can be adjusted to accommodate various focal lengths, plate sizes and camera orientations. Since the principal distance on a universal instrument can be made equal to the camera focal length, equal horizontal and vertical compilation scales can be used. In this case either normal or convergent photography can be plotted accurately. If these values are not equal, as was the case in this investigation, accurate compilation is limited to photography taken normal to the base. The disparity between the instrument principal-distance and the camera focal-length results in a variable vertical scale when convergent photography is used. If a universal instrument is not available, a camera transit or phototheodolite having a focal length within the principal distance range of the appropriate Kelsh projectors is desirable since equal horizontal and vertical scales could then be used.

ACKNOWLEDGMENTS

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*Project-Glacier**

An Improved Method of Recording a Glacial Advance

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LYING nearly 110 miles north of Seattle, Mount Baker thrusts its peak above the surrounding Cascade mountain range. On the northwest slope of this majestic mountain an interesting change has been taking place since about 1949, in that Coleman Glacier halted its retreat and began a rapid advance.

Attention was first focused on the glacier's advance by interested students and instructors of the University of Washington.

The data which the party recorded this summer showed an advance of 250 feet from last year's position. Over a period of six years since 1949, the glacier has advanced nearly a thousand feet.

During the first five trips to Coleman Glacier, profiles and significant points on the glacier were located using transit and stadia. Difficulty was encountered in moving about on the glacier because crevasses 20 to 100 feet in depth and varying in width from 1 foot to 10 feet were encountered frequently. Spires and blocks of ice towering approximately 30 feet above

AUTHOR'S NOTE: Figure I is from an article which I wrote and contributed, without monetary return, to the student published *Washington Engineer;* November, 1955. This paper is a re-write, in more technical form, of that article.

* This paper was submitted in competition for the Bausch & Lomb Photogrammetric Award, 1955.

the glacier often blocked the view of the transitman. Such conditions required that experienced "Mountaineer" rodmen, like the one shown in Figure 1, carefully traverse the glacier for appropriate stadia points. The rope in the foreground of the picture indicates the trail that the rodman followed over the ice. Trails of this type are the rule rather than the exception in glacier work.

Because the glacier is continually moving and changing shape, transit points on the glacier are worthless after a few days. Besides encountering the impracticability of locating permanent transit points on the glacier, there is the problem of locating them too close to the snout or side of the glacier. Points may become covered or dangerous when the glacier advances and increases its volume. Grouping the aforementioned problems causes a glacial survey with transit and stadia to be an immense undertaking.

It became evident that accurate surveying methods and equipment were necessary. Equipment of this nature was obtained through the aid of a Research Grant. In the summer of 1954 a Professor from the Department of Civil Engineering accompanied one of the parties to Coleman Glacier to help with the new mapping method. This method is terrestrial photogrammetry, which eliminates many of the problems of a transit survey and also provides more data for the same field time.

The medium of photogrammetry is most frequently associated with aerial photos but in this case they are taken from a vantage point overlooking the glacier.

Photogrammetry consists of constructing a parallel projection from two separate central projections. These are photographs of the same area taken from two different but adjacent points. The distance between these points is called the base. Though the view in each of the two photographs remains the same, a point in one picture is shifted relatively sideways in the other picture. The human eyes have the property of seeing such sideways shifting of identical parts called parallax, as a solid effect.

For the purpose of plotting, the following measurements must be made in the field so that the relative and absolute position of a pair of photos in space can be found.

1. The fixation of one end point of the base by resection. Resections are angles observed between known triangulation points.
2. The length of the base.
3. The Azimuth of the base, and its inclination with the horizontal.
4. Azimuth and inclination of camera axis.

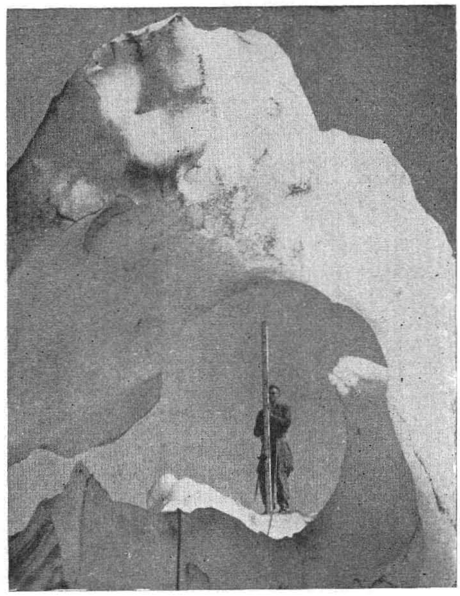

FIG. 1. "Mountaineer" rodman on Coleman Glacier.

The principle of plotting is that the photo-pair is so placed that the photos are oriented relatively and absolutely as were the exposures in the field. All length measurements are reduced to a definite scale, and the plotting operating is started. It is beyond the scope and purpose of this paper to give the details of plotting.

The ground positions or vantage points, formerly mentioned must fulfill the following requirements.

1. The area to be photographed must lie frontally opposite the station.
2. The station must be higher than the observed area in order to permit seeing into all of the valleys and contours.
3. A pair of photos must contain the same view or be overlapping.
4. The minimum base-length must be sufficient to provide the required accuracy. For ground photographs the base-length should lie between $\frac{1}{4}$ and 1/20 of the mean distance to the area plotted.

The control points in a photograph area

fall into three categories, according to the mode of fixation:

1. Station or vantage points by a 3-point fix.
2. Ground control points intersected from the station points with the Phototheodolite.
3. Control points produced during plotting.

For the fixation of an end point of the base, sufficient third- and fourth-order triangulation points are needed.

The accuracy with any instrument is dependent on the base length used. The greater the distance to the photographed area the longer the base which must be chosen.

The glass-plate negatives of the photos taken on this summer's trip to Coleman Glacier have been sent to Germany where they will be machine-plotted into contour maps. With the aid of these maps, it is felt that an accurate measurement of the glacier's volume growth can be computed.

Meteorologists are interested in the action of Coleman Glacier because many glaciers in the Cascade Mountains are advancing. It is felt that this may be attributed to a change in climate. A study of the situation was launched this summer by the University of Washington Department of Meteorology and Climatology. Terrestrial photogrammetry will aid the researchers in securing quickly and accurately the necessary data and resulting contour maps for calculating the glacier volume change.

*The TAF Phototheodolite and Its Use in Glacier Surveys**

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STUDIES of glacial dynamics involve the precise determination of x, y, and z coordinates, and their correlation with time. This problem is in effect a typical surveying problem, in specialized terrain. The common data obtained results in (a) Velocity profiles, and (b) Topography of the glacier and its environs.

Due to the inaccessibility and danger associated with many glaciers, standard surveying techniques are impractical. Figure 1 shows a view near the front of a glacier. The topographer is confronted with obtaining critical spot elevations, yet his two roped rodmen may not safely venture to many critical areas. If the whole glacier is considered, as Figure 2 shows the Coleman Glacier on Mount Baker, the impossibility of stadia is evident, and one immediately looks to photogrammetry for a solution. The advantages of photogrammetry are numerous, for in addition to the production of an accurate map, a perfect visual record in third dimension can be had.

Photogrammetry connotes to most of us the application of aerial photographs. In certain instances, however, terrestrial photogrammetry is superior. Some cases where terrestrial work should be considered are in mapping small steep areas, gorges, and large scale work in mountainous terrain. Since the Coleman project fell into the last classification and was repetitive in nature, terrestrial photogrammetry was chosen.

The most common terrestrial instrument is the Wild Phototheodolite, see Figure 3. This instrument consists of the combination of a T-2 with a camera suspended in V-bearings with a series of predetermined tilt positions. The precision of the theodolite is sufficient for all geodetic work that may be required, and also permits use of the subtense bar for base-line lengths. The camera can be oriented quickly to any desired direction. The vertical range of the Wild camera is from plus 15 degrees to minus 40 degrees. The weight of the theodolite and camera is about 60

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