Bulletin of Glacier Research 7 (1989) 1–5

Surveying and mapping on Chongce Ice Cap in the West Kunlun Mountains

CHEN Jianming, WANG Yan, LIU Lansheng and GU Pei
Lanzhou Institute of Glaciology and Geocryology, Academia Sinica, Lanzhou, China

(Received December 5, 1988; Revised manuscript received January 17, 1989)

Abstract

Using a combination of terrestrial and aerial photogrammetry (aerial photographs were taken in 1970), mapping of Chongce Ice Cap and of its adjacent glaciers covering 700 km^2 has been carried out on a scale of 1:50,000. The map will be published by the end of 1990. The accuracy of surveying and mapping is in conformity with the national standard. The surveying network of control is an independent plane coordinate system with Gauss projection. The morphological presentations applied in the map are contours, symbols, hachure points, brush shades and colors to bring out basic features such as glacial topography, glacial geomorphology, climate conditions and sites providing evidence of Quaternary glaciation and recent advance or retreat of existing glacier termini. It is the basic map for glaciology and geomorphology investigation in this region. The techniques used are described.

1. Introduction

The Chongce Ice Cap (35.2°N, 81.1°E) was taken as the main object for a Sino–Japanese Joint Glaciological Expedition in 1987 to the West Kunlun Mountains, which lie in the northwestern part of Qinghai–Xizang Plateau along the border between Xinjiang and Xizang. Many valley glaciers and flat–topped glaciers have developed in this range. It is an ideal place for research on existing and Quaternary glaciers of the northwestern part of the Qinghai–Xizang Plateau.

The survey group of the Sino–Japanese Joint Glaciological Expedition in the West Kunlun Mountains included 2 trained and experienced photographers and a land surveyor. The survey group carried out their own work and service work for other scientific groups, that is, to survey and map the Chongce Ice Cap, to measure glacier surface velocity, strain rate and terminal changes of glaciers.

During the 1970's, the mapping department of China surveyed this region and an aerophotogrammetric topographic map was made on a scale of 1:100,000. But the map does not satisfy the needs of the glaciological expedition at this time, because it does not express enough details of glacier geomorphology. Consequently, mapping the Chongce Ice Cap was planned to depict the physical geographic features of glacier topography and geomorphology in this region and to provide basic information for further scientific research. A map of the Chongce Ice Cap and its adjacent glaciers, covering 700 km^2, was made by using combined terrestrial and aerial photogrammetry (aerial photographs were taken in 1970) on a scale of 1:50,000 with a contour interval of 20 m. The techniques used are reported in this paper.

2. Combined terrestrial–aerial photogrammetry program

During 1982–1984, we succeeded in surveying and mapping (the Gongga Glacier in the Hengduan Mountains along the eastern end of the Qinghai–Xizang Plateau) by means of a combination of terrestrial and aerial photogrammetry methods on a scale of 1:25,000, and discussed the feasibility of combination mapping (Chen, 1985). We have accumulated some successful experience in using this method for mapping.

In the area of our survey in 1987, the difference in altitude between the top of Chongce Ice Cap and Gozhaco Lake is 1400 m, and its average slope is only 3.5 degrees in angle, 5.5 degrees on the Chongce Ice Cap, which is a very inconvenient condition for terrestrial photogrammetry, because photo stations have not enough difference in altitude for photos to be taken from the ground surface. In addition to such condition, the Chongce Ice Cap adjoins the Gozha Glacier (area 32.74 km^2, length 12.2 km) in the west, while in the east it adjoins the Chongce Glacier (area 158.3 km^2, length 27.2 km in 1970 and 26.8 km in 1987). Since the glacier surface with its network of crevasses was very hard to climb, the photographic base lines were limited. Therefore, there were large photogrammetric gaps in the survey area caused by foreground shrouding the background.

Since aerophotography was done in 1970, changes have taken place in those glacier zones, particularly in the glacier terminus, in the past 17 years. Consequently, the present situation of the glaciers cannot be presented on the map of 1970. In order to remedy the above mentioned defects and to meet the needs of glacier research at this time, we used a combined terrestrial–aerial photogrammetric mapping method which is different from the method used for mapping the Gongga area due to the difference of the data condition.

In the survey area, the mapping of topographic and geomorphic features were completed on a Topocart–B autograph, with the data from aerial photography in 1970 and air triangulation. Chongce Ice Cap and termini of its adjacent glaciers were drawn on a stereoautograph–1318/19, with data from terrestrial photography in 1987.

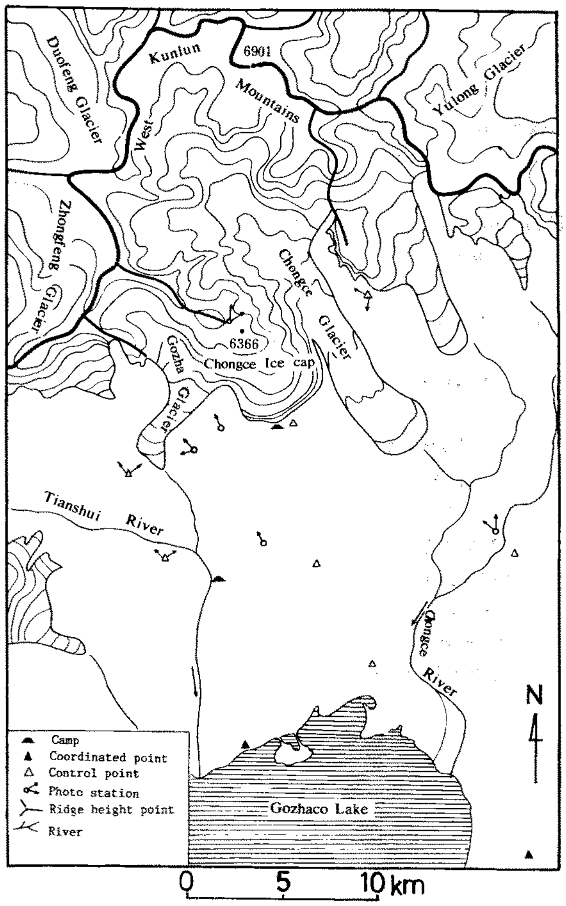

Fig. 1. Map showing the triangulation points and photo stations.

3. Mapping control basis

Control points are the basis of a topographic map. So all control points have to be united in the same coordinate system for the combined terrestrial–aerial photogrammetric mapping. The coordinate system used a Gauss projection. There is no coordinated point in the survey area of Chongce Ice Cap. The mapping control network included 9 points, which were extended to the survey area from 2 coordinated points on the shore of Gozhaco Lake, with 5 seconds order control surveying standard. Fig. 1 shows a sketch map of the control network. The photo control points of the terrestrial photographs were determined by an unclosed analytic method of terrestrial photogrammetry.

Field control surveying was carried out from the end of June to the middle of August. Survey work to select control points and construct beacons proceeded smoothly at the beginning, because surveyors could travel by car. But survey work met difficulty in July, as the mountain slope became muddy, caused by snowfall over several days which induced melting of frozen ground. Hence, the car met very hard and slow going.

Triangulation was carried out by a Wild T2 theodolite and a Zeiss 010 theodolite. Horizontal direction in the triangulation network was observed 3 sets in round method. The heights of the control points were determined by trigonometric leveling in forward and reverse. Two sets of vertical angles were observed in middle–wire. The mean error of horizontal angle observation was 3.29 seconds. The mean error of vertical angle observation was 2.4 seconds. The check-

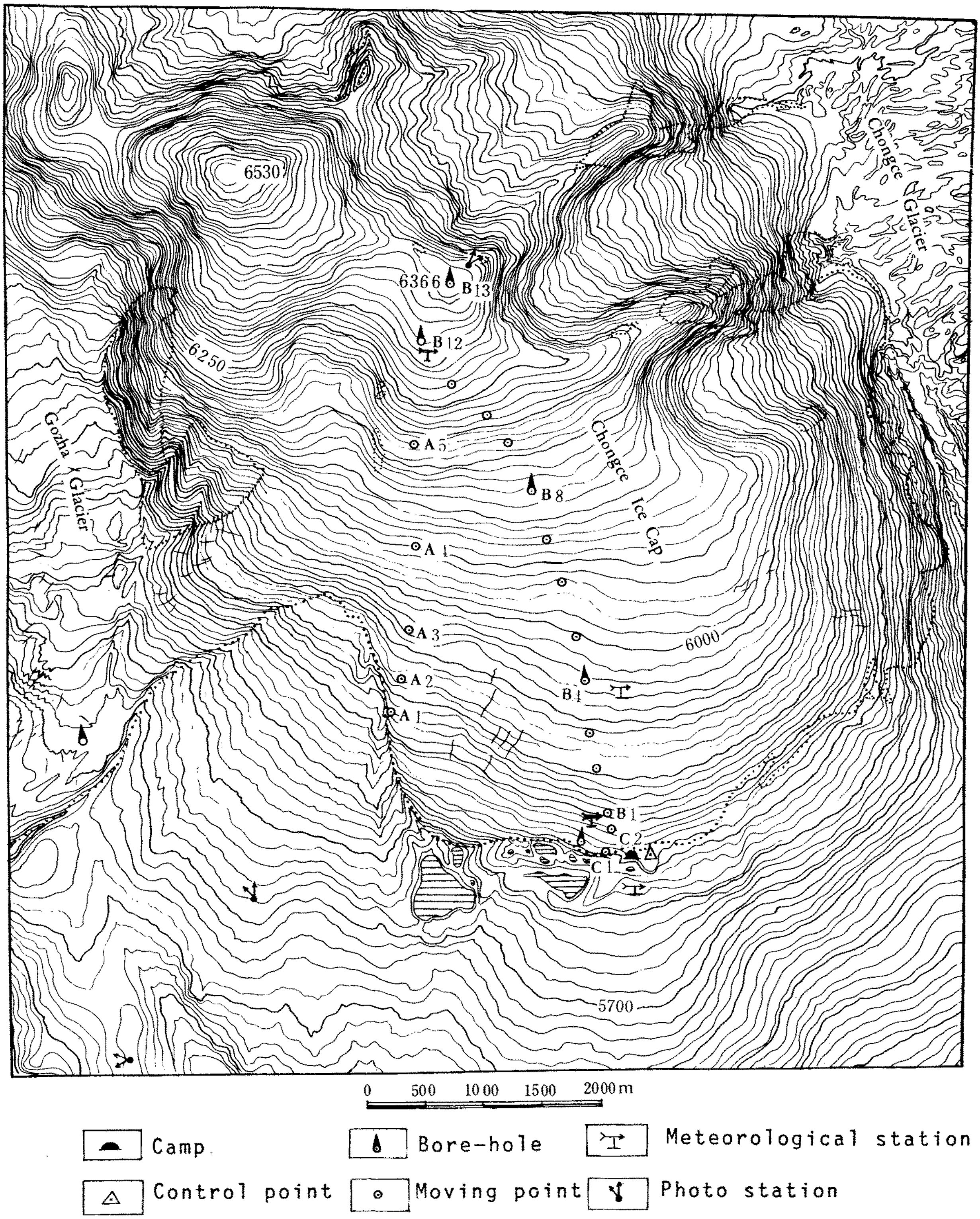

Fig. 2. Map showing Chongce Ice Cap.

ing points were determined by forward intersection with 2 sets.

The adjustment calculation of the control network was carried out on the same plane. The control network plane system was adjusted by conditional observation. The adjustment calculations were completed on a micro–computer. The mean square error of a weight unit was 2.64 seconds after adjustment. The relative error of the weakest control point was 1: 25,000, and positional error of the weakest control point was 0.4 m. The height adjustment of the control network was carried out by a graphic successive approximation method. After adjustment, the mean square error of the weight unit in the trigonometric leveling was 0.0449 m for a kilometer.

Earth curvature and refraction have a great effect on trigonometric leveling, but the effect can be almost eliminated for height of control points which was surveyed by bilateral observation. So the height of mapping control points was not corrected accurately, but the effect of earth curvature and refraction have to be corrected in computing height of the checking points and photocontrol points of terrestrial photography. The factors affecting refraction are complex (Gu, 1976); in the survey area, the coefficient of earth curvature and refraction can be computed inversely from height difference in the direct and reverse directions. The coefficient, 0.093, in this survey area is approximately equal to those in the high mountains regions, Qomolangma and Gongga.

4. Terrestrial photogrammetry

On the basis of analyzing the topography in the survey area, the position of photo baseline was planned first on a map with a scale of 1:100,000. First the main baseline was selected, later the secondary baseline, to make photographic gaps as small as possible. Then the positions of photo stations and length were determined according to topographic conditions and photo range in the field. Photo stations were joint–surveyed with the control points. According to requirements of the combined terrestrial–aerial photogrammetry program, 10 photo baselines covering about 300 km^2 (40 % as total area in the survey area) were set up (Fig. 1). Photo stations had an averaged height of 5800 m, and a highest at 6366 m. The photo baselines averaged 560 m in length, with maximum photogrammetric distance about 10 km.

Photo stations were surveyed directly in the field. Half of photo baselines were connected directly with control points and the other half were located by resection, with a mean positional error of 0.78 m. The length of the photo baseline was determined by using an invar subtense bar. Two sets of parallactic angles were observed, with a mean error of 1 second.

5. Photography

The photographic material used was a kind of ultraviolet II type photo–plates. It is well known that on snow and ice, it is very hard to take ideal photographs. In the survey area, the area of snow and ice to be covered extended from the glacier terminus to the north neat line. On a fine day, the snow surface appears so pure white that people cannot distinguish its topography. Therefore, to take black–and–white or color photographs with good stereoscopic effect, it is important to select the optimum photographic periods. From practical experience, the optimum photographic periods in a glacier region are, at the end of snow–ice ablation; not only are the grains destroyed by snow surface melting, weakening diffuse light, but also the snow surface can be become moist which cuts the glare. Second, in a day, the best time is about 2 hours after sunrise or before sunset. It is necessary to avoid cloudy or back lighting; side light is best. In short, photographs are taken when people with eyes can distinguish the topography best.

6. Photo control extension

In terrestrial photographs, there are unavoidable effects caused by interior and outer orientaion. In order to achieve accuracy comparable to surveying and mapping, 3 photo controls in each stereo pair are needed to achieve absolute orientation of the stereo model and to correct for the errors. General mapping becomes uneconomical if all photo controls were determined in the field. In the survey area on the Chongce Ice Cap, since topography appears very smooth, accuracy of checking points cannot be assured. Thus, checking only 3 outstanding topographic points cannot achieve the requirements of mapping, so photo controls have to be completed in the office.

The space coordinates of photo controls were extended by analytical terrestrial photogrammetry.

The photo coordinates were measured by Zeiss coordinatometer.

From analysis of error theory for terrestrial photogrammetry and practical experience, it has been shown that photo controls can be extended only using an approximation closed analytical method in which the error of convergence is corrected. In unlarge-scale mapping with general accuracy, the accuracy of extension points are obtained to achieve requirements for mapping. Consequently, it is not necessary to use a closed analytical method, because a closed analytical method needs 4 coordinated points in a stereo pair (Wang, 1979), so that photo controls in a stereo pair need not be extended again for terrestrial photogrammetric mapping. A closed analytical method is used for nontopographic photogrammetry and large-scale mapping with high accuracy.

The error of convergence is calculated in various ways (Institute of Geography, Academia Sinica, 1980). This time, the error of convergence, r, was determined from the difference value between the homologous angles of horizontal swing, α, at left and right stations on the same baseline, that is $r=\alpha_L-\alpha_R$, but the angle of horizontal swing is computed from horizontal angles of homologous points on the photographic overlap. It must be pointed out that the method is not closed to determine error of convergence, because it is assumed that the optic axis of normal photography is located correctly. In fact, the direction of the optic axis in normal photography is used to make the correction, but there are some setting errors, at least in the direction of the optical axis.

Analytical computations for photo control were carried out on a pocket computer (PC-1500). The accuracy of extension was sufficient for mapping.

7. Concluding remarks

As mentioned in this report, the mapping of glacier topography and geomorphology in the region of the Chongce Ice Cap and its adjacent districts was completed by combined terrestrial-aerial photogrammetric mapping.

The morphological character of the glacier surface and periglacial geomorphology in the survey area are presented in detail on the map. The accuracy of surveying and mapping of this map conforms to the national standard. It is a basic map for studying existing and Quaternary glaciers. The area, length of glaciers, height of snow line and others can be obtained from the map. Figure 2 shows a part of the Chongce Ice Cap. The multicolor map of Chongce Ice Cap and the neighboring area on a scale of 1:50,000 will published at the end of 1990 with place names in both Chinese and English.

References

Chen, J. (1985): Map of the Mount Gongga Glacier, a combination of terrestrial and aerial photogrammetry. Annals of Glaciology, **8**, 34-36.

Gu, D (1976): Surveying of the summit of Qomolangma in height. Scientia Sinica, **1**, 74-78.

Institute of Geography, Academia Sinica (1980): Terrestrial photogrammetry and its application. Beijing, Surveying and Mapping Press, 378-406 (in Chinese).

Wang, Z. (1979): Photogrammetric priniple. Beijing, Surveying and Mapping Press, 315-316 (in Chinese).