*Status of Photogeology in the U. S. Geological Survey**

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ABSTRACT: *Photogeology in the U. S. Geological Survey is discussed from the standpoint of operations, research and training. Studies of stratigraphy, structure, specific mine areas and dam sites, and compilation of isopachous maps are described.*

Photogeologic research is grouped in three categories: (1) instrument design and adaptation to photogeologic problems, (2) research on geologic problems using aerial photography, and (3) development and adaptation of film types to geologic problems.

Photogeologists are trained in the basic principles of photo interpretation and the use of photogrammetric instruments at Menlo Park, Calif., Denver, Colo., and Washington, D. C. The objective is to stimulate interest in and use of photogrammetric procedures in photogeologic mapping.

PRIOR to discussing photogeology in the U. S. Geological Survey, in reference to operations, research, and training primarily by personnel of the Photogeology Section, it seems appropriate to define the term "photogeology."

Despite the increasing use of aerial photographs in geologic study during the past few decades, it was not, to my knowledge, until 1941 that a definition of the term "photogeology" appeared in the literature. H. C. Rea then defined it merely as "geologic interpretation of aerial photographs." I emphasize the word "geologic" in his definition to contrast geologic interpretation of photographs with the many other types of photo interpretation. I hasten to add, however, that our present feeling carries a definition of photogeology a bit further. Just as completion of a geologic map is normally a part of field geologic study, so too is the completion of a photogeologic map normally a part of photogeologic study. This implies that certain methods of compilation, as well as techniques of measuring such data as strikes and dips of beds, displacements of faults, thicknesses of strata, etc., are a necessary part of a definition of photogeology. In other words it may be said that photogeology basically involves 1) interpreting, 2) measuring, and 3) compiling.

OPERATIONS

With the preceding as a background consideration will be given to photogeologic work in the Photogeology Section.

Most of the current work is devoted to operations. This photogeologic work involves 14 geologists working on numerous projects at the three main headquarters of the Geological Survey activity: Washington, D. C.; Denver, Colorado; and Menlo Park, California. The variety of projects, including stratigraphic and structural studies of areas of well-exposed to poorly exposed rocks, studies of structure in heavily forested igneous-metamorphic terrane, studies of specific mine areas and dam sites, as well as compilation of isopachous maps, may give some idea of progress in the geologic interpretation field when one considers that almost all photogeologic effort of a few years back was directed toward studies of sedimentary terrane for petroleum purposes, and only terrane that was gently folded or only slightly disturbed.

Much of the current photogeologic effort is directed toward studies in the Colorado Plateau of Utah, Arizona, and New Mexi-

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co. This vast area of well-exposed, predominantly little-disturbed sedimentary rocks, lends itself ideally to photogeologic study. Here the primary objective is mapping the distribution of uranium-bearing formations, as shown in Figure 1. It will be noted that the beds are clearly exposed and how easy it is to map such an area from aerial photographs.

By way of contrast, let us look briefly at the Prince William Sound area of southern Alaska (Figure 2). This is a heavily forested area of some 4,000 square miles. Access is difficult. Ground photographs (Figure 3) show the dense tree cover and general nature of the terrain. Rock outcrops (Fig. 2) are scarce except along the shoreline and and above the timberline, which ranges from about 500 feet to more than 1,500 feet above sea level. In aerial view (Figure 4) the structural patterns are evident, even in the heavily vegetated areas. These structural patterns are believed to hold some of the answers to possible new discoveries of mineralized areas in this former copper-mining district.

A quite different type of terrane (Figure 5) is found in the northern part of Alaska where an area of some 60,000 square miles has been studied and mapped photogeologically. This is an area of gently folded, locally faulted sedimentary rocks that may be petroleum bearing. Throughout most of the area, outcrops are scarce except along major streams, but topographic and vegetation changes (Figure 5) clearly reflect the underlying strata in many places. Thus geologic structures may be delineated and even contoured.

Locally within the broad areas just mentioned are smaller areas where more detailed study is desired. In southeastern Utah, for example, detailed measurements of stratigraphic intervals are made from aerial photography so that isopachous maps of a particular formation may be prepared. Isopachous maps are those that show lines of equal thicknesses of rock formations. These equal-thickness lines—isopachous lines—may reflect old swales and associated locally thickened parts of formations that are in places loci of radioactive deposits. In Figure 6 the thickening of one formation is apparent; from appropriate measurements on aerial photographs it is commonly possible to delineate such locally thickened strata, which may represent old stream courses. Herein lies the immediate value to the prospector and developer of radioactive deposits.

Research

Operations in photogeologic work of course would not be possible without instruments, and progress would probably not be as rapid without research in instru-

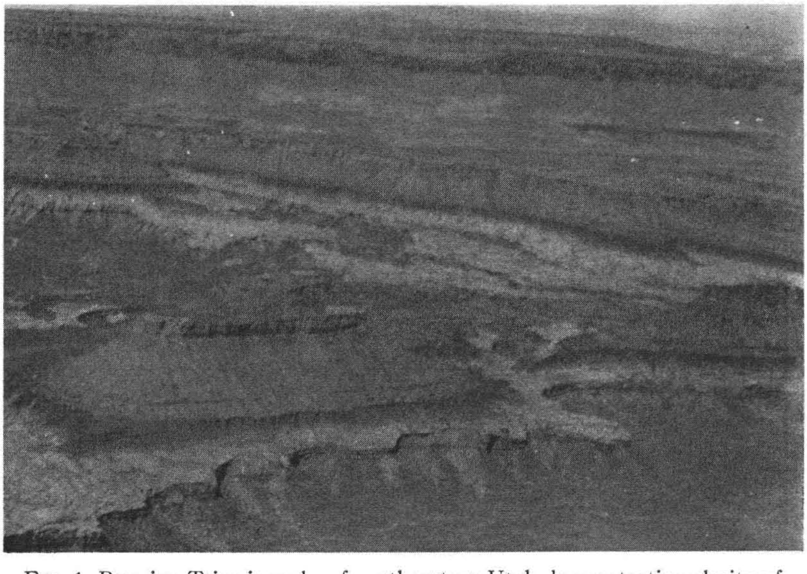

FIG. 1. Permian-Triassic rocks of southeastern Utah demonstrating clarity of different rock formations in aerial view.

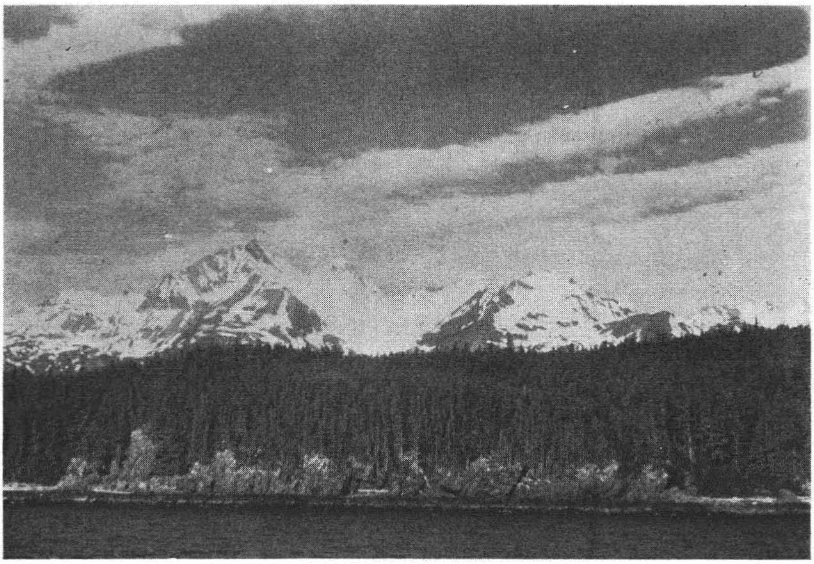

FIG. 2. Typical view of heavily forested Prince William Sound area, Alaska. Rock outcrops are confined primarily to the shoreline area and to the area above timberline.

ments, either through devising new instruments or in adapting existing ones to different jobs. Progress would also suffer without research in photogeologic study per se, using existing instruments as incidental to that study, And, of course, research in recording media, primarily film types, can be considered essential in the evolution of photogeology. Thus, photogeologic research may be grouped into three broad categories, namely:

1) Instrument design and adaptation to photogeologic problems,
2) Study of selected geologic problems through the medium of aerial (and terrestrial) photography, and
3) Development and adaptation of film types to geologic problems. At present no research on selected geologic problems is being carried on by the Geological Survey.

Although many photogrammetric instruments have been adapted to geologic study of aerial photography, the relatively recent use of stereoplotting instruments, particularly the Kelsh plotter in conjunction with high-altitude photography, stands out. In areas tested, verti-

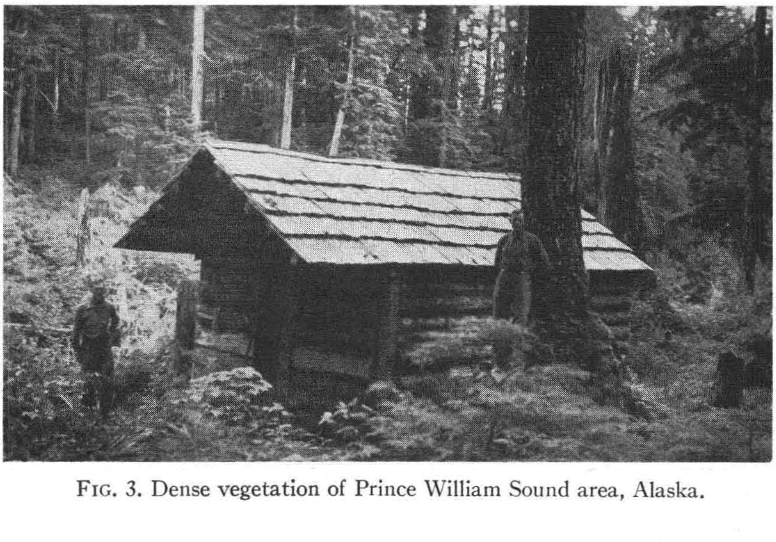

FIG. 3. Dense vegetation of Prince William Sound area, Alaska.

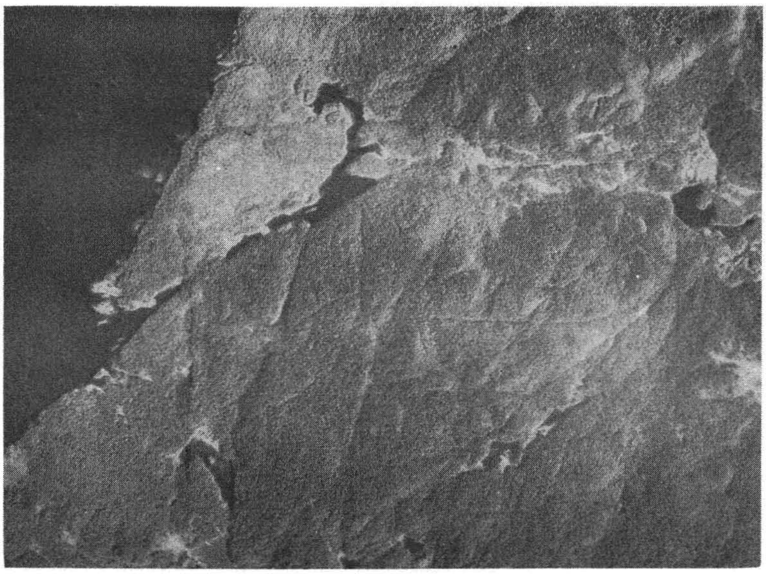

FIG. 4. Aerial view of Prince William Sound area, Alaska, showing structural patterns in timbered areas.

cal photography of about 1:60,000 scale was enlarged to a working scale of approximately 1:12,000 in the Kelsh plotter. For the areas selected, and for the results desired, this combination of instrument and photography proved highly successful. It was demonstrated not only that satisfactory interpretive results can be obtained from 1:60,000-scale photography, but also that they can be obtained in less than half the time required when the normally employed 1:20,000-scale photography is used. Further, it was demonstrated that reliable positioning of geologic detail was obtained in this procedure.

Among recently designed instruments currently being evaluated is the profile plotter, a device permitting terrain profiles

FIG. 5. View of Arctic Plateau, northern Alaska, showing topographic expression of rock formations. No outcrops are present.

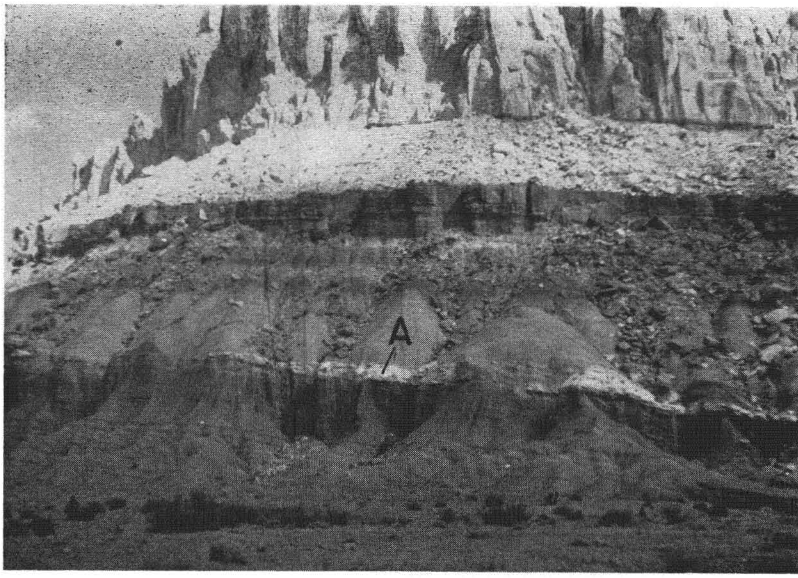

FIG. 6. View of Triassic rocks in southeastern Utah, showing thickening of formational unit (A).

to be sketched from multiplex-type stereoscopic models (Figure 7). With this instrument a pencil attached to the multiplex platen is moved by varying the height of the platen as the tracing table is pushed in the direction selected. There is no vertical exaggeration of the resulting profile, although the instrument could be designed to permit this.

A tilting platen (Figure 8) is also being tested for determining angles of slopes in stereoscopic models of the multiplex type. The platen is raised or lowered to an appropriate level in the stereoscopic model and

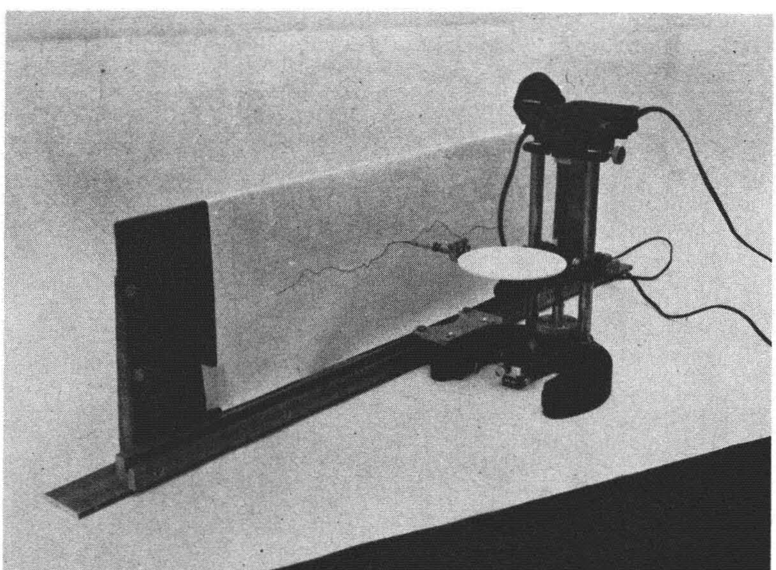

FIG. 7. The profile plotter, an instrument for sketching terrain profiles from multiplex-type stereoscopic models.

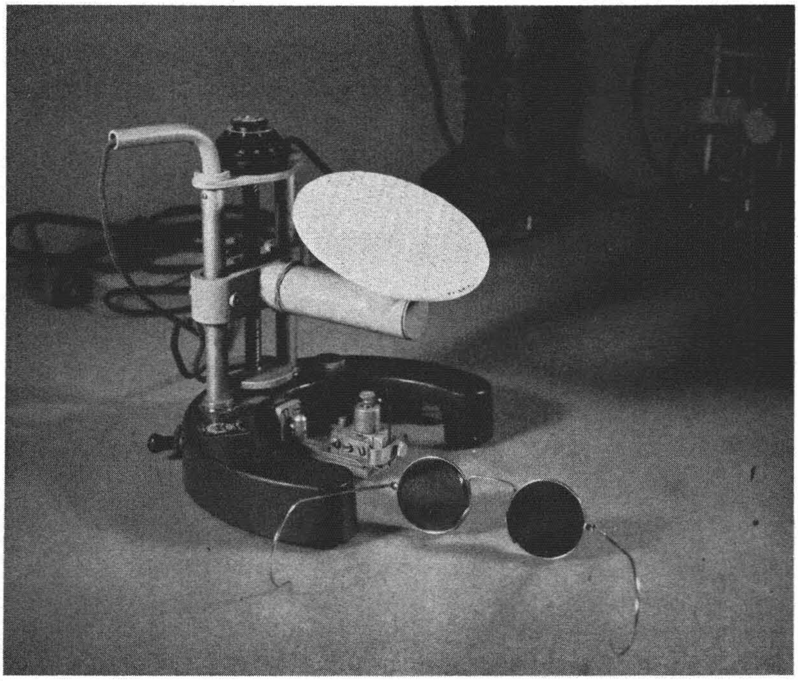

FIG. 8. The tilting platen used in determining angles of slope in multiplex-type stereoscopic models.

is then tilted to coincide with the slope desired. This is a true angle of slope that can be read on a clinometer.

Also among recently designed instruments currently being evaluated is a slope-measuring device, the Stereo-slope Comparator (Figure 9). The instrument is used with contact prints. It uses two small targets that may be fused with contact prints. It uses two small targets that may be fused stereoscopically into a single target, which is raised or lowered with respect to the stereoscopic model by varying the horizontal separation between individual targets in much the same way that the fused dot in stereometer-type instruments is raised or lowered. However, the dip is determined by actual physical tilting of the target in space. Because of vertical exaggeration inherent in most stereoscopic models, the dip determined is an exaggerated dip that must be reduced to true dip. This photogrammetric instrument is one of the first designed primarily to meet specific needs of the geologist, although it may prove applicable in other fields of photo interpretation.

Another phase of research is the evaluation of color photography. In small areas in California and Nevada 580 linear miles of color photography have been flown over sedimentary, metamorphic, and igneous terrane. This photography, primarily vertical, has a scale of 1:10,000 and was taken with a 12-inch focal length lens. It is being evaluated not only as to applicability in geologic study, but also more fundamentally from the standpoint of understanding color differences seen in the transparencies and those seen in the field. Preliminary evaluation has not yet been completed.

Although research is a necessary part of any progressive scientific field, there is no organized photogeologic research program within the Geological Survey, but instead research is carried on primarily as part of an outgrowth of operations. Without doubt there is a need for a continued and an even greater amount of research in photogeology.

TRAINING

Training in photogeology by personnel of the Photogeology Section has the twofold objective of familiarizing geologists with the basic principles of photogeologic

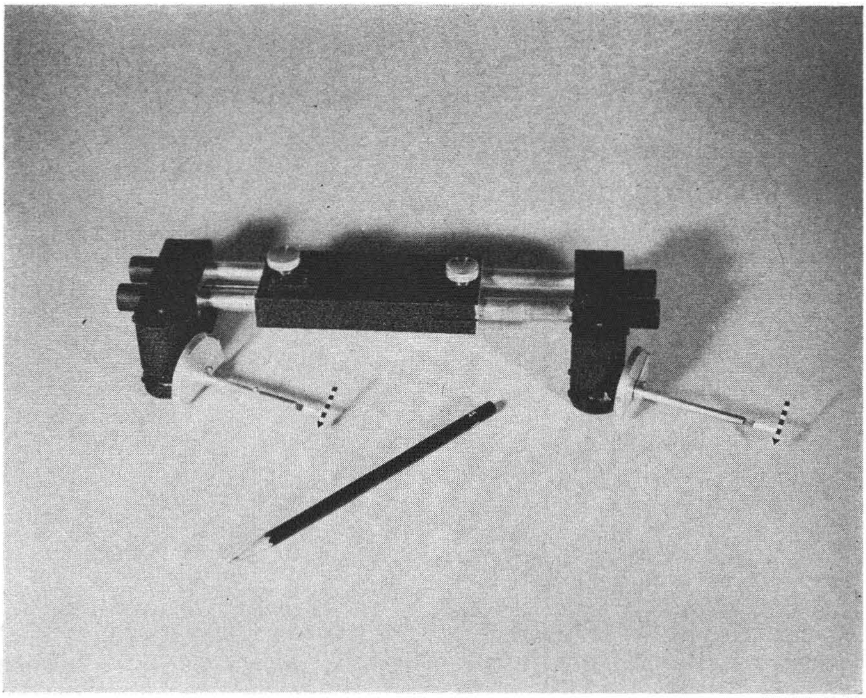

FIG. 9. The Stereo-slope Comparator, an instrument for determining angles of slope in stereoscopic models from paper prints.

interpretation and with the various photogrammetric instruments, such as stereometers and planimetric plotters, used in photogeologic study. Training is carried on formally in Menlo Park, California, and Denver, Colorado, and informally in Washington, D. C.

Specially designated training personnel are in charge of instruction in Menlo Park and Denver where large numbers of field geologists are headquartered. Instruction is offered to Survey geologists who may be interested. Obviously a short training period is insufficient for one to become a a proficient interpreter or skilled technician with various instruments, but the background is given for continued training on an informal basis, and personnel are available to assist all interested geologists on that basis. Approximately 125 geologists have completed the training courses offered. The long-range objective of this training is, of course, to stimulate interest in and use of photogeologic-photogrammetric procedures in geologic mapping.

It is gratifying to know that this training has been well received and that for the number of persons who have taken the courses, several more have become aware of and developed an interest in photogeologic procedures. All three of the Geological Survey centers provide instruments, insofar as supply permits, to geologists who wish to use them in their studies. The establishment of formal training positions in Denver and Menlo Park some two years ago is in itself an indication of progress that has been made in promoting the use of photogeologic techniques in geologic study within the Geological Survey.

Some training in photogeologic procedures is also offered in formal courses of instruction given by the Topographic Division in Washington, D. C., and Denver, Colorado. Photogeologic training complements these courses, which are designated to familiarize geologists with photogrammetric principles, instrumentation, and techniques.

SUMMATION

To sum up the present status of organized photogeologic work carried on primarily by personnel of the Photogeology Section of the Geological Survey, it may be said that operations account for the greatest expenditure of effort; that research on a small scale is conducted primarily along with operations; and that formal and informal training has been established on a permanent basis.

DISCUSSION OF DR. RAY'S PAPER

MR. EARL ROGERS: You mentioned a training program, quite a formal one, as I understand it. I didn't understand about the length of time.

DR. RAY: It is a two-week training period, ten days of intensive training.

MR. FRANCIS ORTIZ: Is the training available to any geologist?

DR. RAY: I am pleased to answer in the affirmative, with reservations. The courses have to be limited in the number of participants. Other than a Geological Survey geologist is permitted to participate in the course, provided this does not interfere with the programmed training of Survey geologists. In other words, if there is room at a particular time, because the number of participants is less than the allowable number, we are very happy to let someone else participate.

MR. HENRY BUTHMAN: You spoke of using a Kelsh plotter. Have you found from its use that it has more or less replaced the use of contact prints in the larger scale photography?

DR. RAY: At present, finite limitations concerning accuracy of geologic maps have been disseminated among the geologists of the Survey. Just as there are standard accuracy limitations of topographic mapping, we now have certain limitations to be met in compiling a Grade A, let's call it, geologic map.

Where such accuracy standards have to be met, the Kelsh plotter, of course is a very fine instrument to give the accuracy required. Undoubtedly there are a great many jobs where simpler, less precise, photogrammetric instruments would be adequate for the problem at hand, and I expect that is particularly true of some of your own work. In our own work, although we have encouraged the use of the Kelsh plotter, the use of contact prints has by no means been replaced.

A Performance Estimate Comparing Conventional Geologic Mapping with that Accomplished with the Aid of Color Photographs

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A COMPARISON between a color photogeological map of one area and geologic maps of the same area produced by other methods was originally scheduled for this panel. However, it was believed that such a limited presentation might miss the broader interests of a large part of those attending this meeting. So I have taken the liberty of broadening the scope of the presentation on an informal basis.

As Mr. Fischer has stated my experience in the past nine years has included a study of perhaps 40,000 large-scale, vertical, stereoscopic, color, aerial photographs covering a large number of mining districts in the Basin Range Province, and several on the Colorado Plateau. This basically was a research project in the use of the color photographs in mineral exploration.

Mineral exploration for the future requires geological analysis of regions and districts, resulting in predicting ore deposits several hundred feet below the surface of the ground. In the past nearly all outcrops of mineralization have been located by ground work; this requires the largest number of the best possible geologic maps. The color photographs function as such geologic maps with great detail; maps for reproduction can be produced quite efficiently from the photographs by simple procedures.

During past studies, color photographs and photogeologic maps produced therefrom, have been compared with many geologic maps of much of the 500,000 sq. mi. of the Basin Range Province and Colorado Plateau. These maps include State, Dis-