Acta Albertina Ratisbonensia Bd. 46, 1989 S. 59-67

ADVANCE OF GLACIER SURVEYING AND MAPPING IN CHINA IN 1958 - 1988

by

Chen Jianming *

Zusammenfassung

Zu Prof. Wilhelm Kicks 75. Geburtstag möchte ich ihm den vorliegenden Aufsatz über "Fortschritte der Gletschervermessung und -kartographie in China von 1958-1988" widmen. Da die weitaus meiste Arbeit auf diesem Gebiet vom "Lanzhou Institute of Glaciology and Geocryology" in Lanzhou, Provinz Gansu, geleistet wurde, werde ich vor allem die Tätigkeiten dieses Instituts in den letzten 30 Jahren vorstellen sowie einige künftige Arbeiten erläutern.

Abstract

For Prof. Wilhelm Kick's 75th birthday I am presenting the following paper on Glacier Surveying and Mapping in China from 1958-1988. Since the main work in this field has been done by the Lanzhou Institute of Glaciology and Geocryology in Lanzhou, Gansu province, I shall discuss in particular its activities during the last thirty years together with some ideas for the future.

General Situation of Glacier Surveying and Mapping in China

Glaciological and geocryological research in China began in 1958, when the Alpine Ice and Snow Utilization Team in Lanzhou under the Academia Sinica started the investigation of glaciers in NW-China. Not long thereafter the Glacier Surveying and Mapping Division of the "Lanzhou Institute of Glaciology and Geocryology" (former name until about 1984 " Lanzhou Institute of Glaciology and Cryopedology") was founded. The research field of the divison concerns glaciers, permafrost, and debris flow. Main part of this work has been the production of special glacier maps, besides measuring flow velocities of the ice and documenting the glacier variations. As an investigation method the division has mainly been engaged in photogrammetric surveying.

Before the People's Republic of China was founded (1949) only a few foreign explorers had begun to investigate glaciers in China. After P.R.China was founded, glacier surveying started with an expedition to the Qilian Mountains in 1958 (about 400 km NW of Lanz-

---

* Chen Jianming, Chief of the Division of Surveying and Mapping, Lanzhou Institute of Glaciology and Geocryology, Academia Sinica, Lanzhou, Prov. Gansu, PRChina

hou). Systematic glacier research began with the establishment of Yema Shan Glacier Station in the Qilian Mountains (on the northeastern border of the Tibetan Plateau), and the "Tianshan Glaciological Station of China". The latter station was established by the Academia Sinica in 1959 at 3.600 m a.s.l. in the vicinity of several glaciers ("N° 1,2,3,...") in the upper Urumqi Valley, sligthly more than 100 km south of Urumqi, the capital of Xinjiang (Sinkiang), Uygur Autonomous Region, which is known in Europe as "Turkestan".
The work there was interrupted during the "Cultural Revolution" (1966-76) but continued in 1980. For several years now the station is open to research work of Chinese and foreign scientists in the fields of geomorphology, quaternary geology, climatology, hydrology, glaciology, cryopedology, and mountain ecology.

Chinese surveyors have worked hard to survey glaciers in the Qilian Mountains, Tienshan, Nyainqen Tanglha range (between Lhasa and Tongri nor lake), in parts of the Himalayas, Kunlun, Altay, Hengduan (with Minya Konka), Karakorum, and Qinghai Xizang Plateau (the Tibetan Plateau occupies most of the Xizang = Tibetan and Qinghai Autonomous Region). In 1974-75 the 59 km long Batura Glacier in Pakistan had been surveyed and mapped at a scale of 1:60.000. In Antarctica a survey of Nelson Ice Cap will be finished soon.

In 1979 the glacier inventory work in China started in accordance with the standard specifications of the World Glacier Inventory.

More than 50 papers and reports on glacier surveying and mapping have been published in scientific journals.

Glacier Surveying and Mapping at a larger scale

The development of glacier mapping in China can be divided into three stages. This applies to finished maps, as well as to mapping techniques.

1958-1962

The survey was done with common techniques. The instruments used were simple. There were a few surveyors with only little glaciological knowledge. Most work was done by section method and route surveying using theodolite and plane table. The first glacier map (1:10.000) of Glacier N° 1 at the headwaters of Urumqi River in Tianshan was published in 1965 (MI, 1965). A map of Mt. Xixbangma region (Shishapangma, 8.013 m) was surveyed by plane table in 1964.

1962-1981

In this stage terrestrial stereophotogrammetry was used. This method is older than aerophotogrammetry. Though it is not suitable for wide-range mapping, is is appropriate to survey large scale maps in mountainous glacier regions. Furthermore it is more precise and less expensive. It compensates for some of the shortcomings of aerophotogrammetry and of plane table techniques.

Since beginning glaciological research, the former Director of the Lanzhou Institute, Prof. Shi Yafeng, had payed extreme attention to the application of terrestrial photogrammetry for glacier expeditions. An expert from the USSR was invited to the Tianshan Glaciological Station to do terrestrial photogrammetric mapping together with Chinese surveyors. In 1959 surveyors were sent to Wuhan Institute of Surveying and Geophysics for training. In 1960 terrestrial photogrammetry was used in the glaciological expeditions to Lenglongling Glacier in Qilian Mountains and Muzhate Glacier in Tianshan. But satisfactory results had not been obtained. An experiment with terrestrial photogrammetry which covered 30 km² area was finished successfully in 1961. We also prepared a topographic map of Glacier N° 20 drainage basin of Laohugou (NW-part of Qilian Mts.) at a scale of 1:10.000, and of its tongue (1:2.000). During 1964-1965 repeated terrestrial photogrammetry surveys were used to research glacial-debris flow in Guxiang District, Xizang (Tibet) which seriously affected the Sichuan-Xizang-Highway. They measured the amount of lost mass, the alluvial variation, and the flow velocities of the glacier surface. A topographic map (1:10.000) of Guxiang debris flow drainage, which covers 40 km² was drawn (CHEN, 1985). This not only provided the basic map and quantitative data for glacial debris flow research, but also set the standards for surveying large scale glacier maps.

During 1966-1978 excellent results were achieved in surveying large scale glacier maps by terrestrial photogrammetry. A map covering East and West Rongbuk Glacier, and the northern slope of Mt. Qomolangma (Mt. Everest) (1:25.000), published in 1968, was produced by this method. The authors were Chinese surveyors, members of the Mt. Qomolangma comprehensive scientific expedition. The expedition consisted of scientists from the Lanzhou Institute of Glaciology and Geocryology, from Beijing Institute of Geography, and Shanxi Bureau of Surveying and Mapping. Then the surveyors from Lanzhou continued to work there in 1968 and 1969 and finished the map which covers 2.000 km² (WANG, 1981) of the northern slope of Mount Qomolangma. The map had attained international standard for glacier maps regardly precision and the representation of glacier morphology. It was displayed in different parts of China as one of the excellent maps by the National Society of Surveying and Mapping of China. Also it won the important achievement award of China National Scientific Congress 1978. A book, "Basic Theory of Terrestrial Stereophotogrammetric Technique" was published.

Afterwards terrestrial photogrammetry was apllied widely and many glacier maps have been published. The map of Mt. Tomur in Xinjiang (Sinkiang) was surveyed in 1974/75. A map of Batura Glacier Drainage Basin (700 km²) had been finished successfully during the Chinese Batura Glacier expedition in 1974 and 1975 (CHEN, 1980; WANG, 1980). A German-Austrian glaciological and geological expedition had surveyed the same area in 1954 and 1959, but had not completed the map. The Chinese Batura map also provided the data for the glacier inventory of this part of the Indus River Drainage Basin (KICK, 1986). Additionally the map of Karela Glacier in Tibet, maps of glaciers at the source of Urumqi River in Tianshan Mts. - re-surveyed many times to calculate the glacier variations - and a map of "7.1 Glacier" in the Qilian Mts. were produced by terrestrial photogrammetry. Some of the national basic maps (1:50.000), which cover some thousands km², had been surveyed round 1970 in Tibet and Xinjiang, which were prized by the local government.

1982-1988

During this period terrestrial- and aerophotogrammetry have been combined to survey glacier maps. The combination method began in 1962, when the experiment was done at Yemashan Glacier Station, resulting in a map (1:10.000). Glacial topography and landforms were surveyed by terrestrial photogrammetry, whereas parts outside the glacier drainage basin were surveyed first by aerophotogrammetry under a stereoscope and were rectified multizonally. The map was the first glacier map finished by this combined technique in China. With the accumulated experience and the improvement of instruments a map of Mt. Gongga Glacier (1:25.000) (Minya Konka) was produced by this method (CHEN, 1986). It was appraised as an excellent map by the Cartographic and Geographic Information System Branch of the National Geographical Society of China. It will also be sent to some foreign countries on display. The combination method consists of the following:

The mapping of planimetric and morphologic features are completed at a stereoautograph, mainly using plates from terrestrial photogrammetry. The non-exposed area is supplemented with data from aerial photography with a photographic plotter. The net of control points of the aerial photographs is extended by the analytic terrestrial photogrammetry and is located on the original protracting map by optic-mechanical rectification. The advantages of terrestrial and aerial photogrammetry are synthesized. The map of Chongce Ice Cap was surveyed in 1987 by the Chinese-Japanese Glaciological Expedition to West Kunlun Mts., and also a map of DunDe Top-flated Glacier was surveyed by the Chinese-American Expedition to the Qilian Mts. All this work was done by the combination method.

The large-scale typical glacier maps of the Lanzhou Institute have a precise mathematical base and show the geomorphologic types, vegetation, etc., by contours, symbols, hachure, and hill shading, with different colours (YIN, 1986). The maps provide a clear and distinct stereoimpression and substantial scientific content, and can be used in scientific research as well as for mountaineering and tourism.

Glacier Mapping at smaller scales

Besides the typical large-scale glacier mapping mentioned above, we started with medium- und small-scale maps at the end of the 1970s. In 1978 the map of glacial distribution on the Xizang Plateau at a scale of 1:1 Million was produced, using satellite imagery. On this basis we completed a glacial distribution map of "Xizang and Adjacent Districts" at 1:2 Millions. In 1980 a 1:200.000 topographic and geomorphologic glacier map of Mt. Tomur region was made (WU, 1980), by using 1:50.000 terrestrial photogrammetric survey and satellite imagery. In 1983 we finished a 1:50.000 glacier distribution map in the Mt. Bogda region, Tianshan, using national basic topographic maps and aerial photographs.

For the glacier inventory maps at the scale of 1:50.000 and 1:100.000 aerial photographs and satellite images have been used. Many maps were drawn which include coding key maps in the Qilian Mts. (1980), Altai Mountains (1982), Tianshan, Interior drainage area of Qinghai-Xizang Plateau, Pamir region, Himalayas, and others. In addition we provided maps of the snowline in China, then a permafrost map of Qinghai-Xizang Highway.

Measuring Movements and Variations of Glaciers

It is one of the important aims of glacier research to measure the temporal and spatial change of glacier surfaces. Since 1958 we have measured and analysed movement velocities and elevation changes of glacier surfaces and changes in the end positions of glacier tongues in all great mountain areas of China. In addition we measured the variations of the end of Batura Glacier, "N° 1 Glacier" near the Tianshan Glacial Station, and "7.1 Glacier" in the Qilian Mts. The data of "Glacier N° 20" in Laohugou cover the longest time period of observation.

Before 1970 the main methods for measuring ice-velocities were theodolite intersections and the setting up of fixed markers for controlling glacier advance or retreat. These methods are still used. In 1958 the Meeting for the International Geophysical Year proposed the use of terrestrial photogrammetry to measure ice-velocities and glacier variations. During 1960-1961 we measured Yema Mts. "N° 20 Glacier" in the Qilian Mts. using repeated terrestrial photogrammetry and got data for the velocity of the glacier surface in summer, winter and for an annual period. By using this method during 1964-1965 we obtained a lot of data for glacier movements and variations of glacier surfaces, for glacier debris flow studies of Guxiang in Xizang. Intensive survey of this kind was done at "Glacier N° 1", Tianshan Glacial Station, and in the study of Batura Glacier in Pakistan (CHEN, 1984; KICK, 1966).

The elements of ice velocities, rise or drop of glacier surfaces, advance or retreat of the end of the tongues are rather complex. Therefore a lot of survey points are needed. Only terrestrial photogrammetry has the characteristics to record all these elements, especially the surface changes of valley glaciers. Aerial photographs, satellite images, and topographic maps are qualified to observe the length variations at the end of the glacier tongues.

HUANG (1982) and SHI (1964) have done valuable work for the study of glacier motion in China. During the last 30 years most glaciers have retreated. Having measured the velocity of changes and the change of the ends, we can state for each region in China, whether the glaciers there are stationary or retreating. Generally the velocities have decreased (SHI, 1979). For example, the average velocity of "Glacier N° 20" of Laohugou Qilian Mts. during the years 1962-1976 have been 0.8 times as much as in 1960-1961. The average velocity of "Glacier N° 1" of Tianshan Glacial Station was 31-73 % slower in 1980-1981 than in 1959-1962 (SUN, 1985). But some glaciers are advancing (ZHANG, 1981). It is a pity that we have not surveyed the ice velocities of these advancing glaciers. Their behaviour is of much interest to water power stations.

Based on the data on ice movements in 1974 and 1975, on accumulation and ablation rates, thickness, and historical changes of Batura Glacier, we made a forecast to the behaviour for the period until 1991-1997. We used the velocity decline method, varying ice mass balance method, and methods of motion calculation in this century of Batura Glacier. By two measurement tests in 1978 and 1980 the forecast proved to be true. This was a good beginning for glacier variation forecast research in China.

Future Tasks of Glacier Surveying and Mapping in China

International glacier surveying and mapping has made great progress in the past 30 years between the International Geophysical Year 1957-1959, the International Hydrological Decade 1965-1974, until the International Symposium of Glacier Surveying and Mapping in 1985. One had begun to concentrate on the glacier variations instead of only mapping the glacier surface morphology. The surveying techniques have developed. The electronic distance meter, photogrammetry, radio echo sounding for measuring the ice thickness, satellite remote sensing and the global positioning sytem, automatic mapping and digital terrain model promote advance in glaciological research. In China terrestrial photogrammetry has become one of the special techniques of glacier surveying.

What are the future tasks in China? First we need wide application of digital data, including digital terrain models and geographic information systems. These should be set up so that the data can be used by scientists from different countries. The quality of glacier surveying and mapping should be further improved to meet the needs of research work. The current tasks are to enhance the quality of surveyors and map makers, to study the glaciological theories further, to improve instruments and equipment, to set up digital terrain models for the determining of glacier variations. However the major point should be to survey and map some selected representative glaciers precisely, including seismic thickness measurements. The variation data will be used to study the relationship between climatic change and glacier variations and to predict the variations so that scientific information will be provided to industry and agriculture.

Magnitude of the ice areas in China (Tab. 1)

The glacier area of the P.R.China reaches 56.500 km², that are 0.59 % of the country (9.6 Mill. km²), or almost one half of the glacier area of High Asia, about as much as the area of the Austrian Alps, if we take these to 2/3 of the Austrian territory. The glacier area of China amounts to 1/4 of all mountain glaciers of the earth outside of the arctic regions. Their water storage comes to about 5.000 km³. Besides the ice of the glaciers permafrost occupies 20 % of the whole of China.

Tab. 1: Some statistic data for comparison

Territory	number of glaciers	glacier area (km²)	percent of the country	volume of water-equivalent (km³)	year of statement
High Asia	170.000 ?	118.300		10.000 ?	1959
P.R.China	80.000 ?	56.500	0,59	5.000 ?	1981
Switzerland	1.828	1.342	3,25	67	1973
Austria	918	540	0,64	19	1969
FRG	5	1,1	0,00	0	1971

References

CHEN JIANMING (1984): Variations of the Batura Glacier's surface from repeated surveys. in: International Karakorum Project 1: 196-204.

CHEN JIANMING (1985): Application of terrestrial stereophotogrammetry in the study of debris flow. in: Memoirs of Lanzhou Institute of Glaciology and Geocryology, Academia Sinica 4: 256-262; Sci. Press (in Chinese).

CHEN JIANMING (1986): Map of the Mt. Gongga Glacier, a combination of terrestrial and aerial photogrammetry. in: Annals of Glaciology 8: 34-36.

CHEN JIANMING & ZHAN HUAIYI (1980): The terrestrial stereophotogrammetric mapping of the drainage area of Batura Glacier. in: Investigation and Research on the Batura Glacier in the Karakorum Mountains; pp. 208-220; Sci. Press (in Chinese).

HUANG MAOHUAN & SUN ZUOZHE (1982): Some characteristics of the movement of continental-type glaciers in China. in: Journal of Glaciology and Geocryology 4, N° 2: 34-46; (in Chinse).

KICK, W.J. (1966): Measuring and mapping of glacier variations. in: Canadian Journal of Earth Sciences 3: 775-781, and in: Journal of Glaciology and Cryopedology (1982) N° 4: 53-58; Lanzhou (in Chinese).

KICK, W.J. (1986): Glacier mapping for an inventory of the Indus drainage basin; current state and future possibilities. in: Annals of Glaciology 8: 102-105.

MEIER, M.F. (1986): Summary of discussions at Symposium on Glacier Mapping. in: Annals of Glaciology 8, p. 210.

LANZHOU INSTITUTE (ed) (1984): Guide to the Institute.

MI DESHENG (1965): Proof of the cartographic methods for glaciers and glacial landforms. in: Glaciological and hydrological research in the Urumqi River Basin; pp. 119-131; Sci. Press (in Chinese).

SHI YAFENG & XIE ZICHU (1964): Basic characteristics of modern glaciers in China. in: Geogr. J. 30, N° 3: 183-208; (in Chinese).

SHI YAFENG, REN BINGHUI & XIE ZICHU (1979): Results of glacier research in China for the past 30 years. in: Journal of Glaciology and Cryopedology: pp. 1-4; (in Chinese).

SHI YAFENG et al. (1980): Forecasting the variation of Batura Glacier for this century and beyond. in: Investigation and Research on the Batura Glacier in the Karakorum Mountains; pp. 191-207; Sci. Press (in Chinese).

SHI YAFENG, WANG ZONGTAI & LIU CHAOHAI (1981): Progress and problems of glacier inventory in China. in: Z. f. Gletscherkunde u. Glazialgeologie 17, 2: 191-198.

SHI YAFENG & ZHANG XIANGSONG (1984): Guide to the Tianshan Glaciological Station of China. Lanzhou.

SUN ZUOZHE et al. (1985): Flow characteristics of Glacier N° 1 at the headwaters of Urumqi River, Tianshan. in: Journal of Glaciology and Geocryology 7, N° 1: 27-39; (in Chinese).

WANG WENYING & CHEN JIANMING (1981): Terrestrial stereophotogrammetric surveying and mapping in the regions of Mt. Qomolangma and the Batura Glacier in Karakorum. in: Proc. of Sympos. on Qinghai-Xizang Plateau 2: 1657-1664; Sci. Press.

WANG YIMOU, PENG QILONG & FENG YUSUN (1980): The cartographic methods of the map of Batura Glacier. in: Investigation and Research on the Batura Glacier in the Karakorum; pp. 221-228; Sci. Press (in Chinese).

WU HUANZHONG (1980): Application of remote sensing data in the glacier mapping work. in: Journal of Glaciology and Cryopedology 2: 60-61; Special issue.

YIN SHICONG & CHEN JIANMING (1986): Cartographic methods for large-scale maps. in: Annals of GLaciology 8: 192-195.

ZHANG XIANGSONG & MI DESHENG (1981): Data on recent glacier variations in China. in: Journal of Glaciologoy and Cryopedology 3, N° 4: 99-100; (in Chinse).