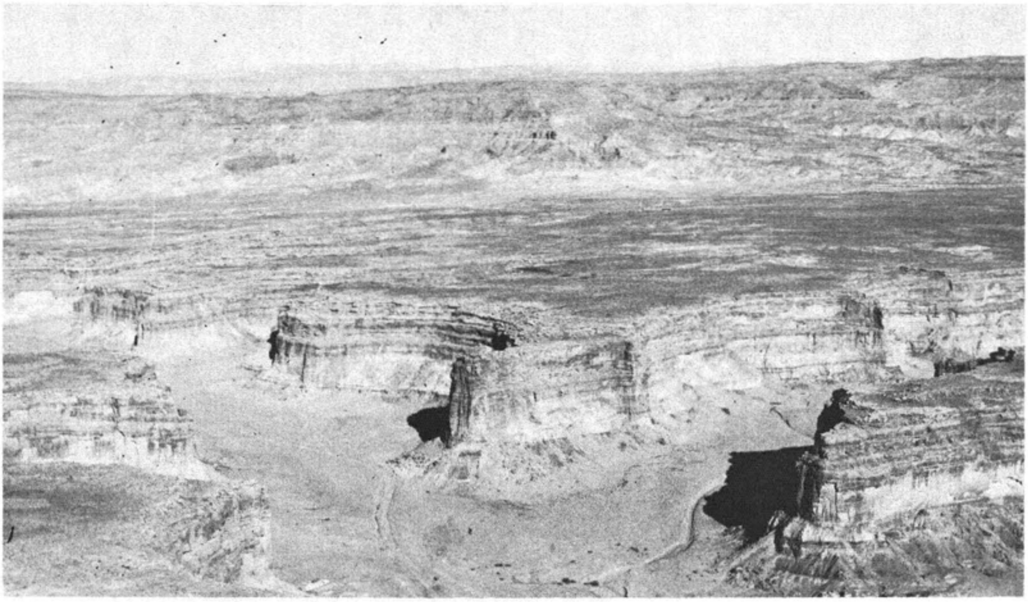

FIG. 1. The Kaiparowits Plateau of southern Utah is rugged and remote; this combined with the well exposed geology make it an excellent area in which to use photogrammetry as an exploration tool.

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Coal Exploration

The photogrammetrist, geologist, and engineer form an effective team for performing numerous valuable services.

(*Abstract on next page*)

A FEW YEARS AGO the Richfield Oil Corporation (now Atlantic Richfield Company) embarked on a diversification program which included a search for coal in the Kaiparowits Plateau of southern Utah. Photogrammetry was a part of this project from the beginning. It is interesting to examine the ways it was applied to the problems that were encountered.

The Kaiparowits Plateau lies across the Arizona-Utah Border north of Page, Arizona and the Glen Canyon Dam (Figure 1). Due to the extremely rugged terrain, the remoteness of the area, and the well exposed nature of the geology, photogrammetry was an ideal tool to be used in conjunction with the usual field exploration methods.

Before the project began it became apparent that base maps would have to be made; photogrammetrically compiled topographic maps were an obvious choice. No topographic maps at scales larger than 1:250,000 were available of the area, and the U. S. Geological Survey had no immediate plans to publish any.

First we checked the available existing aerial photography coverage. We found that the Geological Survey would be able to supply us with 1:48,000 photography flown in 1958. This photography was of excellent

ABSTRACT: *The use of photogrammetry as a tool in the exploration for natural resources has many varied applications. In the search for coal in the Kaiparowits Plateau of southern Utah, some of these applications relate to planning, procedures, and coordination. The particular phases of photogrammetry that are applied include the compilation of a topographic base map, the assembly of a semi-controlled mosaic, a photogeological project, the making of large scale topographic maps for plant and dam site evaluation and determination, and the organization of a proposed project involving the planning of the road bed alignment, grade, and earthwork computations for a railroad spur. The value of using the photogrammetrist in a team with the geologist and engineer is a key to success in this type of work.*

quality and the scale was almost perfect for our purposes.

At the same time we checked the photo coverage; we also tried to determine what mapping control was available. We were fortunate in that both the northern and southern edges of the area that we wished to map overlapped areas which had been mapped by the USGS. Adequate control existed along these edges and some additional stations were scattered through the rest of the area. Our own field program called for a grid of test holes to be drilled throughout the area. These were to be controlled by a ground survey and were dense enough to meet most of our control requirements. Any additional points that we would need could be added by our field crews.

It was decided that we would compile the entire area of about 450 square miles on our Kelsh Plotter at a scale of 1 inch = 800 feet (1:9,600). Due to the rugged nature of the terrain, a 40-foot contour interval was selected with 20-foot supplemental contours in the flat areas. The scale of 800 feet to an inch was excellent for the detailed geological and engineering work that was planned (Figure 2). It was also decided that we would construct another series of topographic maps at a reduced scale of 1 inch = 2,000 feet (1:24,000) (Figure 3).

The photographs and Kelsh Plotter plates were ordered from the USGS and their photo-identified control was transferred to our photographs at their office in Menlo Park, Calif. The layout for our drill hole survey had been examined and the required additional control was noted. Both the drill holes and additional control points were photo-identified by our people on the ground. It was con-

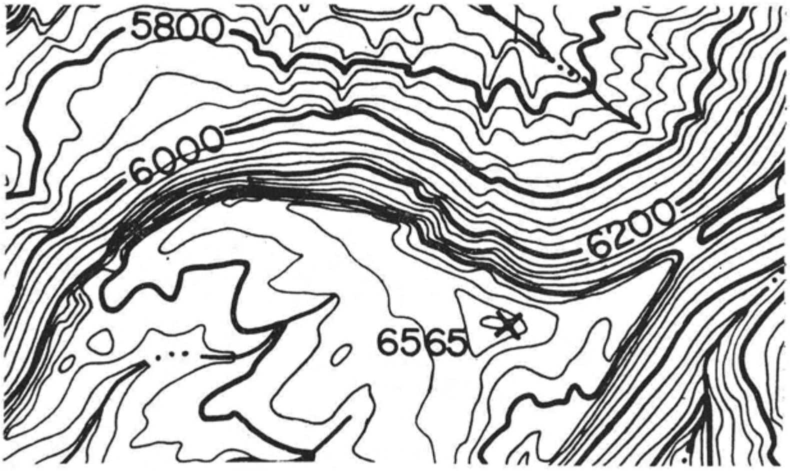

FIG. 2. Topographic map at a scale of 1 inch = 800 feet (1:9,600). Note the use of rapidograph pen for drafting contours.

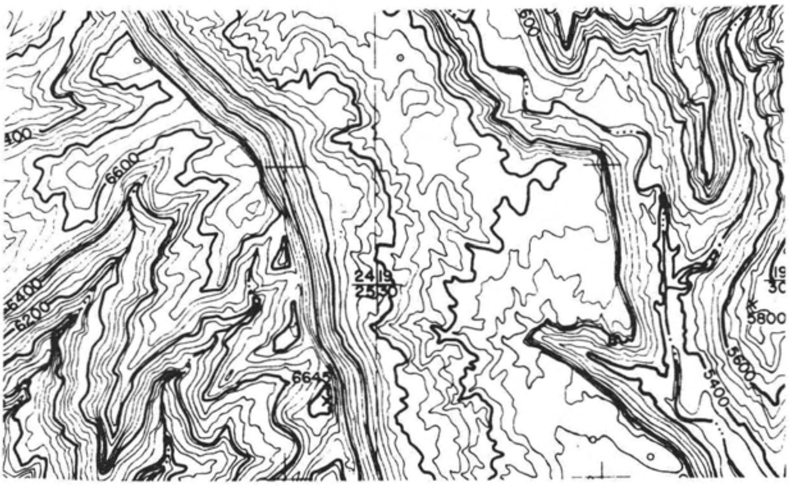

FIG. 3. Topographic map at a scale of 1 inch = 2,000 feet (1:24,000).

sidered that the drill hole program should be able to keep ahead of our mapping; this was the case with only a few delays.

As THE COMPILATION began, blueline copies of the first stereo-models were sent to the geologists who would be using them for approval of detail and content. The compilation continued on a double shift and bluelines of the models were shipped to the field as soon as they were completed. We eliminated a tremendous amount of drafting by compiling on Cronaflex and inking the models with Rapidograph pens right on the instrument. The contour numbers and spot-heights were drafted on and the sheets were quite presentable. The drafting time saved by using Rapidograph pens was great on this particular job because of the heavy density of the contours.

As the compilation neared completion the final sheets were put together and the geologists and engineers were furnished with screened film positives of the maps at both scales. The screening meant that geological information could be placed over the dense contours without reducing legibility.

At the same time as the topographic base map was being compiled a semi-controlled mosaic was assembled for the entire area at a scale of 1 inch = 4,000 feet (1:48,000). This was used for an overall study of the entire area, the mosaic proved to be very useful.

THE ACTUAL HEART of the project was the photogeologic mapping phase of the job. The key to success in a project of this type is the complete coordination and cooperation between the geologist and photogrammetrist. If this is not achieved, the full potential of this type of work cannot be attained. The geologist must understand what the photogrammetrist is capable of doing and the photogrammetrist must know what the geologist requires. As a result of much planning and conferring the precise goals and procedures evolved.

Key marker beds were selected from the photos and several stereo-models were set up on the Kelsh Plotter and studied. Six or seven of these beds were chosen by the geologist and photogrammetrist on the basis of geological significance and ease of identification in the model, on the photos, and on the ground. The amount of detail to be shown was decided on. In some areas of high interest, every bed that could be seen was plotted; and in other places only the key beds were carried throughout the area. The compilation was done on screened Cronaflex positives of the original compilation manuscripts. Each model was reset for the geological compilation.

In addition to showing the key marker beds, dips and strikes were measured at frequent intervals. Very detailed cross sections were measured in designated areas, faults and lineations were mapped, and the vertical component of fault displacements was measured wherever possible. Many thicknesses were computed throughout the entire area. Most often the key beds were measured, but in some areas other selected beds were measured if the geologist had a particular point of interest to examine. The key beds were carried from model to model in most instances.

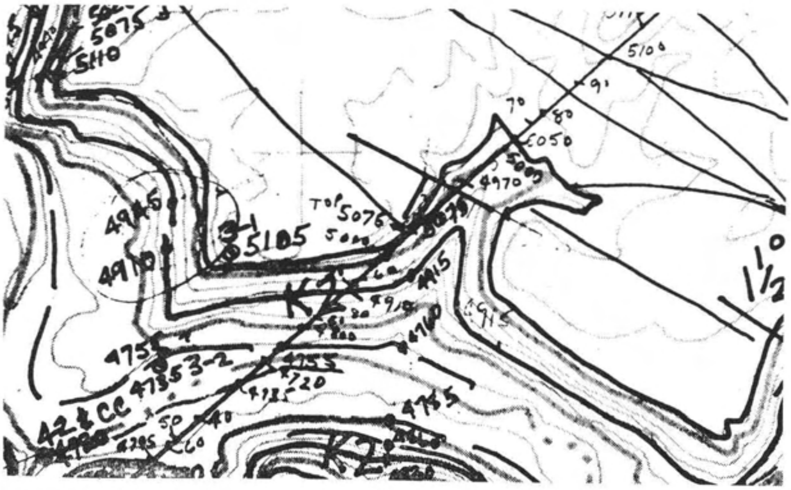

FIG. 4. Photogeologic map at a scale of 1 inch = 800 feet (1:9,600) on a screened copy of the topographic base map. The work was done with a Kelsh Plotter and used in the field in this form.

Special requests for information were received from the field during the job. This information was added to the maps and sent back to the field. One such request was for areas that had been burned; these showed up on the photos and could be mapped. Even though the burn had taken place in the coal under the ground, surface indications showed on the photographs.

FROM TIME TO TIME the geologists came into the office to study the photographs set in the Kelsh Plotter; questions and problems were easily resolved in this way. The photogrammetrist also went into the field, and this too proved to be extremely beneficial.

In addition to the detailed mapping at 1 inch to 800 feet (Figure 4), a photogeologic map of the area was made at 1 inch = 2,000 feet (Figure 5). This map showed the key beds, dips and strikes, and other important information without the extreme detail of the larger scale maps.

As this phase of the job neared completion, the USGS published two preliminary Geologic and Coal Deposit Maps that tied into the southern edge of our job. We matched their work beautifully, and although we selected slightly different key beds for our mapping in some instances, it was easy to identify the ones that they had selected on the photographs, corroborating our work.

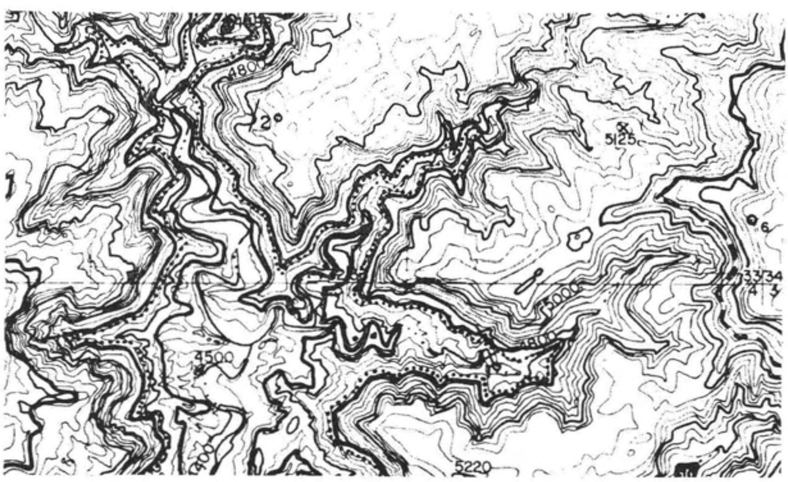

FIG. 5. Photogeologic map at a scale of 1 inch = 2,000 feet (1:24,000) on a screened copy of the topographic base map showing only the more important information without the extreme detail of the larger scale map.

ANOTHER INTERESTING project which was very successful was the use of stereo-pairs taken on the ground by one of our geologists with a Polaroid camera. The purpose was to aid in drawing detailed geologic sections in spots where the cliffs were vertical. The procedure was simple but very effective. Scale points at the top and base of the cliff were noted and pricked on the polaroid photos and also on the vertical aerial photographs. The vertical aerial photos were air-mailed to the photogrammetrist from the field and elevations were determined for each scale point with the Kelsh Plotter. The geologist was then able to draw rather accurate geologic sections quickly and with a minimum of time spent in the field.

As the photogeological mapping progressed our engineers indicated the need for larger scale topographic mapping to be used to help in the location of a plant site and dam within our area. The USGS again had photographs available that we could use. Maps of two possible plant sites were compiled on the Kelsh Plotter at a scale of 1 inch = 300 feet (1:3,600) with 10-foot contours. With these maps the proposed plant site was evaluated and determined and the best location for a dam was established.

PLANS FOR ANOTHER photogrammetric project were made also but it has not been implemented. As a part of the development of the coal mining facility a railroad spur of about ten miles would be needed to connect the plant site and the mine area. For this work photos would have to be flown by an aerial photography contractor at a scale large enough to permit us to map the ten mile strip at 1 inch = 200 feet (1:2,400) with a 5-foot contour interval. It was considered that this scale would be sufficient to lay out the grade and alignment of the railroad siding. By reading cross section elevations along the proposed right of way with the Kelsh Plotter, earthwork computations could be made for the construction of the spur.

PHOTOGRAMMETRY HAS BEEN a part of our Kaiparowits project from the beginning. The area is ideal for photogrammetry and a large amount of field time has obviously been saved. The ability of the exploration people to visualize the ways in which photogrammetry could be used to help them has been a key factor in its successful use. Our policy has been to use the geologist and photogrammetrist as a team with the geologist taking the lead in the exploration and the photogrammetrist backing him up with his technical services and know how. In order for this to be successful it is necessary to have a high degree of coordination and cooperation between the geologist and photogrammetrist. This cannot be stressed enough and is probably the single most important factor in a project of this type. Our first venture into the search for coal has been interesting, informative and very rewarding.