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# A Brief Introduction to Contents

This book is a concise and synthetic monograph of *Glacier Inventory of China*, which consists of 12 volumes and 22 books. For convenience, we predigest the detailed data in *Glacier Inventory of China*, and add some new information about glaciers and environmental changes in each glaciered region, and new knowledge about glacier changes and their influence on water resources. This book consists of nine chapters, including the distribution of glaciers in each drainage system in China, glacier changes and its meltwater runoff. Especially is given an in-depth discourse by drainage basin, the amount of glaciers in statistics tables and maps of glacier distribution, classic glacier images and photos supplemented newly.

This book is a systematic, all-round work in glacier resources and environmental changes, with abundant and original data and a mass of beautiful pictures. This book has offered a scientific support to natural strategy of water resources and management in Development of the West Regions of China. It is a useful reference book for those who do research in geography, water conservancy, disaster prevention and environment, and also for educational and productive purpose.

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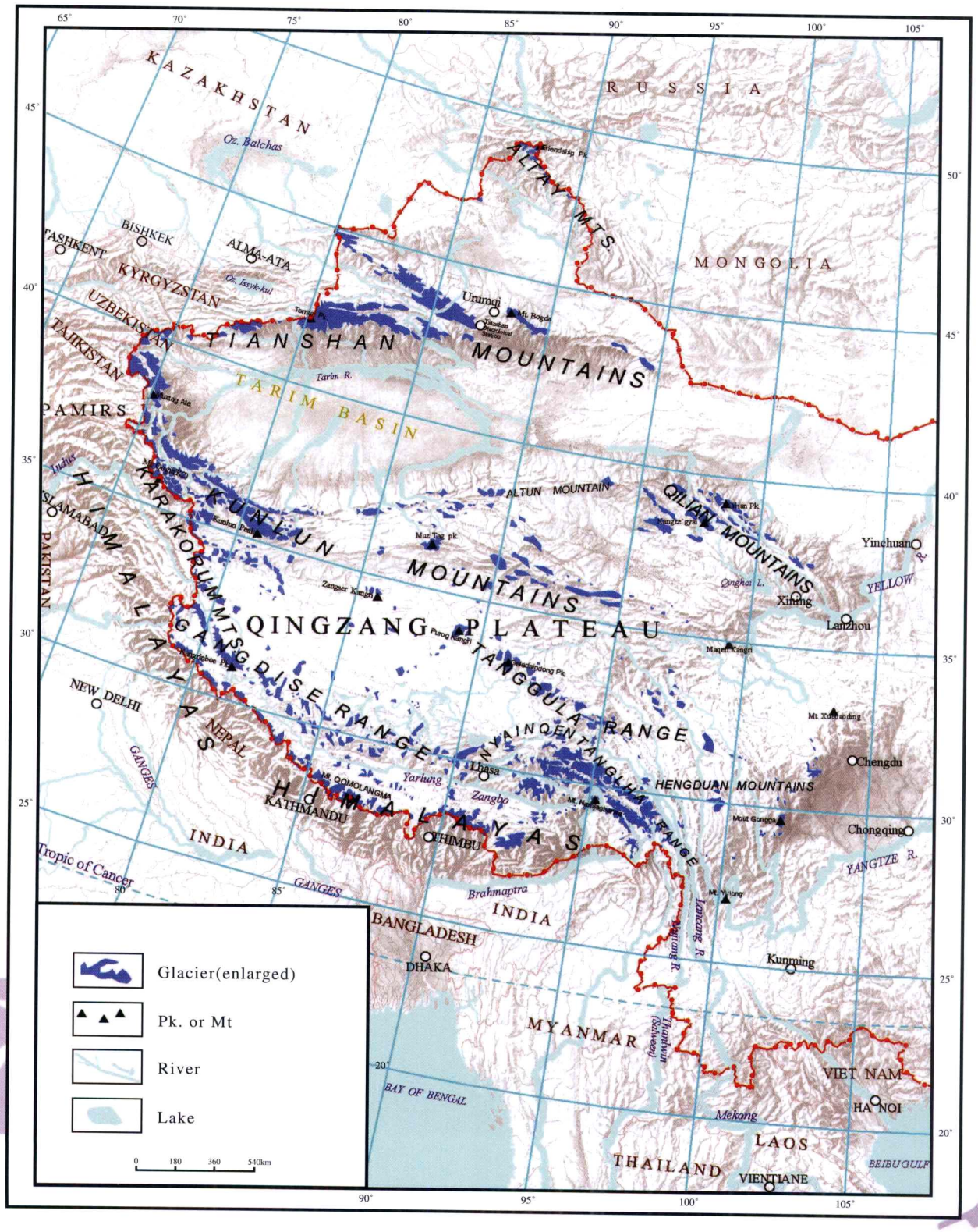
*Concise Glacier Inventory of China* (CGIC) is an integrated and simplified introduction to glaciers in China, based on individual volumes of *Glacier Inventory of China* (GIC) for a series of mountains in West China contributed by many researchers from the Lanzhou Institute of Glaciology and Geocryology, the Chinese Academy of Sciences (LIGG, CAS), now re-organized into the Cold and Arid Regions Environmental and Engineering Research Institute (CAREERI), CAS. The authors of the present book would like to give their thanks to those not included in the book for their zealous, though exhausting, dedication to compile glacier inventories for all mountains in West China during the last 24 years. We are grateful to the continuous support from LIGG for compilation of GIC, also to CAREERI for funding the publication of this book. The working group of CGIC also received the support of projects from the National Natural Science Foundation of China (NNSFC) (90202013), the Chinese Academy of Sciences (KZCX3-SW-339). All the color figures and maps were prepared by Mi Desheng and Wu Lizong. The following colleagues provided precious photos that make this book interesting and vivid. They are Ding Liangfu, Pu Jianchen, Wang Zongtai, Yao Tandong, Qi Long, Deng Xiaofeng, Su Zhen, Ma Qiuhua, Shen Yongping, Zheng Benxing, Lu Anxin and Liu Chaohai. Julia Taylor Broussard arranged the language editing; Liu Shiyin, Liu Chaohai and Ye Baisheng made the final editing both in language and science. Shanghai Popular Science Press covers expenses in editing and printing this book.

# Glacier distribution in West China



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# PREFACE

Shi Yafeng

For the wide interests in glaciers in China and convenient application of *Glacier Inventory of China*, we compile this book. This book is a brief introduction to *Glacier Inventory of China* which consists of 22 books in 12 volumes. To this aim, we analyze and summarize all findings in the 22 books of *Glacier Inventory of China*; in addition, we complemented new information about changes of glaciers and environment in each glacierized area after compilation of glacier inventory in the region. This book consists of nine chapters, introducing the distribution of glaciers, glacier changes and glacier meltwater runoff in every mountain range or water system in West China. The most obvious advance in this book is the complete information about glaciers in different water systems, statistic tables, maps, photos or figures of typical glaciers in the individual basins, which is thought to be helpful to readers related to studies and planning performance on water resources and environment.

This book is a systematic, all-round work concerning glacier resources and environmental changes. It composes of abundant and original data and a mass of beautiful pictures. It offers the background information in connection with large-scale management of water resources, mitigation and prevention of glacial disasters, planning of glacier parks and so on, especially, with such activities during Development of West Regions of China. It is a useful reference book for graduate students, policy makers working in the field of geography, water conservancy, disaster prevention, and environment.

November 2005

# CHAPTER 1 INTRODUCTION

Shi Yafeng

## 1.1 Significance of compiling *Glacier Inventory of China*

Glacier is a natural ice body formed by accumulation and deformation of perennially precipitated snow in cryogenic areas. Glaciers slowly flow from the higher accumulation areas above the equilibrium line altitude (ELA) to the lower ablation areas where the melted glacier ice forms the sources of many rivers. Interactions between glaciers, the atmosphere and the lithosphere produce a sequence of changes in water and heat budgets, forming complex glacial systems.

Most global glaciers can be found on the Antarctic continent and Greenland Island near the Arctic Pole. Alpine glaciers also cover the mid- and-low-latitude mountain areas. Glaciers roughly cover 11% of the total landmass and hold 80% of global fresh water. The population explosion and increasing demand for clear and fresh water require a thorough investigation of the quantities and characteristics of glacier resources. Compiling a global glacier inventory can be of great help to this end.

Geologic history recovered from paleoclimatological research provides another reason for such a glacier inventory. During the Last Glacial Maximum (LGM) approximately 20,000 years ago, 30% of the total global landmass was covered with glaciers and ice sheets, transferring a large body of water from the oceans to the land and lowering the sea level by about 130 m relative to the modern sea level. The ancient coastline in China during that time was 600 km east of the current Yangtze River estuary. The Bohai Sea and the Huanghai Sea were totally converted to land, as well as most parts of the East and South China Seas. Roughly 6000 years ago the global temperature was 2~3℃ higher and the sea level was 1~3 m above the present levels (Shi Yafeng *et al.*, 1992). Accelerated anthropogenic emissions of greenhouse gases, such as carbon dioxide, have contributed to the irrepressible trend of climate warming, subsequently increasing glacial melting and causing the sea level to rise, threatening the safety of island countries and coastal lowlands. An evaluation report issued by the Intergovernmental Panel on Climate Change (IPCC) in 2001 proposed that 1.4~5.8℃ rise in global mean air temperature and 0.1~0.9m rise in

sea level can be expected in the 21st century despite the large uncertainties in numerical modeling and significant differences between regions. In order to calculate the impact of glacial melting on the sea level accurately and precisely, we are in great need of a detailed compilation of glacier inventory that provides essential information about surviving glaciers.

China is in more urgent need than many other countries for such a compilation of glacier inventory because most of the meltwater from alpine glaciers flow into Chinese giant arid inland basins such as the Tarim, the Junggar, the Qaidam, as well as the Hexi Corridor. These regions have been relying heavily on the glacial meltwater as the key source of oasis irrigation for a long time. With the rapid development of agriculture and industry and continuous population growth, the supply of and demand for water has become an urgent problem. Glaciers, acting as alpine solid reservoir of water that regulates seasonally and annually stream flows, are a reliable water source for sustainable development in arid regions. Glaciers and their meltwater not only become the basis upon which an oasis can stably form and develop, but also become an indispensable and lively part of the environment. In the 1980s a national leader of China once said: "Alpine glaciers are a reliable and relatively stable water resource in solid form. We should cherish this precious resource, allowing it to create more wealth and benefit the people." China also has quite a number of glaciers that contribute to major seaward rivers with an important role in regulating yearly runoff, producing hydropower, and preventing floods.

In the early years before the establishment of the People's Republic of China, little is known about glaciers in China until a milestone investigation of glaciers in the Qilian Mountains was carried out in 1958 initiating formal glacier research in the nation. The Investigation Team on Utilization of Snow and Ice Resources in Mountain Regions, the Chinese Academy of Sciences (1959), a body of 120 personnel from the Chinese Academy of Sciences headed by Professor Shi Yafeng, was divided into seven groups with the goal of finding out the distribution and features of glaciers in the Qilian Mountains. After a long expedition of more than four months, traversing 2500 km on foot and climbing more than 60 glaciers, combined with the visual interpretation of aerial photographs of some areas, the scientific expedition has documented roughly 941 glaciers with a total area of about 1149 $km^2$ equivalent to $33.2 \times 10^9$ $m^3$ of water. However, the exact number of glaciers was greatly underestimated. Although several subsequent investigations have

expanded, to some extent, our knowledge on glaciology, they still could not meet the need for a detailed calculation of nationwide glacier resources. In 1978, in response to the international project of compilation of glacier inventories, the Chinese scientists began to offer a systematic effort to compile *Glacier Inventory of China*, finally leading studies on glacier resources in China to regular, reasonable and effective tracks.

## 1.2 International Glacier Inventory and Glacier Inventory of China

In 1955, a working group of the International Geophysical Year (1957~1959) first proposed all member countries to register the position, altitude, area, volume and activity of glaciers. The coordinating council of the International Hydrological Decade (IHD) during 1965~1974, further called on the participating countries to map the distribution of perennial ice and snow and to record relevant data in detail. Sponsored and supported by the Secretariat of the IHD, a work group guided by Swiss Professor F. Müller published in 1970 *A Guide for Compilation and Assemblage of Data for a World Glacier Inventory*, which provides rules for the standard measurements of 40 glacier parameters. After years of practice, this book was modified for reprinting in 1977 and was widely accepted as the criterion for compilation of glacier inventory worldwide. In 1973 the Temporary Technical Secretariat (TTS) of the World Glacier Inventory was set up at the Department of Geography of the Switzerland Federal Institute of Technology (SFIT), directed by Professor F. Müller who was responsible for promoting and coordinating the compilation of glacier inventory. In September 1978 the International Commission on Snow and Ice (ICSI) organised a workshop, participated by scientists from 19 countries, on the World Glacier Inventory in Switzerland. Before the opening of the workshop, Professor F. Müller delivered an official letter in the name of TTS to the Chinese Academy of Sciences (CAS) in which he invited delegates from China to attend this meeting and to initiate the glacier inventory task over China. CAS and the Ministry of Foreign Affairs of China jointly submitted an application to the State Council of China. In this application Shi Yafeng, head of the Lanzhou Institute of Glaciology and Geocryology (LIGG), CAS of the time, was officially appointed chief of the delegation to participate in the meeting in Switzerland and undertake the glacier inventory on behalf of China. Professor F. Müller pointed out in the report of the meeting that the compilation of World Glacier Inventory would be of great significance in three aspects: 1) to enrich knowledge on local, regional and global hydrological cycles and water

budgets; 2) to provide basic data for freshwater resource planning, hydropower generation, irrigation, disaster prevention, relaxation and tourism; 3) to obtain the necessary background data for studying climatic processes and monitoring climatic change. By the time the workshop was convened, five nations (the USSR, Norway, Austria, Switzerland and Sweden) had already finished compiling their glacier inventories, and most of the countries were carrying out the compilation of their own glacier inventories.

After LIGG undertook the compilation of the glacier inventory in China in 1978, the group coordinated by Prof. Shi Yafeng chose the Qilian Mountains as the first prototype of the Chinese glacier inventory. Then a working team was sent to investigate the glaciers in the Altay Mountains and began working on the difficult task of compilation of glacier inventories in the Altay and Tianshan Mountains. The project group estimated that the national glacier inventory could be finished within ten years. While the inventory was smoothly progressing, the unfortunate news came that Professor F. Müller died of a heart attack in the field work on the Rhone Glacier in Switzerland. His death was a great loss to the course of glacier inventory compilation. In the autumn of 1981, K. Scherler, an assistant of Professor F. Müller, presided over a glacier inventory inspection symposium at Zurich, which Shi Yafeng attended and reported the progress of the Chinese glacier inventory. At that time the atmosphere of the symposium changed greatly. Some speakers thought the originally conceived glacier inventory was too difficult to be completed. They in turn proposed that simple methods, such as using satellite imagery, should be adopted and quickly put into practice. In response to such suggestions, researchers from some countries simplified the former glacier inventory procedures according to their own conceptions. Only a few researchers, including those from China, adhered to TTS criterion of 1977. Since then, TTS and the Permanent Service on the Fluctuation of Glaciers (PSFG), formerly directed by F. Müller, merged with the Institute of Hydro-Engineering, Hydrology and Glaciology. In 1986 the World Glacier Monitoring Service (WGMS) headed by Dr. Haeberli founded and ran into operation. In 1989 WGMS published its world glacier inventory, in which the global glacier coverage area was estimated to be 15,861,766 $km^2$. In this publication, the glacier area in China was estimated by Shi Yafeng to be 56,482 $km^2$, including three fully inventoried mountainous regions and nine mountainous regions where the inventories were based on satellite imageries. Thereafter the glacier

inventory of China continued with more than 50 participants in total, who made a great effort to overcome difficulties such as low fund, shifts in the research paradigm, manpower alteration, and problems within the collection of aerial photographs and topographic maps. However, the project of compiling glacier inventory in China was finally completed and the 12 volumes of *Glacier Inventory of China* with additional maps were all published in 2002. Meanwhile the Chinese team established a large-scale, unified glacier inventory database with the Geographical Information System technology. In September 2004 an expert team including academician Li Jijun and Chen Zhikai unanimously issued positive comments on the inventory and suggested to publish *Concise Glacier Inventory of China* for the general public's convenience.

## 1.3 Achievements of *Glacier Inventory of China*

The main achievements of the compilation of *Glacier Inventory of China* include the Glacier Inventory in detail, glacier information system databases and application of the glacier inventory.

1. Publication of *Glacier Inventory of China* in 12 volumes and 22 issues (Table 1-1). The inventory for the first time accurately determined the number of glaciers in all drainage areas, mountains and provinces across the nation, providing basic scientific information for the reasonable utilization of water resources and implementation of global climate change research. Among the four major nations with glaciers, *i.e.* China, U.S.A, Canada and Russia. China has the maximum distribution of Alpine glaciers in mid-and-low latitudes and is the only country that has finished its glacier inventory in accordance with the glacier inventory criteria.

2. Establishment of a digital database for *Glacier Inventory of China*. This database was the first attempt to vectorize glacier coverage with attributes of *Glacier Inventory of China*. This has greatly promoted the practical and illustrative applications of glacier inventory data, bringing great convenience to use the inventory.

3. Promotion of widespread applications of the glacier inventory (Photo 1-1). While compiling *Glacier Inventory of China*, glaciological researches in China were activated with the applications of the glacier inventory data in the fields of glaciology, hydrology, paleoclimatology and so on, for example, estimations of glacier runoff and changes of glaciers since the Little Ice Age and during recent decades, as well as on projections of future changes in glaciers and their impact on river runoff. This research had great theoretical and practical significance and important impact

**Table 1-1 List of *Glacier Inventory of China**

| Volume | Issue | Authors | Publishing Year |
|---|---|---|---|
| I Qilian Mountains | Qilian Mountains | Wang Zongtai and Liu Chaohai *et al.* | 1981 |
| II Altay Mountains | Altay Mountains in China | Liu Chaohai *et al.* | 1982 |
| III Tianshan Mountains | Interior Drainage Area of Scattered Flows in East | WangYinsheng and Liu Chaohai *et al.* | 1986 |
| | Interior Drainage Area of Junggar Basin in Northwest | Lai Zuming and Liu Chaohai *et al.* | 1986 |
| | Interior Drainage Area of Tarim Basin in Southwest | Xie Weirong and Ding Liangfu *et al.* | 1987 |
| | The Ili River Drainage Basin | Ding Liangfu and Xie Weirong *et al.* | 1987 |
| IV Pamirs | Pamirs | Luo Xiangrui and Mi Desheng *et al.* | 1988 |
| | Drainage Basins of the Kaxgar River and Others (Revised Edition) | Liu Chaohai and Wang Zongtai *et al.* | 2001 |
| V Karakorum Mountains | Drainage Basin of the Yarkant River | Yang Hui'an and An Ruizhen | 1989 |
| VI Kunlun Mountains | Drainage Area of Southern Qaidam Basin and Upper Reaches of the Yellow River | Yang Hui'an and An Ruizhen | 1992 |
| | Interior Drainage Area of the Hotan River | Yang Hui'an and An Ruizhen | 1992 |
| | Interior Drainage Area of the Karamiran-Keriya River | Yang Hui'an and An Ruizhen | 1994 |
| | Interior Drainage Area of the Miran-Qarqan River | Yang Hui'an and An Ruizhen | 1994 |
| VII Qinghai-Xizang (Tibetan) Plateau Inteiror Area | Drainage Basins of the Ayakkum Lake and the Hoh Xil Lake | Yang Hui'an and An Ruizhen | 1988 |
| | Drainage Basins of the Bangong Lake | Jiao Keqin and Zhang Zhenshuan | 1988 |
| | Drainage Basins of the Dogaicoring and Yibuchaka Lakes | Jiao Keqin and Zhang Zhenshuan | 1988 |
| | Drainage Basins of the Siling Lake | Jiao Keqin and Zhang Zhenshuan | 1988 |
| | Drainage Basins of the Zharinam Lake | Jiao Keqin and Zhang Zhenshuan | 1988 |
| VIII The Changjiang (Yangtze) River | The Changjiang (Yangtze) River | Pu Jianchen | 1994 |
| IX The Mekong River | The Lancang River | Pu Jianchen | 2001 |
| X The Salween River | The Nujiang River | Pu Jianchen | 2001 |
| XI The Ganges Drainage Basin | The Ganges Drainage Basin in China | Mi Desheng and Xie Zichu *et al.* | 2002 |
| XII The Indus River | The upper reaches of Indus River in China | Mi Desheng and Xie Zichu *et al.* | 2002 |

* "Pamirs" and "Drainage Basins of the Kaxgar River and Others" in IV Volume are considered as one because the latter is a revised edition of "Pamirs".