AERIAL PHOTOS IN GEOLOGIC TRAINING*

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DURING the past 15 years, aerial photos have come into wide use by geologists. A trend gathering impetus in pre-war years was further accentuated by war-time experiences. During the war years, many geology departments, in response to military requirements, introduced courses in photo-mapping and photo-interpretation for the first time, and many geologists had their first opportunity to see the advantages of photos for their work. Today, probably a major portion of the geologic mapping on this continent is based on aerial photos. The use of photos has provided a powerful new tool for the study of geologic phenomena, and the world-wide extent of aerial photography has made ready a fertile field in which to use this tool. For the teacher of geology, this situation has a two-fold significance. In the first place, the way is pointed to a new medium for presenting many phases of the science with maximum clarity and effectiveness. In the second place, a need is suggested for specific instruction in a most important new technique for geologic mapping and research. Each of these points merits some discussion.

In the classroom presentation of geology, one of the objectives is to give the student a clear mental picture of structures, landforms, and rock bodies in their three-dimensional relations. There are various ways of doing this, but one of the most effective is the use of lantern slides made from aerial photos. The aerial perspective reveals innumerable geologic features in a degree of detail and in a faithfullness to proportion otherwise difficult to attain. The use of photos in color gives added realism, and three-dimensional projection, now possible with Vectograph slides in any standard projector, makes the stereoscopic view available to large groups, giving a vivid impression of earth features in their true spatial relations.

In the geologic laboratory, the study of physiographic and structural features generally has been based to a large extent on maps. The student learned to read maps and then was given exercises directing his attention to typical map examples of geologic features, their relations in space, and the evidences for their relations in time. Some training in the use of maps certainly is essential. The use of maps as a medium of instruction, however, is not without certain shortcomings. Many students, particularly at elementary levels, find map studies dull and unfruitful. The use of aerial photos, both as an aid in map interpretation and as an independent basis for presenting geological relationships, helps overcome this and other difficulties, and offers important advantages over laboratory teaching based on maps alone:

(1) Geologic features are shown as they actually are, rather than in generalized form through the media of conventional symbols. The limitations and imperfections of maps are avoided.

(2) Where photos and maps of the same area are used together, the photos contribute to a better understanding of the maps—their content, their merits, and their limitations.

(3) Photos show a degree of detail rarely attained on existing maps. Geomorphic features having a relief less than or but slightly greater than the standard contour interval—beach ridges, dunes, floodplain features, glacial markings, and the like—are faithfully represented. Narrow stratigraphic horizons may be

* Abridged from a paper published in the Interim Proceedings of the Geological Society of America, for March, 1947.

distinguished and traced. Structural details, such as fractures and minor faults, are recognizable even where difficult to detect in the field.

(4) The study of photos is the closest equivalent to actual field examination, and it is field study that has provided the very foundation of geologic knowledge. By means of photos, a significant part of the field, the world over, is literally brought into the laboratory for deliberate inspection.

(5) The range of choice in selecting study material is much greater with photos than with maps. Excellent photos are available for large areas, in this and in other countries, where topographic and/or geologic maps are either inadequate or wholly lacking.

(6) Most students find photos inherently more interesting than maps. The direct and natural picture of earth features challenges their attention.

The selection of suitable photos is the first step in their use for teaching purposes, and upon this step depends the effectiveness of their subsequent use. The problem of making judicious selections from the vast bulk of photographic material available from governmental and commercial agencies is a large one, and calls for the co-operation of all individuals concerned. As a guide to the individual teacher, it would be desirable to have an annotated list of representative photos, covering the various branches of geology, from which choice according to the needs of particular courses could be made. It would be desirable also that all of the photos on this list be obtainable from a single distributing agency, so as to obviate the difficulty and confusion of distributing orders among the various separate agencies from which photos are available, and which total more than a dozen. As a start in the general direction noted above, I am preparing a list of photos which have been found useful for teaching purposes at the University of Kansas, with the idea of making it available to all who are interested. Suggestions from other geologists and teachers are solicited, and eventually it is hoped that something suitable for publication in this journal may be assembled.

A second aspect of our topic has to do with techniques for finding and recording new geologic data. So far as surface geology is concerned, this means methods of discovering and assembling field data and making maps. Obviously, some training in field work is fundamental here. The desirability of additional training concerned specifically with the use of aerial photos involves two considerations: (1) the importance of photos in modern geologic study and mapping, and (2) the need for specific instruction in the use of photos.

The importance of aerial photos in mapping is twofold: photography provides a basis both for the making of base maps, and for the interpretation of geology and the plotting of geology on base maps. The processes of making base maps lie within the field of photogrammetry. Planimetric mapping in this and in other countries is now based almost entirely on photogrammetric methods. Contour mapping also is turning rapidly to photogrammetric techniques. Greater accuracy and lower costs are the results.

In purely geologic mapping, the use of photos is now standard practice with oil companies, federal surveys, and others. Specific applications vary with circumstances. Perhaps the commonest use of photos is simply as a base for plotting field observations. For this purpose, photos frequently have the advantage of permitting easier and more accurate ground location than maps, and in many places photos are the only type of base map to be had. Another valuable aid to the field geologist is the use of photos as a guide to the best places for making observations. Significant localities for studying outcrops, structures, or other features may be determined in advance of ground work, and the best routes to such localities may be selected. In this way, much random traversing is avoided, and much time is saved. A still more important use of photos is for interpolation between places examined on the ground. Frequently it is found that structures, formation boundaries, and physiographic features may be traced across long distances between traverse lines, simply by photo interpretation. The need for much laborious ground work is eliminated, and at the same time accuracy is increased. Of course, not all areas are alike, and what is possible in some is not possible in others. The experience of recent years has shown, however, that in nearly all instances the use of photos serves to expedite field work to a greater or lesser extent. Indeed it may be said that the advent of aerial photography has changed the entire mode of approach in geologic mapping.

Where systematic areal mapping is not the goal, much useful geologic information may be extracted from photos without even going into the field. To the skilled interpreter, the various lineaments, textures, and patterns of the photo all have their significance in terms of rocks and structures. Partial or approximate maps may be prepared for distant or inaccessible areas, the possibilities of finding mineral deposits appraised, and localities promising for ground examination selected. To the economic geologist in particular, this method of attack is of real practical importance.

In many fields of geologic research apart from routine mapping, the value of aerial photos has been demonstrated also. Already important advances in our knowledge of sand dunes, glacial features, and other geologic phenomena have resulted directly from the study of photos. In geology as in other sciences, the introduction of new techniques of investigation have made possible new advances in knowledge. Modern petrology began with the introduction of the thin section and the petrographic microscope. It is my belief that the introduction of aerial photography will prove to have been of comparable importance in general geology. In several important respects it constitutes a revolutionary advance in method:

(1) Relationships which previously could be apprehended only by the indirect process of laboriously collecting and plotting field data now may be seen directly, at a glance, often without even going into the field.

(2) Structural, stratigraphic, and geomorphic features which frequently have been passed unnoticed in the field are clearly revealed.

(3) A new degree of accuracy and detail in geologic mapping is made possible without increase in time or cost.

(4) Study of photos frequently shows features and relationships either previously unrecognized or at variance with accepted ideas, and thus points the way to specific research projects.

(5) The speed and economy of aerial photographic mapping make possible a far more rapid increase in our knowledge of the little-known parts of the earth than would have been possible otherwise. Recent progress in the study of the Canadian Shield is illustrative.

The value of aerial photos in modern geologic investigation having been reviewed, there remains the question as to need for specific instruction in the use of photos. Such instruction would have two phases, which are best considered separately: (1) geologic interpretation of photos, and (2) the mechanics of making measurements and preparing maps from photos. The first of these is of a qualitative nature, and is concerned with the accurate identification, correlation, and delineation of structural, stratigraphic, and geomorphic features. In areas where geology is fairly simple and well exposed, photo interpretation is simply a direct application of general geological principles, and no special guidance or instruction is required. In many types of terrain, however, these simple conditions do not exist, and correct interpretation requires considerable skill and experience. A thorough knowledge of geomorphology and structural geology is the first prerequisite, and to this must be added a familiarity with a wide range of geologic features, and with other non-geologic features, *as they appear on aerial photos* of different scales. This type of experience is best acquired by a study of selected photos, under proper guidance. By this route, the student is led to recognize the subtle markings that characterize innumerable obscure features, and is placed on guard against the many sources of confusion and the many pitfalls awaiting the unwary. He comes to recognize differences between things which seem similar, and similarities between things which seem different. He is put on the lookout for physiographic, vegetational, or man-made features which may simulate structures. Ideally, at least, he becomes acquainted with all possible types of landforms and geology, under the widest possible range of environmental conditions.

A second phase in the use is of a quantitative nature. It involves determination of the scale of photos, the making of measurements of distance, direction, and elevation on photos, and the preparation of maps from photos. These operations require at least an elementary knowledge of photogrammetric principles and methods. As a foundation, the modern geologist should understand the perspective geometry of vertical and oblique photos, the causes and corrections for distortion, and the principles of stereoscopy. Next, he should be familiar with methods for preparing his own base maps from both vertical and oblique photos, particularly with the simpler graphic and instrumental methods which require a minimum of special equipment. It is desirable also that he be at least acquainted with the capabilities of somewhat more advanced instrumental methods, such as the use of the Vertical Sketchmaster, Multiscope, Kail Radial-line Plotter, Slotted Templets, K. E. K. and Mahan contour plotters, Rectoplanigraph, and Rectoblique Plotter. Basic training in the above aspects of photogrammetry is fully as valuable to the geologist of today as was training in the use of the plane table to the geologist of former years. The mastery of photogrammetric methods, however, requires considerably more time, attention, and guidance than did the simpler plane table methods, and is accordingly more difficult for the geologist to acquire on his own initiative away from school. Unless specifically trained in photogrammetric methods, the geologist is unlikely to appreciate their value or recognize opportunities for their application, and thus will be unprepared to attain maximum efficiency in the practice of his profession.

From the pedagogical standpoint, a practical problem is concerned with the placing of aerial photographic subjects in the established curriculum. Three different approaches are possible:

(1) Work with photos may be incorporated in courses already offered. Thus an introduction to the use of photos may be given with the laboratory work for the first course in physical geology. Various phases of interpretation may be presented in courses on structural geology, geomorphology, economic geology, map interpretation, etc. Mapping methods may be included in field mapping courses and/or laboratory courses on cartography. If the subject matter of the various courses involved is properly integrated, all of the essential material may be presented in this way, and the advantages of photos as a medium for teaching geology may be exploited at the same time.

(2) One or more new courses devoted exclusively to aerial photos may be introduced. Under certain circumstances, this approach may permit a more direct and concentrated attack on the subject, and provide an effective review for previous work on physical geology.

(3) A combination of the above approaches may be used. For example, a basic course on photo-interpretation and/or photogrammetry might be followed by specific applications in courses on structural geology, geomorphology, field geology, etc.

Each of the above approaches has its own particular advantages and disadvantages, and these vary with circumstances. Choice of the course to be followed depends on the flexibility of individual curricula, time allowable, equipment available, and qualifications of students and instructors. Whichever course is followed, the important thing is for the basic topics discussed on preceding pages to be treated as fully as possible.

In conclusion, aerial photographic methods are here to stay. Their use is now standard as a method of geologic investigation. Their advantages apply alike to theoretical geology and to applied geology. Their application already has given rise to appreciable advances in geologic knowledge, and now holds much promise for future progress. Their value merits a definite place in the training of the professional geologist. If the teaching of geology is to keep pace with the practice of geology, photo-interpretation and photo-mapping must be included in the curriculum.

A METHOD OF PREPARING STEREOSCOPIC AERIAL PHOTOGRAPHS FOR REPRODUCTION IN QUANTITY

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THE vertical aerial photographs which have been made in the past few years by several governmental organizations covering the greater part of the agricultural lands of the United States constitute a mine of material useful for instruction in geology and geomorphology and provide also excellent base maps for geological field work. These photographs have been taken with stereoscopic overlap so that the element of relief is fully represented.

For instructional purposes, however, and for use in the field as base maps for geological or geographical studies, the contact prints are difficult to use because the prints must be accurately adjusted to an overlap suited to the eye-spacing of the individual and they must be properly aligned and held rigidly in place by draftsman's tape or otherwise. For use with the simplest type of stereoscope, the lens stereoscope utilizing simple lenses spaced at the same distance apart as the eyes, only part of the stereoscopic area of a pair of prints can be viewed at one time, and for the larger square prints of 9″×9″ or 10″×10″ size it is still more difficult to view the entire stereoscopic area. Both for instruction in elementary classes and for work in the field these objections are serious.

This brief note is written to describe a method by which a pair of overlapping vertical photographs of any of the standard sizes can be prepared for cheap reproduction in quantity, each pair as a single print showing the entire stereoscopic area of the two prints ready for viewing without any preliminary spacing or alignment difficulties.

The method by which this is accomplished consists in laying the two stereoscopic prints side by side with their centers properly aligned along the line of flight (Fig 1). The prints are then temporarily fastened down and the area including the stereoscopic portion of the two of them is photographed onto a single negative. The photography can conveniently be done with a miniature camera or if desired it may be done with any copying camera. If the negative