entire channel with considerable accuracy. It is this synoptic picture which is perhaps the most valuable part of the technique. Under winter conditions where floating ice is present, there is no question that the method will work perfectly.

The range of measurement is very great. Speeds of any magnitude over 1 m.p.h. can be measured if the proper flying speed-current velocity—photo scale ratios are used. Speeds below 1 m.p.h. down to $\frac{1}{16}$ m.p.h. are measurable if the natural water marking persists long enough to be registered on successive flights. In case of speeds below 1 m.p.h. where the natural water markings are poor, it may be necessary to resort to marking floats.

It is concluded that a number of controlled experiments should be carried out to test the application of this technique under "service conditions" to areas which are to be surveyed by conventional methods. A comparison of the time involved and the costs can then be made. This would permit estimates being made on areas to be done by this method alone.

Further research in this field is indicated. Obviously from the results obtained from the RAF Maple Scan photography, it should be possible to obtain much unique and useful data if side-to-side coverage of the Bay of Fundy can be obtained.

In the case of arctic research, where poor flying or photographic weather can drastically limit the coverage obtained in a single season, it is suggested that radarscope photography can be used instead of conventional photography. Experiments to date indicate that the same time lapse methods can be used with successive "overlap" pictures of the P. P. 1. scope. It is also suggested that radarscope photography offers a feasible method of ice survey in the Gulf of St. Lawrence.

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Some Photogrammetric Applications to Geophysical Surveying

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(Abstract is on next page)

PHOTOGRAMMETRY is constantly expanding and becoming more versatile due to the continuing efforts of photogrammetrists everywhere to find new areas and applications for its use. Passing this information along to others to use and to adapt to their own specialized cases ensures the continued growth and development of the whole field of photogrammetry. This time it is the oil industry which has contributed another step in the growth process. In this particular application of photogrammetry, the Kelsh Plotter* is used to tie down the location of seismic shot points in geophysical surveys.

The seismic survey is used extensively in search for oil. Briefly, the procedure used in a seismic survey is as follows:

A shot hole is drilled in the ground by a light drilling rig and a small charge of dynamite is inserted into the hole. Geophones or

* The Kelsh plotter is the only stereo-plotting instrument referred to in the paper. I do not intend to imply that other instruments would not do the job as well. The Kelsh plotter was the instrument available to Richfield and is therefore the one that is referred to in the paper.—THE AUTHOR.

FIG. 1. Terrain in southern Alaska typical of that in which Richfield Oil Corporation conducted its geophysical surveys.

small receivers are placed in a pattern around the shot hole, and the dynamite is detonated. The geophones transmit the ensuing shock waves to the seismograph nearby where they are recorded on seismograms. The shock waves are then timed to obtain the depth and dip attitudes of subsurface strata. This procedure is repeated at each shot point. As the lines of shot points are completed they show a picture of the attitudes of the rock strata and possible oil bearing structures below the earth's surface.

ABSTRACT: *The practical application of stereo-plotting instruments to solve problems of Geophysical Surveying is another of the many uses being found by the Oil industry for photogrammetry. The Kelsh Plotter has been very successfully used both directly and indirectly in accurately pinpointing the location of Geophysical points, particularly in remote parts of the world in both on-shore and off-shore surveys.*

The usual method of locating the position of seismic shot points is by means of a transit traverse or plane table survey. The seismic shot points are normally positioned in lines. A traverse is run along each line of points and tied to existing field control. This procedure can be difficult and expensive in areas that have little existing field control, local magnetic deviations, long periods of inclement weather, or difficult terrain. (see Figure 1)

The employment of a Kelsh plotter can be a tremendous advantage in areas of this type, since it can be used to make accurate measurements on aerial photographs. The need for surveying in the field is not eliminated, but it is supplemented and greatly reduced.

The Richfield Oil Corporation has used procedures described in this paper in geophysical surveys in southeastern Alaska for the past few years; Standard Oil Company of California also has had excellent results with these methods in the Rocky Mountain area of the United States. In using the Kelsh plotter to locate the position of seismic shot points the first step was to determine whether or not existing aerial photography was available covering the area of interest. Data concerning the focal-length and lens of the aerial camera had to be checked to see that they were compatible with the Kelsh plotter. If existing photography had not been available it could have been flown by an aerial survey company.

Once the aerial photography is obtained the proposed location of each line of seismic shot points may be indicated on the photos. A temporary medium, such as grease pencil, was used to mark the proposed line locations on the photos so that they could be adjusted or removed at a later date.

Auxiliary points are located on the photos.

These points are objects that were easily identified on the photos and are positioned near each end and at intervals along the proposed lines of shot points. A stereoscope was used to identify these points which were then pricked and labeled on the front of the photo, and were described on the back. All existing field control was identified on the photos using the same marking procedures. If the photography is being flown especially for a particular job, it may be possible to panel or mark the field control and auxiliary points on the ground before the photography is taken so that these points will be visible on the photos.

The actual photo-identification of the auxiliary points on the photos could be handled in one of two ways. The first would be as an office procedure following the steps above. However, it could also be done in conjunction with the next step of the operation which is in the field. This method is preferable if the field party has someone available who is experienced in the use of aerial photography.

The auxiliary points were located in the field and their position marked on the ground with a stake or flag. At the same time the auxiliary points were also identified and described on the aerial photographs. If however the auxiliary points had been selected in the office, the field crew identified these same points that had been pre-selected on the photos and marked them with a stake or flag in the field. This field marking of the auxiliary points was most efficiently and economically performed by a small field party working ahead of the geophysical crew.

Once the auxiliary points had been identified on the photos and marked in the field the geophysical surveyors were able to lay out the positions of the shot lines. As they were running their traverse the surveyors tied each of the premarked auxiliary points into the line. By tying the shot lines to the photo-identified auxiliary points there was no longer a need for the surveyors to tie the lines to existing field control and to each other. This elimination of the need for long ties in the field has been one of the big advantages of this system.

In order to save time the diapositives or film-positives (film-positives printed on stable base film have proved to be satisfactory for this type of work) were obtained while the field work was being done. Preparation work, if necessary, was also done on the base map before the field notes and photos were received in the office. When they arrived, the Kelsh plotter operator proceeded to locate the auxiliary points, which were identified on the aerial photographs, in the stereo-model and to plot their location accurately on the base map. Since the scale of the Kelsh plotter model was substantially larger than that of the base map, the reduction of the model scale could be accomplished by a pantograph directly on the base map, or by the photographic reduction of the Kelsh manuscript or compilation sheet to the scale of the base map.

While the location of the auxiliary points were being established on the base map, the lines of shot points were plotted from the field survey notes on drafting film at the scale of the base map. The auxiliary points and any stadia or triangulation ties that had been made were also plotted from the field notes on the drafting film. Next the drafting film was overlaid on the base map and the auxiliary points which had been plotted on the drafting film were matched to the auxiliary points on the base map. The overlay was fitted and shifted until any field errors were located and adjusted to a minimum, after which the shot points were transferred to the base map from the overlay.

At times it was not possible to select photo-identified points before the seismic survey was completed; or there were unforeseen problems with the location of shot points that had been surveyed and located by conventional methods. In each case it was still possible to obtain accurate results. Instead of photo-identifying points that were then tied into the line of shot points when the traverse was run, a few of the shot points themselves were photo-identified or tied by field survey methods to photo-identifiable objects. These key shot points were plotted on the base map using the Kelsh Plotter and the rest of the procedure was the same as that described above. (see Figure 2) However it should be emphasized that extreme care must be taken in the photo-identification of the key shot points since this determines the accuracy of the job. It was also of importance that photo-identified points be selected at or near the end of each line of shot points. This helped insure accurate results and prevented any accumulative errors in bearings. These procedures proved successful and were well received.

This season however, Richfield conducted *offshore* seismic operations. This operation involved over 100 miles of southern Alaska coastline. Shot points were located by a radar system called "Harru" in which the Marine Geophysical Services Corp., Houston, Texas did the seismic work. Due to the indefinite

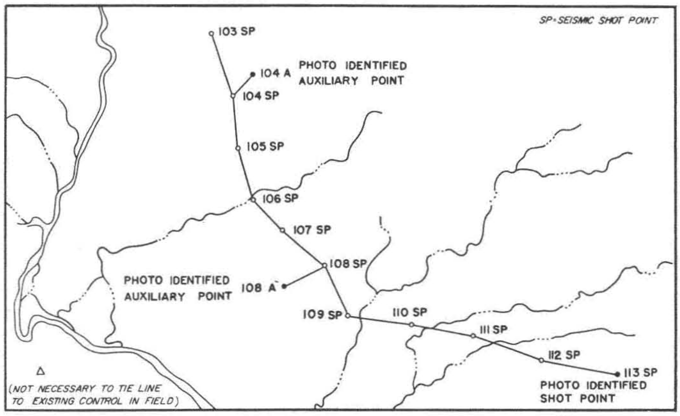

FIG. 2. Location of Seismic Shot Points with the Kelsh Plotter. The locations of Auxiliary 104A, 108A and Shot Point 113 were established on the base map with a Kelsh Plotter.

nature of the coastline it was necessary to use beacons located on the shore to pick up the radar signal, to amplify it and to send it back to the ship. These beacons were small, battery-powered, self-operating units weighing about 200 pounds. The beacon units were installed at intervals along the coastline, having been transported to these locations by a light aircraft which was equipped with oversized tires to enable it to land on the beach or mud flats at or near the desired location. The problem consisted of accurately determining the exact location for the beacons before they were placed in position. Using existing photography obtained from the U. S. Government, mosaics of the area were laid. Base maps were compiled by Richfield from USGS topographic sheets and from Kelsh Plotter compilation. Topographic maps have been compiled of a large part of the area by Richfield because of the incomplete coverage by accurate topographic quad sheets.

The first step was to select easily identifiable points on the aerial photographs. With a stereoscope, points were selected at intervals of about one-and-a-half miles along the coastline. Each point was pricked on the photo, numbered and described on the back of the print. The density of the points selected was much greater than was necessary due to the fact that it would be impossible to identify some of the points in the field. Also others would be inaccessible. The ship conducting the seismic survey was operating about two miles offshore and at that distance could operate with beacons located up to about six miles apart.

After the points had been located on the aerial photographs, they were then transferred to mosaics of the area. The mosaics made it easier for the personnel who were to install the beacons, to orient themselves from the aircraft. Using the mosaics in conjunction with the photos and stereoscope, the job of locating the points in the field was greatly simplified.

It was important that the operation be kept as simple as possible since the crew which set up the beacons was not highly trained in the use of aerial photography. The high density of points from which to choose, and the use of the mosaics, helped insure the success of the venture to a large extent.

The photo-identified points were also located on the plotter manuscripts using the Kelsh plotter. After all the points had been located on the manuscripts they were sent to Richfield's Photo lab where they were reduced photographically to the scale of the base map. The points were transferred to the base map from the reduced manuscripts (see Figure 3). The photogrammetry was completed before any work was done in the field. The mosaics and air photos were delivered to the Beacon installation crews, and the base map went to the radar operator on the survey ship.

Installation of the beacons was the next step. Photo-identified points were located on the ground every four to six miles, by the beacon-installation crew in the aircraft, using the mosaics and air photos. The beacons were then put into position on these points. In some instances points were located but could not be occupied due to not being accessible. An auxiliary point was then established by survey methods in the field and was tied to the photo-identified point. The auxiliary

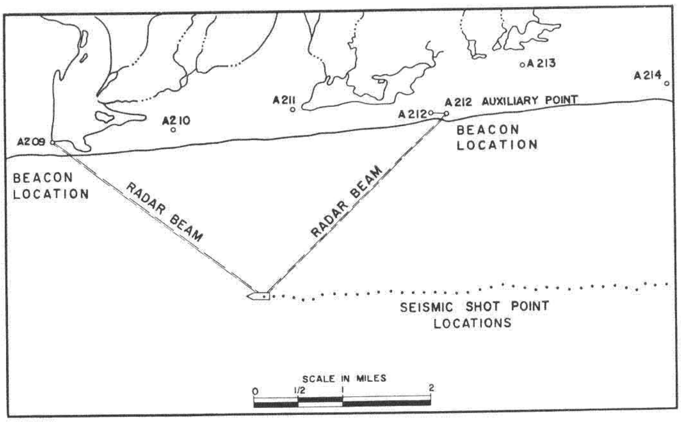

FIG. 3. Location of Radar Beacon Positions with the Kelsh Plotter. The location of points A209 through A214 was established on the base map by a Kelsh Plotter. Only points A209 and Auxiliary Point A212 were used as Radar Beacon Positions.

point was also plotted on the base map. The installation crew had a sufficient number of points from which to choose, and no serious problems in photo-identification were encountered.

With the positioning of the beacons, the radar-equipped ship was able to move along the coast. By taking a radar fix on two of the beacons at pre-determined time intervals, the radar operator was able to locate the position of each shot point and to plot it on the base map with precision well within the accuracy requirements of the job. The method of establishing the locations of the beacons proved to be very successful. By using the Kelsh Plotter it was possible to insure fast and accurate results.

These are only a few of the uses that have been found for photogrammetry in the search for oil.

Mosaics You *Can Make*

DAN MEYER

ABSTRACT: *Photo mosaics provide a wealth of pictorial detail that no map can equal. This paper describes a simple method of making uncontrolled mosaics.*

INTRODUCTION

A MOSAIC is an assembly of individual photos which have been trimmed and matched to form a continuous photographic representation of a large area. Mosaics are particularly useful in studying certain natural resources where a comprehensive view of an entire area is needed for a better understanding of any given part (e.g., geological formations, forest types). Construction of the more sophisticated controlled and semi-controlled mosaics requires specialized equipment and highly trained personnel, but useful uncontrolled mosaics are not difficult to make and are well suited to "home construction." Like the more refined techniques the "home construction" method utilizes only the center portion of each print where there is the

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