interest regarding vegetation is usually confined to the identification of a limited number of types whose selective preference for the more common rock formations is generally well known. In view of the large number of aerial photos taken in the Pacific theatre of operations by the Armed Forces and donated to the School of Mines by former students, the writer has found useful and interesting the publication "Pacific Landforms and Vegetation,"[2] in indicating not only (1) the extent to which the identification of vegetation types can be helpful in military operations, but also (2) the good pedagogy employed by the Armed Forces in utilizing many stereopairs as the best means of illustration in this particular field of intelligence.

In order to familiarize the student with photo mapping procedure, it has been customary to invite a specialist to give a talk, from nearby Lowry Field (U. S. Army Air Corp) or from Geophoto Services, Denver.

Relatively little attention has been given to the methods of preparing and revising planimetric maps from both vertical and oblique photographs, due mainly to lack of available time, but steps have been taken to remedy this deficiency in the near future as it is believed that such training is essential to geologists who use photographs as a basis for geological studies in the field.

Practice in the methods of measuring elevations and drawing contours on vertical photos is gained by the student using the simple stereoscope and spot elevations and by using the stereocomparagraph. Here again, it may be of some interest to point out the existence of a government publication on photogrammetry, namely, "Phototopography."[3] Whereas this book is not intended to be a textbook on photogrammetry, it does present most attractively the special mapping techniques developed by the Base Map Plant in two and one-half years of mapping in the Pacific area. "The book opens with a digest of aerial

[1] Belcher, D. J., Gregg, L. E., Woods, K. B., and Jenkins, D. S., "The Origin, Distribution, and Airphoto Identification of United States Soils": U. S. Dept. Commerce Tech. Devel. Rept. 52, Civil Aeronautics Administration, vol. 1 202 pp., appendix B, 62 aerial Photographs, Supt. Documents, Govt. Printing Office, Washington, D. C. May 1945, $2.00.

[2] *Pacific Landforms and Vegetation:* Photographic Intelligence Center, U. S. Navy, Rept. 7 (restricted), May 1945.

[3] *Phototopography:* Prepared and reproduced by 2821st Eng. Base Photomapping Co. Base Plant No. 1, GHQ, AFPAC, 156 pp. 1945.

photography as it applies to mapping. The bulk of the book consists of two sections, Production, treating the assembly-line compilation of a map, and Methodology, detailing the component operations."

It is probably true that this government publication, like the one previously mentioned concerning the identification of landforms and vegetation, is restricted and hence not available to the general public. They came into the writer's possession accidentally and are mentioned here as excellent examples of effective teaching aids used by the Armed Forces.

In the final portion of the work the class is divided into groups numbering three, each group being assigned the task of compiling a geologic and/or structure contour map with cross sections on very transparant film base from the mosaic, supplemented by the vertical prints of a mineralized area on which a geologic report is available.

The following informative statement of both the pre- and post-war status in Great Britain of the utilization of aerial photos in mineral exploration and academically was kindly contributed by Professor J. S. Sheppard of the Imperial College of Science and Technology, London:

"Prior to 1939, the usefulness of air photos to the geologist and the mining engineer was not clearly appreciated by English mining corporations. The big oil companies carried out part of their geological mapping from air photos, but, with this exception, few air survey projects were undertaken.

As a result, the advent of war found us completely unequipped for photogrammetry or air photo interpretation of any kind; likely theatres of operation were devoid of photo cover and skilled operators were non-existent. The neglect of peacetime was remedied as rapidly as possible and by the end of the war most English engineers and geologists had had experience of the value of the air photograph.

Much of the blame of this pre-war ignorance must be laid at the doors of the Universities of Great Britain, for few, if any, of them gave courses relating to air survey or its applications. This deficiency has now been remedied and courses in elementary air survey are now an integral part of the student training in many University departments. As an example, students in the departments of Geology, Mining Geology, Oil Technology and Mining at the Imperial College of Science and Technology all attend a course in the elements of photogrammetry followed by a further course of lectures and practical work in geological interpretation from air photographs."

From an authentic source in Canada comes the statement that "Here in Canada, courses are not much past just being planned. They will probably be started next year as offshoots from the Photogrammetry Departments, with lectures on geological applications and interpretation by Geology and Geophysics Departments."

Appended herewith is a selected list of R.C.A.F. aerial photos in the Northwest Territories showing striking geological features. This list was made available to the writer through the courtesy of the Bureau of Geology and Topography, Department of Mines and Resources, Ottawa, Canada, and is submitted here with the thought that it may be of interest to others.

A 5710-6	Folding in pre-cambrian sedimentary rocks. *See* Gordon Lake South, Geol. Survey Canada Map 645A near centre western border.
A 5598-11	Folding and faulting in pre-cambrian sedimentary rocks. *See* Gordon Lake South, Geol. Survey Canada Map 645A, in southwest corner.
A 5032-62R A 5032-62C	Granitic intrusions in folded pre-cambrian sedimentary rocks. *See* Beaulieu River, Geol. Survey Canada Map 581A, west centre half.
A 5033-27L A 5033-27C	Granitic mass intruding folded pre-cambrian sedimentary rocks. *See* Beaulieu River Geol. Survey Canada Map 581A, southeast quarter.
A 5120-105R	Macdonald Lake fault—south shore of Great Slave Lake. *See* Great Slave Lake (East and West), Geol. Survey Canada Maps 377A and 378A.
A 5619-27	Granite intruding Early pre-cambrian sediments 20 miles northeast of Yellowknife.

A 5619-36 A 5619-38 A 5619-40	Granite and pegmatite intruding pre-cambrian sedimentary rocks and cut by late diabase dikes. *See* Prosperous Lake, Geol. Survey Canada Preliminary Map 45-4, northeast corner.
A 2711-94	Esker and morainic topography near Wholdaia Lake, N.W.T.
A 3783-41	Fault extending N.E. from Hornby Bay on Great Bear Lake. Late pre-cambrian sandstone on left—older granite and porphyry on right.
A 8668-71	West Bay Fault—Yellowknife Bay. *See* Yellowknife Bay, Geol. Survey Canada Map 709A.
A 4848-1L	South Nahanni River Country, N.W.T.
A 5414-75C	Outpost Island, Great Slave Lake.
A 3701-85	Giant quartz vein at Beaverlodge Lake. Contains lenses and stringers of pitch-blende.
A 5611-98	Highly contorted early pre-cambrian sediments 8 miles east of Yellowknife.
A 3914-58	Belcher Island, Hudson Bay. Highly folded late pre-cambrian sediments and volcanics.

USE OF AERIAL PHOTOGRAPHS IN GLACIAL GEOLOGY

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IN MAPPING the deposits left by continental glaciers topographic form is a very important criterion. For this reason aerial photographs are of immense value to the field geologist. Only in vertical aerial photographs may all sides of a hill be examined at once. This ability makes the discrimination of drumlins, which are defined in terms of their streamlined form, possible in circumstances where ground observation is not only difficult but uncertain (Fig. 1). The topography resulting from a change in direction of ice movement across an area of drumlins is most confusing on the ground but is as clear from the air as it is on the best contour map. With photographs there is no excuse for confusing drumlins with knobs of a terminal moraine as has often been done in the past, particularly in heavily forested terrane. Other common errors of the past include mistaking of gullied areas and highly pitted outwash for true terminal (end) moraine. Figure 2 shows a typical rough terminal moraine with associated plain of sand and gravel outwash on the right (north). Views from above disclose that the details of the topography of many moraines are not entirely without system. Even in this apparently lawless confusion of knobs and hollows there are many

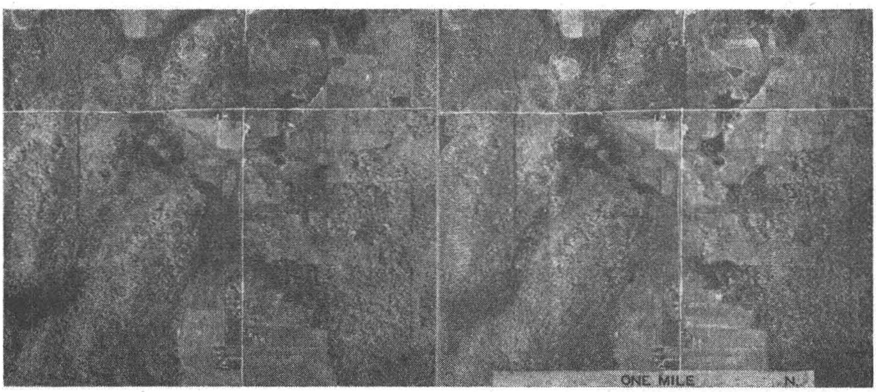

FIG. 1. Drumlins made by ice moving north of west. Deposits between drumlins are pitted outwash.