# *Report of Commission VII (Photographic Interpretation) to the International Society of Photogrammetry*

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## INTRODUCTION

REVIEWING, organizing and compiling information on all phases of photo interpretation over the past four years is a tremendous task. This report, as an attempt to accomplish this task, is far from complete. At best, it represents only a cross section of such information on photographic interpretation activities as was available to the compilers.

Information presented in this report was largely contributed by the various national reporters and their sub-reporters. In addition, free use was made of data from some of the excellent recently published papers reflecting photographic interpretation progress.

The material is in four major sections: *General, Natural Resources Applications, Engineering Applications* and *Military Applications.* This organization follows the suggestion made in the 1952 Resolutions of Commission VII.

Under the general section is discussed the new developments in material which have led generally to the improvement and accuracy of photo interpretation. Another part deals with equipment developments that have improved photo interpretation. Personnel and training are briefly reviewed. In order not to duplicate the work of the Commission on Education, only a brief treatment of training is included, with emphasis on its effects on the photographic interpretation picture as a whole. Another part of this section covers the research and deals with the projects and developments that have taken place during the past four years. A short final portion contains information on the photographic interpretation manual being prepared by the American Society of Photogrammetry and in addition several other reference publications of interest.

The *section on natural resources* has been divided, for convenience, into two general topics: (*1*) *geology and* (*2*) *forestry and land use.* The geologic part of this section points out the great increase in the number of geologic mapping and prospecting projects in which photographic interpretation is a vital factor. The part dealing with forestry and land use seems to indicate that photographic interpretation is making tremendous strides in all phases of forestry, agriculture, and other related fields which deal with interpreting the earth's surface.

The *section on engineering* covers the use of aerial photos in mapping, railroad and highway engineering, urban planning and other engineering uses.

The *fourth section covers the field of military intelligence.* While national security prevents a complete progress report being made by any of the reporting nations, a summary of some of the present problems faced by the military photographic interpreter has been presented.

The authors express their gratitude for the assistance and data furnished by the many who submitted information for this report. They are especially grateful to the following country reporters:

*A. Haider*<br>
Oslo, Norway<br>
*M. Mathieu*<br>
*Rueil-Malmaison*<br>
(Seine et Oise), France<br>
*Earl J. Rogers*<br>
United States of America<br>
*H. E. Seely*<br>
Ottawa, Canada<br>
*Surveyor General of Pakistan*<br>
Karachi, Pakistan<br>
*B. Von Vegesack*<br>
Boden, Sweden<br>
*F. Walker*<br>
Bristol, England<br>
*Richard H. Yuan*<br>
Taipei, Taiwan

In addition to the above, the following contributed substantially to the material used in this report. The authors express many thanks for these contributions.

John Carrow<br>
Robert N. Colwell<br>
Henry W. Dill<br>
John R. Dilworth<br>
W. A. Fischer<br>
Nils Hagberg<br>
Aulis Kallioinen<br>
Daniel Leedy<br>
S. T. B. Losee<br>
Arthur Lundahl<br>
Paul Maynard<br>
Karl Moessner<br>
Sven Moller<br>
Arne Sandberg<br>
John Sammi<br>
H. T. U. Smith<br>
Harald Svensson<br>
Allan Tanneryd<br>
B. A. Tator<br>
Percy Tham<br>
Robert Thurrell<br>
Page Truesdale<br>
Paul Willen<br>
Harold E. Young

## GENERAL

### General Summary

Reports received for the period 1952–1956 evidence an accelerated spread of photographic interpretation knowledge and use into many fields of science. Much of this expansion has been in such sciences as geology and forestry, where photography has been used in some form for many years. However, there has also been application of photographic interpretation in a number of new areas. Some general observations on the nature of this expansion are set forth briefly in the following paragraphs.

Most striking is the application of photographic interpretation to the field of large-scale mapping, where the many detailed annotations required for the special purposes for which the maps are designed requires a great deal of analysis of the earth's surface. This is being done either by teams of interpreters working with the photogrammetrists, or by compositely trained personnel.

In geologic fields, photography is being analyzed, for purposes of geologic mapping, for engineering purposes, and also for the mineral prospecting which is proceeding intensively in many parts of the world. In many geologic projects, field work is being used to supplement photo analysis, rather than the reverse, as was formerly the case.

In forestry, two items of note are (1) the widespread popularity of photographs as forest maps for field use, and (2) the development of rapid forest sampling techniques by means of photography. Forest photo interpretation research is also proceeding at a very high rate. Applications in agriculture and land use are also increasing, though perhaps at a slightly slower rate. An interesting feature in this connection is the use of photography for large-area land-use studies, involving whole countries or agricultural regions, and resulting in long-range development plans.

In engineering, photography continues to be used in highway design and industrial site planning; however the most rapidly growing field seems to be in urban area analysis, where uses are found in municipal planning for residential and industrial development.

In addition to uses of photography in the specific fields of science above, noted, there were general geographic applications of considerable interest. These have, in the report, been placed under the most convenient section; however in many cases they cut across disciplinary boundaries. These are perhaps testimonials to the wide application of aerial photography.

## PHOTOGRAPHIC INTERPRETATION TECHNIQUES

Photographic interpretation is a tool of science. As such, it is used in an endless number of ways, depending on the requirement to be met and the ingenuity of the scientist. In the reports received from many countries, however, there was a recurrent emphasis on certain interpretation techniques. Several of these are briefly discussed below. It is emphasized that this is an indicative and not a comprehensive listing.

1. *Identification and Census:* This old reliable technique of photographic interpretation is as useful now as when it was applied to counting enemy gun positions in World Wars I and II. It is widely used in traffic surveys, wild life counts, military applications, and for that matter, in almost all other types of photographic interpretation. The technique has changed little, except perhaps the addition of "dot counters" recognition keys, and other aids.

2. *Sampling:* This is a technique of accurate estimation through using photography, of the number and characteristics of a population where it is too numerous to count. This technique developed rapidly during the reporting period, particularly in the field of forestry. It is also being used in the field of urban area analysis, where a study of randomly selected unit areas of a city can be projected to conclusions concerning quantity and structural characteristics of the whole.

3. *Detailed Analysis:* This somewhat unspecific title is here used to embrace the process of detailed study of photographs used by an expert in a given scientific field. As scientists become more and more qualified in photographic interpretation techniques, the dependence they place upon the results of photographic analysis becomes greater. The reporting period is one where an upsurge in this use of photographs appears evident. This, of course, has brought to these many fields of endeavor some of the speed and economy of operation which can be realized by use of photography.

4. *Collaborative Analysis:* This phenomenon is taking place slowly but certainly in the field of photographic interpretation. What is referred to here is the use of photographs as a base upon which a number of scientists of various disciplines may work together. Examples are the large-scale resource and land-use surveys in several parts of the world, the application of photography to international boundary fixing (Pakistan), and the adoption of photographs as a base for general municipal and rural planning in several countries.

## Source Materials for the Photographic Interpreter

Developments in cameras and photography are the responsibility of other commissions of the International Society. Therefore only brief mention will be made of the effects of a few recent developments on photographic interpretation.

### 1. Advances in Cameras and Emulsions

During the past four years there had been considerable progress toward the providing the high quality photography needed for detailed interpretation. Of particular interest has been the steady advance toward higher-speed, finer-grain emulsions. In general, it may be said that, with the lenses and films now available, image clarity and sharpness appear no longer to be the major limiting factors in interpretation. It might also be noted that certain of the thorny problems which still plague the photogrammetrist (such as stabilization of cameras, and the lack of film flatness) are of somewhat less moment to the photographic interpreter.

### 2. Advances in Photo-Processing and Photo-Materials

There have been a number of developments in the photographic field which are being used to advantage in photographic interpretation work. A few are cited briefly below:

a. *The development of automatic-dodging printers*: While quite new, the electronic type of printer has demonstrated that it can produce materials of the tonal gradations and contrast best suited to photographic interpretation. Since tone and contrast are important clues in the interpreter's problems, the value of such controlled printing should not be underestimated.

b. *Increased use of "dry" (diazo-type) reproduction equipment in photographic interpretation work:* By simply and rapidly reproducing annotated photographs, overlays, and report materials, this equipment enables the interpreter to disseminate the results of his work in graphic form, rapidly and efficiently to the user.

c. *Development of special plastic bases for photographic mosaics and photographs:* Now being used are photo bases serving both as direct viewing positives and reproducibles. Mosaics or prints reproduced on this material can be viewed directly with reflected light, marked on with ordinary pencil (which can then be erased), viewed over light tables as positive transparencies, and placed in a printer for reproduction of a duplicate negative. Expanded use of these products may contribute greatly to the flexibility of the photography or photo-map as a base for planning and operations in many fields.

## Photographic Interpretation Equipment

### Summary

The basic tools of the photographic interpreter are still the stereoscope, the magnifier, and the measuring scale. Depending on the individual and the type of interpretation he performs, the interpreter may also employ a variety of other aids and instruments. The period 1952 to 1956 was one of increasing emphasis on photographic equipment of all types.

### Trends

The following apparent trends were noted:

1. Apparently a greater utilization, in photographic interpretation work, of photogrammetric-type equipment, such as stereo-plotters, comparators,

etc. Some of this occurred in organizations where photogrammetric mapping and photographic interpretation work were being carried on simultaneously over the same area; however, equipment such as stereo projection plotters are in use for photographic interpretation work apart from topographic map requirements.

2. Continuing progress was made during the reporting period in improving the basic equipment of photographic interpretation. Development effort was directed toward designing stereoscopes with improved optics and variable magnifications. New monocular magnifiers and new-type measuring scales were developed.
3. A whole family of supplementary equipment and devices for the photographic interpreter came into being. Much but not all of the emphasis was on inexpensive portable equipment, designed to give rapid solutions of photographic interpretation problems with moderate accuracies.

FIG. 1. This experimental table-top size stereo-projector developed for the U. S. Navy, permits two or more viewers to study a stereo-model projected on the ground glass screen.

SPECIFIC EXAMPLES

Some specific examples of photographic interpretation equipment use and improvement are:

1. *Lens stereoscopes:* Several designers worked on the problem of providing better optics in the magnification (2 to 3 power) lens stereoscopes; a few models were produced. Also several lens stereoscopes (*United States*) were developed in which supplementary lenses could be moved in or out of the optical system, to permit a choice of magnification. The increasing employment of aerial photographs as field maps resulted in greater use of "field stereoscopes" of various types. A stereoscope in use by forest personnel of the Korsnas Company in *Sweden* is built in the form of a lightweight aluminum carton, in which the photographs are mounted for convenient use in the field.

2. *Mirror Stereoscopes:* The scanning-type of mirror stereoscope with variable magnification came into widespread use during the reporting period, thereby supplementing the many other excellent types of mirror stereoscope already available.

3. *Stereo-projection Instruments:* The use of the stereo-projection principle in photographic interpretation work received new impetus during the reporting period. In *France* and the *United States*, projection equipment in use permits the simultaneous viewing by several interpreters, through polaroid or analgyph glasses, of aerial photography projected stereoscopically. The French equipment uses a metallic screen, has two projectors which project aerial photographic positive transparencies, and a third small projector which throws a movable light spot on the screen for pointing out image details. The *U. S.* equipment, shown in Figure 1 is a "rear-view" type projector in which the image is thrown on the *opposite side* of the ground glass screen from the viewer. Its optical system permits the stereoscopic projection of images from two adjacent frames of an aerial film transparency, without the frames being cut apart. Equipment of this type will permit rapid assessment of the results of a photographic mission to be made without the time-consuming handling of individual prints. As

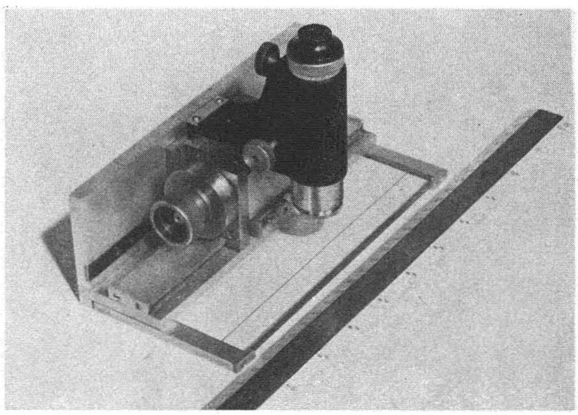

FIG. 2. The Micro-linear scale. A compact instrument developed to measure distances up to 6 inches on photographs. The screw is calibrated to read linear motion of the magnifier directly to 0.0001 feet. Wooden scale is shown for size comparison.

earlier stated in this report, use is also being made of photogrammetric stereo-projection plotters in photographic interpretation work.

4. *The Magnifying Measuring Scale:* For some years the photographic interpreter has been using scales mounted in monocular magnifiers for measuring small objects imaged on photographs. For measuring distances of several inches on photographs, he usually used a wooden, plastic or metal scale, viewing the graduations through a separately held magnifier, when necessary. During the reporting period, a combination scale and magnifier made its appearance. This device, shown in Figure 2, is a compact portable instrument, permitting fairly rapid measurement with very good accuracies.

5. *Stereo-elevation Meter:* A simple instrument based on the parallax ladder principle, the stereo-elevation meter is designed to permit determination of elevation differences from vertical stereo pairs without resorting to mathematical computations. The device is pre-set by the operator for the particular photographs on which it is to be used; after this has been done, elevations are read directly.

6. *Stereo-slope Devices:* A number of devices for measuring slopes from vertical photography came into use during the reporting period. One here described is the *Super-Duper-Dipper*, developed by Robert J. Hackman of the U. S. Geological Survey, and used in that agency. The device has two small

identical targets which are fused stereoscopically into a single target. The fused target is raised or lowered with respect to the stereoscopic model by varying the horizontal separation between targets. However, the angle of slope is determined by the actual physical tilting of the targets in space. The device is used in conjunction with the Supplementary Slope Model, a set of line drawings which provides instant correction for the vertical exaggeration induced in the original reading by factors of focal length, photo base, and image separation.

A second ingenious device for rapid measurement of slopes is also in use in the U. S. Geological Survey. Developed by William R. Hemphill, it consists of a tilting platen for use in Kelsh or Multiplex-type stereo projection equipment. In contrast to the usual horizontal platen, the tilting platen has a hinged joint above its base, and can be tilted to any angle up to 42 degrees. The surface of the platen is patterned with dots or small crosses, to enable the operator to relate it more clearly to slopes in the steroscopic model. The angle of inclination is measured by means of a clinometer.

7. *Plastic Scales:* Many photographic interpreters are using "packs" of graphic measuring scales, printed on plastic transparent sheets, and pre-computed for various scales of photography. These are widely used in *Europe* and the *Americas* in such work as timber surveying, where precise measurement of distances is not required, and where speed is essential.

8. *Sampling Guides:* Plastic guides for various types for statistical sampling have been devised and used by interpreters in various fields. These vary widely, depending on the subject of interpretation, and the sampling procedure to be allowed. Most are for use over single photographs; however, a stereoscopic sampling device, consisting of a series of triangles etched on two glass plates for estimating forest crown diameters, has been developed in *Canada* by S. T. B. Losee. The stereoscopic facility in this case permits the sampling templet to be "floated" at tree-top height for more accurate reading.

9. *Instruments for Oblique Analysis:* While the analytical, graphical or mechanical rectification of images from oblique photography is, strictly speaking, a photogrammetric matter, it is also of considerable interest to the photographic interpreter who must study and measure oblique photography in the course of his work. This reporting period saw much emphasis being placed on simple and rapid methods of handling oblique mensuration problems, specifically for photographic interpretation work. The results of these investigations included the development of at least one mechanical plotter, and number of graphical techniques involving such pieces of equipment as sets of plastic overlays, and nomograph scales. Development in this field is still going on.

## Personnel and Training

### SELECTION OF PHOTOGRAPHIC INTERPRETERS

The problem of selecting photo interpreters has recently become a topic of serious thought. Colwell (1954) discusses this under two main factors—visual acuity and mental acuity. Visual acuity he defines as the ability of a photo interpreter to perceive a photo image by the characteristics of tone or color, image sharpness, and stereoscopic parallax. He point out that there is a "threshold range" of contrasts, in which a rather slight increase in relative contrast between an object and its background greatly increases the probability of detecting that object. Furthermore, the human eye seems to be more sensitive to the light end of the gray scale than to the dark end. Also the human eye is found to be more sensitive to the green and yellow light than to the blue and red parts of the visible spectrum.

Stereoscopic visual acuity of the human eye is perhaps the most critical human factor governing the detection of small objects from photographic images. The eye functions best for visual acuity when the diameter of the pupil is 4 mm.

The power of mental acuity is associated with the training, experience, professional background of the photo interpreter, as well as with his powers of observation, powers of imagination and powers of judgment.

All of these factors point to the need of carefully selecting photographic interpreters, and to requiring rigorous eye examination prior to selection to such positions.

One author, Moessner, states, that simple devices for testing stereo perception has handicapped practicing foresters, geologists, engineers, and others who employ photo interpreters. Although many technical schools now include training in photogrammetry and photo interpretation, few have adequate classroom facilities for testing the stereo perception of their students.

The floating-circles stereogram as described, is designed to be used with the inexpensive lens stereoscope, and furnishes a practical means for testing this rather elusive sense. It is an improvement over previously used stereograms since it provides a measure of the degree of stereo perception rather than merely giving a yes-or-no answer.

The 171 tests which were made form the basis for a rating scale with a mean of 87.7 and a median of 92. Experience indicates that unless a student makes a grade of 80 or higher on the test, he will be seriously handicapped as a photo interpreter.

Others point out that there is no single vision test that is completely adequate, since the photo interpreter needs more than stereoscopic acuity. Among other requirements are: good distance vision, acceptable near vision, good reserves for accommodation and convergence, good extra-ocular muscle balance, and the visual capacity to maintain an exacting search for small details. A person having a very high rating in one of these vision tests, may prove on further testing to have the poorest over-all vision characteristics, from the PI standpoint.

In the military field, selection of personnel for training in photographic interpretation is a long continuing problem. In many cases this selection has been arbitary with the result that those given training in photographic interpretation often have neither the requisite qualifications nor the interest for the field.

It has been suggested that the military would do well to draw their personnel for training from those who have had civilian education or experience in earth science or engineering. For example, in the U. S. Forces at the present time, it is estimated that there are about 1500 earth scientists in uniform, about half of whom appear to have assignments which do not utilize their technical backgrounds.

Since, in the civilian field, the demand for photographic interpreters exceeds the supply, civilian selection for photographic interpretation is generally done on the basis of the individual's personal interest in pursuing the field. This method at least assures that the important factor of personal interest in the subject is present.

## TRAINING

A professional field requires a professional man at the helm. Photo interpretation is a professional field which may cross several professional fields and needs professional men at the helm. Basically a photo interpreter must first of all understand photogrammetry. (This is frequently overlooked.) A person trained in the fundamentals of the aerial photograph will make a better photo interpreter.

For photo interpreters the military will accept persons without broad technical training. However they prefer candidates with technical background. The primary ambition is to build a nucleus, or cadre, of skilled military photo interpreters who will be continually combat ready and capable of producing sound military intelligence. To produce such a group, training must include basic intelligence, military tractics and techniques, and the basic principles of such diversified subjects as the natural sciences, engineering and manufacturing. Furthermore, the individual must be taught and encouraged to think both inductively and deductively. It must be realized that schools—civilian and military—provide only initial training for the task ahead. The individual must be broadened by field experience. He must be constantly tantalized with problems which will keep him keenly aware of his function and responsibility as a photo interpreter.

It is assumed that in time of war the military will obtain the services of experts in various civilian professions by one means or another. There are, however, many skills unique to the military profession. The conversion of a civilian, even with excellent basic qualifications, into a first class military photo interpreter cannot be done overnight. Accelerated indoctrination in this field will not suffice. Time is required. During this hiatus the nucleus of professional military interpreters will have to do the job until help arrives. This is possible only if the military nucleus is of high caliber and is able to meet and solve new problems.

During the post-war decade, while military PI training first was in a decline because of demobilization and then reached a relatively stable state, civil PI training has grown quite remarkably in certain areas. For example, at the end of World War II there were only two or three schools in the *U. S.* where a student could receive any formal training in photo interpretation for forestry purposes. Today such a course is required for graduation in the majority of the forest schools of the *U. S.*, and is offered as an optional course in most of the remaining schools. A similar situation prevails in other professions which employ photos extensively. In addition, special PI field schools and "short courses" are being offered to various types of professional men who can afford a few days in which to learn PI techniques that might prove useful to them in their daily work.

Basic courses in photogeology are given in most schools in geology. In addition advanced courses are optional. Several foreign students are sent to the *U. S.* under the International Cooperative Administration programs for training in photogeology. Such specialists are in great demand for work in oil exploration work in all sections of the world.

Formal training should be followed by on the job training, since after such training the interpreter needs someone to take him over the bridge into the job. Most training programs forget this and send men to the job fully equipped, fully armed but not broken in. Like a new car the photo interpreter needs a breaking in period; this may make or break him. Improper breaking in may ruin an excellent interpreter. The breaking in period frequently is usually two to three times the formal training time.

In *Sweden*, each surveyor and surveying technician receives a certain training in photo interpretation, in the course of his education. Continuation courses in photogrammetry i.e. including photo interpretation, have been arranged for surveyors and surveying technicians who have already completed their study. Courses in forest photogrammetry (photo-interpretation), 2–4 days in the room and 1–2 days in the field, have been given about ten times since 1952, and nearly 200 foresters have taken part. Some big forest companies have their own courses and research in smaller scale. At the Royal School of Forestry as well as at the School of Forestry there are longer courses, and the five subordinate forest schools now have training in photo-interpretation for 2–4 days.

In *Norway*, training in photographic interpretation is now started at the forestry schools and at the University of Agriculture—forestry division—and some short courses are arranged for special groups of forestry employees.

In *Pakistan* the officers of the survey department have been trained in the application of photo interpretation for topographical and large-scale surveys required for development projects, etc.

## PHOTOGRAPHIC REFERENCE MATERIAL

### A REPORT ON THE AMERICAN SOCIETY'S PHOTO INTERPRETATION HANDBOOK

About $2\frac{1}{2}$ years ago, the American Society's membership was interrogated as to the desirability of the Society's undertaking the preparation of a MANUAL OF PHOTO INTERPRETATION, Such a manual was to constitute a companion volume for the Society's highly successful MANUAL OF PHOTOGRAMMETRY. Care was taken to sample the opinion of a representative group of members, photogrammetrists as well as photo interpreters. Approximately 80 per cent of those interrogated expressed the opinion that the preparation of this MANUAL should be undertaken at an early date. Accordingly, the Society's Board of Direction authorized the Committee on Photo Interpretation to proceed with this preparation.

It is appropriate to present the general organization of the MANUAL, as decided by the Committee after due consideration of the many helpful suggestions which Society Members submitted. Further suggestions and offers of help are solicited from all those interested in photo interpretation, and should be sent directly to those responsible for the various chapters.

### TENTATIVE CHAPTER OUTLINE—MANUAL OF PHOTO INTERPRETATION

PREFACE (Comparable to page v of MANUAL OF PHOTOGRAMMETRY)
ACKNOWLEDGMENTS (Comparable to pages vii and viii of MANUAL OF PHOTOGRAMMETRY)
CHAPTER I.—The Development of Photo Interpretation
  (Author-editor: Arthur C. Lundahl, 4401 Chestnut St., Bethesda, Maryland)
  Historical Background
  Present Status
  Future Prospectus
  Bibliography
CHAPTER II.—The Procurement of Photography
  (Author-editor: Robert N. Colwell, 243 Forestry Bldg., University of California, Berkeley 4, California)
  Introduction: (Brief statement of scope and purpose of chapter)
  Present Status of Photo Coverage Throughout the World
  The Procurement of Photos from Existing Coverage
  The Procurement of Photos When Suitable Coverage Is Not Available
  Aerial Photo Specifications (Consideration of Film, Filter, Scale, Parallax,

Time of Day, Season of Year, and other factors, with aerial photo examples showing the importance of each factor)

Bibliography

CHAPTER III.—The Fundamentals of Photo Interpretation

(Author-editor: Ellis L. Rabben, 1007 Kerwin Road, Silver Spring, Maryland)

Introduction: (Brief statements of scope and purpose of chapter)

Basic Mathematics of Photo Interpretation

Visual Requirements for Photo Interpretation

Other Human Factors Affecting Photo Interpretation

Instruments and Equipment for Photo Interpretation

General Techniques of Photo Interpretation

(*Specific* techniques are to be treated in subsequent chapters although some examples used in this chapter may overlap slightly the examples in later chapters)

Presentation of the Results of Photo Interpretation

Bibliography

CHAPTER IV.—Photo Interpretation in Geology

(Author-editor: Ben A. Tator, Gulf Oil Corporation, Gulf Building, Pittsburgh 30, Pennsylvania)

Introduction: (Brief statement of scope and purpose of chapter)

Basic Considerations.

A. Background data—History of Development of the Photo as a Vehicle for Geological Exploration and Research.

B. Areas of Application of Photo Interpretation in the Geological Sciences (Academic Research in Stratigraphy, Structural Geology, Geomorphology and Physiography; Commercial Exploration in Petroleum Geology, Mining Geology, Engineering Geology, etc.; as a Tool of Military Geology)

C. Inter-relationships with Allied Sciences (Forestry, Pedology, Engineering, Geography, Archaeology, etc.)

D. Methodology—(Training the Photogeologist; Methods Employed in Stratigraphic Work; Structural Geology; Geomorphological Analysis and Physiography)

Specific Applications—Examples of Successful Applications of the Photograph to Geological Reconnaissance in

A. Petroleum Geology

B. Mining Geology

C. Engineering Geology

D. Other Geological Studies

Bibliography

CHAPTER V.—Photo Interpretation in Forestry

(Author-editor: Richard C. Wilson, Photo Interpretation Project, Division of Forest Economics, U. S. Forest Service, Washington 25, D. C.)

Introduction: (Brief statement of scope and purpose of chapter)

Basic Considerations

A. Factors Peculiar to Forest Photo Interpretation

B. Qualitative Factors of Importance in Forest P.I.

C. Quantitative Factors of Importance in Forest P.I.

D. Specifications for Forest Photography

Specific Applications

A. Forest Stand and Type Classification

B. Forest Volume Inventory
C. Forest Engineering
D. Forest Mortality and Depletion Surveys
E. Estimating Volumes of Forest Products
F. Wildlife Studies

Bibliography

CHAPTER VI.—Photo Interpretation of Soils

(Author-editor: Robert E. Frost, Engineering Experiment Station, Purdue University, Lafayette, Indiana)

(Detailed outline not yet received)

CHAPTER VII.—Photo Interpretation of Agriculture

(Author-editor: Ralph H. Moyer, 705–18th St., N.W., Washington, D. C.)

(Detailed outline not yet received)

CHAPTER VIII.—Photo Interpretation in Urban Area Analysis

(Author-editor: James R. Wray, Dept. of Engineering, University of Chicago, Chicago 37, Illinois)

Introduction: (Brief statement of scope and purpose of chapter)

Basic Considerations

A. Definition of Terms Peculiar to Urban Area Analysis
B. Questions to be Answered by Urban Area Analysis
C. Sources of Information; Tools and Methods
D. Description of Urban Area Analysis
E. Development of Urban Area Analysis
F. Photo Interpretation and Graphic Methods of Area Analysis
G. Procuring and Manipulating the Photography
H. Procedure for Extraction of Basic Information
I. Multipurpose Urban Area Analysis
J. Transferability of Procedures

Specific Applications

A. Delimitation of Urbanized Areas in the 1950 U. S. Census of Population
B. Delimitation of Unincorporated Places in the 1950 U. S. Census of Population
C. Estimation of Bldg. Use, Bldg. Density and Bldg. Ht. from Aerial Photos
D. Unit Area Method for Describing Physical Characteristics of an Urban Area, and the Residential Distribution of Its Population
E. Urban Land Use
F. Morphology of the Urban Area
G. Photo Interpretation of Some Foreign Urban Areas
H. Transportation Routes and Facilities
I. Urban Planning, Municipal Government
J. Location of New Car Salesrooms
K. Prospects for Continued Development

Bibliography

CHAPTER IX.—Photo Interpretation in Engineering

(Author-editor: Donald J. Belcher, 130 Forest Home Drive, Ithaca, N. Y.)

Introduction: (Brief statement of scope and purpose of chapter)

Basic Considerations

A. Photo Interpretation Standards in Engineering
B. Photo Scales
C. Obsolescence of Photography
D. Type, Amount and Value of Field Support; Accuracy; etc.

Specific Applications
- A. General Project Planning
- B. Damsites
- C. Reservoirs
- D. Flood Control Structures (levees)
- E. Highways and Airports
- F. Railroads
- G. Pipelines
- H. Irrigation
- I. Seepage
- J. Landslides
- K. Foundations
- L. Industrial Sites
- M. Beach Erosion and Coastal Protection
- N. Traffic and Related Studies
- O. Watershed Engineering
- P. Hydrology
- Q. Materials Surveys
- R. Excavation

Bibliography

CHAPTER X.—Photo Interpretation in Geography

(Author-editor: John H. Roscoe, Reconnaissance Branch, Directorate of Intelligence, Hdqs. U. S. Air Force, Washington 25, D. C.)

(Detailed outline not yet received)

CHAPTER XI.—Other Applications of Photo Interpretation

(Author-editor: Not yet assigned)

Introduction: (Brief statement of scope and purpose of chapter)

Basic Considerations

General Applicability of *Aerial* P.I. Techniques to the interpretation of photos taken with telescopes, microscopes, oscilloscopes, radio-autographs, etc.

Specific Applications
- A. Astronomy
- B. Medicine
- C. Criminology
- D. Motion Studies (Interpretation of Time Lapse Photography)
- E. Archaeology
- F. Other Applications

Bibliography

CHAPTER XII.—Education and Training in Photo Interpretation

(Author-editor: Not yet assigned)

Based largely on Boston University Technical Note 119, "A Comparative Analysis of Curricula and Techniques Used in the Training of Photographic Interpreters," by Lt. Col. S. A. Custer and Sylvia R. Mayer.

APPENDIX A.—Definition of Terms Used in Photo Interpretation

(Based largely on P.I. Glossary prepared by U. S. Armed Forces plus Contributions from Author-editors of the Various Chapters)

APPENDIX B.—General Tables and Graphs Submitted by Author-editors of the Various Chapters

### OTHER RECENT REFERENCE PUBLICATIONS

1. A list and description, of the photo interpretation aids with the names of the manufacturers and the prices have been prepared by Clarence D. Chase,

and S. H. Spurr, Lake States Forest Experiment Station, University Farm, St. Paul 1, Minnesota.

2. John O. Eichler, M. C. E., Assoc. Professor of Engineering and Harry Tubis, Instructor in Photogrammetry, The Cooper Union, School of Engineering, New York 3, N. Y., have prepared a 28-page publication for presenting to students some basic considerations about aerial surveys. It attempts to accomplish this by a series of laboratory problems in photogrammetry and photo interpretation.

The so-called "Kit" consists of 28 pages of text material, is divided into five chapters and is bound in a paper folder. In a back cover pocket are six $9'' \times 9''$ contact aerial photos, two control overlays and a photo index.

Chapter I covers "Planning and Executing the Photographic Flight," Chapter II, "Basic Photo Interpretation," Chapter III, "Selected Problems in Photogrammetry," Chapter IV, "Radial Line Plotting," Chapter V, "Compilation of Mosaics."

3. In late 1955 the Society of American Foresters' *Forestry Handbook* came off the press after eight years in the making. This monumental authoritative document had an editorial board of 145 consulting and contributing editors, including foresters, administrators, research workers and educators.

One whole section, 27 pages, is on aerial photography. It comprehensively covers the general uses of aerial photos in forestry, other problems of obtaining and handling aerial photos, and photo specifications. Types and kinds of photos are discussed. Stereoscopy is covered in a very interesting manner. Measurements are discussed by covering the geometry of the aerial photograph, measurements of area, slope, tree heights, crown diameter and stand density. Map making briefly covers the essentials of such as radial line triangulation, planimetric detail, topographic detail and locating ground points on photos.

The discussion of stand classification from aerial photos covers species, type and site identification. Combined aerial and ground forest surveys are discussed under area determination by mapping. Photo sampling, adjustments of area estimates, ground plots needed, locating ground plots and volume computations are outlined. Last but not least is a discussion of estimating volume direct from aerial photos. Every forester interested in photo interpretation should be familiar with this section of the *Forestry Handbook.*

## Research

### PHOTO INTERPRETATION RESEARCH WANTED

A growing reservoir of research is the only assurance of continued progress in photo interpretation. This pool of ideas, techniques and knowledge is subject to continued filtering to photo interpreters; all progress is limited to concepts drawn from this reservoir.

The development of new equipment or new methods depends upon ideas and techniques created by research. There first appears an awareness of a need. This results in looking toward agencies for equipment or techniques to meet the need. These agencies, in turn, call upon the work of research (not exclusively today's but alsc generally accepted facts of today resulting from research of years ago). From this field of existing knowledge and tools are pieced together the equipment or techniques that satisfy the requirement.

In the complexity of present society, research is rarely a one-man job. Conferences between researchers working in the same area, and designed to promote the sharing of ideas, skills, and goals, are now common and almost requisite. The recognition of the impingement of disciplines, one on the other, demands, insofar as possible, team approaches based on utilization of training and talents from many disciplines. Group discussion is one of the most powerful tools. From it evolves one of the greatest efficiencies that can be applied to this recognizedly inefficient process called research, for one of the greatest inefficiencies occurs in the form of invalid results. If the findings are recognized as invalid, the invested time and money are lost; if not so recognized and therefore accepted, the findings can lead directly away from progress, and only through more research and re-education can they be corrected. Group discussion, during the planning phases, is one of the best safeguards against invalid experimentation.

Research is an art practiced by a man skilled in that field in which he practices the art. It is essentially a creative technique applied to a problem. It must also be noted that research never produces the wrong answer. The wrong answers come about only when the incorrect interpretation is applied to the results, or the wrong methods are applied to research. One might insert that wrong answers, wrong interpretations, and wrong methods are distinct probabilities when the non-artist practices research.

It can be stated that research involves (1) recognition of the problem, (2) detailed specification and outline of that problem, (3) evaluation of previous research in and related to that field by means of recourse to books, journals, and other researchers, (4) the establishment and analysis of methods and procedures, (5) the gathering of data (in the fields of science, this includes making systematic observations), (6) analysis (in experimental work, this includes a statistical treatment of results to assess the precision of the experiment), and (7) the evaluation of the results. In all this, a large share of the experimenter's time goes into the development of the final experimental design.

Research management has two important responsibilities in the area of human factors. First, the responsibility to select a staff possessing the innate ability to do good creative work. Second, there must be recognition and understanding of the incentives making or producing this will to create. There must be the definition of a mission which is broad enough and yet not too broad, the provision of a coincidence of authority and responsibility, the recognition of accomplishment, and the recognition of the dignity of the individual. A research administrator who achieves these objectives to a high degree will have an effective and productive organization.

The worker, not the administrator, must design the research and select the areas for research. To do this, the researcher must be well informed about the plans and problems of his organization, must assist in establishing the proper communication and must defend the interpretation of his work, assuming the responsibility for channeling these results to the point where they can be effectively utilized.

### APPROACH TO PHOTOGRAPHIC INTERPRETATION RESEARCH

Systematic approaches are proposed to the study of problems in photo interpretation. Such a study would include problem analysis, preparation of work plans and execution of work plans.

The immediate problem is to arrange all factors that effect probability of recognition of an image. It is essential that there be an evaluation of these factors in light of the recognition of an image and then an investigation of methods of controlling these factors.

Photo interpretation is defined as the act of examining the photographic images of objects for the purpose of identifying the objects and deducing their significance.

Consistent with this definition, factors which are basic to photo interpretation are listed under two main classes suggested by Colwell. These are (1) factors governing the quality of the photo images and (2) factors governing the perception and interpretation of photo images. Under quality are characteristics of color or tone, image sharpness, and stereoscopic parallax. Under perception and interpretation are characteristics of visual and mental acuity of the photo interpreter, his equipment and the techniques employed by him. Many of these factors have been or are being studied.

Much work is going forward in the areas above listed; reference will be found in other sections of this report and in the reports of other commissions.

One of the more interesting facets of photographic interpretation research is the recent emphasis on developing means for qualitative and quantitative evaluation of the results. The creation and application of such evaluation methods would go far toward making the practice of photographic interpretation a science rather than an art.

## PHOTOGRAPHIC INTERPRETATION KEYS

Photographic interpretation in its various applications, is confronted with the task of producing information relative to many areas of human knowledge and endeavor. Therefore reference materials of a tremendously varied nature must be developed and made available in readily usable form. In the military services, where a single individual may be required to perform interpretation in many subjects, keys and other reference materials must be designed for use by all photographic interpreters, regardless of the educational or specialized background of the individual.

In the civilian field, the field of reference is not normally so broad for any particular individual. However photographic interpretation keys, carefully prepared and properly used, are found to be of use in many programs. A point to be kept in mind is that keys are not a cure-all for all photographic interpretation problems, nor are they a substitute for professional training and experience.

The development of keys has been proceeding at a steady rate during the reporting period. Of interest has been the continued development in the United States of "mechanical" type (punch-card) keys for identification of man-made objects.

Very little objective testing of the effectiveness of keys has been performed to date. This should receive high priority in the future.

## RESEARCH PROJECTS ARE ON THE MOVE IN AGRICULTURE AND FORESTRY

In forestry, new techniques are being investigated. Photo volume tables are being constructed. The use of larger scales is being explored, as well as several combinations of film and filters. Effects of season of year are being studied for the purpose of increasing the efficiency of the *U. S. Forest Survey*. Studies are also considered or under way to examine accuracy of stand height measurements in the Rocky Mountains. Studies of dot sampling bias on contact photos in mountain regions are under consideration. Aerial photo stand volume tables are being constructed; these will greatly aid photo interpreters in forestry.

Research in forest insect surveys is undertaken by the *U. S. Forest Service* to develop methods for conducting such surveys from the air. Both visual and photo methods are investigated for detecting and appraising forest insect damage. Studies are conducted on sample strips of Ektachrome or Anscochrome film. The instruments used are the Ryker or Old Delft mirror stereoscopes. Information studies involves area of insect damaged timber, number of trees killed, volume of timber, location and concentration of infested timber with comparative photography to study changes.

Aerial photographic tests are made for detecting damage by the white pine weevil (*Pissodes strobi* (Peck), the spruce budworm (*Cacaecia fumiferana* Clem.), and the southern pine beetle (*Dendroctonus frontalis* Zimm). Also large aerial color photos were taken in 1951 of a number of blighted areas to establish a visual record for studying the intensification and spread of the disease.

Photo mensuration studies in second-growth Douglas-fir forests are designed to meet forest management surveys. Species identification and volume estimates on aerial photos are the objectives. Study is made on 1:10,000 or 1:12,000 scale photos. The photo interpretation techniques used include light tables, Walthen lens stereoscope, $\frac{1}{5}$-acre plot overlays, crown diameter scales and Abrams height finder.

In the northernmost part of *Sweden*, certain jobs have been executed concerning the parcellation of forest land where photo interpretation has been used for the photogrammetric mapping, and for the assessment and classification of the forest soil. It has proved advantageous to use a helicopter for checking the photo interpretation. The experience of this work is favorable. It will probably be possible to report the results at the beginning of 1956.

The Swedish Committee on Forest Photogrammetry, appointed in 1948, has a considerable sum of money set aside from the Fund of Forest Research, for research work in 1955 to 1960. The purpose is to study the possibilities for rationally exploiting aerial photographs in Swedish forestry. Thanks to this committee much research, training and service in the field of photo-interpretation has been achieved. In 1953 a bulletin from the committee was published, "Mapping of Forest Stands from Aerial Photographs," by Nils Hagberg. Recently a book on photo-interpretation (*Tolkning av flygbilder*, 157 pages) appeared. For the present there is a study into the most satisfactory photographic scale.

No organized research works are carried out in *Norway*, but a few sparse investigations are made. The first trial of classifying forest stands is now under way. A committee is at work studying these questions, taking into consideration a special research institution and a more organized activity in this field.

In *Canada* studies are in process on large-scale photos for the purpose of examining the accuracy of measuring average heights of dominant and codominant trees, to study crown cover, preparation of photo volume tables, and the accuracy of estimating photo volumes. Tree species, tree heights and stand densities are determined from photos. The equipment used includes parallax bar, modified Zeiss binocular stereoscope and density scales. Accuracy standards are set at 10 per cent at .95 probability.

The National Research Council of *Canada* has cooperated in a program conducted by Purdue University of Lafayette, Indiana for the Corps of Engineers, United States Army. The purposes are: to extend the range of arctic and subarctic airphotosoil patterns to include terrain conditions found in Northwest Canada, to obtain field data on some of the soils and permafrost in northwestern Canada (the patterns that these soils present on aerial photographs are being studied and analyzed with respect to the field data), and to further develop methods of using airphotos to identify and evaluate significant characteristics of terrain conditions that influence engineering operations in the arctic and subarctic.

In *Britain*, in collaboration with the forestry commission, Hunting Aerosurveys has been conducting experiments to investigate the possibility of differentiating between hardwood species by photographic interpretation methods. Color photography was tried but was entirely satisfactory only where there was a highly distinctive foliage color as in the case of the copper beeches. On the other hand infra-red photography seemed to offer more considerable prospects of success. If this proves to be the case it will offer many additional advantages, not the least of which is its possible application in tropical and equatorial areas since exposure times are not as critical as for color film and the film can be processed on location.

Research in using photographic interpretation methods in soil mapping in *Britain* is currently being pursued by R. G. Clarke, Department of Agriculture, University of Oxford. The main object is to explore the possibility of producing "soil-unit" maps, probably on a scale of 1:25,000 using photographic interpretation aided by considerable ground checking. Certain areas have already been mapped experimentally with marked success and Mr. Clarke is at present engaged in similar mapping to test the minimum ground check requirements in areas of moderately complex soil conditions. One very useful outcome is the preparation of a schedule of edaphic features which are of value in soil mapping from air photographs.

The use of photo interpretation to obtain land use and other data for economic studies has been begun in the Agricultural Research Service, *U. S. Department of Agriculture*. A test study in the Coastal Plain area of North Carolina has been made using photo interpretation to get data on acreage and types of land clearing. In this area, comparison studies of recent and earlier photography appear to give very satisfactory results particularly in consideration of time and funds expended. Final procedures have not yet been established, and results have not been published. It is expected that photo interpretation will also be used to obtain data on amounts and types of land drainage.

### RESEARCH IN PHOTOGEOLOGY TAKES SHAPE

Probably the most surprising tendency has been regarding the relationship of photogeology to field geology. Indicated is a considerable decrease in field activity since the introduction of photogeology, and a large increase in geologic field work stemming from the many "leads" provided by preliminary photogeologic studies.

Photogrammetry and photography in general are well ahead of photogeologic techniques as now practiced by most geologists using aerial photographs.

Though air photos have earned wide regard as research tools in many areas, recognition of their value in geographic investigation has come belatedly. Progress in recent years has done much to relieve early apathy, and numbers of geographers are presently engaged in developing and testing specific applications of air photos to field problems.

A study of twenty sawmill towns in southwestern Louisiana was completed. These settlements, and many like them, came into being during the timber boom of the early twentieth century, and have since almost vanished. Inquiry into the nature of these "ghost towns" was greatly facilitated through the extensive employment of aerial photographs in each of the principal phases of the work: the location and identification of the mill town sites, the detailed study of each town, and the presentation of data gathered.

Obstacles to more complete reliance upon air photos were raised primarily by the very temporary nature of the forms and patterns being examined. Ponds were often drained as their earthen dams deteriorated. Trams were lightly built, and were usually removed as quickly as timber in the vicinity was exhausted. The towns themselves, though often sizable, were not constructed on a genuinely permanent basis, and their streets were generally not surfaced.

In spite of such hindrances, the study here summarized would have been much more difficult and costly without the aerial photographs. They served reliably as primary sources of information, and if not available and used, some phases of the work would probably have remained undone. Air photos will, in the future, enjoy much wider general employment among students of cultural landscapes.

Mr. Jean Gandillot, in charge of a course in aerial photography as applied to geology, is studying the utilization of emulsions and colored filters for making a better contrast with gray tints and, by studies about assemblies and stereograms, he has discovered some geological facts which had not been seen by geologists examining the earth.

These studies extend to lithology and tectonics, hydrography, volcanism, glaciology and littoral oceanography.

In the field of archeological research, it has permitted the discovery of the Roman centuriations of Tunisia, where several very significant systems totalling almost 30,000 centuries have been identified, and in France, the centuriation of the region of Narbonne.

### RESEARCH LEADS TO NEW IMPROVED DEVELOPMENTS

In *New York State*, investigations and studies have indicated the best scales, film, season, and kinds of air photos to use for forest survey purposes. Methods and techniques in timber cruising have been developed to fit local situations. One method is used for large areas of even aged softwood forests, another explains a plot scheme for hardwood areas, and still a third tree method is recommended for large softwoods scattered in hardwood types. This study used crown width and tree heights measured on aerial photographs. Tables showing accuracy are given. Comparison of theoretical volume are made with volumes obtained from field samples.

In *Canada* a research project was initiated in 1952 to test the value of large scale photography for detailed forest surveys. Two experimental areas, one of 40 square miles and one of 10 square miles, were photographed with snow on the ground at 1:8,000 scale and with strips at 1:1,600 taken on the same flight lines. A method of accurately determining stand density from the photographs was developed, and suitable techniques of measuring average stand height and arriving at a volume estimate were worked out. According to tests of the methods against ground surveys the desired accuracy could be obtained at costs less than those for equivalent ground surveys. A final test against the amount of wood actually cut from a 3 square mile area is under way at the present time.

Other developments in *Canada* include the successful use of large-scale sampling photographs to facilitate the interpretation of the general coverage photographs; experiments in the use of moving film magazines to minimize the effect of the forward motion of the aircraft; and trials of the application of special camouflage film to the determination of amounts of insect-killed timber.

Studies of the systematic errors in measuring tree heights indicate that interpreters have different bias for tree sizes, species, photo scales, and seasons. In *Canada* crown diameters could not be satisfactorily measured at 1:7,200 scale, but results were quite satisfactory at 1:12,000. New methods are being developed for measuring crown density and the results are very good. Preliminary reports on volume estimating at large scales appear satisfactory. Similar studies in Pennsylvania show that crown diameters can be measured with a 6 to 8 foot error, crown cover within 10 to 20%, and tree heights range from 14 to 20 foot errors at .95 probabilities using 1:12,000 photos.

An experiment to test whether tree heights could be measured as accurately on glassy prints as on transparencies proved that transparencies were superior.

Large pulpwood piles can be measured by photogrammetric means. Studies demonstrated this in the *State of Maine*.

Results of studies show that photo interpretation of the extent of insect damage to Douglas-fir and ponderosa pine results for substantial savings in survey costs.

Another study has demonstrated a method of taking and processing aerial photos in a rapid manner and making photos immediately available to fire crews.

A study shows that standard government specifications for aerial photography, at a scale of approximately 1:20,000, are satisfactory for soil mapping. For some purposes, larger scales are desirable and for others smaller scales would be better, but such needs are a minor part of the total. The timing of photography by seasons could be improved in a number of instances, with the result of the photographs being more useful for soil survey field work. Although time preferences vary in different regions, they largely coincide with the period of the year when soil cover is at a minimum. In other words, the aerial photographs showing the surface of the soil itself as clearly as possible are of the greatest usefulness. Thus, the preferences identify the time of year when vegetative cover is at a minimum, and the ground is free from snow. By and large, more states preferred the second quarter of the year than any other.

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# NATURAL RESOURCES

## Geology

### SUMMARY

The use of aerial photography for geologic analysis and mapping continues to be one of the more thriving applications of photographic interpretation. Activity in petroleum prospecting from photography continues at a high level in many parts of the world. The use in prospecting for other mineral resources is also increasing. Also there are a large number of non-commercial programs, aimed at producing geological maps and studies from aerial photographs, in the various countries covered by this report. See Figure 3.

### MINERAL PROSPECTING

In the field of prospecting, detailed information for the areas covered and the techniques used are frequently held as commercial secrets, and are therefore unavailable for a report of this type. However it is well known that most of the large oil companies, as well as geologic branches of the various governments, are actively using photography for this type of work. The *French Petroleum Institute* is currently engaged in preparing photogeological maps for petroleum prospecting mainly in the Sahara Desert area, and for mining territories in various overseas areas. Reports from *Pakistan* indicate that in the search for oil and other minerals a great deal of photogeological prospecting is being carried on by foreign firms. Photography is also being used for metallic mineral prospecting in *Norway* and *Sweden*.

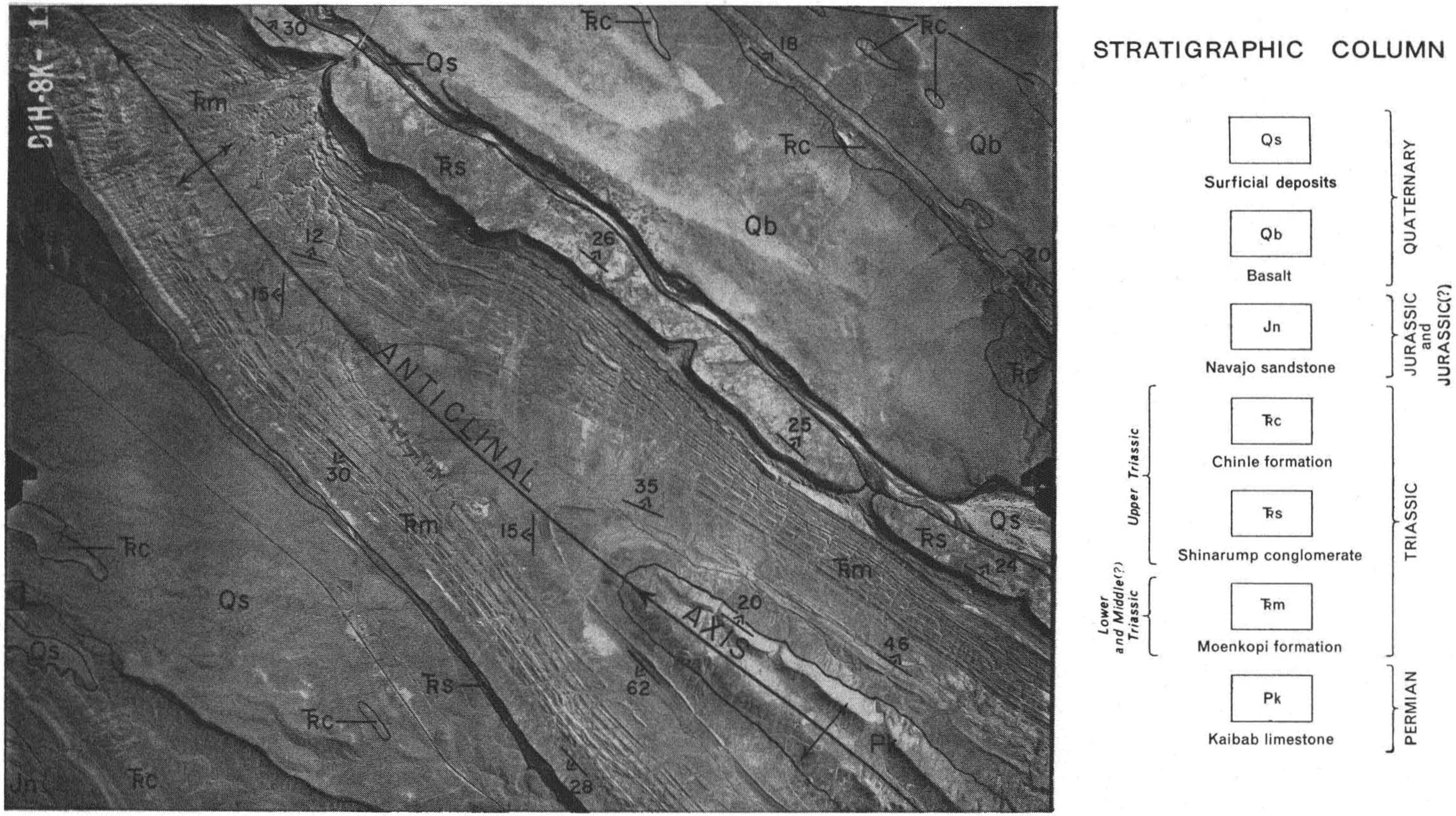
In the *United States*, photogeologic prospecting is being continued at an accelerated rate. In the petroleum field, work is being done, not only by photographic interpretation units on the staffs of oil companies, but by various commercial photogeologic companies and individual consultants. Several oil companies are directing significant amounts of research effort toward the problem of improving photogeological prospecting techniques.

The greatly increased emphasis on uranium prospecting during the reporting period provided a considerable challenge to the photogeologic prospector. In the *United States* and *Canada*, consistent use is being made of aerial photography. In the western United States, the Geological Survey made available to prospectors, photo maps principally of scales 1:24,000 or 1:48,000. These were used by prospectors on the ground, and by photographic interpreters, commercial organizations and photo-interpretation consultants engaged in analyzing aerial photography to select outcrop areas in which detailed ground reconnaissance might be promising. This "pinpointing" of areas for terrestrial prospecting was particularly valuable in the more rugged areas of the American Rockies and western Canada.

Much of the petroleum and uranium prospecting in both the *United States* and *Canada* is being accomplished on existing photography of varying scales for reasons of economy. If given a preference however, the photogeologic prospector is often likely to select vertical photography of approximately 1:20,000, with occasional larger scale photography for detailed analysis of specific outcrops. In certain instances color photography was taken from the air and used with some success in locating likely-looking mineral deposits.

### PHOTOGRAPHY ONE OF THE GEOLOGISTS' BEST TOOLS

In *British Colonial Territories*, aerial photographs continue to be used as an additional tool in the hands of geologists on the staffs of Geological Survey De-




THE VIRGIN ANTICLINE, UTAH

A plunging anticline in well exposed sediments

FIG. 3. An illustration of the interpretation of geologic characteristics. Photographs are used by geologists both as a source of information and as a base for detailed annotation.

partments. Photographic coverage in these territories is not yet complete but is nevertheless available for very large areas. The photographs, taken at a compromise scale are verticals of about 1:30,000, taken with a 6″ lens, and although not always ideal, are generally well suited to photogeological work. Early in 1949 a photogeological section was set up in the Directorate of Colonial Geological Surveys in London to handle specialist problems in this field for the individual territories. This section at present has a staff of four full-time geologists who, as the need arises, may also make visits abroad for the purpose of following up or checking in the field the results of their work. This does not mean that Colonial photogeological work has been centralized, but the section is able to act as a clearing house for this type of work, to make sure that its value and use are not overlooked, and to spend a certain amount of time on work of a research character.

It is well known that the most extensive and, so far, probably the most rewarding geological work on aerial photographs has been done in areas of sedimentary rocks. Large areas of the British Colonial Territories are occupied by the ancient metamorphic and igneous rocks, so that a good deal of attention has been paid to the question of getting results of geological value from areas of this type, particularly in Africa. Interesting results, to name one instance, have been obtained in the study of ring structures.

Apart from day-to-day use of photographs by geologists in the field, the headquarters section has included in its work the making of photogeological maps of selected areas of Karroo rocks in *Northern Rhodesia* and *Nyasaland* (a detailed structural study of a coal-bearing area being made in the latter country), initial reconnaissance maps followed by field visits in the British Territories in *Borneo*, and studies of areas of ancient rocks in *Somaliland* and *Nigeria*.

Photogeological methods are sometimes of particular value and interest in connection with special problems, and a small case in point is provided by the geological examination of a proposed dam site in *Malaya*. A description of this will shortly be published in Vol. V, No. 4 of *Colonial Geology and Mineral Resources* entitled "Investigations upon a Proposed Dam Site at Klang Gates, F.M.S." by J. B. Alexander and W. J. Procter.

The photogeological section also gives a three and a half weeks course annually to all geologists newly appointed to Colonial Geological Survey Departments, to acquaint them with the techniques and range of photogeological work.

As the actual interpretation in photogeological work is largely qualitative, no instruments other than a good mirror stereoscope are normally used, but for special problems and for the transfer of work to maps, use is of course made of standard photogrammetric techniques. It is however of paramount importance that the stereoscope be mounted on a good parallel guidance mechanism; through its interest the photogeological section was partly responsible for the appearance on the market in the *United Kingdom*, of a satisfactory parallel guidance mechanism.

British commercial air survey companies have also shown very considerable interest in geological investigations and to this end employ geologists, either as consultants or on their own staff. Here too there has been a recent tendency to study areas of ancient metamorphic and igneous rocks as well as more recent sedimentaries. Hunting Aerosurveys is currently carrying out, solely by means of photographic interpretation, an initial geological mapping project in part of *Mauretania* where existing geological maps comprise only a reconnaissance sheet. The same company recently completed a map at a scale of 1:50,000 of structural trends in the pre-Cambrian in the Tekhammalt region of the Hoggar.

In most cases the mapping of structures has been facilitated by the absence of a dense vegetation cover, but in one case in *Southeast Asia* an investigation has been made into the possibility of tracing structures in densely forested areas, the work being carried out on mosaics at a scale of 1:31,680.

Whereas the main function of photographic interpretation in British geological work is still concerned with the tracing of structures, a certain amount of direct lithological interpretation has been done. But it is emphasized by the interpreters that in general this is possible only where some detailed knowledge of the area in question is already possessed from ground investigations, as in the case of work in *Jordan* referred to below.

Many of the British lithological studies have been carried out in areas of hot arid climates and it is emphasized that climatic circumstances are important in interpreting rock types. In particular it is pointed out that, in the *Saharan* and *Middle East* arid regions, outcrops of sandstones, grits and quartzites which contain iron always show up as dark or black zones on the photographs. Again, photogeological methods have been applied to specific detailed problems by the commercial companies, one example being the plotting of the outcrop of a comparatively narrow band of manganese-bearing and characteristically stained flags and shales in the Duna-Feinan district of *Jordan*.

The interpretation of the geophysical results of airborne magnetometer and scintillation counter surveys is regarded as being outside the scope of the present report. It should be noted, however, that the interpretation of surface features which may be related to the anomalies revealed by this type of survey is a specialized branch of geological and morphological interpretation which is rapidly increasing in importance.

As a state office for geological broad mapping the Geological Survey of *Sweden* has had a very great use of air photos and photographical maps for ore prospecting and geological works, especially in northern Sweden, where the roads are sparse, the country is difficult to traverse, and the topographical maps leave much to desire. For other state offices the Geological Survey investigates such problems as the river erosion at the water plants. At these works air photos have been very valuable. Repeated photographing after some years in the same locality will give an exact and objective picture of the progress of the erosion. Because of the land upheaval in *Central Scandinavia* and the erosion of the rivers, landslides often have happened in the steep clay slopes of the rivers. A region of current interest in this respect is the valley of the Gota River between Lake Vanern and the sea at Gothenburg. Here, old slide scars have been mapped by the aid of air-photos.

In mapping and examining peat bogs in *south* and *middle Sweden* air pictures and photo maps have saved much work of manual survey.

In the *United States*, since 1952, numerous geologic mapping projects involving primarily interpretation of geology from aerial photographs have been undertaken and completed; certain projects are continuing. Of particular significance is the variety of terranes that have been studied. These include well exposed, gently folded rocks of the Colorado Plateau area, in western United States; poorly exposed, tundra-covered sedimentary rocks of northern and northwestern *Alaska;* heavily forested igneous and metamorphic rocks in southern and southeastern Alaska; and sparsely forested areas in Alaska underlain in large part by superficial deposits. A variety of projects of different mapping scales, objectives, and techniques used have been undertaken within these terranes. In northern and northwestern Alaska general mapping of stratigraphy and structure has been completed at scales of 1:96,000 and 1:250,000. Numerous potential oil structures within northern Alaska have been structure-contoured at scales as large as 1:10,000. This work was accomplished in spite of a paucity of outcrops, but with widespread tundra cover. Some aspects of this work are described by W. A. Fischer in "Photogeologic Studies in Arctic Alaska and Other Areas."

Other sedimentary rock studies have been completed in the Colorado Plateau area, *western United States*, where structures and distribution of rock types have been mapped at a scale of 1:24,000. Here rock exposures are excellent and permit such recognition of detail that stratigraphic thicknesses in many areas have been measured with sufficient accuracy to allow isopachous maps to be compiled with an isopachous interval of ten feet. The isopachous maps show stratigraphic thickness variations that may be significant with regard to uranium mineral deposition. Correlation studies in part of the petroliferous Tertiary Basin of northeastern Utah have also been completed. Beds as thin as five feet have been mapped over wide areas.

Photogeologic mapping of heavily forested parts of *Alaska* has been accomplished at scales of 1:8,000 to 1:250,000 depending on the objectives of the study. Large-scale mapping has been done in mine areas and potential dam site areas; small-scale mapping has been carried out in other areas at scales of 1:62,500 to 1:250,000. In these studies the mapping of structures like faults and shear zones was the primary objective. In some sparsely forested areas surficial deposits have been mapped at a scale of 1:250,000.

Instruments and procedures used in these photogeologic studies have been described by W. A. Fischer in "Photogeologic Instruments Used by the U. S. Geological Survey," and by R. G. Ray in "Photogeologic Procedures in Geologic Interpretation and Mapping."

### ACTIVITY IN GEOMORPHOLOGY

The largest *British* project involving interpretation of a geomorphological character is at present being undertaken by Hunting Aerosurveys in *Jordan*. Though the ultimate object of the survey is mapping vegetation units throughout the country, the present operations consist mainly in the preparatory land classification mapping, based largely on geological and geomorphological criteria. Much of the work is being carried out by photographic interpretation methods, though the definition of the classification types is based in considerable measure on detailed field investigations by ecologists and geologists in all parts of Jordan. Illustrations based on the preliminary stages of this project were used by Dr. V. C. Robertson in a paper read to the Photogrammetric Society entitled "Aerial Photography and Proper Land Utilization" (*Photogrammetric Record*, Vol. 1, No. 6). An interesting example of a correlation between vegetation forms and geology, which has been proved on the ground and traced by photographic interpretation methods in Jordan, is provided by the way in which, in the West Central woodland scarp area of the country, oaks are found on the limestone and marl areas, whereas the juniper occurs on the sandstones.

In *England* a paper on "The Value of Air Photographs in the Analysis of Drainage Patterns" was given to the Photogrammetric Society in March 1953 by Dr. S. H. Shaw; this included details of investigations on this subject in the Lake Nvasa region (*Photogrammetric Record*, Vol. 1, No. 2).

During the reporting period, the U. S. Geological Survey, in cooperation with the Corps of Engineers, U. S. Army, has also engaged in field studies of the geology and vegetation of *Alaska* with particular reference to the relationship between permafrost, land forms, and vegetative cover. A major aim has been to develop means of photo interpretation of Arctic terrain in terms of the significance of plants and land forms in the determination of ground conditions. A summary of the results to date is presented in Professional Paper 264F of the U. S. Geological Survey, by David M. Hopkins, Thor N. V. Karlstrom, and others, entitled "Permafrost and Ground Water in Alaska."

In connection with a program of geologic mapping in the islands of the *western North Pacific*, carried out by the U. S. Geological Survey in cooperation with the Corps of Engineers, U. S. Army, photo interpretation was used in preparing a large scale map of *Pagan*, a small volcanic island in the northern Marianas Group, prior to the beginning of field mapping of the island. The use of photogrammetric techniques in delineating lava flows of different ages greatly expedited field work, and proved to be of satisfactory accuracy.

RESEARCH IN GEOLOGIC PHOTOGRAPHIC INTERPRETATION CONTINUES

In *Sweden*, at the geographical department of Lund University, air photos have, with regard to photo interpretation, chiefly been used for tectonic-morphological and glacial-morphological investigations.

In the tectonic-morphological work, air photos have been processed to detect and identify tectonic lines in the landscape. It has thus been possible to obtain a far more complete picture of the structural conditions of the bedrock than the map material in common use can offer. Consequently, there is also the possibility to obtain a more exact interpretation of tectonic influence on the genesis of land forms. The investigations include the hogbacks of Skane, the littoral of Blekinge and the Fjelds of *northern Norway*.

In glacial-morphological investigations, air photo material has chiefly been used to identify terminal moraine lines, drumline and "flybio-glacial" hogback formations. In this connection vegetation and cultivation as appearing in the photo, have often been able to support the interpretation. In the field regions above the tree limit where the solid layer is often thin or entirely missing, formations from the glacial period as noted above (with the exception of drumlins) appear clearly through their contrasting color. In the study of nunataks which are mostly very difficult to climb, air photos are an invaluable aid. The investigations yielding the above experience were carried out in *south Smaland* and on the *west coast of north Norway*.

The geographical department of Lund University has also been working on terrestrial photos from the *Andes*, taken with a Leica in conjunction with a theodolite. The experience and a discussion of the method have been published in *Bilmessung und Luftbildwesen* number 4, 1954.

An intensive research study in the geomorphology and photo-interpretation of sand dunes has been carried on for the past few years by Dr. H. T. U. Smith of the University of Kansas, under a research contract with the U. S. Office of Naval Research. This has involved field studies in *southwestern U. S.*, *Peru*, and the *coastal areas* of *northwestern Europe*, and of course, correlation of field data with photographic expression. These studies are still in progress and should lead to perhaps the most comprehensive study ever prepared of the photo interpretation of one single type of landform. This in itself is one unit in a long-range program which, if circumstances are favorable, may be extended to other types of landforms.

Projects of a research nature have also been undertaken by the U. S. Geological Survey during the reporting period. These include a diversity of studies such as: (1) an evaluation of color aerial photography of certain small selected areas in *western United States;* (2) experimentation and development of an instrument for use with aerial photographic prints, that permits determination of slope angles in stereoscopic models; (3) experimentation with a tilting platen for use with Multiplex-type instruments for determining slope angles in stereoscopic models, and (4) experimentation with constructed stereoscopic models for training purposes. The results of this latter work are described in "Construction of Controlled Stereoscopic Models" by R. J. Hackman.

Some particularly interesting experimentation has been conducted at the U. S. Geological Survey in the use of high altitude photography (1:60,000 scale) for geologic mapping. By the use of a Kelsh-type plotter, the stereo-model is enlarged approximately five times from the original scale of the photography. This technique permits relatively large areas to be studied from the same stereoscopic model, as contrasted with the limited area of the usual 1:20,000 scale photography. This permits the interpreter to recognize geologic relationships in the single model which with large-scale, smaller area photography might be discovered only after prolonged study. Further advantages of the technique are that excellent plotting accuracies are realized due to the use of a high order stereo instrument, and that greater speed and economy in map compilation is obtained since a fewer number of stereoscopic models are required per unit area.

SOME ADDITIONAL PRODUCTION AND RESEARCH PROJECTS

In the interests of brevity, the following additional photogeologic projects active during this period are listed in outline form below:

*Title: General geologic mapping, Colorado Plateau, U.S.A. (production)*

General description: 1:24,000 scale mapping of distribution of sedimentary rocks in Colorado Plateau. Mapping all structure, such as folds, faults, and joints

Dates: Begun—1952. This is a continuing project

Types and scales of Photography: Primarily 1:20,000-scale, vertical 6″–8¼″; and 1:60,000-scale, vertical 6″ photography. All photography is black and white

PI instruments used: Stereoscopes, stereometers, Kail plotter, Kelsh plotter, and Multiplex

Types of information furnished: Structure and distribution of mineralized formations, largely Mesozoic in age

*Title: Reconnaissance mapping, Alaska*

General description: Photogeologic mapping in connection with field-photo compilations of Alaskan 1:250,000-scale quadrangles. Photo work to show geologic information interpretable from photos and commensurate with plotting at above scale

Dates: Begun—1954. This is a continuing project

Area: 54,000 square miles

Types and scale of photography: Primarily 1:40,000-scale, vertical, 6″ photography. Black and white

PI instruments used: Stereoscopes, stereometers

Types of information furnished: Generalized structural and stratigraphic information

*Title: Uinta Basin, Utah, U. S. A. (production)*

General description: Detailed mapping of Green River and Uinta formations

Dates: August—1952 to March—1954

Area: 1,200 square miles

Types and scale of photography: Primarily 1:20,000 vertical $8\frac{1}{4}''$ photography. Also some 1:35,000 vertical 5.2″ and 1:32,000 four-lens, vertical 4″ photography. All photography is black and white

PI instruments used: Stereoscopes, stereometers, Kail plotter

Types of information furnished: Detailed information on correlation of thin beds within the Green River and Uinta formations. Terrain profiles

*Title: Isopach map, Monument Valley, Utah, U. S. A. (production)*

General description: Detailed study and measurement of stratigraphic intervals to permit isopachous map compilations

Dates: Begun—1953, to be completed by 1957

Area: 1,500 square miles

Types and scales of photography: 1:20,000-scale vertical 6″ photography, black and white

PI instruments used: Stereoscopes, stereometer, Kelsh plotter (primarily the latter)

Types of information furnished: Isopachous maps showing swales and channels, some of which are known to be mineralized in a certain formation

*Title: Kuparuk-Aufeis area, Alaska (production)*

General description: Photogeologic mapping of area between two field-mapped areas, gently folded sedimentary terrain

Dates: Begun 1954. To be completed 1956

Area: 600 square miles

Types and scale of photography: 1:10,000-scale vertical, 6″. 1:40,000-scale, trimetrogon 6″, high angle obliques 24″, both black and white and Kodacolor

PI instruments used: Stereoscope, Super Duper Dipper

Types of information furnished: Structural and stratigraphic

*Title: Permafrost studies in Alaska*

General description: Field studies, supplemented by photo interpretation aimed at increased knowledge of the distribution and characteristics of permafrost and the means of determining these from aerial photography

Dates: 1954 to present. Continuing project

Area: Selected photographs from various parts of Alaska

Types and scale of photography: Mostly verticals at scale of 1:20,000 and 1:40,000, also low-level obliques

PI instruments used: Stereoscope

Types of information furnished: Distribution of bedrock and surficial deposits

*Title: Military Geology, Pagan Island, Northern Marianas (Pacific Ocean)*

General description: Photogeologic mapping and field mapping of geology and vegetation of Pagan Island

Dates: June—1954 to present. Report writing nearly completed

Arêa: Vertical coverage, 16 square miles

Types and scale of photography: Vertical, 1:20,000

PI instruments used: Kelsh plotter

Types of information furnished: Report

*Title: Evaluation of color photography in geologic study (research)*

General description: Office and field evaluation of vertical color photographs of selected areas in California and Nevada (U.S.A.)

Dates: Begun 1955. This is a continuing project

Area: 348 linear miles
Types and scale of photography: Ektochrome, 1:10,000 scale vertical photography, 12″
PI instruments used: Stereoscopes, stereometers
Types of information furnished: Eventual research paper

*Title: Swan Lake, Alaska (research)*

General description: Photogeologic mapping of a small area proposed as a dam site
Dates: Begun and finished 1955
Area: 200 square miles
Types and scales of photography: 1:40,000 scale, vertical, 6″ photography, black and white
PI instruments used: Kelsh plotter
Types of information furnished: Structural setting in vicinity of dam site. Area heavily vegetated. Results not yet field evaluated

*Title: Salt Chuck mine area and Hollis mine area, Alaska (research)*

General description: Photogeologic mapping of small areas adjacent to certain copper and gold mines, igneous metamorphic terrain
Dates: begun and finished 1955
Area: 45 square miles
Types and scale of photography: 1:40,000 scale, vertical 6″ photography, black and white
PI instruments used: Kelsh plotter
Types of information furnished: Structural setting (faults and shear zones) in vicinity of mines. Area heavily vegetated. Results not yet field evaluated

*Title: Prince William Sound area, Alaska (research)*

General description: Mapping of regional structural setting in igneous-metamorphic terrain
Dates: Begun 1953. This is a continuing project
Area: 4,000 square miles
Types and scale of photography: 1:40,000-scale vertical, 6″ photography, black and white
PI instruments used: Stereoscope, stereometer
Types of information furnished: Detailed fracture pattern in an area of former copper mining activity. Area heavily vegetated. Results not yet field evaluated

## TYPES OF PHOTOGRAPHY USED IN GEOLOGIC INTERPRETATION

The geologist-photographic-interpreter frequently works for reasons of economy, with whatever photography already exists in the region with which he is concerned. However, as a result of research into the effectiveness and limitations of various types of photography for geologic purposes, ideas of geologists as to desirable types and scales of photography are well developed. These ideas may change with the individual, and will certainly vary with the particular type of geologic problem to be solved, but the general requirements are fairly consistent.

In papers presented at a symposium on photogeology sponsored by the U. S. Research and Development Board in 1953, some comments on photographic requirements were made by two experienced photogeologists, Mr. R. F. Thurrell, Jr., and Dr. F. A. Melton. Since this is believed to represent perhaps the best information on this subject published during the reporting period, it is summarized briefly below. It will be noted that while there are differences in the two lists, these are not major ones.

*R. F. Thurrell (1943)*

Scale: Vertical, 1:20,000. Obliques desirable as supplementary source materials.

Size: 9 or 10 inch square photographs represent answer to the opposing requirements of economy of photography, and ease of handling.

Focal length: $8\frac{1}{4}''$ best from point of view of stereo-exaggeration provided at 50% overlap.

Overlap: 50% normal. Increase as necessary for special problems (6″ focal length at 80% will provide both high exaggeration and low exaggeration stereo pairs of the target area.

Color: Highly desirable, but usually not practicable due to cost and difficulty of handling.

Other: Early spring and late fall best seasons due to lack of vegetation camouflage. No snow cover. Cloud cover less than 10%.

*F. A. Melton (1943)*

Scale: Vertical normally 1:20,000.

Size: 7 by 9 inch prints preferred to 9 inch square or larger, because of ease of handling and less stereo distortion at edges.

Focal length: 12″ preferred to shorter focal lengths due to flatter field of view in stereo model.

Overlap: 65% to 70%, with side lap of 20% to 25%.

Color: Highly desirable but usually not practicable due to cost and difficulty of handling.

Other: Photographs should not be indiscriminately "dogged" in printing, since significant tonal changes on the ground may be minimized.

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## FORESTRY AND LAND USE

### AERIAL PHOTOS ARE REPLACING FOREST MAPS

Sweden reports that the Korsnas Company which owns vast forest areas in the central part of *Sweden*, is using aerial photographs as forest maps. Within a short time these photographs will completely replace the ordinary drawn maps earlier used. However it has become apparent that photographs can be applied to more extensive parts of forestry than drawn maps. Photographs are thus used as a tool in the everyday activities of the forester. This application of photographs is believed to be the most important of all.

A condition for using photographs in this way is, however, that the material be comfortable to use, and that the staff get an opportunity of learning photo-interpretation. Therefore, the activity up to now, has been concentrated on preparing the material in a suitable way, and on introducing the aerial photograph as a forest map. Thereby a procedure has been worked out, under which the photographs are cut and pasted on an aluminium-carton, so that one can comfortably see stereoscopically even in the field. In the *United States* the forester is often substituting the photo-map for the conventional map. Timber sale areas and specific logging areas are outlined on photos and then checked in the field.

*Sweden*, a land of forests, is interested in technical progress, forest photogrammetry and especially photo-interpretation. In the small-scale forestry, including half of the forest area of the country, the interest in photo-interpretation is fairly new. In the big forest enterprises photo-interpretation is well known, and the period of photogrammetric experiments is already passing over to a period of stabilized practice. In the main, photo-interpretation is used instead of drawn maps. In the last years the photos have been used to some extent in planning the logging operations, and in locating forest roads. On the other hand, photogrammetric methods have not yet been able to supersede the well-tried old Swedish timber cruisings on the ground. However, in general the activity and progress since 1952 are important, as can be seen from following examples:

The Board of Crown Lands and Forests has decided that (vertical) aerial photographs shall be used as the basis of forest mapping in *North Sweden*, where the mapping area amounts to about 40,000 km.$^2$ (c. 10 million acres). Last year only 1,250 km.$^2$ state forests were mapped, but 3,900 km.$^2$ were photographed for mapping in 1956. An increasing part of the mapping work is done indoors and checked in the field, to some extent from aircraft. Helicopters have been used for 50 hours for checking the stand boundaries, drawn on the photographs, and at the same time for description of the stands. However, transferring the details from photographs with a scale of c. 1:25,000 to ordinary drawn maps with a scale of 1:10,000 (in *Lapland* 1:20,000) by using plotted bench marks, demands more adequate instruments than are now available. A great deal of attention is paid to training in photo interpretation, and according to a plan forest officers of all grades attend five day courses of instruction. The Board also has brought forward the project for photographing all *Sweden* every 10 years.

FOREST SURVEY PHOTO TECHNIQUES INVADE NEW AREAS

The first significant forest photo interpretation in *China* was in 1954. Photo interpretation was used in the land use and forest resource survey project of *Taiwan*. The objective of this project was to yield (1) an inventory of forest resources including current volume, growth, drain and other data needed to formulate forest management plans directed toward maximizing a continuous harvest of indigeneous forest products; (2) A vegetational cover map to facilitate the classification of land according to present use and soil and water conservation problem areas, as a first step in formulating a program of land use readjustment.

The result of this survey led to the organization of the Chinese Society of Photogrammetry. On December 26, 1955 this Society held its second annual meeting. The displays, under preparation for several weeks, were viewed for four days. More than 500 people attended this meeting. Folks showed tremendous interest; many people attended the meeting twice and studied exhibits at great length. Groups of students and teachers took many notes and were loaded with questions. As a part of this meeting a United Technical Conference was held which was attended by 30 government agencies, 10 societies and 8 schools. This conference discussed problems related to the use of aerial photos in the economic development of *Taiwan* and was divided into three parts. The first presented seven aerial survey projects. The second discussed problems raised by specialists in various fields. The third part was the exhibits. This Society now has a periodical called *Photogrammetry Notes* with 4 issues a year, each with 9 technical papers.

*England* reports that a land classification overlay for a photo-mosaic of a proposed sisal plantation on the Kenya coast was prepared by photographic interpretation methods, with minimum ground checking, and provided the necessary basis for locating rocky areas, eight natural vegetation units, shifting African cultivation and land in the process of regeneration, as well as a means of selecting sample sites in areas representative of uniform vegetation classes.

In *Britain* land-use mosaics at a scale of 1:10,560 have been prepared, although in this case the interpretation is restricted to the identification of such categories of agricultural utilization as grass, crops, root crops, woodland and orchard.

Photo interpretation does not furnish knowledge about the forests in *France*—these have been known for a long time—but interpretation does present two very appreciable advantages in intensive forestry. On one hand it permits simplifying and specifying the location of observations. On the other hand it permits generalizations to a certain degree. The organizations for Colonial Forces working in black *Africa* have begun to use photo interpretation in prospecting the Colonial forests.

Air photographic interpretation is being employed in forest inventories throughout *Canada* to minimize the labor of field sampling.

Forest sites are also being interpreted and a system has been developed whereby land form, land form position, and vegetation are employed to indicate soil moisture, parent soil material, and great soil group.

In *Norway* great studies have been made in use of aerial photos. Aerial photos are used for preparing management plans, for analysis of soil, and analysis of vegetation cover. Also special surveys in logging, reforestation, survey boundaries, and land use surveys have been developed.

In 1955 the Airborne Mapping Ltd. of *Sweden* photographed about 2,000,000 hectares of forest. These photographs will be used for the plotting of special forestry maps of the scale of 1:10,000 and 1:20,000.

New approaches are developed to inventorying timberlands with the aid of vertical aerial photographs. New survey methods are applied in *New York State* to a sample forest classification of northern hardwood type growing on land of medium site quality. The importance of field reconnaissance is emphasized. Procedures are presented for collecting and analyzing data from forest plots, including the method of constructing tree volume tables based on crown sizes. Three methods of estimating timber volumes were used: (1) plot cruise on photos, (2) mean crown diameter, and (3) tree crown count. Photo volume tables are developed for use in estimating timber volumes for twenty four forest type and site classifications.

### PHOTO INTERPRETATION IN LAND USE MOVES AHEAD

*France* has found that interpretation facilitates the identification of parcels of land and the classification of soils in order to work them.

The Prairie Farm Rehabilitation Administration of the Department of Agriculture, *Canada*, has found that, with a knowledge of geological processes and soil peculiarities, soil conditions may be interpreted from air photographs, and that preliminary irrigation and water development surveys can accordingly be facilitated.

In the *United States* photo interpretation was used to obtain land use data by selected soil groups for agricultural and urban land. These cover classes included small grain, hay, pasture, etc. The soil-cover information was used for hydrologic analysis of the basin and for program planning. Photo interpretation was used to obtain land use data by flood frequency zones on a large river flood plain, for use in economic appraisal of the flood control program. Data were obtained for natural conditions and the modified conditions prevailing after construction of flood control dams. Information of flood plain land use is difficult to obtain except by field mapping because most land use information is inventoried by political subdivisions.

### AERIAL PHOTOS EXPEDITE FOREST LOGGING OPERATIONS

Since 1949, the *Swedish Pulp Company* (Svenska Cellulosa AB) has been using photographs instead of drawn forest maps for about 8,000 km.[2] It now has found it appropriate to plan loggings by studying aerial photographs. The logging areas are marked and described by using Old Delft scanning stereoscopes. This chart-room work is checked in the field. Korsnas AB is another big forest company, that has resolved to use photographs instead of drawn forest maps. Much attention is paid to the quality of the photographs as well as to arranging the photographs for comfortable use in the field. In connection with expensive uprooting of timber by unusually severe storms, aerial photographs have been taken of the areas in question and their limits determined by means of interpretation. It has also been possible by these means to decide by which routes the felled lumber should be transported. In this way great profit has been derived from what otherwise would have been a more or less total loss.

In the *United States*, access and spur road locations are first determined under the stereoscope or on topographic maps made by photogrammetric methods. Photos are used by foresters as a guide in locating rock or gravel for road construction. Photo interpretation is being relied upon to provide information on stream conditions when water transport of logs is contemplated.

Aerial photos are commonly used to search out scattered patches of merchantable timber, or to determine the boundaries of an area needed in scattered timber to include the desired sale volume. Residual stands are carefully studied on aerial photos to establish the feasibility of a salvage or relogging chance. Snag sales are sometimes based on photo counts. Numerous operators have their newly logged areas photographed at the end of each logging season to provide (1) a cutting record for inventory, (2) location of new roads, (3) condition of the residual stand, and (4) extent of slash problem, and other pertinent information. Timber sale officers often use photos to make quick checks on the feasibility of volume estimates submitted by cruisers.

### AERIAL PHOTOS LOCATE FOREST INSECT DAMAGE

In the *United States* two forest insect laboratories—one at Beltsville, Maryland, and the other at Portland, Oregon—have made extensive aerial photographic and interpretation tests for the detection and appraisal of insect damaged timber. Because of the dynamic nature of insect populations, photography must be restricted to sampling methods due to cost, and to films and filters which record a discoloration of the normally green forests. Preliminary tests were aimed at determining whether certain types of insect damage could be detected on film; these tests indicate that infrared film is of no value, panchromatic film with an A-25 filter can be used for certain kinds of damage, but that color film produces the most accurate results when the interpretation is compared with ground study plots. Scales of the color photography varied from 1:1,200 for detecting weevilled white pine leaders, to 1:5,000 and 1:7,920 for identifying insect killed pine and fir trees. If a reasonable degree of interpretation accuracy can be determined for each type of insect damage, sampling surveys will be designed so that appraisals of timber damage can be made from the color pictures. Any aerial method has the limitation of being able to detect only faded trees; it does not account for surrounding infested trees which are still green but dead. Only ground inspection will reveal this ratio.

### PHOTO TECHNIQUES ARE VITAL TO FOREST FIRE CONTROL

Forest fire protection is an activity in which aerial photo interpretation is playing a vital part. This is particularly true in the *U. S.* where there are vast wild forest lands and the fire hazard is particularly severe. Where fires are commonly large, the photo interpreter has a designated place in the fire organization. Photo interpretation is making it possible to quickly and accurately obtain information on fuel types, slope, topography, natural barriers, water sources, existing roads, travel routes, safe campsites, and fire line locations. Air photos are used for general planning as well as for detailed orientation and instructions for fire crews. Often they are the only source of information for the Fire Boss. Aerial photos of the fire in progress provide information needed to combat it successfully. After the fire is over, the forester uses aerial photos in assessing the fire loss. On the Tillamook Burn aerial photos were used to establish the location of permanent fire breaks.

PHOTO INTERPRETATION AIDS REFORESTATION

While aerial photos cannot provide all the information needed for artificial reforestation they do eliminate a considerable portion of the ground examination. The largest single project in the *United States* is being conducted by the Oregon State Board of Forestry on the Tillamook Burn. Five hundred square miles were photographed at a scale of 1:12,000 on panchromatic film during the summers of 1953, 1954, and 1955. Infrared photography was also completed on a portion of the area. This photography was used in classifying the extensive burned areas as to the degree of stocking present. Areas that appeared understocked were further classified as to suitability for aerial seeding. Topography, aspect, density of vegetational cover, and abundance of snags were considered in setting up priorities for aerial seeding areas. Aerial photos were also used to set up priorities for hand planting areas. Ground examination was still needed on areas where seedlings were too small to resolve on the photos or where brush covered the small trees.

PHOTO INTERPRETATION MAKES PROGRESS IN WILDLIFE

Progressively greater use has been made of aerial photographs by wildlife research and management agencies. The most wide-spread use has been as maps and as an aid in cover-mapping. Probably all of the State Fish and Game Departments now utilize aerial photographs in their wildlife habitat improvement programs. Somewhat greater use has been made in inventorying wild animals, such as wintering concentrations of waterfowl, caribou and moose. The photos are used also in checking the accuracy of ground counts of game animals.

So far as is now known, no noteworthy new techniques or instruments of particular importance to photo interpretation in the wildlife field have been developed in the past four years. Progress has been made, however, in refining stratification and sampling techniques in interpreting photos of waterfowl concentrations.

Ducks, numbering about $1\frac{1}{3}$ million and concentrated on about 1,000 acres of water, may be photographed and counted with a fair degree of accuracy. Photos were taken at height of 700 to 1,800 feet, at air speeds of 120 to 160 m.p.h., with K-22 camera, at about f-8 with speed of 1/150 sec.

Vertical aerial photos at a scale of 1:15,840 or 1:20,000 are adequate for informative cover mapping for wildlife purposes, when ground checks are made of the vegetation as a control.

"Water-course" rather than a "strip census" method of inventorying moose from the air has been suggested for use in remote isolated areas. Aerial photography was used to check the accuracy of aerial observations and for analyzing habitat types in which the moose were found.

RESEARCH LOOKS AHEAD

Investigations were proposed to study the problems of photo interpretation. It has been suggested that better organized research will result if guided by a problem analysis and work plans. Such an analysis covers those factors that govern quality of photo images, discusses characteristics of the photo interpreters' equipment, and reviews techniques employed by the photo interpreters. Ability of photo interpreters is emphasized as a major problem in photo interpretation. More careful research has developed. Investigators have examined factors such as tree heights, crown diameters, density, volume estimates, species identification, soil classification and volume tables.

EDUCATION IS STRESSED

The need for education is evidenced by the many short courses in photo interpretation techniques. Such are designed for the practicing men in professional fields of forestry and agriculture. Also more thought and training are being incorporated in college courses. Forestry training in photo interpretation and photogrammetry is being expanded at rapid rates; this is a great help to the field foresters.

PROJECTS

A number of projects, underway in the fields of forestry and land use, are believed worthy of description in some detail. The remaining paragraphs in this section summarize some of these projects. See Figure 4.

*Forest Survey projects are many: Sweden* divides forests into treatment units

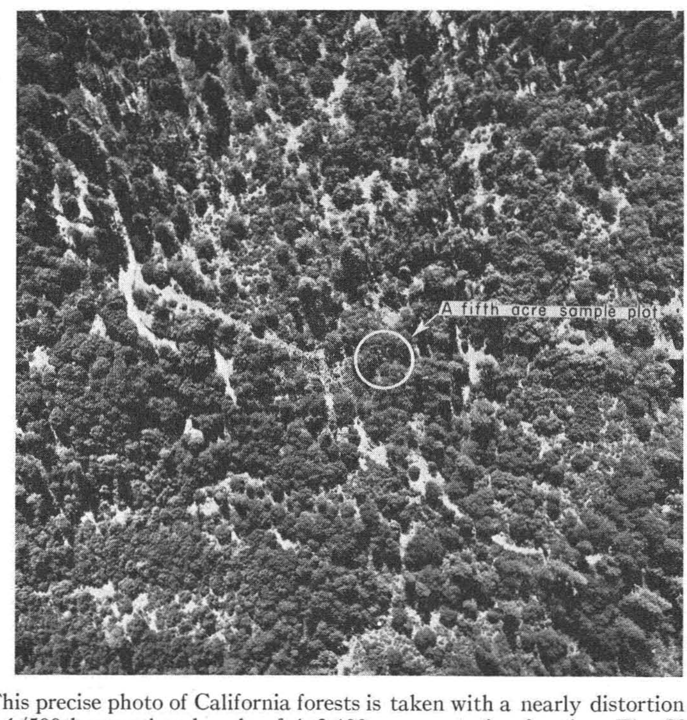


FIG. 4. This precise photo of California forests is taken with a nearly distortion free, 211 mm. Topar lens at 1/500th second and scale of 1:2,400 representative fraction. The fifth acre sample plot—on the original photo and prior to reduction—is typical of the photo plot scheme used in forest surveys. Tree heights, crown diameters and crown density are measured in this plot; forest type, species of trees are interpreted by the shape of crown, tone of crown, patterns formed and shadows. This information reduces ground plot work and increases efficiency of forest surveys.

for planning logging and cutting operations. Special maps with such units have been made during the last two years. The contact prints are first studied in a stereoscope; the watershed and drainage systems are then drawn on the prints; after that the forest is divided into treatment units. For each unit the kind of stands, the volume, the mixture of tree species, and sometimes also the plan for needful measures are noted. To get the correlation factor, some of the units are checked in the field.

On an experimental district of 5,000 hectares, mapping of this kind has been carried on in the current year. The photographs were taken by the Geographical Survey Office on a scale of 1:25,000 The instrument for indoor work was a mirror stereoscope, model Old Delft. Every unit was checked in the field. A comparison between the values obtained by stereoscope and the field measurement resulted as follows:

1. *Volume*

   The total volume of the whole district was overestimated by 9.5%. The mean error was equal to +9 cubic meters per hectare.

2. *Kind of stands*

   91% of the units was correctly identified.

3. *Mixture of tree species*

   Tree species in majority: 94% correctly identified.
   Tree species in minority: 77% correctly identified.

The efficiency of the stereo method was 1,500 hectares/day (6 hours a day). The character of the district somewhat favored identifying stands and tree species; the southern part consists merely of old stands of spruce while the northern part is mainly a middle-old stand of pine. The volume was throughout overrated probably because of the lateness of the photography (3 p.m.). The quality of the prints was otherwise very good.

A ranger district was estimated by photo interpretation. Photos of the Geographical Survey Office, photographed in 1949 to a scale of 1:20,000, were used. The needed instruments were a mirror stereoscope and a pocket stereoscope. The estimation was carried out by the field. A comparison between the photoscopic and the field estimation gave the following results:

1. *Site*

   The greatest difference with respect to the total areas in the different site classes was ±5%. The medium site in photo estimates was 3.7 cubic meters per hectare, and in the field measurements 3.6 cubic meters per hectare.

2. *Kind of stands*

   The difference between the principal types was very little, 2 to 3% for the young thin stands. The different types of mature stands and cleared areas under different stages of reforestation were not satisfactorily identified due to the photographs not being up to date.

3. *Plan for logging*

   The logging plan for the different stands was proposed on stereo prints. This method compared favorably with the field plans.

4. *Barren land*

| | *Barren land* | *Swamp forest* |
|---|---|---|
| By stereoscopic method | 19% | 6% |
| In field measurement | 17% | 4% |

The quality of the prints was moderately good, haziness at the borders often caused troubles. The photographs were too old (4 years) for experiments of this kind.

During the last ten years more than a million square miles in *British colonies* have been covered by aerial photographs taken for the Directorate of Colonial Surveys with funds provided by the British Government. This photography is mainly intended for the production of 1:50,000 maps, but was mostly taken at a scale of 1:30,000 in the hope that the larger scale would be useful to other users concerned with interpreting vegetational, geological and soil details. Several sets of the photo prints have been supplied for the use of such workers in the colonies. These photographs have been of great assistance to the Colonial Forest Departments. Many of them are still engaged in locating and assessing their resources; the 1:30,000 photos have also served well for reconnaissance work and for stock-mapping on extensive lines.

Due to the difficult weather conditions, little photography has been taken so far over the tropical rain forest zones of *West Africa* and *British Guiana*; such as has been obtained has not proved of much help for forestry purposes. On the other hand useful separation of forest types can be effected on the 1:30,000 photographs of *Sarawak* and *North Borneo*. As the aerial view concentrates attention on the forest canopy, the size and character of the tree crowns and the topographic site are the main criteria used in classifying the forests in those territories.

Throughout much of *Central and East Africa* the tree cover is associated with a ground flora of grasses, and varies in density from woodland with a closed, although light, canopy to open grassland with scattered trees. The many variations can be distinguished on the 1:30,000 air photos, which have been used both for forestry purposes and for general land use surveys. The latter type of work was pioneered in *Central Africa* by C. G. Trapnell, who in recent years has conducted an Ecological Training Scheme, which makes extensive use of air photo interpretation.

For detailed forestry investigations the 1:30,000 scale is too small, and photographs of between 1:10,000 and 1:20,000 are required. Photography of this nature has been secured for special projects in some colonies where forestry practice is more highly developed. In *Cyprus* 1:10,000 air photos are available; their use has been described in the Forest Department's Technical Pamphlet No. 17, "Classification of Forests into Crop Types and the Preparation and Interpretation of Stock Maps in Cyprus" by A. Polycarpou. Photographs at the mean scale of 1:15,000 have been taken for detailed stock-mapping in *Kenya* and *British Honduras*. In the latter project some experimental color photography was also taken from a height above ground of 7,500 feet; this revealed practically no detail not visible on high quality black and white prints; it may prove possible, however, to identify the distinctive color of mahogany and one or two other species provided photography is available at the appropriate season.

Two projects at present being undertaken by Hunting Aerosurveys, Ltd. are concerned with forms of vegetation mapping.

In the mountain area of *Northern Iraq* a forest survey was recently completed with two main purposes in view. The first was to assess the value to the Iraq Forest Department of the existing 1:40,000 air photographs covering the whole of the forest area. The second was to provide certain basic data on the forest types by making detailed enumerations of sample plots. Enlargements to 1:200,000, made to assist preliminary photographic interpretation, made possible making distinctions between forests in different density and site classes and even, to a more limited extent, to determine exploitation and botanical composition. The fact that the photographs were taken in December was important in that the oak still retained some pale foliage; this greatly facilitated separation of the oak and pine groups. On the basis of crown closure, the pine areas were divided into two density classes and the oak into three classes. Since the crown closure method afforded little or no opportunity to distinguish the actual form of the woodland, exploitation classes were defined, i.e., unexploited, lightly exploited and heavily exploited. The field work, based on the preliminary work, proved the value of the photography and allowed truly representative plots to be selected, and access to them planned with a minimum waste of time. Plot enumeration will provide valuable basic data on age, size and growth rate of different tree species—data never before obtained in Iraq and very necessary for the reforestation programs now being considered.

In January 1954 many millions of trees were blown over by a violent storm in *Middle Sweden*. Especially to the most damaged province of Gastrikland, woodcutters and hauling equipment had to be brought together rapidly from other parts of Sweden, new roads built, etc. But the problem was how much work and equipment was needed and the location of all the windfall areas. Aerial photographs were used. The appearance of the woods before the storm could be seen from summer pictures taken a few years earlier by the Geographical Survey office. The Board of Crown Lands and Forests proposed that new pictures of the snow-covered landscape should be taken by the Air Forces as soon as possible. Two days later the new pictures, showing the woods after the storm, were delivered. By comparing the old pictures and the new, all with a scale of about 1:20,000, the windfalls could be fixed concerning location as well as area. The volume per hectare of the fallen trees was approximately estimated on the ground or from a helicopter. After that the needed arrangements for taking charge of the windfallen wood were made by different authorities and forest-owners.

Aerial photos were used very intensively for the Land Use and Forest Survey in *Taiwan* from 1954 through 1956. Panchromatic photos covered the entire 3,596,121 hectares at scales of 1:40,000 to 1:50,000. For the agricultural lands ($\frac{1}{3}$ of the Island) photos were used at 1:16,000. In addition, sample infrared photos in strips were used at 1:4,000 to 1:10,000 scales. Photo interpretation aids included parallax wedges, crown density scales, crown diameter scales and dot grids. For the forest inventory, the following forest types were recognized on aerial photographs.

Spruce and/or fir (Picea morrisonicola and Abies Kawakamii)
Hemlock (Tsuga Chinensis)
Cypress (Chamaecyparis formosensis and Chamaecyparis taiwanansis)
Pine (Pinus spp.)
Other conifer (Coniferous species other than the above-listed)
Conifer and hardwood mixture
Hardwoods (Tropical, subtropical and temperate, mainly based upon elevation)
Commercial Bamboo (Phyllostachys makinoi, Phyllostachys edulis, Sinocalmus latiflorus, and Bambusa Stenostachya)

Stand volume was determined by an aerial volume table in which average stand height and crown closure were the basic factors. Stand size was classified as shown in Table 1.

TABLE 1

CLASSIFICATION OF STAND SIZE SURVEY IN TAIWAN

| For photo plots (Scale: 1/4,000–1/10,000) | | For forest type and stand size mapping (Scale: 1/40,000–1/50,000) | |
|---|---|---|---|
| Code | Volume (cu. m./ha.) | Map symbol | Volume (cu. m./ha.) |
| 00 | 0– 49.9 | 0 | 0– 99.9 |
| 05 | 50– 99.9 | 1 | 100–299.9 |
| 10 | 100–149.9 | 3 | 300–499.9 |
| 15 | 150–199.9 | 5 | 500 and over |
| 20 | 200–299.9 | | |
| 30 | 300–399.9 | | |
| 40 | 400–499.9 | | |
| 50 | 500–699.9 | | |
| 70 | 700 and over | | |

With respect to land use aspects, the land use and/or cover types were interpreted on the photographs, as shown in Table 2.

TABLE 2

INTERPRETATION OF LAND USE AND COVER TYPES SURVEY IN TAIWAN

| Symbol | Description |
|---|---|
| G | Tall or short grasses excluding commercial bamboo groves |
| Cp | Continuously cultivated land primarily managed for, or already installed with facilities capable of paddy rice production |
| Cd | All cultivated land other than Cp as described above, thus including all dryfarming land under either continuous, intermittent or shifting cultivation |
| U | Urban or residential use |
| W | Water areas including lakes, rivers, and reservoirs |
| Lp | Bare land such as denuded and/or badly eroded land that is capable of being planted |
| Lu | Bare land such as landslides, unstable alluvium and bare rock that is not capable of being planted |

Five soil and water conservation problem areas on nonforest land were recognized on the photographs.

*Problem area I* Lands with no appreciable conservation problem.

*Problem area II* Nonforest lands with minor to moderate conservation problem.

*Problem area III* Nonforest lands that are marginal. In this group are lands where continuous farming causes serious soil losses unless intensive treatment and conservation practices are followed.

*Problem area IV* Nonforest lands with sufficient soil material for reforestation. Special care should be taken in establishment and management of such forests to prevent water concentration and check soil erosion.

*Problem area V* Denuded lands with insufficient soil material to support forest cover. Such lands include landslides, alluvial fan at river bottoms where swift flood water deposits boulders, gravels or coarse sand. Only by excessively expensive measures can such lands be made productive.

The soil and water conservation problem areas were determined by the combination of (1) slope, (2) degree of erosion, and (3) combined rating of soil depth and texture. A combination guide was used to help the interpreters to determine problem areas.

An intensive forest survey was started in August 1955 for the management plan of the Experimental Forest, National Taiwan University which uses 1:12,000 scale infrared photos. The area is approximately 34,000 ha. The minimum mapping area is 3 ha. on the 1/20,000 scale forest type and stand size map. In addition to the forest types for the over-all survey, the following forest types are added:

| *Common name* | *Scientific name* |
|---|---|
| Chinese fir | Cunninghamia lanceolata |
| Japanese fir | Cryptomeria japonica |
| Bamboo-hardwood mixture | |

Bamboo stands are separated as follows:

| *Map Symbol* | *Scientific name* |
|---|---|
| Bl | Sinocalmus latiflorus |
| Bm | Phyllostachys makinoi |
| Be | Phyllostachys edulis |

In nonforest cover type delineation, banana is recognized and added.

Abitibi Power and Paper Company of *Canada* has completed the forest inventory of all of its holdings, using 1:15,840 summer panchromatic photography. This required four years with a staff varying between 30 to 45 men. Six areas of forest were involved, varying in size from 1,090,000 acres to 6,400,000 acres. Sample areas amounting to less than 1 per cent of the total were studied on the ground to provide basic stand volume table data; utilizing experience in interpretation of the men involved. The remainder was interpreted in the office. Maps showing the species, composition, age, and volume of merchantable timber in cunits per acre were prepared, along with detailed estimates by species for each type area. The accuracy required and achieved was $\pm 10$ per cent by volume with a probability of 0.95 that the error did not exceed this in any 100 square mile unit.

Also detailed photo interpretation on 1:15,840 summer panchromatic photography was studied for detailed surveys for logging purposes. The accuracy required is $\pm 10$ per cent at the 0.95 probability level for areas of 5 square miles. To obtain this accuracy with these photographs, ground samples were taken in every merchantable forest type interpreted. Each of the six Divisions of the Company using this method averaged approximately 25 square miles a year.

Instruments used consisted of lens type stereoscopes, parallax wedges, multiscope, and wedge scales. Photo techniques required identification of tree species, measurement of tree heights and stand densities.

The nationwide Forest Survey program of the *U. S. Forest Service* uses aerial photos intensively. Photos are used to interpret forest areas, forest sites, stand size and condition, and forest types. Complex sampling schemes are used which combine the use of aerial photos with ground techniques.

*Soil surveys use aerial photos:* "The use of air photographs in soil surveys" was the subject of a discussion at a meeting of the photogrammetric society in March 1954 which was opened by Dr. A. Muir (*Photogrammetric Record*, Vol. 1, No. 6, pages 50–57). The interpretation of air photographs continues to be used by the soil survey of *England* and *Wales* in conjunction with ground methods and some experimental work has been carried out in an attempt to assess the value of photographic interpretation methods in *Britain* (op. cit, p. 53).

The most extensive and detailed investigation of soil conditions carried out, in part, by photographic interpretation methods has been undertaken in *Iraq* by Hunting Aerosurveys, Ltd. The scheme is part of a soil and land classification survey on four major irrigation projects in central Iraq and is being prepared for the consulting engineers to the Iraq Development Board. This work involves a great deal of ground work, with a team of 10 men permanently in the field over a period of 8 months, including 8 soil surveyors, 1 chemist and 1 soil engineer engaged on field permeability tests. In addition the team has included for part of the time an ecologist and an agriculturalist, with a visit from a consultant specializing in the reclamation of salty land.

The work has been based on 1:15,000 photography which has proved of great value in (pedalogically) rather difficult country. The ancient irrigation layout is clearly visible on the aerial photographs and provides clues to many soil problems which would have been very puzzling without their aid. The full survey involves soil and land classification (for irrigation) maps at 1:50,000, together with a comprehensive report recommending systems of agriculture for the new areas when brought under irrigation, and the size of holding which would support a settler family at a reasonable standard of living. Mosaics at 1:20,000 and 1:50,000 have proved very valuable as working maps for the field parties. It should be emphasized that initial photographic interpretation was used to identify major topographical units and that detailed interpretation was only attempted in close association with the most elaborate field checking and research. The project is, however, demonstrating the applicability, under such conditions, of photographic interpretation methods even in areas of arid and saline soils.

Detail soil maps rely upon field identification and delineation but use aerial photos to guide placement of boundaries. Complexity of landscape reduces accuracy of photo interpretation as well as the importance of soil properties not associated with land farms. Semidetailed soil maps that rely upon photo interpretation produce moderate to good accuracy in simple landscapes. These are satisfactory for associations of agricultural uses but field checking is essential for most objectives. Those soil features, closely associated with prominent land farms and vegetation, most aid photo interpretation of soils. Maps for farm planning require detailed soil maps and extensive field work. This combination will generally produce maps ranging from 80 to 90 per cent accurate.

*Pasture surveys are helped by aerial photos:* In *Jordan* the U. S. Operations Mission is working on methods of pasture improvement, livestock being the mainstay of the bulk of the population. As a necessary first step in pasture improvement or vegetation and soil conservation measures, a basic survey of present conditions is being carried out using the complete photographic cover of Jordan obtained in 1953. Preliminary work by an ecologist, to determine the extent to which the existing photography could be used in mapping uniform vegetation types, was undertaken in the spring in 1954. In the spring of 1955 a team consisting of an ecologist and a geologist spent three months in the field, visiting all parts of Jordan. Their field work will provide a key for the mapping of vegetation units. Jordan will, therefore, be supplied with vegetation maps based on mosaics constructed from the aerial photographs; these will form the necessary basis for a pasture improvement program.

*Irrigation surveys use aerial photos*: In *Pakistan* aerial photos are finding extensive use in irrigation projects. In *Bengal* aerial photos of 1:40,000 scale covering 15,424 square miles were used in planning. Table stereoscopes were used. Another area of 3,200 square miles in East Bengal used 1:40,000 scale photos. Photos were interpreted using mirror stereoscopes. On another project 231 square miles was interpreted using 1:30,000 photos. Plans for another irrigation scheme used 1:30,000 photos covering 390 square miles for the Kurramyarki Irrigation Project. Maps were made of all these projects by the radial line technique.

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## ENGINEERING APPLICATIONS

### PHOTOGRAPHIC INTERPRETATION IN THE MAPPING PROCESS

During the reporting period, there has been a consistent increase in the extent to which photographic interpretation has been applied to large-scale mapping problems. This has been accomplished generally in two ways. First, there has been a tendency on the part of the mapping agencies to acquire or train personnel who can perform a certain amount of photographic interpretation and who can also operate photogrammetric equipment in the plotting process. Second, many mapping agencies and commercial concerns have established units of experienced photographic interpretation personnel within their organizations.

In *England* differences of opinion still exist as to the administrative arrangements to be made for photographic interpretation within survey organizations. Most government bodies and one commercial survey company hold the view that interpretation can be carried out during the process of plotting planimetric detail when dealing with medium and small-scale work. One commercial firm on the other hand has established a separate section to carry out certain interpretation processes before the actual plotting is commenced. At present the section is interpreting topographical detail, and in particular water courses and vegetation boundaries, by means of hand stereoscopes and contact prints, the marked-up detail being then adjusted by means of pantographs to the Multiplex model scale and transferred to transparent sheets which are passed to the Multiplex operator. In certain cases, for example in a survey of the *Zambesi* region, specialist interpreters produce a separate vegetation trace which is similarly scaled for use by the plotters. There seems to be general agreement that such a system of pre-interpretation has definite advantages but many people doubt whether the separate process is necessary in all cases. It has been suggested, however, that the marked-up photographs have an additional value when carrying out ground checks.

At large scales, interpretation in England is universally incorporated in the plotting process. The availability of high quality photography referred to above has greatly facilitated detailed interpretation on plotting machines providing a considerable degree of magnification. Until comparatively recently almost all of this work was carried out on first-order machines, such as the Zeiss Stereoplanigraph or the Wild Stereoautograph, but in addition one concern is now using Kelsh plotters on large-scale work and the development of the Williamson LSP machine, also capable of working at large scale on the anaglyphic projection principle, should be noted (*Photogrammetric Record*, April 1954).

In *Pakistan*, where since the creation of the state, great emphasis has been placed on photogrammetrically mapping the entire country, the impetus is now shifting to large-scale, special-purpose maps. Photography is interpreted to derive information on geology, soils, and vegetative cover for inclusion on these maps. Photography used are mapping verticals, varying from 1:25,000 to 1:40,000.

In the *Ganges Kobadak* irrigation project in *East Bengal* (Pakistan), some 3,200 square miles was mapped from vertical photographs (1:40,000 scale); simple photographic interpretation techniques were employed to set stone position markers for the project. Theoretical positions for the stones were first transferred from the maps to photographs, then the photographic detail was used to establish the monuments on the ground by check of surrounding ground detail.

## Road, Railway and Highway Engineering

### GENERAL APPLICATIONS

In this, as in other fields of engineering, the use of photogrammetrically prepared maps has been known for some time. The full application of photographic interpretation techniques has been somewhat slower in being realized. During the past four years, however, the use of photography in this latter way has been increasing.

In *Norway*, the Road Department uses aerial photography not only for mapping transportation routes, but for studying geologic and soil characteristics along proposed routes, for locating tunnel sites, for predicting landslide areas, and for locating gravel pits for road construction. Quite recently, photography has also been used in Norway for making traffic counts.

Much of the road planning in *Sweden* is also done from aerial photographs. The preliminary location, or "staking out" of roads on stereo models is now quite generally practiced, both at the Central Administration and at the local sections. Processing then takes place in less complicated stereo-instruments, such as mirror stereoscopes, in order to establish the line on which detailed staking with ground survey methods will take place. In a few cases this processing is done using precision stereo-instruments. Photographic interpretation techniques are used in this planning process to determine the characteristics of the proposed route with regard to topography, build-up areas, cultivated areas, estate boundaries, and other factors which appear more or less clearly from the photograph without the application of special photographic interpretation techniques.

In the forested areas of both *Norway and Sweden*, photography is used extensively in selecting routes for logging roads.

These photographs are also used as field maps for the personnel constructing the roads. Since in these areas, aerial photography is regularly taken for forest estimation purposes, prints are readily available for road planning.

### THE HIGHWAY PLANNING PROCESS

In the *United States*, both photogrammetry and photographic interpretation are becoming more and more an integral part of the highway planning process. Many of the State highway departments maintain photogrammetric sections in which photogrammetry and photographic interpretation are accomplished. Also the various types of specialist engineers who participate in highway design and construction are becoming trained in the use of photography as a base for their various analyses.

Pryor (1954) lists the eight stages in the highway engineering cycle in which aerial photographic analysis is used:

1. Planning;
2. Reconnaissance of area and determination of route possibilities;
3. Reconnaissance of route alternatives and their comparison in selecting the best route;
4. Preliminary survey of the selected route for design of the location and preparation of plans;
5. The location survey staking of the highway on the ground for construction;
6. Condition and inventory surveys;
7. Maintenance and betterment surveys;
8. Surveys for highway improvement and reconstruction.

Mr. Pryor, in the same paper, gives a most concise and informative description of the procedure followed in analyzing photography to provide information for use in these engineering phases. This section of his paper is reproduced below. Note that while certain photogrammetric techniques are involved, the process as presented here is basically one of photographic interpretation.

"Sequential steps in the full employment of photogrammetry in each stage will usually follow a logical pattern. These steps are not rigid. Deviation is possible whenever situations and exigencies require it. Usually the steps are eight in number. Progressively, they will provide, in both qualitative and quantitative form, nearly all that is needed for making most highway engineering decisions.

"The first step is *identification or recognition of images* on the aerial photographs. The identification is restricted generally to those images which will have an influence on decisions for specific purposes.

"The second step is often inseparable from identification or recognition. It is *interpretation of the images*, their pattern, their relationship one to another and to the highway engineering problems they represent.

"The third step is *number*. This is the count of all identified and interpreted images either individually or by groups, which must be considered in making decisions while solving the highway engineering problems. Like the first and second steps, the third and fourth are often inseparable.

"Essentially, step four is the *measurement* of position, shape and size—usually mapping of either the planimetric or topographic type, or both. In the first three highway engineering stages, this mapping is reconnaissance in character—seldom done precisely as in the subsequent stages.

"Step five is *classification*. All features of importance that have been identified, interpreted, numbered and measured, are classified according to the effect or influence they will have on the making of decisions and on preparing plans. In this step lies one of the greatest needs for the many specialists. Each specialist is concerned by degree or magnitude with certain types of features and has no concern about others.

"Four examples are: By use of sequentially taken stereoscopic aerial photographs and other data, traffic engineers will classify the principal traffic arteries, the traffic "bottle-necks," vehicles by type and number, and where traffic came from (origin) and is going (destination). Rights-of-way experts (land appraisers) will classify the land by type and intensity of use, and value it in terms of cost for a highway right-of-way. Soils engineers will classify the topographic area by soil types and their condition, or by the indicators of soil types and their condition as land form (including geologic structure), ground slope, drainage pattern, position, color tone, vegetation, and types of land use. Drainage engineers will do their classification according to the physiographic region, by drainage area, channel length and slope, and at bridge sites by profile and cross sections of channel and flood plain for considerable distances both upstream and downstream from each possible site.

"The sixth step is *evaluation*. While this is akin to classification it is also different, especially in degree or quality. Evaluation is the process of ascertaining the degree of importance of the classified features. It is easy to realize at this point why evaluation is essential. It is actually a process of elimination by degree after selection by classification. A highway engineering problem could not be solved at reasonable cost in terms of both time and money, unless the features of influence are chosen, evaluated, and the unimportant eliminated. Evaluation is actually the determination of the weight that should be given each feature in the decisions that must be made.

"The seventh step is *the decision*—the utilization of all qualitative and quantitative features obtained, classified and evaluated which have influence on results. Here again each specialist does his part in cooperation with all others concerned. Team work is strength at this point.

"Step eight is *preparation of a description* of the results of the work of all contributors. The description is usually in one of three forms or any combination. The first is of words (a report); the second is a pictorial presentation (a perspective drawing or notations on aerial phtotographs, either of the oblique or vertical type, or both); and the third is orthographic plans of the map, profile and cross section type. The degree of refinement and accuracy of the description is gauged according to the purpose and the highway engineering stage in which prepared and used.

"Once step eight has been completed for one stage of the highway engineering cycle, the specialists are prepared to begin work on the next stage. Progressively they can, in that manner, attain the ultimate in satisfactory results. No factor of importance need be overlooked. Moreover, they have prepared themselves to do the best work possible from stage to stage."

PHOTOGRAPHIC INTERPRETATION IN RAILWAY SURVEYING:

Considerable railway surveying by means of aerial photography was performed during this reporting period in *England*. The requirement was primarily photogrammetric, and resulted in the preparation of large-scale railway plans. Equipment used included in some cases Kelsh plotters, as well as such first-order equipment as the Wild Stereoautograph and the Zeiss Stereoplanigraph. With respect to the interpretation aspects, the production by both types of machine, of railway plans at a scale of 1:480 has called for very precise interpretation of engineering detail, although the survey companies concerned insist that elaborate ground checking of interpretation is essential, possibly more so in the case of railway plans than in the case of factory and site plans at the comparable scale of 1:500 of which considerable numbers have been produced.

The 1:480 railway surveys are used extensively for the purpose of scheming reconstruction work of station, goods and marshalling yard layouts and also permanent way layouts and the amount of detail required for this purpose is considerable. It requires, for example, the plotting of such details as the tips of switches and noses of crossings, manhole and inspection covers, mile posts and gradient posts. It has been found necessary in some cases to ease the problem of interpreting and locating some of these objects, especially on the permanent way, by pre-marking them on the ground with white paint, but on the other hand some surveys of this type have been carried out successfully entirely without pre-marking.

## Urban Planning

Urban planning has been informally defined (Witenstein 1955) as an orderly process of organizing or altering the physical plant of a city to meet changing economic and social needs of the community, and guiding its future growth and development. The practicability of aerial survey to provide the large-scale maps necessary to such planning has long been recognized. Also, the preparation of such maps in itself requires a certain amount of photographic interpretation in the correct identification and symbolization of objects observed on the photography.

However, the application of photographic interpretation to the problem of analyzing the urban area for purposes of urban planning, has lagged. One of the reasons is that adequate photographic interpretation techniques for this type of work have been slow in development. However, experimental work is going forward in this field in *Holland*, the *United States*, and other countries. A few examples of these applications follow:

In the *United States*, the City of Rockville, a suburban town in the metropolitan area of Washington, D. C., has been for the past four years, serving as a test area for various applications of aerial survey to urban planning and administration problems (Witenstein 1954 & 1955). Here photography has been used in a study of the five main aspects of urban living:

Land-use
Movement of people and goods
Utilities, community services, and public facilities
Industry and commerce
Recreation.

The results of these studies have been assembled on overlays keyed to photographic mosaics of the area. These overlays can be used singly or in combination as an aid to urban planning, in predicting the effect of any of the factors portrayed on present or proposed urban development.

At *Oak Ridge, Tennessee*, U.S.A., photography has been used to readjust property lines on a community of more than 6,000 dwellings (Warnick 1954). Since property boundaries had not been established in the original settlement, it was necessary to study each residence on aerial photography enlarged to 1/600, in conjunction with street survey drawings. The landscaping and other improvements accomplished around the houses, as determined from the photography, were used as an aid in establishing the most acceptable property divisions. This project, which might have taken several years by ground survey, was accomplished in a relatively short time and with a minimum of cost.

In other U. S. cities, photographic interpretation has been used in estimating requirements for expanded water services and sanitary facilities. Data such as the number of homes in the area, the distance between them, the vacant land, type of land use (commercial, industrial, residential) has been effectively and economically estimated from aerial photography.

### Other Engineering Applications

In other engineering applications, photographic interpretation was used during the reporting period in the location of proposed electric transmission line routes (*Canada, Norway*), and in planning telegraph cable lines (*Norway*). It was employed in the determination of location, and making preliminary plans for the development of rural public works (*France*). It was also used in the planning of dam-sites and installations for hydro-electric development (*Canada, Norway, Pakistan*). And in the problem of locating new industrial installations, aerial photographic interpretation was extensively used in several instances to analyze the merits of alternate sites (*United States*).

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## MILITARY INTERPRETATION

The military section of the 1952 Commission VII report covered the science of military photographic interpretation since its development at the beginning of World War II, and including use in the Korean conflict. As much of the development in military photographic interpretation since 1952 is held under security classification by the various countries concerned, this section of the present report will necessarily be brief.

#### ACTIVITY IN MILITARY PHOTOGRAPHIC INTERPRETATION SINCE 1952:

The following developments in military photographic interpretation since 1952 should be noted:

1. During the conflict in *Indo-China*, the photographic interpretation organizations of the French land and air armies made many studies and did much intelligence work in the locating of objectives, and in developing supplementary data in support of tactical operations.
2. Research. Much of the research work in photographic interpretation, particularly in the *United States*, has continued to be supported by the military services. Such research has resulted in new interpretation equipment and publications of value in many fields of photographic interpreta-

tion other than military. Some of these developments are noted in other sections of this report.

3. Strong indication of the effectiveness and reliability of photographic interpretation was given by President Eisenhower of the United States at the Geneva Conference in 1955, when he proposed the free exchange of aerial reconnaissance between the USSR and the United States as a means of inspection for possible military build-up in the two countries.

PRESENT STATUS:

The following discussion of some of the factors affecting present-day military interpretation was prepared by Lieutenant Colonel B. v. Vegesack of the Royal Swedish Army, as a part of *Sweden's* contribution to the Commission VII report. As it is believed to represent perhaps the best summary of present problems in military interpretation which can be prepared in the light of security restrictions, it is reproduced here without change.

* * *

"*Military Interpretation*

"B. v. Vegesack
Lieutenant Colonel Royal Swedish Army

"Military photo interpretation differs from other forms of interpretation in two important ways, among others.

"Military photo reconnasisance is systematically obstructed on the part of those who risk being exposed to it. By means of aerial counter-attack, attempts are made to hinder or impede the taking of photographs. Camouflage has the purpose of hiding the reconnaissance targets, dummy constructions aim to confuse the photo interpreters.

"Aerial photo reconnaissance and interpretation must be fitted into their military place. They must be accommodated to each phase of warfare. The practical value of the interpretation is to a great degree dependent on rapid results. The time ingredient is often of decisive importance.

"These reasons, among others, make it inexpedient to deal with the progress of military photo interpretation as a subject by itself, unrelated to the general changes of modern warfare. Notwithstanding the fact that the process of interpreting the photos under the stereoscope has not changed to any great extent in prospect, for example, of an atomic war, still, the aims and composition of photo reconnaissance will be influenced by the new age. On this account it is necessary to view the aims, means and development of military photo intelligence in the light of those preconceptions under which it is practised. Here an attempt shall be made to demonstrate some of the new factors which can be taken into consideration for bringing changes.

"Nowadays camouflage technique continually reckons photo reconnaissance as its most formidable enemy, and it tries to evolve means to evade discovery by photography. The fact that units have been provided with modern camouflage material has made it much more difficult to pin-point targets photographically. Consequently the demand for clarity of detail has increased. Furthermore, a larger negative scale than earlier is occasionally required, which entails an increase of the number of photographs. Film emulsions with 'de-masking properties' have come into use more and more as an aid in discovering camouflaged targets. When the identical target is photographed with both ordinary black-and-white film and camouflage-detecting film, the number of photos is doubled.

"In order to lessen the risk from AA fire it has been found necessary to increase the speed of the photo reconnaissance planes at least to equal that of the fighter planes. Frequently, photos can only be taken alternatively from great altitude, or from height which is very low in relation to the speed of the planes.

"The continually increasing plane speeds and the higher standard of photographic clearness and accuracy makes it imperative that motion-compensated cameras be used on a larger scale than heretofore. Reconnaissance from low altitude is a special problem.

Each photo depicts only a very limited area, causing among other things an enormous output of photographs. This is especially true in the case of rapid serial cameras, where the number of pictures is imposing indeed. Another difficulty is the determination of position of the different objects discovered in the photos. Each photo depicts such a small area that it is hard to find definite points of orientation which allow determination of position. If, however, a wide-angle camera is used simultaneously with the large-scale camera, this determination can as a rule be carried out by comparison—but on the other hand, the total amount of photographs is increased.

"Without taking into consideration the special case of an atomic war, the following fundamental facts will be apparent from the above:

1. The interpretation of aerial photographs frequently demands greater exactitude and consequently more time than earlier, when camouflage technique had neither reached our present standard nor had the same scope.
2. The number of photos has increased enormously, which makes a great demand on the capacity of interpretation organization.

"Moreover, as a rule, the results of the interpretation must be delivered without loss of time—at least in periods of activity—in order to be of practical use.

"In the case of an atomic war, the demands made on photo reconnaissance will be greater still. One of the most basic innovations in a war, where atomic weapons are used or may be expected, is the increased spreading out of the units. This is especially true of an attacking force. The ensuing larger reconnaissance area necessitates a greater number of photographs.

"In an atomic war it is of greater importance than in a conventional one to keep continual track of the grouping and activities of the enemy. In the war area there are such weapons as atomic artillery, guided missile batteries, etc., whose positions it is of vital importance to locate. Any concentration of troops or any other target suitable for one's own atomic weapons must be localized without delay so that an attack may be made before the situation has changed. Photo reconnaissance is doubtless the most effective means of acquiring such information. The demand for continual photo reconnaissance is thus accentuated. To a certain degree the work of the photo interpreter is made easier by the fact that field fortifications—on the part of the attacker as well—will be extensive and not too well camouflaged, especially in the case of mobile fighting.

"Thus, the conditions of atomic warfare accentuate the value of photo reconnaissance and emphasizes the above motivated demand for an extensive interpretation capacity.

"The greatest problem of today and tomorrow, therefore, seems to be sufficient speed in manipulating and utilizing the enormous number of aerial photos which, without a doubt, will be taken in a modern war and especially in an atomic war. The difficulty lies in the processing as well as in the interpretation service.

"The primary solution to the interpretation dilemma to present itself is the increase in number of the interpreters. It is open to question, however, whether this is a rational solution. It is difficult to procure qualified photo interpreters. One way of increasing the interpretation capacity and working speed would perhaps be to put assistants at the disposal of the photo interpreters, who could be assigned less qualified tasks and to put specialists on special interpretation targets. Interpretation can be organized in many various ways.

"The following classification is only for the purpose of elucidating some problems in connection with a feasible working routine.

"*Determination of position of the photographs*

"Owing to the high velocity of the planes and the ensuing difficulties of orientation, the pilot is easily tempted to let the cameras start before he reaches the area to be photographed, and also to let them continue long after he has passed the target. Thus, during an aerial photo mission, a great number of exposures are made of terrain which is of no interest. In order to relieve the photo interpreters of unnecessary work, irrelevant photos should be eliminated in advance. Before interpretation can begin the photos must be determined as to position. This is an especially intricate problem in the case of low altitude photography, all the more so when the pilot has been forced on account of enemy activity to relinquish the set course of flight.

"The determination of position of aerial photographs must frequently be carried out by comparing the terrain on the photos with either a map or, still better, with a series of wide angle photographs whose position is known. (The pilot's idea of the positions of the photo strips is often too diffuse to render more than a rough orientation of the strips.) A special photographic memory is necessary for the determination of position of the photos. By means of constant practice, however, it is possible to become proficient in this determination. For this angle of interpretation a special group of personnel should be available, here called position determinators. This group should, however, have a certain training in recognizing the simplest outlines of military objects (fortifications, vehicles, battery emplacements, the general outline of aerial strips and guided missile runways, different types of vessels, etc.) in order to be able to report such information regarding military objectives which they may have gathered while scrutinizing the photos in question.

"During the determining of position, the photographed area should be delineated on a map, showing the general position of each photograph.

*"Selection of photos for interpretation*

"Through knowledge of the existing strategic position, and sometimes in accordance with suggestions from the position determinators, photo series are selected which have been found to cover the proposed target area. If other information regarding the enemy is available, from earlier photo missions or from other sources of intelligence, it is often possible to decide which photos contain the most important information and consequently are to be given interpretation priority. This decision should be made by an officer who can appraise the existing military situation. The selection of the photos is carried out simultaneously with the determination of position and thus it causes no delay. As a rule the sector of most current interest is known before processing begins. As soon as the photo strips covering the area is question are determined as to position the series is passed to the interpreters.

*"Interpretation*

"The interpretation of the photos is done by interpreters in the usual manner. It should be possible to begin this work as soon as photo strips of the terrain of current interest have been sifted out by means of determination of position. The interpretation must be carried out simultaneously over a large area in order that the photo material at hand may yield information quickly enough.

"Since a large number of different targets, especially at the beginning of a war, cannot be recognized even by qualified photo interpreters, it is desirable that specialists on guided missile weapons, field fortifications, vehicle types, vessels, planes, etc., are available to assist the interpreters at their work.

"The results can hardly be said to offer any new problems, and will not be expatiated upon.

"The results of photo interpretation constitute an excellent basis for the study of enemy tactics. If the reconnaissance is carried out at regular intervals a good general view of enemy movements is acquired.

"It is a fact that atomic weapons must cause changes of tactics and warfare technique. No prediction can be made as to how the enemy proposes to do this. It is, however, possible by means of such intelligence as may be acquired through photo interpretation to form a fairly accurate opinion in the matter. It is therefore important that the results achieved by the photo interpreters are studied from a tactical point of view as well. For this purpose specially qualified personnel should be detailed, persons whose training makes them capable of deducing the principles put into practice from the study of sequences of aerial photographs of any given area. The mission of 'tactical photo interpreters' is of great importance.

"*Summary*

"Military photo interpretation found its form during the second World War, which it has maintained since then.

"Changes have occurred mainly in the form of improved equipment (optics, cameras, film, stereoscopes, et al.).

"It would seem, however, that photo intelligence already—or soon—will be accorded a still greater importance since warfare, threatened with atomic weapons, is on the eve of great changes. The most decisive factors can be summarized as follows.

1. The number of intelligence photos will be far greater, making a correspondingly great demand on the photo interpretation capacity.
2. The enemy camouflage technique, developed to counteract photo reconnaissance, makes the discovery of targets slower and more difficult—although field-fortifications, erected against the risk of atomic attack, may not be as well camouflaged as others, owing to insufficiency of time.
3. The demand for speedy results is accentuated in atomic warfare, where it can be a question of utilizing a favorable occasion for one's own atomic weapons or to hinder the enemy from using his.
4. It is of supreme importance to exploit entirely the results of the interpretation in order to ascertain enemy tactics without delay, since they are of vital interest.
5. A great amount of interpretation material will cause difficulties in procuring a sufficient number of qualified interpreters. The military objectives multiply and become more and more difficult to discover. The demand for specialists on certain types of interpretation targets will probably increase.

"Without a doubt the future will hold a number of tasks of the traditional kind where the demand for speed of interpretation and number of photographs will not be as overwhelming as has been outlined here. Perhaps these traditional tasks will be the most common ones.

"The above mentioned points do not, taken each by itself, give one reason for holding any other view as to the future direction of military photo interpretation. Taken all together, however, they tend to give the impression that, in a future war, a greater task may be imposed on photo interpretation than can well be managed, unless it is given facilities on a much broader basis.

"Therefore, it would seem reasonable to take into consideration the demands of the future."

## CONCLUSION

In view of the rapid expansion in photographic interpretation applications which is indicated in this report, and the probability of equally rapid advances in the period to come, any attempts to predict the future in any detail are considered to be impractical and probably misleading. It is further believed that the members of the varied professions which utilize photographic interpretation are much better qualified to predict its future employment in their field of interest than are the compilers of this report.

It is suggested, however, that perhaps the most significant indication of future development in photographic interpretation is found in the increasing acceptance of the photograph as the planning base for many of the present day engineering, scientific and social problems. This is heralded in the vital part played by photographs and mosaics in the large land-use and urban planning projects. Present day scientific planning, with respect to the earth's surface, requires the observation and correlation of a vast amount of detailed information in many fields. Photography which records, clearly and objectively, *all* of the visible detail in an area, which is susceptible to an endless variety of uses as a field map, as an interpretation source, as an annotation base, and which can be used in every form from individual prints to controlled mosaics, is gaining recognition as the most practical base for such planning.