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A PHOTOGRAMMETRIC SURVEY OF HOSEASON GLACIER, KEMP COAST, ANTARCTICA*

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ABSTRACT. A study of Hoseason Glacier was made to test whether photogrammetry could yield meaningful glaciological information from repeated series of air photographs without ground control. Three maps indicate that large time differences, different camera systems, and the use of sea ice as a level datum do not present insurmountable difficulties in photogrammetric reduction. Surface horizontal movement was determined and level profiles were compiled. Hoseason Glacier is probably in equilibrium.

RÉSUMÉ. *Une étude photogrammétrique de Hoseason Glacier, Kemp Coast, Antarctique.* On a éxécuté une étude du Hoseason Glacier pour voir si la photogrammétrie pouvait apporter des informations glaciologiques significatives à partir de séries successives de couvertures photographiques aériennes sans contrôle au sol. Trois cartes prouvent qu'un large échelonnement des vues dans le temps, l'usage de différents types de caméra et l'utilisation de la glace marine comme niveau de référence ne conduisaient pas à des difficultés insurmontables pour la restitution photogrammétrique. Le déplacement horizontal de la surface a été déterminé et des profils calculés en nivellement. Le Hoseason Glacier est probablement en équilibre.

ZUSAMMENFASSUNG. *Eine photogrammetrische Vermessung des Hoseason Glaciers, Kemp Coast, Antarktika.* Am Hoseason Glacier wurde eine Untersuchung angestellt, um zu prüfen, ob die Photogrammetrie aus wiederholt aufgenommenen Luftbildreihen ohne Festpunkte am Boden glaziologisch verwertbare Informationen liefern kann. Drei Karten zeigen, dass grosse Zeitunterschiede, verschiedene Kamerasysteme und die Benutzung des Meereises als Ausgangsniveau bei der photogrammetrischen Auswertung keine unüberwindlichen Schwierigkeiten bieten. Die horizontale Oberflächenbewegung und Höhenprofile wurden ermittelt. Der Hoseason Glacier ist wahrscheinlich im Gleichgewicht.

INTRODUCTION

Photogrammetric surveys of Antarctic glaciers for glaciological studies date from 1957 when Mellor (1958) determined surface velocities on Hoseason Glacier, Kemp Coast, Antarctica, over a short time interval and noted the general applicability of the method. Since then, methods of aerial and terrestrial photogrammetry have grown in importance in Antarctica and have been used by many workers, e.g. Adler (1963), Cheremnykh (1962), Weissman (1964), and Morgan (1970). Most of these studies, however, have used similar camera configurations, some degree of geodetic control and intervals of about one year.

Coastal areas of Antarctica between long. 50° and 75° E. have been repeatedly photographed by Australian National Antarctic Research Expeditions (ANARE) using 150 mm and 90 mm focal lengths, 230 × 230 mm format cameras at different times. The time interval between two sets of photographs is in some cases as great as 1 500 days. The problems posed by lengthy time intervals and different cameras, coupled with lack of normal geodetic control, made it uncertain whether valid information could be extracted from the photographs. A study was undertaken in 1965 of the feasibility of extracting meaningful glaciological information from such photography.

The questions to be answered by this study are:

1. Can consistent absolute orientations be obtained from successive surveys despite a lack of control and differing unknown distortions resulting from lack of knowledge of camera interior orientation, refraction and film instability?

2. Does glacier ice hold a recognizable form over such periods as to make surface velocity determinations possible?

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PHOTOGRAMMETRY

Hoseason Glacier (lat. 67° 10′ S., long. 58° 20′ E., some 240 km west of Mawson) was chosen because:

1. Repeated aerial photographic coverage was available, namely:

7 August 1957—K17 camera
13 October 1960—RC9 camera
20 January 1965—K17 camera

2. The glacier is small and flanked by rock which could supply necessary relative planimetric control, while sea ice, which abuts the tongue of the glacier, could supply a needed level datum and elevation control.

3. Limited plotter time was available, and it was necessary to choose a small area over which profiles could be obtained without using aerial triangulation techniques.

The simple photogrammetric reduction was accomplished without difficulty, using a Wild A6 stereoplotter for the 150 mm photography and a Kern PG2 stereoplotter for the 90 mm photography. Scale was obtained by using a single line scaled from a 1 : 40 000 map.* For elevation control, sea ice was assumed to be a level datum 0.3 m above mean sea-level. Production proceeded with a planimetric scale of 1 : 15 840 and a contour interval of 10 m on the glacier. The resulting maps (Figs. 1, 2 and 3) show changes in the long-term shape and position of the glacier. An important aspect of reduction was the use of sea ice as a known level datum and also as an assumed elevation control. The sea-ice surface in all three instances was assumed to be 0.3 m above mean sea-level, based on an estimate of ice thickness. The reliability of the assumption of constant sea-level can be gaged by referring to the rock area to the east of the glacier (Figs. 1, 2 and 3) over which there is excellent agreement of contouring. This indicates that in an open area where ocean tides are small, the assumption was justified in the absence of tidal information. This is perhaps the most reliable means of supplying elevation control for photogrammetric work near the coast of Antarctica. An alternative method of supplying control would be to use rock areas whose elevations had been determined relative to some arbitrary level surface as datum. Unfortunately, this method has the disadvantage that most often the distribution of rock is so limited that precision of leveling of the model is inferior to the sea-ice method; indeed, frequently no rock is visible.

From one time to the next it was possible to identify a number of points on the glacier from which surface velocity could be determined.

	1957 *7 August*	*1960* *13 October*	*1965* *20 January*
Number of points near edge of glacier	7	12	5
Number of points near middle of glacier	1	1	0

The selection of points 1 to 7 on the 1957 survey and their subsequent identification on the 1960 survey was simple, as the edge shape of the glacier had changed very little over this period (Figs. 1 and 2). The same ease of identification with the single middle point was not possible as the deep snow cover during the 1960 survey coupled with the long time interval altered the appearance of the large crevasse on which this point was situated. There is no doubt, however, that the same crevasse has maintained its general shape over the intervening period while moving in relation to the fixed rock east of the glacier. The additional points 8 to 12 on the 1960 survey and their reidentification, together with the identification of point number 6 of the original survey on the 1965 photographs, allow estimates to be made of the

* Unpublished map, scale 1 : 40 000, compiled by Antarctic Branch, Division of National Mapping, Melbourne, Australia.

surface velocity over a $7\frac{1}{2}$ year period. It should be mentioned that the increased interval between the 1960 and the 1965 surveys made the photointerpretation task more difficult.

Although the stress environment of Hoseason Glacier may be expected to produce a sequence of broadly similar features in time such as the crevasses along its eastern margin, care was taken to reidentify the same feature and not merely a similar feature. The agreement of results with those of Mellor (1959) demonstrates that accurate reidentification is possible.

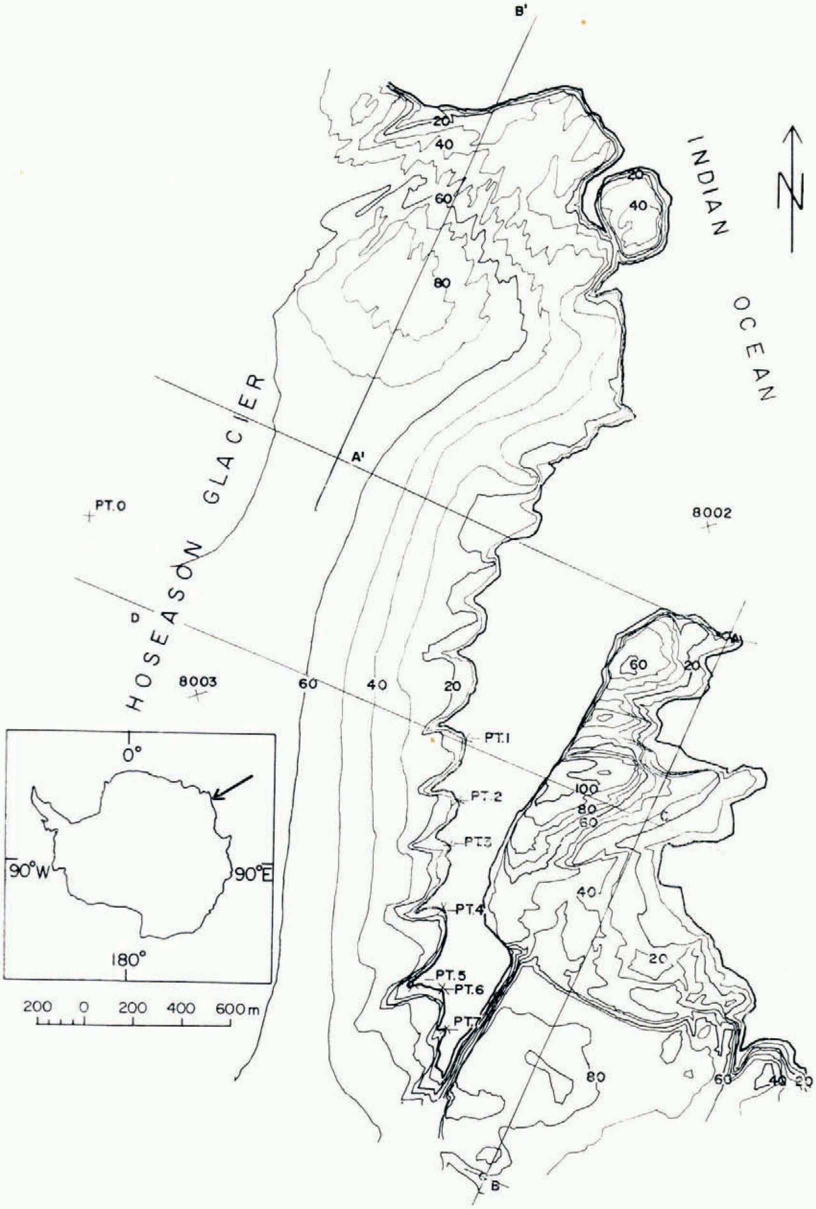

Fig. 1. Hoseason Glacier. Photographic run 73, Nos. 8002/8003 taken on 7 August 1957 with K17 camera. Contour interval: 10 m.

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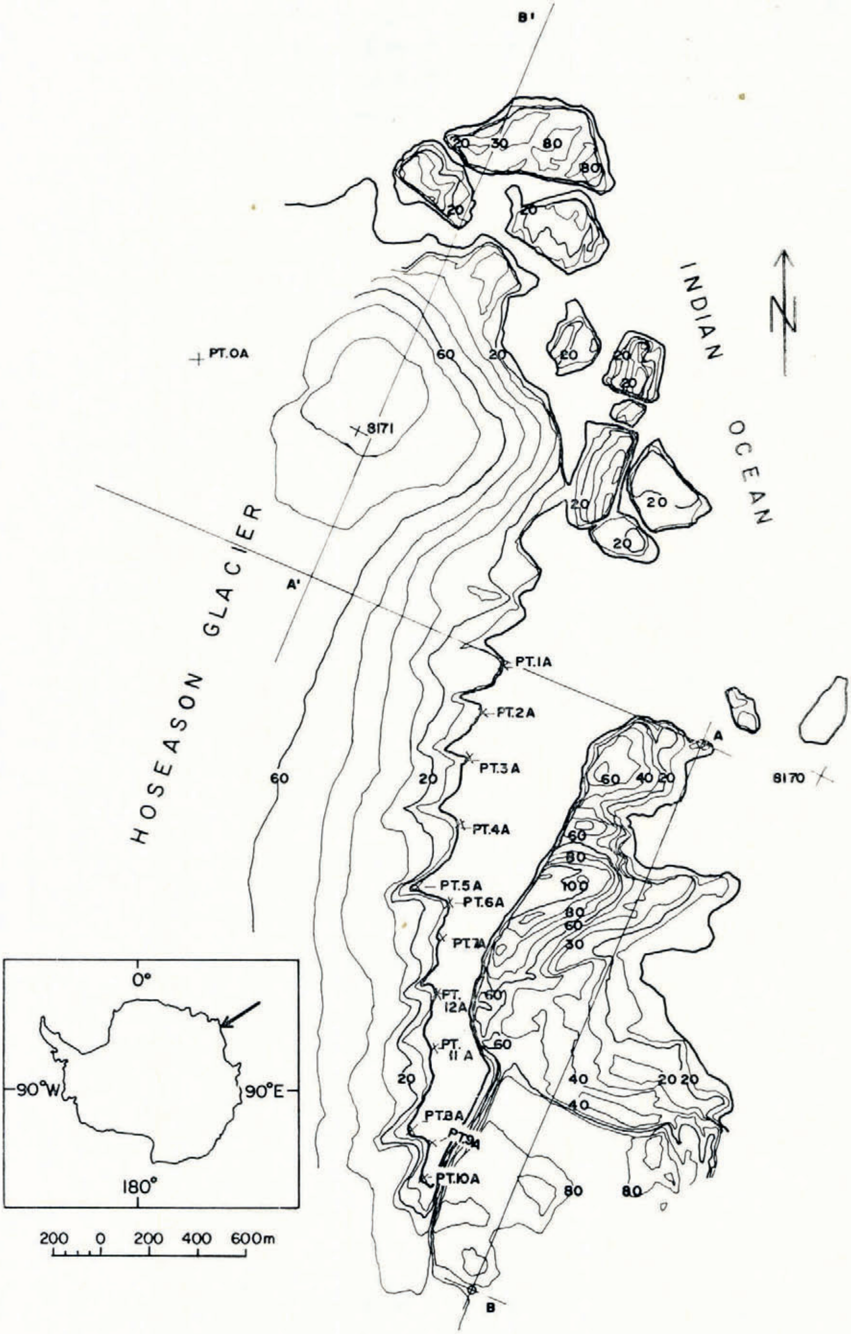

Fig. 2. Hoseason Glacier. Photographic run 2R, Nos. 8170/8172, 13 October 1960 with RC9 camera. Contour interval: 10 m.

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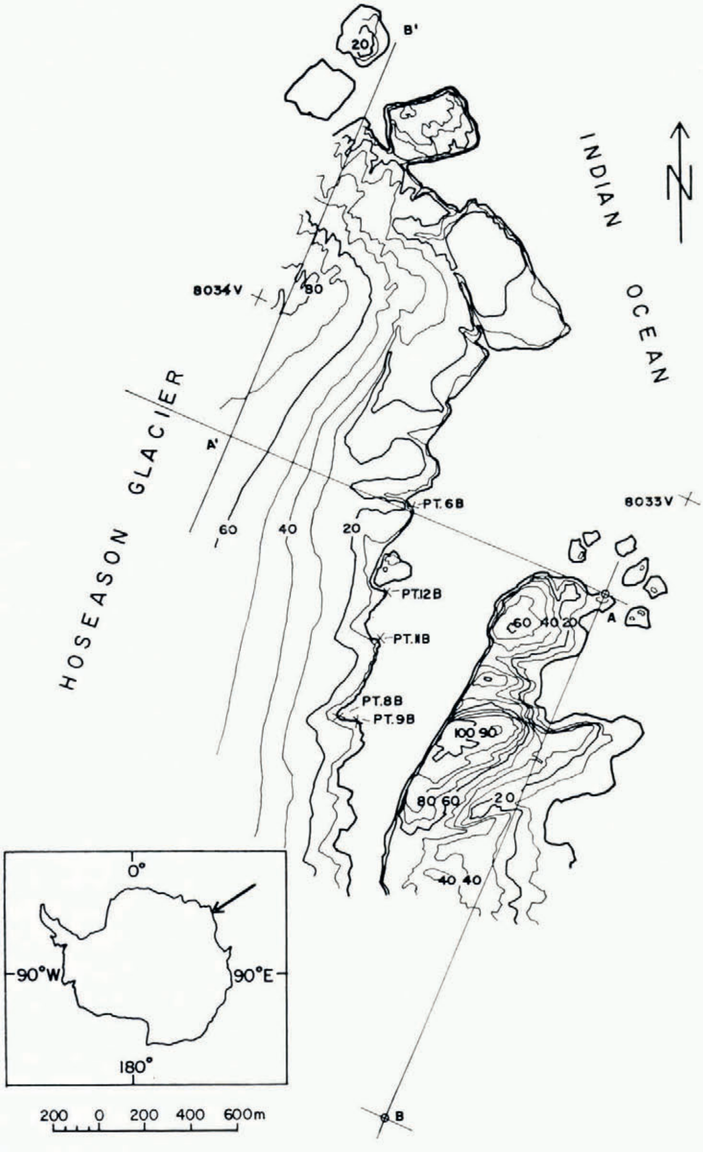

Fig. 3. Hoseason Glacier. Photographic run 6, Nos. 8033V/8034V, 20 January 1965 with K17 camera. Contour interval: 10 m.

Results

Movement. The movements of 13 points were obtained by plotting the position of each point at the time of each survey and measuring the distances between plotted positions. These results are presented in Table I. The results for the period 7 August 1957 to 13 October 1960 are not significantly different from those determined for the period 13 October 1960 to 20 January 1965. No attempt was made to correct for ablation, for which no information is available. The mean velocity for the edge of the Hoseason Glacier for the interval 7 August 1957 to 20 January 1965 was determined to be 0.74 m/day with a standard error of 0.02

m/day. The error of 0.02 m/day is almost entirely due to inaccuracies of measurement and identification. This error is about 20 m at terrain scale, or 1.3 mm at map scale. The velocity for the center of the Hoseason Glacier was 1.12 m/day for one time interval and one point. It is estimated, due to greater uncertainty in identification of the point, that movement of point "0" is probably in error by 2.5 mm at map scale, giving an error of 0.04 m/day at this point.

TABLE I. FLOW RATES OF HOSEASON GLACIER

Point No.	*Glacier position*	*Interval*	*Period* days	*Movement* m	*Rate* m/d	*Approximate direction*
0	central	August 1957 to October 1960	1 163	1 307	1.12	025°
1	edge	August 1957 to October 1960	1 163	847	0.728	010°
2	edge	August 1957 to October 1960	1 163	885	0.761	010°
3	edge	August 1957 to October 1960	1 163	869	0.747	010°
4	edge	August 1957 to October 1960	1 163	861	0.740	010°
5	edge	August 1957 to October 1960	1 163	891	0.766	010°
6	edge	August 1957 to October 1960	1 163	853	0.733	010°
7	edge	August 1957 to October 1960	1 163	869	0.747	010°
Average	edge		1 163	867	0.744	010°
6	edge	October 1960 to January 1965	1 560	1 118	0.717	010°
8	edge	October 1960 to January 1965	1 560	1 154	0.740	010°
9	edge	October 1960 to January 1965	1 560	1 152	0.738	010°
11	edge	October 1960 to January 1965	1 560	1 124	0.721	010°
12	edge	October 1960 to January 1965	1 560	1 118	0.717	010°
Average	edge		1 560	1 134	0.727	010°
6	edge	August 1957 to January 1965	2 728	1 971	0.723	010°

Average edge movement rate 0.74 ± 0.02 m/d

These results differ by 10% from those determined by Mellor (1959) but the difference may be caused by factors other than changes in glacier movement. The most probable cause is a difference in scale: the present work used a value scaled from the compilation sheet, while Mellor used a principal point distance calculated from the ground speed of the aircraft; either of these scales may be in error. A consistent scale must be adopted for any set of data sequences. Elevation control does not enter into the determination of horizontal motion and is not a source of error.

Profiles. Transverse profiles of high precision can be made photogrammetrically, but such detail was not required in this study. Profiles have been constructed from contour data on the topographic maps (Fig. 4). These profiles show that across line AA′ the general shape of the glacier is maintained with time. The position of the edge of the highest part of the glacier as well as the average slope of the surface all remained constant over the 7½ year period. Additionally, the profile across line CD is not significantly different from those across AA′. This indicates that there has been no major change in the transverse profile of the glacier. Similar profiles (Fig. 4) are shown for the longitudinal line A′B′. The agreement between these profiles is not as close as that obtained between transverse profiles, since surface slope in the ice-fall region was steeper in 1960 than in 1957 and 1965. Moreover, the position of a local maximum elevation is also different in the 1960 survey. The cause of these changes is not known. Despite such small variations, it appears that over the 7½ year period of this study the Hoseason Glacier was probably near equilibrium. The reproducibility of the rock contours demonstrates that the assumed constancy of the sea-ice datum was adequate at the scale of contouring used.

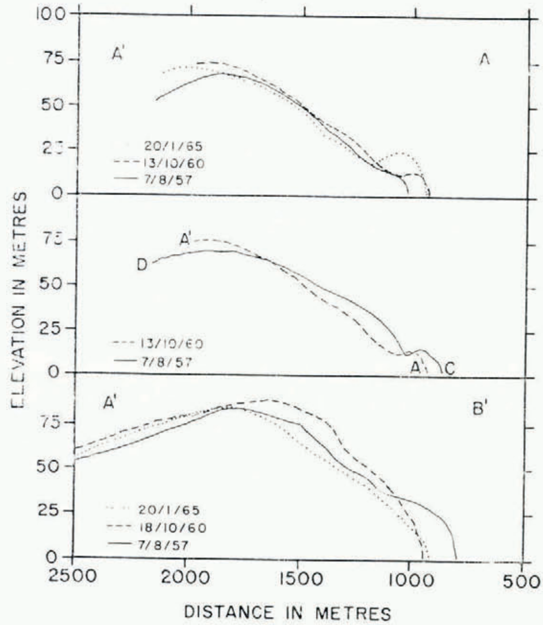

Fig. 4. Vertical profiles across Hoseason Glacier along lines AA′, CD and A′B′.

Conclusions

Aerial photography can be used for glaciological purposes even when photographic runs are separated in time by many years and utilize quite different camera configurations. For Hoseason Glacier, and probably for regions of similar stability, it appears that periods of three years are not too great for successful interpretations. As the time interval increases, so too does the difficulty of interpretation. Natural ice features suitable for determining surface movement are restricted to ice margins and disturbed regions. A more complete movement picture could be obtained by installing markers. The installation of a fixed baseline is essential for accurate scale control. For this purpose the method of Independent Geodetic Control (Brandenberger, 1959; Ghosh, 1962; Morgan, 1971) appears to be most practical. However, in coastal areas it is not essential to supply vertical control because the sea ice offers an excellent natural datum if tidal data are available. Finally, profile information derived from topographic maps provides a tool for the investigation of steady state and mass balance problems in remote areas. Lengthy periods such as the $7\frac{1}{2}$ years of this study can provide the glaciologist with an insight into the nature of these problems, although the accuracy of determinations over long periods is limited by the quality of the photointerpretation.

Acknowledgments

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