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UNIVERSITY INSTRUCTION IN PHOTOGEOLOGY*

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MODERN search for mineral resources, particularly petroleum, demands more rapid exploration techniques than those employed in the past, as well as greater accuracy in the location and mapping of potential areas of production. Various methods of speeding up surface and sub-surface analysis are in vogue as evidenced by the number and variety of service companies which remain operative. A most economical type of reconnaissance, Photogeology, revitalized by the need for cheaper and more rapid surface mapping, is gaining its proper perspective in this scene.

A fundamental requirement for mineral search and production is the existence of adequate topographic and geologic maps. This is true whether the method of exploration is of surface or sub-surface type. As a matter of fact, these two lines of approach to the location of mineral deposits are supplementary, the need for adequate base maps, in planning and accomplishing geophysical surveys, for example, being well recognized. Unfortunately, however, except for the more recent maps produced from photographic coverage by photogrammetric techniques, most areas requiring exploration have been mapped inadequately or not at all. In some regions, where terrain is such that field reconnaissance may be accomplished with relative rapidity, normal surface mapping has proved adequate for most types of exploration activity. However, the location of potential petroleum and mineral bearing structures, by ordinary field methods more often than not requires months of intense effort, and is a relatively slow process.

In the search for accelerated methods, mining and oil companies are rapidly recognizing that efficient field reconnaissance can be accomplished by analysis of aerial photographs. As Brundall stated in the *Oil Weekly* of December, 1946 (1): "Photogeology . . . an improved and speedy method of reconnaissance surface mapping. . . has already been successfully used in many areas in the United States and foreign countries."

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Photogeology is not a new tool of the science. It was used in somewhat limited application, though often to great advantage, in the several decades prior to World War II. Numerous references, citations of which are beyond the scope of this paper, are available in the literature, papers for the most part concerned with photogeology's potential usages in various geologic capacities. Widespread application of photogeologic principles, during this period however, was lacking. It was not until the aerial photograph had been thoroughly exploited as an offensive weapon in World War II that its true value as a tool of geology became widely recognized. A rapid development is now taking place and various applications in fields requiring work of reconnaissance nature are being made.

The writer was greatly pleased when, upon his return to academic life, he was requested to devise a course in photogeology at his university. I confess that I could not qualify as an expert photogeologist then, nor am I able to make that claim at present. However, considerable experience gained during the war, coupled with geologic background, had created an avid personal interest in the subject. Methods which I have used in instruction, admittedly, are the results of trial and error. Perhaps much of this instructional technique will not meet with the approval of more astute scientists interested in this field. This is not intended as a critical analysis but rather as a vehicle to promote constructive criticism and discussion. If is felt that more concrete foundations of preparation are needed in this field, in order that the student geologist map have adequate and systematic knowledge to meet the demands of his profession.

PROBLEMS OF INSTRUCTION

REFERENCE MATERIAL

Recent requests from many sources for geologists, trained in the interpretation of aerial photographs, has led to the development of courses of instruction in a number of academic institutions. Precedent established by such pioneers as Melton of the University of Oklahoma, Eardley of the University of Michigan, and Smith of the University of Kansas has prepared the way for such instruction. The textbooks of photogeology produced by Eardley (2) and Smith (3) contain abundant material of real value for teaching. However, it has been my experience that these texts contain a great deal of material extraneous to the preparation of the photogeologist. Admittedly, instruction must be adjusted to the students' background, considerable difference existing on this score in different centers of learning. The scholastic circumstances which have been encountered in my particular case require a very clear-cut approach of elementary nature. A work which has been found to more closely fit this requirement is Lobeck and Tellington (4), although even this has inadequacies.

The periodic literature contains abundant reference material covering many phases of photo analysis. A concentration of the best of this material in one cover is a prime requirement of the moment. Such a work should be kept free of such subject material as elementary geomorphology and structural geology, as these should be prerequisite to photogeologic training. An elementary textbook of photogeology is required, one which will suit the needs of students already well prepared in the above-mentioned branches of the geology. It is also recognized that map-reading ability must be gained preceding, or concurrently with, photo-reading proficiency. This should perhaps also be made prerequisite, though this writer has had reasonable success in a course of instruction which combines the two. Admittedly, however, this is a compromise to meet particular student background, and is not the ideal condition that one would desire.

Lack of a proper textbook covering the subject, along with the rather scattered occurrence of papers of reference nature, combine to make a bothersome, but not insurmountable, academic obstacle. A properly stocked library is, of course, necessary to alleviate this situation. The scientific periodicals most valuable in content of photogeologic and related reference material are *The Oil Weekly*, *World Oil*, *Institute of Petroleum Technology*, *Oil Field Engineer*, *Oil and Gas Journal*, PHOTOGRAMMETRIC ENGINEERING, *American Institute of Mining and Metallurgical Engineering*, *American Association of Petroleum Geologists*, *Engineering and Mining Journal* and the *Journal of Geology*. Excellent usage may be made of the several fine bibliographies which have been published. Smith (3) and Eardley (2) are useful on this score, as well as various others including Cobb's (5) well-prepared work.

STUDENT BACKGROUND

Wengerd (6) states: "There are few better techniques than those resulting from hard work and experimentation with photographs in the field and in the laboratory." In this the author agrees, wholeheartedly with him as he has seen the successful application of effort and experiment in all branches of geology. It must be agreed, however, that insufficiency of background is often difficult, if not impossible to overcome. The first requisite for photogeologic training is that the trainee have a working knowledge of geomorphology and structural geology. Such is rarely obtainable in practical form from the various textbooks and classroom techniques used to instruct in these subjects. Usable knowledge of either of these can only be gained with field experience. Except for the most advanced students, few can qualify as properly prepared for training in photo analysis on this score. The required adjustments in curriculum should be made to provide adequate courses of preliminary instruction preparatory to photogeologic training.

Nevertheless, compromise may be a necessity, and the results, though not entirely satisfactory, may yield some measure of success. The writer has found the undergraduates in his particular academic setting woefully unprepared in the above-mentioned prerequisites, a condition which appears to be rather prevalent in many of our institutions of learning. Few student geologists gain proper field experience as undergraduates. As a matter of fact, relatively few gain geomorphic or structural field experience even as graduate students. Thus, unless photogeologic training is to be ignored entirely until geologic training programs are adjusted to meet its particular requirements, a relinquishment of the specific standards set forth above must be allowed.

That the embryo photogeologist should as Van Nouhuys (7) stated: ". . . apart from the sound basic knowledge of geology, botany and pedology, . . . also possess the ability to appreciate the interaction of factors that have produced the appearance before him." This is also fundamental. But such ability comes only with long experience, and it is impossible to impart the same in the brief span of the classroom. Furthermore, a working knowledge of the geologic relationships of soils is almost never possessed by the undergraduate and rarely by the graduate. Plant Ecology is rarely covered in geological training. It would be impossible to include an intensive course of instruction in these factors, along with photogeologic training. It is more important to acquint the student with only the basic applications of these sciences, and trust that experience will give to him the finer details of their usage.

INSTRUCTION TECHNIQUE

MAP READING

Examination of aerial photographs for purpose of geologic reconnaissance does not differ essentially from topographic map reading. Experience has shown that those who show capability in analysis of topographic sheets for geomorphic data; provided of course that there exists the ability to see stereoscopically, may also become proficient photogeologists. The first step therefore is to either bolster the student's ability in map interpretation, or to provide a rapid basic training in this field. As mentioned previously, a thorough understanding of relief features, and the relationships these bear to underlying rock structures is prerequisite to such training. To attempt instruction in topographic analysis, without this background to draw from, may be likened to instructing students of photogrammetric engineering who have not had proper mathematical foundations.

It has been this writer's experience that few students are well versed in map reading. Elementary courses in general geology do not accentuate this training in the proper degree. Ideally, a course in the analysis of topographic and geologic maps should precede the instruction in photogeology. Under any consideration, it is difficult to understand how one can qualify as a field geologist without a thorough knowledge of maps, how they are made, and how they may be used. If such a deficiency exists in a curriculum it must be taken into account. It is quite often necessary to treat the most basic map reading fundamentals in preliminary fashion, prior to the instruction in elementary photogeology. Such items as map types, scale, methods of location, direction, determination of distance, elevation and relief, contours and their significance, gradient, profile construction, and the like must be thoroughly understood. These may be combined in a series of practical laboratory exercises which will provide both review for those who need a refresher, and usable information for those who have not been properly exposed. A few weeks of such review will save many weeks of fruitless labor later on. Even though photogeology is a specialization, it should be remembered that its foundations depend on a rather simple knowledge of map reading techniques. Of these, perhaps the greatest single problem is the concept of contours and, as a matter of fact, the map depiction of relief in general. Invariably, this is a source of mental disturbance to the untutored which must be overcome. In this respect, mention of a technique now being perfected by the Topographic Branch of the United States Geological Survey should be made. In a recent tour of the Denver office of this organization, I was greatly impressed by map drafting techniques showing both visual and contour relief on the same sheet. I believe that this may be used advantageously in presentation of the relief-depiction problem to the student map reader.

THE GEOLOGIC MAP

The geologic map must be thoroughly understood, in order that the proper application of the principles of geologic mapping procedures may be applied to the reading of aerial photographs. Eardley (8) states that: ". . . geologic maps and aerial photographs are horizontal projections . . . amenable to the same interpretative treatment." Hence, adequate training must be given to insure understanding of the principles of geologic map interpretation, so that the latter may be applied in photo analysis. Production of a geologic map with information gleaned from photographs is normally the aim of the interpreter. It is necessary in this light to make certain that the student gain understanding of such fundamentals as relationship of geologic contact to contour lines, the determination of structural attitude, and patterns of outcrop. The three simple "Rules of the V" as applied to dipping planes should be included in laboratory exercises along with the items just mentioned. These fundamentals are directly applicable to photo analysis and, though work of review nature for most students, are a necessary preliminary to photo instruction. Problems in the determination of strike and dip on geologic maps are of great value in preparing the student for similar methods used on aerial photographs. This writer has found it valuable to place particular emphasis on this procedure.

TOPOGRAPHIC FORM

Stream patterns are the most important key to the underlying rock structure and the lithology of a region. Particular patterns may indicate the presence of tilted, folded, domed or basined, faulted, or jointed structures, as well as features produced by such surface agencies as glaciers, volcanoes, wind, and water. A basic understanding of stream patterns is therefore necessary and useful in the analysis of topographic form and geologic structure, both on topographic sheet and aerial photograph. The essential nature of stream patterns in this respect makes advisable some means of quick review of the genetic relationships between stream pattern development and landform, both of which are closely related to pattern of rock outcrop. This may be accomplished in simple outline in laboratory exercise. Many excellent discussions of this phase of geomorphology are available, the treatment by Zernitz (9) being a good reference.

The analysis of topographic sheets for landform types should occupy some considerable portion of the student's time. Assuming that the student background includes an understanding of the development of landform as related to structure, the geomorphic interpretation of topographic maps should cause no particular difficulty. Nevertheless, some rapid review treatment may prove necessary. Brief discussion of the various types of constructional landforms and their appearances on topographic sheets has worked to advantage for this writer. As a supplement to such discussion a set of selected maps to show the various types of landforms proves invaluable. I have found the selected map listings in Dake and Brown (10) extremely valuable on this score, as is also Lobeck and Tellington (4). Such classroom discussion and laboratory analysis of topographic maps is, of course, not capable of supplying the needs of advanced students of geomorphology. However, it should prove adequate in most cases for reviewing the subject in preparation for application of landform analysis to aerial photographs. In the course taught by the author, a set of annotated maps is supplied for this purpose. I have found that proper application of the student to such a study set supplies him with at least a rudimentary ability in topographic interpretation.

PHOTO ANALYSIS

THE SINGLE VERTICAL

Photogeology is best accomplished with the aid of the stereoscope. Skill should first be developed, however, in examination of a photograph without the assistance of three-dimensional means. The three important factors of tone, light and shadow, and shape and size may be approached to advantage by means of the single vertical photograph, ideally an enlargement of an area of relatively rugged terrain. Instruction in this is greatly aided by topographic and geologic maps for comparison, and the photograph should be chosen with this in view. Exercises involving the proper orientation for most effective light and shadow detail, determination of directional data, location of objects, and identification of artificial and natural features should be devised. The use of some simple type of grid, such as the Atlas Grid, for locational purpose is necessary. At this point in his training, the student should be acquainted with methods of representing details of the photograph in map form. The overlay method provides a simple start in this direction and is instructive for later more-detailed effort by stereoscopic means. With the single vertical, a good preliminary understanding may be had of the problems inherent in tip and tilt and increase in degree of distortion outward from the principal point. One who becomes proficient in the simple photogrammetric problems of, and the identification of, features on the single vertical photograph will rarely have difficulty when the greater advantages of stereoscopic vision are made available to him. It is advisable, in this simple approach to stereoscopic analysis, to avoid reference to photogrammetric principles of involved nature; such items as orientation, direction, scale, relief displacement, and distortion due to tip or tilt are necessary and unavoidable. However, there is no need for the photogeologist to become a photogrammetric engineer. He can gain proficiency in his art of interpretation without becoming deeply involved in the intricacies of photogrammetry. Analogy may be drawn here by an apt comparison. Many expert petrographers are ignorant of the more complex workings of the petrographic microscope, a condition which does not seem a deterrent to their proficiency. It is not necessary to know precisely why a tool works, but rather to know how to manipulate it so that it will yield the best results.

Prior to introduction to stereoscopic methods, the student should be made cognizant of the various types of aerial photographs and the composites made therefrom. It is not necessary, however, to train him in the techniques of aerial photography, nor to enlighten him concerning the complex mechanism of the aerial camera. He is not striving to become a "jack-of-all-trades." Admixture of extraneous items in his training, however interesting they may be, is quite nonessential.

STEREOSCOPY

Few individuals with average vision have any real difficulty in gaining the ability to view photographs stereoscopically. Hence, constant practice with sets of stereograms is the only major requirement. For most students a short period of preparatory instruction suffices. On the other hand, a few have difficulty, usually of psychological nature, and their problem becomes an individual one for the instructor. With the normally acceptable set of visual exercises no real obstacle is posed. Following the first sense of relief with the attainment of true depth perception, the student's interest quickens and his eagerness to enjoy his new found art increases his desire to practice.

I have found it advantageous to supply stereograms, mounted for such purpose, to each member of the group. Following simple instruction in the principles of stereo vision, the students are then required to practice relief perception without the aid of the stereoscope. The ease with which many of them master this technique is ever a source of amazement to me. After this introductory exposure, the guided perception of third dimension by means of the stereoscope seems a much simpler process. Easy stereoscopic ability is simply a matter of constant practice. For classroom use the Abrams B-3 (folding model) or the Zeiss Pocket stereoscopes are the best instruments. Any course of instruction in photogeology should be equipped with these or similar mobile instruments. The larger reflection type stereoscopes are not satisfactory for most photogeologic work.

PHOTOGEOLOGIC TRAINING

GENERAL

Any geological analysis, whether it be topographic mapping or photogeologic mapping, must depend fundamentally on the skill of the interpreter collecting the data. Such skill requires, in addition to the prerequisites of sound geomorphic, structural, and field training, the added factor of keen observation of details. Hence, a successful career in the photogeologic field, given the correct basic knowledge as foundation, must depend on continuous practice with photographs showing all types of topographic and structural relationships. It should be emphasized that a geologic map, or a photogeologic map, is the interpretation of geological detail whether it be in the field or on photographs, such an interpretation depending on the decisions of an individual.

As is the case with normal field reconnaissance, photogeologic reconnaissance similarly is called upon to solve a wide variety of geologic problems. In any case, however, the desired goal is the production of an accurate map depicting the geologic findings. This is fundamentally true whether the efforts are confined to a small area covered by only one or two photographs, or are extended to a broad region represented by a great number. Any instructive technique must therefore have as its aim the proper representation of the details observed in map form. An obvious and simple approach to this is to tutor the student in annotation of the details observed, directly on the photograph. (Grease pencil should be used.) Later this detail may be transferred to transparent overlay. The latter, with the appropriate data, becomes a map depicting the geologic features required. It is a simple step from this to instruction in the use of the pantograph for enlargement or reduction. After reasonable capability in analyzing detail stereoscopically has been developed, it is no great problem to instruct in the more refined technique of transfer of data from photograph directly to map base by using the Camera Lucida.

PHOTOGRAMMETRIC REQUIREMENTS

Numerous conversations with professional photogeologists have convinced this writer that the more complicated photogrammetric engineering devices are quite unnecessary in preliminary photogeologic instruction. An understanding of these is a necessity for perhaps more advanced, more quantitative photogeologic effort. This is not an attempt on the part of this writer to negate the value of photogrammetric engineering, but rather to relegate the more involved techniques to a more advanced bracket of instruction. I feel, in agreement with Wengerd (11), that the "present status of most geological interpretation from aerial photographs is mainly qualitative." Quantitative interpretation, involving photogrammetric engineering, should be reserved for more advanced geologic and topographic problems. The photogeologist is not fundamentally a photogrammetrist. His contribution is the interpretation of geologic observations in which, of course, he may gain considerable assistance from the use of several of the less complicated photogrammetric devices and principles.

The latter implication is that instruction should be given in the basic course in photogeology in the use of such elevation-finding implements as the Abrams Contour-Finder, the Fairchild Stereo-comparagraph, or the Zeiss Tracing Stereometer. The usage of the extremely complicated Fairchild Multiplex or the Aero Service Corporation Brock Process should not be attempted in detail, but should be reserved for more advanced instruction. It suffices to prepare a series of exercises in determining spot elevations on stereo pairs, to acquaint the student with manipulation of height-finding instruments. The even simpler stereoscopic method of determining elevations described by Desjardins and Hower (12), a method requiring considerable practice in judgement of perspective, is also a very useful laboratory exercise. Practice of this type is excellent for training the eye and hand, developing strong cognizance of detail and, as such, being valuable in fostering skills other than photogrammetric.

GEOMORPHIC INTERPRETATION

The aerial photograph, particularly when viewed stereoscopically, provides a splendid means for topographic analysis. However, if the analyst has economic aims, there is little need for him to become involved in empirical physiographic description. The topography to him is merely a means of establishing structural relationships. This requires considerable geomorphic understanding, but involves little beyond the interpretation of existing landform types which will enable the tracing of outcrop patterns, thereby delineating structural features. The emphasis is of course on the interpretation of form which must then be applied to certain established associations of landscape and structure.

Since the genesis of landform depends primarily on the effect of geologic process operating on geological structure, it is necessary to accentuate this combination in instruction. Thus, the work of running water, the most active of all the geological agencies, provides an excellent basis for geomorphic analysis of aerial photographs. Stream patterns, due to their striking adjustment to structure, form a good starting point for such analysis. Delineation of the drainage network is the first requirement of most photogeologic interpretation. Application of the art of topographic map reading may here be employed. Ideally, laboratory exercises using photographic coverage demonstrating examples of the several major stream patterns should be included. Here again, given sufficient basic knowledge, the key to successful analysis lies in continuous practice to develop a keen sense of observation.

In the same sense correct analysis of the inter-stream areas is important. Recognition of slope differences falls in this category. If a particular slope element is distinct enough to be traced linearly for any distance, it may prove an important key serving to outline structural features. Further, the distinction between scarp slope and dipslope in stratified rocks may be possible, a factor of importance in the calculation of strike and dip by estimation or photogrammetric process. Practice in the recognition of differences in slope is extremely important. Not only do such reflect the bedrock structure, but broad generalizations concerning lithology may also be possible. The limitations placed on the geomorphic requirements for the economic photogeologist in this discussion do not reflect a feeling that the aerial photograph is a poor vehicle for geomorphic analysis. Quite to the contrary, this writer knows that the aerial photograph is a very potent tool in the hands of the trained geomorphologist. The student geologist, however, is poorly equipped to involve himself in this more advanced phase of interpretation. Proper instruction in the basic essentials of topography will fulfill his elementary requirements.

The relationships which exist between soil and vegetation and the underlying bedrock are of great importance. Few students have sufficient knowledge of either pedology or botany. As a matter of fact, few professional geologists could qualify on this score. There is no really adequate work which establishes a definite set of criteria suitable for instructional purpose. Until such is available, unless the student has a comprehensive knowledge of these relationships, there is little of specific nature that one can do to train along these lines. The ability to distinguish soil and vegetation types depends fundamentally on sensitivity to tonal contrast in the photographs, such being a function of practice. The development of ability to recognize soil and vegetation contrasts in photographs is therefore not difficult. It is in the application of recognized patterns to gain geomorphic or structural data that the difficulty lies. Much work remains to be done in this field. A few references are of value, including the *Civil Aeronautics Administration Technical Development Report No. 52* dealing with the origin, distribution, and airphoto identification of United States Soils (13).

LITHOLOGIC INTERPRETATION

The interpretation of lithologic types lies somewhat beyond the scope of elementary photogeology. It is generally sufficient to engender in the student consciousness of tonal differences in the bedrock exposed which will allow him to trace a particular rock outcrop for purpose of delineating structure. Without field check to determine lithologic types present and associated topographic expression, it is impossible to be certain of lithologic analyses. The general criteria which have been established regarding the distinction of tone value in aerial photographs, as indications of lithologic types, however, are of importance and should be discussed by the instructor. It is only after extended experience as a photogeologist that identification of lithologic units with any degree of certainty is possible. The application of any set of criteria is local in scope because mode of weathering, topographic expression, vegetative and soil types, and tonal contrasts are all used to determine lithologic types. These are all variables controlled by climate, and no tangible uniformity of appearance could be expected to exist in photographs. Considerable success may be had, however, in exposure of the student to stereo studies of areas of known lithology. I have used this approach in more advanced photogeologic work with gratifying results.

STRUCTURAL INTERPRETATION

Structural interpretation is the main objective of most photogeologic work of economic nature. The aim is to produce a geologic map, similar to that produced by normal field analysis, but with considerable saving in time, effort, and expenditure. This is a qualitative job consisting of the mapping of outcrop patterns, the determination of dip and strike wherever possible, the computation of thicknesses, and the plotting of structural axes. No photogeologic reconnaissance should be considered complete until field check is made at key points, for final accuracy.

The mapping of outcrop patterns is a relatively simple process if the bedrock is exposed in continuous sequence; or if the bedrock, though masked in places by the regolith or vegetation, has sufficient continuity to allow for the tracing of extent of individual rock units. In some cases, the panoramic view presented in the photography is such as to present broad structural relationships almost immediately to the interpreter. Thus, the photogeologic technique becomes simply the collection of data for detailed description of the relationships and construction of the geologic map. In other instances, where structural relationships are not immediately discernible, the methods of determining structural data are similar to those used in normal field reconnaissance.

A major capability which must be developed is the determination of strike and dip from the photograph. This may be done, if great accuracy is desired, by photogrammetric devices. In many instances, however, the angle of dip may be a matter of estimation, phenomenal accuracy in such ability having been developed by some photogeologists. This of course requires long experience and practice. The ground-work for the estimate method may be established in the classroom by devising a number of exercises involving dip and strike determination on stereo pairs. It has been found advantageous to select some area where the attitude of the rock layers varies considerably from place to place, certain key points on the structure having been checked for this data in the field. Constant practice in dip estimation is required. The student must be made particularly aware of the tendency to overestimate as a result of relief exaggeration and the distortions inherent in stereo view. Surprising accuracy can be gained, however, even in regions where the dip is very slight.

Dip and strike are determinable more accurately by photogrammetric devices in the same general fashion that the attitude of beds is established on the geologic map. After preliminary instruction in the choice of appropriate locations on the photograph for the measurement of these items, the only instruction necessary is in the proper usage of one of the simpler height-finding devices. I have found the Fairchild Stereo-comparagraph easy to work with in this respect, though the Zeiss Stereometer and the Abrams Contour-Finder are just as adequate. The student should be briefed in the functioning of one of these, and then allowed to work a series of problems until he has mastered the technique. Spot elevations, chosen on the proper exposure of bedding plane surface, allow for the determination of dip, by simple three-point method. Here again, for instructional check the area photographed should be one in which the dips are known or located so that the student can check his findings. Several good reference works are available which clearly explain the techniques, including Abrams (14), Desjardins (15), Smith (16), Eardley (17), and Desjardins and Hower (12).

The interpretation of such structural features as joints and faults combines a number of factors which are difficult to designate precisely. The gamut of criteria for identification includes vegetative patterns, soil coloration differences, topographic expression, drainage anomalies, and breaks in outcrop pattern. The detection of these requires practice in observation, and considerable knowledge of geomorphology as related to structure. The assumption must be made that the student is versed in the latter, and will gain the former through continuous exposure to examples of these features in photographs.

SUMMARY

The problem of adequate instruction in the techniques of photogeology is an immediate one. Exploration of the reconnaissance type, best accomplished through the medium of the aerial photograph, has been established as the first requisite for the discovery of mineral resources. The rather haphazard nature of the reference material required for preparation in the subject necessitates a clear-cut approach to the instructional methods which should be used in such training. Certain training elements, heretofor considered necessary, should be eliminated and others, perhaps considered not so important, should be excluded.

Because of the negligence of college curricula in providing the mental essentials in training for a course in photogeology, certain compromises are necessary. A geomorphic and structural comprehension is essential to successful application of the principles of the subject. Lack of understanding of the practical applications of these subdivisions of geology is a serious handicap and can be overcome only by field experience. Rarely does the average college curriculum provide a basic understanding in these subjects. Normally, proper field experience is only gained after entrance into a career as a professional geologist, and not then unless the individual is located in circumstances favorable to the acquisition of such experience. Thus, with instructional methods faced with these lacks, any course of photogeologic instruction must be so devised as to counter the deficiencies.

This can be done by providing the student with such a fundamental framework that experience will furnish the additional ingredients which he needs to properly accomplish his professional objectives. It is apparent that each academic institution, with its particular geological training formula, is faced with an individual solution. It would be impossible to devise any single program to suit all academic environments.

Only those students who show marked capabilities in the two prerequisites,

geomorphology and structural geology, should be accepted for instruction in the analysis of aerial photographs for professional purposes. The usual program of elementary training in geology is a rather poor substitute for these prerequisites. An additional item of study, structural geology, is a welcome supplement to such training. Rarely will the average undergraduate have had any sufficiency in preparation in geomorphology. Only those students who show the greatest aptitude in the more elementary aspects of the science should be trained in photogeology. Critics of such policy should remember that this attitude is conditioned by present academic circumstance; and, should the marked insufficiencies of educational programs be corrected, greater numbers of trained photogeologists may be produced.

It is impossible to include the elements of geomorphology and structural geology in instruction in photogeologic analysis. Proper selectivity of student personnel will eliminate this necessity. It is, however, possible to review certain items of map interpretation in which the individual must be proficient. A series of exercises containing the fundamentals of map reading are considered essential in order that the groundwork for photo interpretation may be formulated. As a supplement to this, and to be offered concurrently, topographic maps showing various structurally controlled landform types should be made available for examination. The student who gains ability in the analysis of topographic maps will have little difficulty in the deciphering of landforms on aerial photographs.

Instruction in the art of stereoscopy should be preceded by direction in the proper technique for examination of the single vertical photograph. The basic essentials for photo interpretation may be taught during this phase of the instruction. Following this, the novice is ready for information which will lead to ability in the proper geologic analysis of aerial photographs. A simple explanation of the photogrammetric theory of stereoscopy will suffice. Practice in the several visual exercises used to develop this ability usually gets the desired results from the majority of devotees. This writer has found that practice without the aid of the stereoscope is often advantageous prior to instruction in the use of this instrument.

Once the ability to use the stereoscope has been mastered, the subject should be exposed to as many examples of landform types as is possible in the time available. A directed effort to foster ability in the observation of detail is a requisite. The caliber of photographic material available must, of necessity, be a governing factor. Every effort should be made to obtain coverages which will show a maximum variety of geomorphic and structural conditions. There are a number of agencies, governmental and private, which will supply instructive material at very reasonable cost.

Instruction in dip estimation is a factor of prime importance. Experience has shown that one can gain an amazing proficiency in this without the aid of photogrammetric devices. The latter, however, should also be presented to the beginner, to insure that he become adept in this more accurate skill. Proficiency in either case is a matter of practice which, beyond the original instructive period, becomes a matter of individual application.

Skill in presentation of data gleaned from the photo analysis is not the least of the requirements for expert photo analysis. Application of the usual field data depiction methods is the normal procedure. The student should be properly schooled in the accepted symbolic designations of geological information in map form. It is vitally important that the photogeologist be able to properly present his findings. Here again, experience is the best teacher.

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RESEARCH COMMITTEE*

THE 1949 Research Committee prepared a letter to fifty photogrammetric or related organizations requesting a brief outline of photogrammetric research conducted during the past year that may be of general interest to the readers of PHOTOGRAMMETRIC ENGINEERING. The Committee expresses its appreciation for the excellent cooperation received.

This report, in effect, supplements the "Symposium: New Developments in Photogrammetric Equipment" compiled by Messrs. Lorenz, Pennington, and Roth in the September 1949 issue of PHOTOGRAMMETRIC ENGINEERING.

Mr. Everett L. Merritt, U. S. Naval Photographic Interpretation Center, and Mr. John V. Sharp, Bausch and Lomb Optical Company, were requested to prepare a paper on research. Inasmuch as PHOTOGRAMMETRIC ENGINEERING has published many fine technical papers, it was believed appropriate for an organization or individual to define his position in photogrammetric research. To stimulate thinking along the line of basic research, papers on "Research" by Mr. Merritt and "Comments on Instrument Research" by Mr. Sharp are included in this report. Although these two points of view may not be concurred with completely by all readers, they are nevertheless presented as a sincere endeavor to initiate a basic concept of photogrammetric research. Comments on these papers are invited by the Research Committee.

The 1949 Research Committee Report is hereby submitted in three parts:

Part I—1949 Research Projects

Part II—"Research" by E. L. Merritt

Part III—"Comments on Instrument Research" by J. V. Sharp

* *Gomer T. McNeil, Chairman, Research Committee.*
U.S. Naval Photographic Interpretation Center