Glaciers of Asia—

GLACIERS OF CHINA

By Shi Yafeng, Mi Desheng, Yao Tandong, Zeng Qunzhu, *and* Liu Chaohai

SATELLITE IMAGE ATLAS OF GLACIERS OF THE WORLD

Edited by RICHARD S. WILLIAMS, JR., *and* JANE G. FERRIGNO

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1386–F–2

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Introduction

China is home to many of the major mountain-glacier systems of the world. Figure 1 shows the distribution of glaciers in China. Western China includes a series of major mountain ranges and plateaus, namely the Himalaya, Karakorum Shan, Kunlun Shan, Qilian Shan, Tian Shan, and Altay Shan, and the *Qinghai-Xizang Gaoyuan*[3] (Qing Zang Gaoyuan) (Tibetan Plateau) where glaciers are located (table 1). Glaciers are widely scattered and cover an area of about 59,425 km^2 (fig. 1). Table 2 and figure 1 show the generalized snowline elevations[4] in China. The elevation of the snowline ranges from 2,800–3,000 m in the Altay Shan to 6,000–6,200 m in southern and western Xizang Zizhiqu (Tibet Autonomous Region). Isolines of snowline elevation make irregular, concentric circles centered near western Xizang Zizhiqu, where the snowline may reach the highest elevation in the world. This peculiar form of variation of snowline elevations is caused by the decrease in precipitation from the peripheral mountains to the interior of the Qing Zang Gaoyuan. The annual precipitation is 800 to 3,000 mm in some of the outer mountains, but is only 200 to 300 mm in the interior of the plateau. High elevations result in greater solar radiation on the Qing Zang Gaoyuan than on the surrounding lowlands and causes an increase in elevation of the interior snowlines.

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[1]This manuscript was originally written in 1981 to describe the glaciers of China during the benchmark period of the late 1970s and early 1980s. Because there was a delay in printing, the authors substantially updated the manuscript in 2005.

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[3]Chinese place-names are used throughout the Glaciers of China subchapter and transliterated English words have been added to assist those unfamiliar with Chinese terms for geographic features: Table 1 provides a list of frequently used words. U.S. Government publications require that official geographic place-names for foreign countries be used to the greatest extent possible. In the Glaciers of China subchapter, the spelling of geographic place-names is derived from the "Gazetteer of China — An Index to the Atlas of the People's Republic of China" published by the Gazetteer Laboratory of Geodesy and Mapping Institute, National Bureau of Geology and Mapping, Beijing, China. Gazetteers of place-names in the Xizang Zizhiqu (Tibet Autonomous Region) and the Xinjiang Uygur Zizhiqu (Uygur Autonomous Region) were consulted. In addition, note that the Government of China employs a different spelling system for geographic place-names in regions of China with large Han, Mongol, Tibetan, and Uygur nationalities; the spelling used combined the Chinese phonetic alphabet and the Wade System. The Chinese place-names were compared with the Gazetteer of the People's Republic of China (U.S. Defense Mapping Agency, 1990) and the U.S. Board on Geographic Names website *http://earth-info.nga.mil/gns/html/index.html*. Names not listed on the website are shown in italics and the spelling of the authors is used.

[4]Snowline elevation is defined in this chapter as equivalent to the equilibrium line altitude (ELA) at which the annual glacier balance is zero, averaged over many consecutive recent years.

TABLE 1.—*Commonly used transliterated Chinese terms for geographic features*

Chinese word	Transliterated* English word
bingchuan	glacier
co (Tibetan term)	lake
feng	summit or peak of mountain, mountains
gaoyuan	plateau
gou	stream
he	river, stream
hu	lake
jiang	large river
kangri	summit or peak of mountain, mountains
kou	pass
ling	mountain range
pendi	basin, depression
qu	stream
shan	mountain range
shankou	mountain pass

*Chinese Pinyin characters transliterated into English.

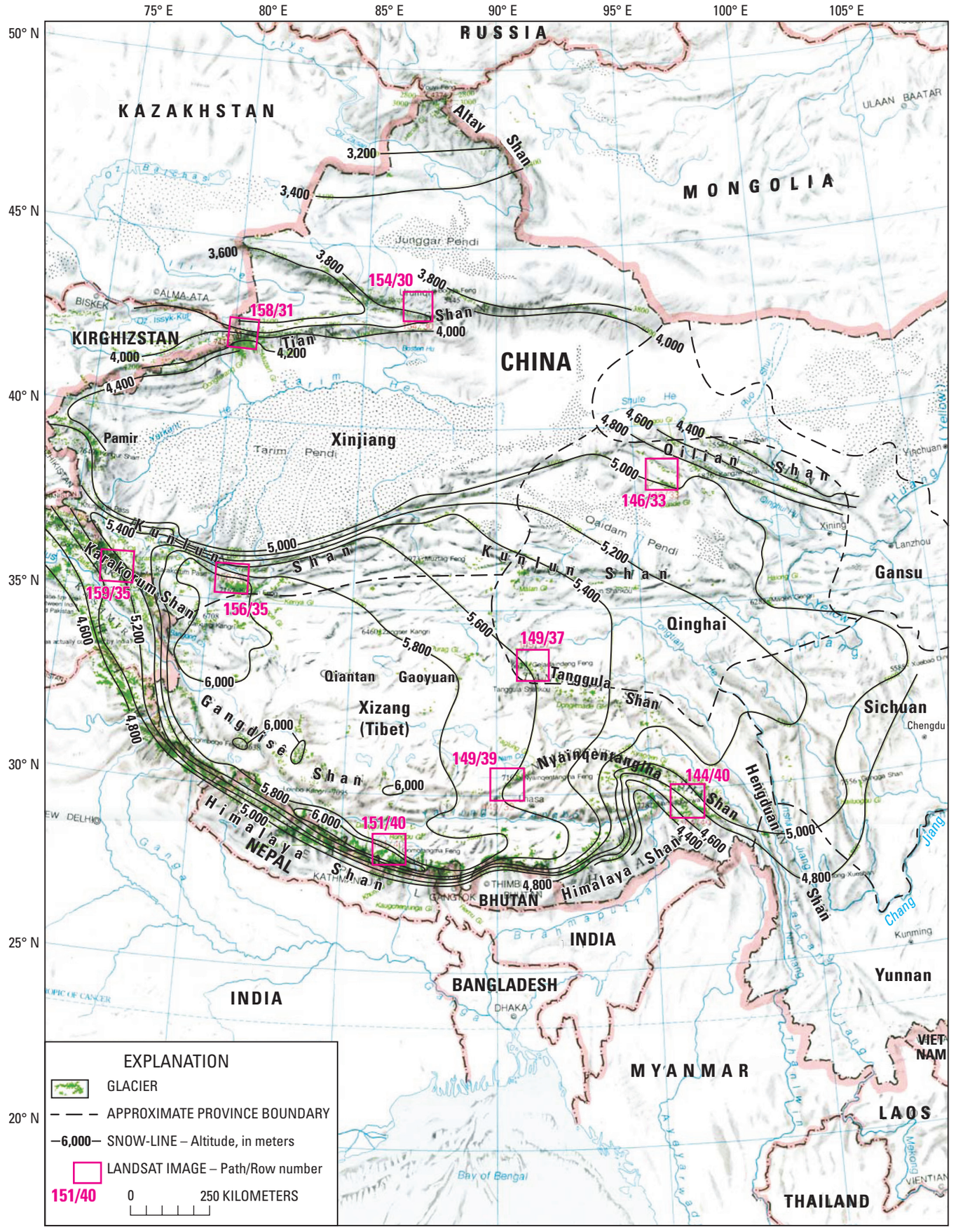
Figure 1.— (at right) *Map of glaciers and snowline altitude (elevation) in the mountain ranges of western China and adjacent countries. The location of the Landsat images used for figures 2–10 is shown. The national boundaries and the geographic place names are taken from the 1:4M "Map of the People's Republic of China," published by China Cartographic Publishing House in 1989.*

TABLE 2.—*Glacierized areas in China*

[Units: m, meter; km², square kilometer]

Mountains, region, or glacier	Elevation of the snowline (m)	Area of glaciers (km²)	Source[1]	Investigator
Altay Shan (including *Muztau Ling*)	2,800–3,200	297	GIC 2, 1982	Liu Chaohai and others
Tian Shan	3,600–4,400	9,225	GIC 3, 1986–1987	Liu Chaohai and others (1987); Shi Yafeng and others (2005)
Qilian Shan (including Altun Shan)	4,300–5,200	2,206	GIC 1, 1981	Wang Zongtai and others
Pamir	5,500–5,700	2,696	GIC 4, 1988, (revised) 1999	Mi Desheng and others
Karakorum Shan	4,700–5,600	6,262	GIC 5, 1989	Yang Huian and others (1989); Shi Yafeng and others (2005)
Kunlun Shan	5,800–6,100	12,267	GIC 6, 1992–1994	Yang Huian and others
Qiantan Gaoyuan (Plateau)	5,600–6,100	1,802	GIC 7, 1988	Jiao Keqin and others
Tanggula Shan	5,300–5,800	2,213	GIC 8, 1994	Pu Jianchen and others
Nyainqêntanglha Shan	4,200–5,700	10,700	GIC 9, 2001	Pu Jianchen and others (2001); Mi Desheng and others (2002)
Gangdisê Shan	5,800–6,000	1,760	GIC 7, 1988	Jiao Keqin and others (1988); Shi Yafeng and others (2005)
Himalaya	4,300–6,200	8,418	GIC 11, 2002	Mi Desheng and others
Hengduan Shan	4,600–5,600	1,579	GIC 8, 1994	Pu Jianchen and others
Total		59,425		Shi Yafeng and others (2005)

[1]Data for glacier area are taken from Glacier Inventory of China (GIC) which was compiled by the staff of Lanzhou Institute of Glaciology and Geocryology and published by Science Press, Beijing, China. The inventory is also available digitally at World Data Center D for Glaciology and Geocryology, Lanzhou, China. The glacier areas were later revised and published in Concise Glacier Inventory of China (Shi Yafeng and others, 2005; Shi Yafeng, 2008).



Chief Editor, Shi Yafeng; Editor, Mi Desheng;
Cartographic fairdrawing and Platemaking, He Baoshan

Mountain glaciers in western China and central Asia may be classified into three types: maritime, subcontinental, and extreme continental (table 3). Glaciers of southeastern Xizang Zizhiqu (Tibet Autonomous Region), including the eastern Himalaya and Hengduan Shan, belong to the maritime type. The majority of glaciers in Altay Shan, Tian Shan, eastern Qilian Shan, eastern Kunlun Shan, eastern Tanggula Shan, north slope of the middle and western Himalaya, Karakorum Shan, etc., belong to the subcontinental type. Glaciers in the western part of Qing Zang Gaoyuan including western Kunlun Shan, eastern Pamir, western Tanggula Shan, western Qilian Shan, *Qiantan Gaoyuan*, etc., belong to the extreme continental type. Their differences are mainly due to regional variation in climate (fig. 1, table 3).

TABLE 3.—*The parameters for three types of glaciers in West China (Shi and Liu, 2000)*

[Abbreviations: E., eastern; N., northern; W., western; S.E., southeastern; km², square kilometer; m, meter; mm, millimeter; ~, approximate]

Parameter	Glacier type		
	Maritime	Subcontinental	Extreme continental
Annual precipitation	1,000–3,000 mm	500–1,000 mm	200–500 mm
Average air temperature at snowline			
a. Summer	1 ~ 5 °C	0 ~ 3 °C	<-1 °C
b. Annual	-2 ~ -6 °C	-6 ~ -12 °C	<-10 °C
Ice temperature within 20-m depth	-1 ~ 0 °C	-1 ~ -10 °C	<-10 °C
Distribution region	S.E. part of *Qinghai-Xizang Gaoyuan*, Hengduan Shan, E. Himalaya Mid E. Part of Nyainqêntanglha Shan	Tian Shan, Altay Shan, E. Qilian Shan, E. Kunlun Shan, E. Tanggula Shan, N. slope of midwest Himalaya, N. slope of Karakorum Shan	W. part of *Qinghai-Xizang Gaoyuan*, W. Kunlun Shan, E. Pamir, Tanggula Shan, W. Gangdisê Shan, W. Qilian Shan
Approximate area	13,200 km²	27,200 km²	19,000 km²

The earliest description of glaciers in Chinese literature was made by the Buddhist monk Xuazang during the Tang Dynasty (618–907 A.D.). Xuazang crossed the *Muzart Bingchuan* in 630 A.D, on the way to India in search of Buddhist Scriptures. In the late 19th century and early 20th century, some western and Chinese explorers observed glaciers in western China. H. von Wissman (1959) made a comprehensive study of the glaciers and snowline elevation in *High Asia (Gaoya)*. In 1958, an expedition called the "Alpine Ice and Snow Utilization Team" (1959), which was the forerunner of what was to become the Institute of Glaciology and Geocryology, was organized under the leadership of Shi Yafeng. In 2000, this institute was renamed the Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences. This team, and later the Institute, investigated glaciers in the glacierized regions of China: the Qilian Shan, the Tian Shan, the western Kunlun Shan, the Karakorum Shan, the Himalaya, the Hengduan Shan and other areas. Monitoring stations were set up on *Ürümqi He No. 1 Bingchuan* in the Tian Shan, on the *Hailuogou Bingchuan* in the Gongga Shan, on the *Tanggula Bingchuan* in the Tanggula Shan and in the Yulongxue Shan. In the 1980s, glaciologists from the United States, Japan, Europe, Australia, Russia, and many other countries came to China to cooperate and exchange

information with Chinese glaciologists. From the middle 1980s, ice-core studies were performed in the *Qinghai-Xizang Gaoyuan* (Tibetan Plateau) to reconstruct past environments and climates (Thompson and others, 1989; Nakawo and others, 1990; Yao and others, 1995, 1996). A comprehensive glacier inventory, begun in 1979 and completed in 2002, provides a detailed account of the distribution of glaciers in China. Most of the data contained in this report are derived from that inventory, the Glacier Inventory of China (table 2) (also available digitally from World Data Center D for Glaciology and Geocryology, Lanzhou, China). A summary of the glacier inventory was published by Shi (2008).

This report first discusses the distribution of glaciers within each of 12 glacierized regions. It then describes the ablation of the glaciers, and discharge of meltwater into the glacierized drainage basins. In the last part of the report, Landsat 2 MSS images and aerial photographs were used as a visual base to describe numerous glaciers in several of the glacierized regions and discuss their retreat or advance. The names of numerous geographic features are used in this report, and the locations (latitude and longitude) of many of the glaciers and glacierized regions, as well as a few other geographic features, are presented on table 4. Additionally, Landsat images (figs. 2-10) and their associated tables (tables 5-13) provide the locations of many of the glaciers, mountains, mountain ranges, lakes, rivers, and other geographic features.

TABLE 4.—*Locations of glaciers, glacierized regions, and other geographic features in China*

Name	Latitude	Longitude
Altay Shan (Chinese part)	45°30′N.–50°10′N.	85°00′E.–91°10′E.
Youyi Feng	49°27′N.	87°56′E.
Kuitun Feng	47°00′N.	85°30′E.
Karaxi Bingchuan	49°25′N.	87°53′E.
Tian Shan (Chinese part)	41°00′N.–45°30′N.	76°00′E.–95°00′E.
Hantengri Shan	42°15′N.	80°15′E.
Harlertau Shan	42°00′N.	82°00′E.
Eren Habirga Shan	43°30′N.	85°00′E.
Bogda Feng	43°50′N.	88°40′E.
Muzart Bingchuan	42°18′N.	80°45′E.
Qilian Shan	36°00′N.–40°00′N.	94°00′E.–103°00′E.
Dangjin Shankou (pass)	39°05′N.	94°08′E.
Wushao Ling	37°30′N.	102°42′E.
Tuanjie Feng	38°30′N.	98°20′E.
Shule Nanshan	38°53′N.	97°16′E.
Laohugou Bingchuan	39°03′N.	96°40′E.
Daxue Shan	39°24′N.	96°36′E.
Lenglong Ling Bingchuan	37°38′N.	101°38′E.
Tergun Daba Shan	38°08′N.	96°21′E.
Chinese Pamir	38°00′N–39°30′N.	74°00′E.–76°00′E.
Muztagata (peak)	38°15′N.	75°10′E.
Kongur Shan	38°40′N.	75°20′E.
Karakorum Shan	35°30′N–36°30′N.	76°00′E.–77°30′E.
Qogir Feng (K2)	35°55′N.	76°30′E.
Yengisogat Bingchuan	36°03′N.	76°17′E.

TABLE 4.—*Locations of glaciers, glacierized regions, and other geographic features in China*—Continued

Name	Latitude	Longitude
Kunlun Shan	33°15′N.–38°20′N.	75°00′E.–105°00′E.
A'nyêmaqên Shan	34°30′N.–33°40′N.	98°00′E.–102°10′E.
Bayan Har Shan	33°15′N.–35°40′N.	96°00′E.–99°40′E.
Yulong Bingchuan	35°27′N.	81°08′E.
Muztag Shan	36°30′N.	87°30′E.
Yaherung Bingchuan	34°54′N.	99°10′E.
***Qiantan Gaoyuan* (Plateau)**	32°20′N.–34°30′N.	80°00′E.–90°00′N
Purog Kangri	34°20′N.	85°30′E.
Caixong Kangri	34°15′N.	80°05′E.
Tanggula Shan	31°30′N.–34°00′N.	89°00′E.–98°00′E.
Mitijangzhanm Co	33°24′N.	90°19′E.
Yushu	32°45′N.	97°00′E.
Zhag'yab	31°40′N.	97°55′E.
Geladaindong (peak)	33°29′N.	91°13′E.
Bija Shan	31°48′N.	94°40′E.
Bija Glacier Group	31°40′N.–31°55′N.	94°35′E.–94°50′E.
Puogou Bingchuan	31°43′N.	94°35′E.
Nyainqêntanglha Shan	28°00′N.–31°30′N.	90°00′E.–100°00′E.
Qungmo Kangri	29°52′N.	90°03′E.
Margyang He	29°48′N.	89°58′E.
Anjiula	29°40′N.	97°45′E.
Rawu	29°30′N.	97°45′E.
Yarlung Zangbo Jiang	29°20′N.	89°30′E.
Kyaggen Bingchuan	30°31′N.	94°42′E.
Yagnung Bingchuan	29°19′N.	96°42′E.

Geographic Distribution of Glaciers in China

There are 12 primary glacierized regions in China (fig. 1, table 2): Altay Shan, Tian Shan, Qilian Shan, Pamir, Karakorum Shan, Kunlun Shan, *Qiantan Gaoyuan* (Plateau), Tanggula Shan, Nyainqêntanglha Shan, Gangdisê Shan, Himalaya, and Hengduan Shan. Altay Shan, located in the northernmost part of China, has the smallest glacier coverage (297 km^2), and Kunlun Shan has the largest (12,267 km^2).

Distribution of Glaciers in the Altay Shan

The Chinese Altay Shan (fig. 1, table 4) extends from the border between China and Russia on the west to the border between China and Mongolia on the east, between latitude 45°30′N. and 50°10′N. The highest peaks are *Youyi Feng* (4,374 m) and *Kuitun Feng* (4,104 m). It is the northernmost glacierized area in China. The glaciers are concentrated in the upper course of Burqin He, a tributary of the *Irtish He* (Irtysh). There are 424 glaciers with a total area of 297 km^2 on the Chinese side of this range, also including *Muztau Ling*, to the south of Altay Shan (table 2, Liu and others, 1982). The *Karaxi Bingchuan*, at the head of Burqin He, is the longest, with a length of 10.8 km. Its terminus descends to 2,416 m, the lowest elevation of any glacier in China.

Distribution of Glaciers in Tian Shan

The Tian Shan (fig. 1, table 4) lies across the middle part of Asia; the part in China is called eastern Tian Shan, extending about 1,700 km in an east-west direction; it is higher in the west and lower in the east. Under the influence of the westerly circulation, precipitation in this region decreases gradually, and the snowline elevation rises gradually, from the west to the east.

A glacier inventory using aerial and ground photographs shows that there are 9,035 glaciers in eastern Tian Shan that cover an area of 9,225 km^2 (table 2, Liu and others, 1987; Shi and others, 2005). This is 15.5 percent of the total glacierized area of China. The *Hantengri-Tomur Feng* area (fig. 3) is the largest glacierized center in the Tian Shan; 4,093 km^2 of the glacierized area is concentrated here, including glaciers of Kyrgyzstan. Eren Habirga Shan (fig. 2) is the second glacierized center in the Tian Shan, and the glaciers cover an area of about 1,400 km^2. Bogda Feng rises abruptly in the eastern part of the Tian Shan and is also a major center of glacierization.

From the beginning of the 20th century to the 1950s, the glaciers of the Tian Shan were in a state of recession. For example, the *Muzart Bingchuan* was first described by the travelers of the Tang Dynasty in the 7th century and, at that time, its spectacular ablation scenery and dangerous passage were vividly written about in the famous book *Records of the Western Regions of the Great Tang Dynasty*. From 1909 to 1950, the glacier retreated 750 m (Shi and Wang, 1979). Analysis of aerial photographs and Landsat images since the beginning of the 1970s indicates that the general glacier recession has been reduced; some glaciers are stagnant but some are advancing.

Distribution of Glaciers in the Qilian Shan

The Qilian Shan (fig. 1, table 4) is situated to the northeast of the *Qinghai-Xizang Gaoyuan* (Tibetan Plateau), extending from Dangjin Shankou (pass) in the west to the Wushao Ling (mountains) in the east. It is about 800 km long. The elevation of the mountains increases from east to west. The highest peak is *Tuanjie Feng* (5,808 m) in the Shule Nanshan (fig. 4). Under the influence of the monsoon, the annual precipitation decreases from the eastern section (800 mm) to the western section (300 mm). The elevation of the snowline is 4,300 m in the eastern section and 5,200 m in the west.

A glacier inventory shows 2,815 glaciers in the Qilian Shan with an area of 1,931 km^2 (Wang and others, 1981). Glaciers in Altun Shan are sometimes also included in Qilian Shan; when included, the number and area of glaciers increases to 3,015 and 2,206 km^2, respectively (table 2). The largest valley glacier is *Laohugou Bingchuan* of Daxue Shan, 10.1 km long, with an area of 21.9 km^2 (fig. 4). *Laohugou Bingchuan* has been studied in more detail than other glaciers in the Qilian Shan**.** A deep ice core from the *Dunde Binggai* (ice cap) (lat 38°06′N., long 96°24′E.), which has an area of 57 km^2 and is located at an elevation of 5,325 m, was analyzed to determine the glacial and climate history from the last glaciation to the present (Thompson and others, 1989; Yao and Thompson, 1992).

Field investigations integrated with analyses of Landsat images during a period of 20 years shows that the *Lenglong Ling Bingchuan,* in the eastern section of Qilian Shan is receding at a rate of 12.5 to 22.5 m a^{-1}. However, in the Tergun Daba Shan (fig. 4) in the southwestern section of the Qilian Shan, several valley glaciers >5 km long advanced 200–400 m from 1966 to 1977. During the past 5 years the recession of glaciers in the Qilian Shan has been reduced. On many glaciers the mass balance was positive during the 1970s (Xie Zichu, 1980) but became negative again during the 1980s and 1990s.

Distribution of Glaciers in the Chinese Pamir

The Chinese Pamir (fig. 1) are called the eastern Pamir; they are located to the south of the Tian Shan, to the east of the western Pamir in Kyrgyzstan and Tajikistan, to the west of Yarkant He, and to the north of the border between Afghanistan and Pakistan with China. The glacierized area in this region is 2,696 km^2 [table 2; Mi and others, 1988, 1999 (revised)]; 80 percent is located in the region of Muztagata peak and Kongur Shan.

In this part of the Pamir, glaciers are mostly situated on the leeward slopes. The snowline elevation reaches 5,500–5,700 m and the termini end at an elevation of 4,000–5,000 m. Ice ablation is relatively minor and the glacier motion is relatively slow. The glaciers are typically of the extreme continental type.

Glaciers in the Karakorum Shan

The Karakorum Shan (fig. 1, table 4) combines extreme ruggedness, high elevation, and extensive glacier-ice cover to a greater degree than any other mountain system in the world. There are four peaks more than 8,000 m in elevation, including Qogir Feng (K2) (8,611 m), the second highest peak in the world (fig. 5). The glaciers are larger than those in the Himalaya and rank among the longest valley glaciers in the world outside the polar regions. In 1959, the total area of Karakorum Shan glaciers was about 15,000 km^2 (von Wissman, 1959), which is 37 percent of the mountain area. The snowline elevation lies at about 4,700–5,600 m. There are six glaciers longer than 50 km in the Karakorum Shan.

The Chinese Karakorum Shan occupies a wide region in the northern part of the Karakorum Shan (fig. 1). Landsat images and aerial photographic maps show the area of glaciers in the Chinese Karakorum Shan to be about 6,262 km^2 (table 2; Yang and others, 1989; Shi and others, 2005). Several large valley glaciers stretch into the upper Yarkant He and its tributary, the *Klejin He*. The *Yengisogat Bingchuan* is 42.0 km long, with an area of 380 km^2 and a terminus at 4,000 m; it is the longest glacier in China. Using data from a map by Shipton (1938), a 1968 aerial photomap, and 1978 Landsat images, it is seen that the debris-covered terminus of the *Yengisogat Bingchuan* was stable from 1937–1978. However, the *Skyang Bingchuan* (northeast of Qogir Feng, 18.8 km long) receded 5.2 km from 1937 to 1978. Some glaciers in the Chinese Karakorum Shan are advancing; Landsat images of 1978 clearly show that a glacier has dammed the *Klejin He* and impounded a lake; serious flooding along the *Klejin He* occurred in 1961 and 1978.

Distribution of Glaciers in the Kunlun Shan

The Kunlun Shan (fig. 1, table 4), extending from the Pamir eastward to the A'nyêmaqên Shan and the Bayan Har Shan, has a total length of about 2,500 km, and its elevation is higher in the west and lower in the east.

The area of the glaciers in this region is about 12,267 km^2 as determined from the aerial photomaps and Landsat images (table 2; Yang and others, 1992–94). About 70 percent of the glaciers are located between the upper reaches of the Kaxgar He and the *Keliyar He* in the western Kunlun Shan. There are 10 large glaciers more than 100 km^2 in area, of which *Dufeng Bingchuan,* in the upper reach of *Yulongkay He*, 31 km long and 252 km^2 in area, is the largest. The snowline elevations in western Kunlun Shan are 5,800–6,100 m above sea level. The *Guliya Binggai* (ice cap) (fig. 6) is the coldest glacier in central Asia. The lowest measured ice temperature was –19 °C at a depth of 10 m. The longest ice core, 309 m long, was analyzed to determine the glacial and climate history for about 0.7 million years (Thompson and others, 1997).

Aerial photomaps and Landsat images show that 20 of the 37 glaciers measured have advanced in the 1960s and 1970s. Some glaciers in the Muztag Shan and A'nyêmaqên Shan have experienced major advances; for instance, the *Yaherung Bingchuan* in the A'nyêmaqên Shan advanced 1,800–2,000 m from November 1966 to July 1977.

Distribution of Glaciers on the *Qiantan Gaoyuan*

The *Qiantan Gaoyuan* region (fig. 1, table 4), a wide inland plateau, lies to the south of the Kunlun Shan, to the west of the Tanggula Shan, and to the north of the Gangdisê Shan. The relative elevation of the mountains in this region is small. The snowline elevation is as high as 5,600–6,100 m. The area of the glaciers amounts to 1,802 km^2 (table 2; Jiao and others, 1988). The glaciers are small and are scattered and distributed mainly near the highest peaks (>6,000 m); for example, *No. 41 Bingchuan* of Purog Kangri (6,482 m) is 13 km long and 5.3 km^2 in area.

Distribution of Glaciers in the Tanggula Shan

The Tanggula Shan (fig. 1, table 4) extends for 500 km from *Chilbuzhang Co* in the west, eastward to the Yushu and Zhag'yab regions in Qinghai Sheng (Province) and Xizang Zizhiqu (Tibet Autonomous Region). The general orientation of this mountain range is from west-northwest to east-southeast. The crest of the range is the divide between the drainage areas of the Chang Jiang (Yangtze River) to the north and the Nu Jiang (Salween River) and some small inland water systems to the south.

The glaciers of Tanggula Shan have a total area of 2,213 km^2 (table 2), and are concentrated around Geladaindong peak (6,621 m) (fig. 7) in the western section and around the *Bija Shan* in the eastern section (Pu and others, 1994). The snowline is higher in the west (5,820 m) and lower in the east (5,300 m).

The *Bija* glacier group exists on the transitional belt between the subcontinental- and maritime-type glaciers; mean temperature near the snowline is –6.0 to –7.0 °C. The *Puogou Bingchuan* on the southern slope of *Bija Shan* advanced from the beginning of the19th century to the 1920s; since the 1930s, the glacier has retreated.

Distribution of Glaciers in the Nyainqêntanglha Shan

The Nyainqêntanglha Shan (fig. 1, table 4) extends westward from *Qungmo Kangri* (7,048 m) to the north to the *Margyang He* and ends in the east at *Anjiula*, north of Rawu, with a total length of 740 km in both the western (fig. 8) and eastern (fig. 9) sections. The eastern section of the Nyainqêntanglha Shan is adjacent to the great bend of Yarlung Zangbo Jiang (fig. 9) (the upper reach of the Brahmaputra River), which is the passage for the warm, damp southwest monsoon of the Bay of Bengal into *Qinghai-Xizang Gaoyuan* (Tibetan Plateau) in summer (April to September). Precipitation here is abundant and hence the glaciers, all of the maritime type, are well developed.

The total area of all the glaciers in the Nyainqêntanglha Shan amounts to 10,700 km^2 (Pu and others, 2001; Mi and others, 2002). The elevation of the snowline ranges from 4,200 to 5,700 m. The *Qiaqin Bingchuan* is one of the largest glaciers in this region, 35 km long, with the snowline at an elevation of 4,850 m. *Qiaqin Bingchuan* terminates at an elevation of 2,900 m, in an

evergreen broadleaf forest amidst pawpaw and vegetable gardens. At present, most of the glaciers located in Nyainqêntanglha Shan are retreating. For example, during the late Holocene glacial advance, prior to 1000 B.P., the *Zepu Bingchuan* extended more than 5 km downvalley from the present-day position of its terminus; it extended 2 km downvalley of its present terminus during most of the past 600 years (Iwata and Jiao, 1993). The *Roguo Bingchuan* has retreated about 20 km from its furthest glacial advance. Between 1940 and 1975, it retreated 2 km, 62 percent of which occurred in 1959–1975 (Li and others, 1986). Since 1975, it has been stable.

Distribution of Glaciers in the Gangdisê Shan

The Gangdisê Shan (fig. 1, table 4), extending from Bangong Hu on the west to the west of Nyingchi Xian (county) in the east, has a glacierized area of 1,760 km^2 (table 2; Jiao and others, 1988; Shi and others, 2005). The glaciers are small and mostly of the cirque-hanging type; they are concentrated in the district of the *Saint Shan* around Kangrinboqê Feng (6,714 m). Precipitation is low and the snowline is high, around 5,800–6,000 m.

Glaciers of the Himalaya

The Himalaya (fig. 1, table 4) consists of high mountains lying along the southern border of the *Qinghai-Xizang Gaoyuan* (Tibetan Plateau) from Namjagbarwa Feng (7,782 m in China) to Nanga Parbat (8,114 m in Pakistan) and extends for a distance of about 2,400 km. Ten of the world's 13 highest mountains (greater than 8,000 m in elevation) are in the Himalaya; Qomolangma Feng (Mount Everest) (8,848 m) (fig. 10), the highest, is on the border between China and Nepal. According to von Wissman (1959), glaciers cover 30,000 km^2 or 17 percent of the total mountain area. More recent work by Qin (1999) increased the glacierized area of the Himalaya to about 20 percent.

Qin (1999), from analysis of 1975–1978 Landsat MSS 7 and false-color images and some aerial photographs, determined that the total glacierized area of the Himalaya was 35,110 km^2 with a total volume of 3,734 km^3 of glacier ice. A total of 18,065 glaciers were inventoried. The glacierized area of the Himalaya within China is 8,418 km^2, or 24 percent of the total (table 2; Mi and others, 2002). The snowline elevation on the glaciers is at 4,300 m in the eastern Himalaya and 6,200 m on *East Rongpu Bingchuan* on the northern slope of Qomolangma Feng. The climate of the Himalaya consists essentially of two seasons: a dry, cold winter and a wet, warm summer. From late May to September, the Indian Ocean monsoon affects the range, especially the eastern part and southern slope. Recent observations in the Qomolangma Feng area indicate that the glacierized area at an elevation of more than 5,000 m receives less than 1,000 mm a^{-1} of precipitation. Glaciers of the eastern Himalaya (for example, on Namjagbarwa Feng and in the Assam Himalaya) may be of the maritime type with high monsoonal precipitation. Glaciers of the central and western Himalaya are of the subcontinental type, and glaciers are not more than 30 km long. The *Rongpu Bingchuan*, which is 22.4 km long and has an area of 85.4 km^2, is the largest glacier on the north slope of the Himalaya.

Distribution of Glaciers in Hengduan Shan

The Hengduan Shan region (fig. 1, table 4) extends from Chola Shan in the north to Yulongxue Shan in the south, and from the Gongga Shan in the east to the Baxoila Ling in the west. The glacierized area of this region is about 1,579 km^2, of which 40 percent is distributed in the Baxoila Ling (table 2; Pu and others, 1994).

Gongga Shan is the highest peak (7,556 m above sea level) in the Hengduan Shan system. Around the main peak are 74 glaciers with a total area of 256 km^2, among which the *Hailuogou Bingchuan* is the longest valley glacier at 13.1 km; its terminus is at 2,980 m, and the snowline elevation is at 4,900 m above sea level (Xie and Kotlyakov, 1994).

With its main peak, *Shanzidou* (5,596 m), the Yulongxue Shan is the southernmost limit (lat 27°N.) where glaciers are found in China. There are 18 glaciers in the Yulongxue Shan; most of these are distributed on eastern slopes and the snowline is about 5,000 m above sea level.

Because the Hengduan Shan is mainly affected by the Indian Ocean monsoon, precipitation is abundant and often reaches 2,500–3,000 mm a^{-1} near the snowline. All of the glaciers are of the maritime type, with snowline elevations between 4,600 m and 5,600 m.

Ablation of Glaciers in China and Discharge of Meltwater into the Glacierized Drainage Basins

Glaciers in China are concentrated in the high mountain ranges and the *Qinghai-Xizang Gaoyuan* (Tibetan Plateau); all of the major river systems of China have their headwaters in this high plateau. In the arid regions of northwestern China, the upper courses of the inland rivers, such as the Shule He, the Manas He, and the Tarim He, are fed by meltwater from the glaciers to varying degrees. Therefore, the presence of glaciers in a drainage basin is important to agricultural production in these arid regions, a fact well known to the ancient cultures of China. According to records of more than a hundred years ago, in the spring of dry years the peasants living at the foot of the northern Qilian Shan blackened the surface of ice and snow to promote ablation to increase the discharge of the rivers (Alpine Ice and Snow Utilization Team, 1959). During 1958–1961, Chinese scientists, using coal or other black powder, by hand or aircraft, artificially blackened the surface of snow, glaciers, and river ice to promote ablation and increase the amount of glacier meltwater from Qilian Shan and Tian Shan (Shi, 1961).

Research data from Chinese scientists suggest that the energy for ablation of continental glaciers in middle latitudes, such as in the Qilian Shan, the Tian Shan, the Kunlun Shan, the Karakorum Shan, and the central and western Himalaya (Kou and others, 1974), comes mainly from two sources: solar radiation and turbulent heat exchange between the surface of ice and snow and the air layer near the ground. It follows that the volume of meltwater from the glaciers can be estimated from radiation and temperature data of glacierized areas (Shi and Xie, 1964).

Many of the modern glaciers in China are of the continental type, which may be subdivided into subcontinental and extreme-continental types, according to the annual precipitation and air temperature (table 3). The temperature at the surface of the extreme-continental type glacier is very low, and the amount of annual ablation is 200–500 mm a^{-1} (water equivalent) at the ice tongue of *Gozhe Bingchuan* region of western Kunlun Shan. The general trend of the ablation of glacier ice decreases from southeastern

Xizang in two directions, west-northwest and northwest (Zeng and others, 1982). For example, the amount of ablation at the terminus of maritime glaciers, such as *Abzha Bingchuan*, in southeastern Xizang is 8,000 mm a^{-1}, but at the termini of the subcontinental glaciers, such as the Bogda Shan glaciers in eastern Tian Shan and the western Qilian Shan glaciers, it is reduced to 1,500 mm a^{-1} and 1,000 mm a^{-1}, respectively, the lowest extreme of the annual ablation of glaciers in China. Ablation occurs mainly in midsummer; July and August ablation is more than 65 percent of the total (as much as 85 percent during certain times) (Yang, 1980).

Meltwater from glaciers indisputably contributes significantly to the seasonal discharge of rivers originating in glacierized regions. This is especially important in the arid region of northwestern China, where precipitation is very low and extremely variable. In dry years, precipitation is low, cloud cover is minimal, and solar radiation is extreme in the mountainous regions. In wet years, the situation is reversed. For example, during 1975–76, the temperature was low, and precipitation was abundant in the Qilian Shan region; at *Laohugou Bingchuan* in the western Qilian Shan, the annual total volume of glacier meltwater was 61,420,000 m^3—only 25 percent of the mean annual runoff in the dry years (1959–1961). Based on analyses of the hydrologic data on the *Ürümqi He No. 1 Bingchuan* in the Tian Shan and the *Laohugou Bingchuan* in the Qilian Shan, the Cv (annual discharge variation) values of glacier-meltwater-fed rivers are relatively large compared to the Cv values of the rivers fed by both glacier meltwater and runoff from rainfall, but are smaller than those of rivers fed only by runoff from rainfall.

Glaciers in China cover less than 0.6 percent of the country, but the total volume of glacier meltwater is about 2 percent of the annual discharge of rivers throughout China. The percentage of glacier meltwater in the total volume of river discharge is different for each drainage basin. The general tendency, however, is for the percentage contribution from glacier-meltwater to increase from the periphery to the interior of mountain ranges. For example, it is only 3.3 percent in the Shiyang He system of the eastern Qilian Shan, but increases to 35.7 percent in the Shule He region of the western Qilian Shan.

Glacier meltwater can be hazardous. In midsummer, the volume of glacier meltwater increases the base flow of rivers, increasing the threat of a flood. Moreover, in summer the ablation of glacier ice is high, and the rivers carry large quantities of sediment, often resulting in high-volume debris flows, particularly in the maritime-glacier region of southeastern Xizang Zizhiqu (Du, 1981). For example, a high-volume glacier-debris flow burst suddenly from the *Guxiang Gully* of Xizang Zizhiqu on the night of 29 September 1953, causing serious damage. Since then, the *Guxiang Bingchuan* glacier-debris flow occurs almost every year. In 1964, 85 of these sudden glacier debris flows occurred. Glacier-debris flows are also a major hazard in the Kunlun Shan, and along the China-Pakistan Highway in the Karakorum Shan.

Landsat MSS Images Used to Illustrate Selected Glacierized Areas

Landsat 1, 2, and 3 MSS Images acquired between 16 July 1973 and 18 July 1978 were analyzed to identify glacial features in nine glacierized regions of China. These images were compared to earlier aerial photography and previous study results, to determine which glaciers are retreating, which are advancing, and the rate of change.

Central Chinese Tian Shan Region

A Landsat 2 MSS image of the central Chinese Tian Shan (fig. 2, table 5) includes Ürümqi (1), the capital of the Xinjiang Uygur Zizhiqu (Autonomous Region), and the region to its southwest. This mountainous area belongs to the central section of the Tian Shan. Elevations of features on the Landsat image (fig. 2) range from about 700 m near Ürümqi to nearly 6,000 m. The broad valley floors visible in the southwest corner of the Landsat image are about 2,700 m in elevation. Precipitation in the region occurs mainly during the summer and decreases from west to east. Air temperatures remain below 0 °C.

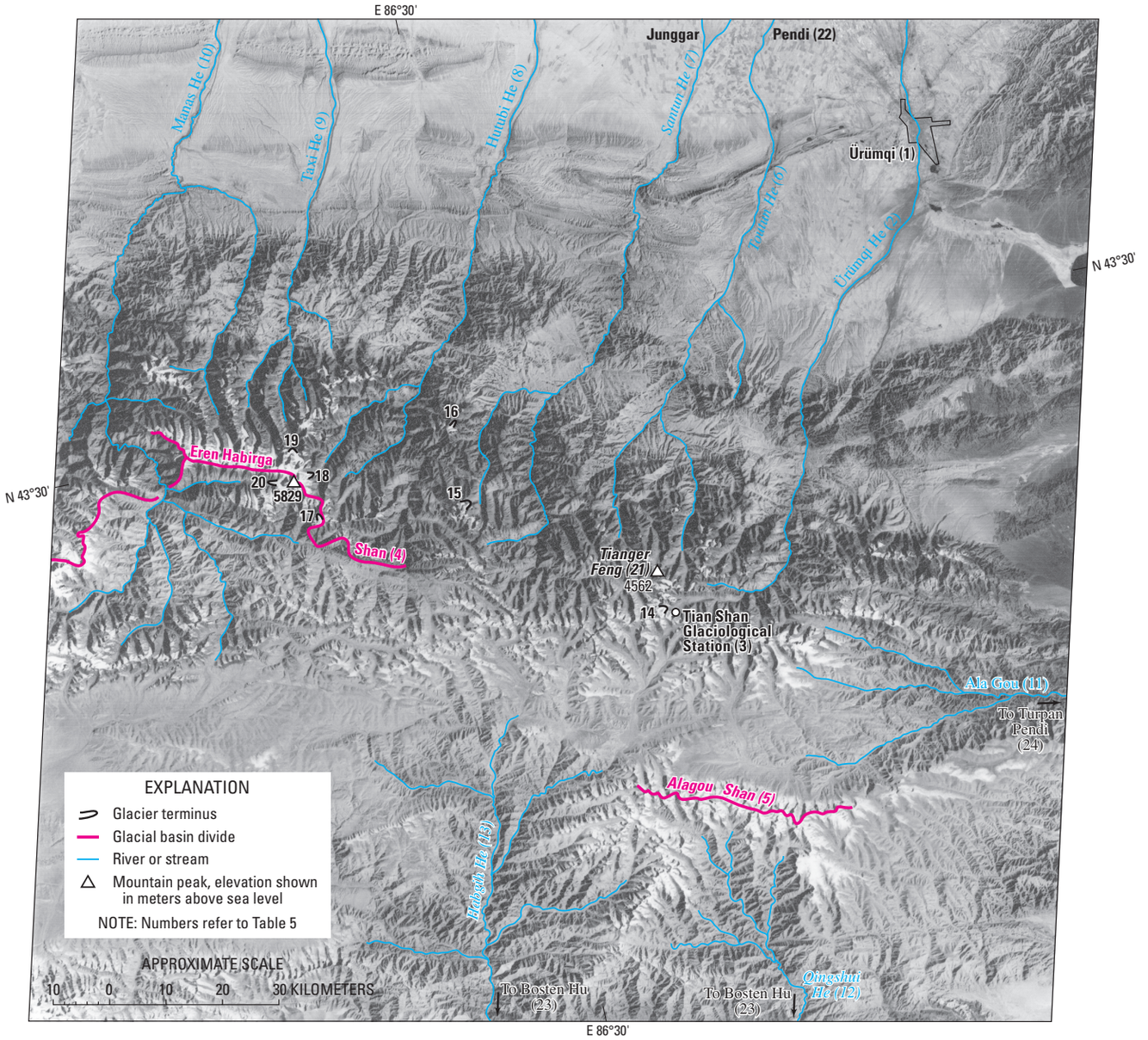


Figure 2.—*Annotated Landsat 2 MSS image of the central Chinese Tian Shan region. Drainage divides between glacierized basins shown in red; selected rivers shown in blue; elevations of selected peaks shown in meters; selected positions of glacier termini shown in black; numbers indicate place-names of geographic features that are keyed to table 5. Landsat 2 MSS image (2971–03523, band 7; 19 September 1977; Path 154–Row 30) from the U.S. Geological Survey, EROS Data Center, Sioux Falls, S. Dak.*

TABLE 5.—*Selected place-names of glaciers and other geographic features of the central Chinese Tian Shan region*

[See figure 2 for numbered locations of the place-names on a Landsat image of the region]

Place-name of glacier or other geographic feature	Latitude	Longitude
Ürümqi (1)	43°46′N.	87°35′E.
Ürümqi He (2)	43°30′N.	87°19′E.
Tian Shan Glaciological Station (3)	43°00′N.	86°30′E.
Eren Habirga Shan (4)	43°30′N.	85°00′E.
Alagou Shan (5)	42°47′N.	86°53′E.
Toutun He (6)	43°35′N.	87°10′E.
Santun He (7)	43°41′N.	86°55′E.
Hutubi He (8)	43°48′N.	86°36′E.
Taxi He (9)	43°51′N.	86°14′E.
Manas He (10)	43°56′N.	85°56′E.
Ala Gou (11)	42°52′N.	87°30′E.
Qingshui He (12)	42°33′N.	86°53′E.
Habgih He (13)	42°44′N.	86°21′E.
Upper Ürümqi He No. 1 Bingchuan (14)	43°05′N.	86°49′E.
Santun He No. 99 Bingchuan (15)	43°21′N.	86°26′E.
Santun He No. 102 Bingchuan (16)	43°27′N.	86°27′E.
Langtekazheng Bingchuan (17)	43°23′N.	86°06′E.
Hutubi He Urcheng No. 21 Bingchuan (18)	43°26′N.	86°06′E.
Taxi He No. 44 Bingchuan (19)	43°29′N.	86°04′E.
Manas He Cailagol No. 17 Bingchuan (20)	43°26′N.	86°01′E.
Tianger Feng (21)	43°10′N.	86°49′E.
Junggar Pendi (22)	45°30′N.	86°00′E.
Bosten Hu (23)	42°00′N.	87°00′E.
Turpan Pendi (24)	42°45′N.	89°00′E.

and glacier accumulation lasts for up to 10 months of the year. The glaciers shown on the Landsat image (fig. 2) are mainly cirque and valley glaciers of the continental type. At the present time, most of them are retreating.

Chinese glaciologists established a glacier research station known as the Tian Shan Glaciological Station (3) situated on the upper Ürümqi He (2) at an elevation of 3,539 m, near *Tianger Feng* (21). At this Station, research has been conducted on glacier flow, mass balance, physics, chemistry, hydrology; radiation and heat balances, and the extent of Quaternary glaciations. The average annual temperature on the surface of upper *Ürümqi He No. 1 Bingchuan* (14) is –8.4 °C. at an elevation of 3,840 m. The annual precipitation from 1959–1962 was 530 mm (Xie and Ge, 1965). Radiation accounts for 84.4 percent of the total summer surface heat input (Bai and Xie, 1965). Data from the

Eren Habirga Shan (4) indicates that the average annual air temperature of the glacierized areas ranges from –10 to –12 °C, and the annual precipitation is about 1,000 mm. Both conditions are favorable for glacier development, and the Eren Habirga Shan has the largest glacierized area of the Tian Shan, including 1,443 glaciers with a total of 1,566 km^2. Glaciers are considerably smaller in the *Alagou Shan* (5), the highest elevation of which is 4,415 m.

The Junggar Pendi (Basin) (22) lies north of the Tian Shan. There are several interior drainages running from south to north: the Ürümqi He (2), *Toutun He* (6), *Santun He* (7), Hutubi He (8), Taxi He (9), and Manas He (10). The Ala Gou (11) flows eastward into the Turpan Pendi (24); the *Qingshui He* (12) and the *Habgih He* (13) flow southward into the Bosten Hu (23).

Investigation of upper *Ürümqi He No. 1 Bingchuan* shows that it retreated 65.5 m during the period from September 1962 to August 1973, with an average recession of –6 m a^{-1}. Comparison of the aerial photograph acquired in August 1964 with the Landsat image acquired on 19 September 1977 (fig. 2) indicates that the glacier retreated about –65 m, or –5 m a^{-1}; for the same period, *No. 99 Bingchuan* (15) on the *Santun He* advanced +84 m, or +7.5 m a^{-1}; and *No. 102 Bingchuan* (16) on the *Santun He* retreated –467 m, or –36 m a^{-1}. A study of the variation of four glaciers in the Eren Habirga Shan [*Langtekazheng Bingchuan* (17), *Hutubi He Urcheng No. 21 Bingchuan* (18), *Taxi He No. 44 Bingchuan* (19), and *Manas He Cailagol No. 17 Bingchuan* (20)] using the same method shows that three glaciers (17, 18, 20) retreated with a maximum recession of –154 m, averaging –11.6 m a^{-1}; one glacier (19) advanced +100 m, averaging +6.1 a^{-1}.

Hantengri Feng and *Tomur Feng* Region of the Tian Shan

This area comprises Kyrgyzstan, the northwest corner of the Landsat 2 MSS false-color composite image (fig. 3, table 6) acquired on 16 October 1976, and the western Chinese part of the Tian Shan. The highest peaks in the area are *Tomur Feng* (2) (7,435 m) and *Hantengri Feng* (1) (6,995 m). The ridges are often 6,500 m high, with 2,500–3,500 m of relief. There are 1,357 glaciers in this region, covering a total area of 4,093 km^2.

Precipitation in this area is abundant; most of the water vapor comes from the west and northwest. About 70 percent of the precipitation occurs May through September, and 30 percent from October through April. Precipitation in the mountains increases with elevation and is 750–1,000 mm at the snowline (3,600–4,000 m elevation). Mean annual temperature at the snowline elevation is –7 to –11 °C, resulting in conditions favorable for glaciers (Liu and others, 1987).

The major mountain ranges are the north-south *Ziwu Ling* (3), Halik Shan (4), *Hantengri Shan* (5), and *Tomur Shan* (6). All of the south-flowing rivers drain inland into the Tarim Pendi: the *Muzart He* (7), *Karayulgun He* (8), Terang He (9), *Kokyar He* (10), and Aksu He (11).

Chinese glaciologists have investigated the *Tomur Feng* region along the *Qongterang He* watershed (Su and Wang, 1985; Su and others, 1985). There are 57 glaciers, with a total area of 266 km^2. The glaciers are an important water resource for agricultural areas to the south. Many of the glaciers in the area are retreating. The *Karagul Bingchuan* (12) retreated 15 m a^{-1} between 1964 and 1978; the *Tugbeliqi Bingchuan* (13) retreated 8 m a^{-1} between 1964 and 1976; the *Kiqikkuzbay Bingchuan* (14) retreated 15 m a^{-1} between 1942

and 1976; the *East Qongterang Bingchuan* (17) retreated 5 m a^{-1} between 1942 and 1978, and the *West Qongterang Bingchuan* (18) retreated 18 m a^{-1} between 1942 and 1976.

Other glaciers in the area are stable; including the *Kiqikterang Bingchuan* (16) and North and South Engil'chek glaciers (24 and 23, respectively) on the west side of *Ziwu Ling*. The North Engil'chek glacier terminates in a large ice-dammed lake that periodically produces jökulhlaups down the Engil'chek valley. The following glaciers are advancing: the *Saysepil Bingchuan* (19),

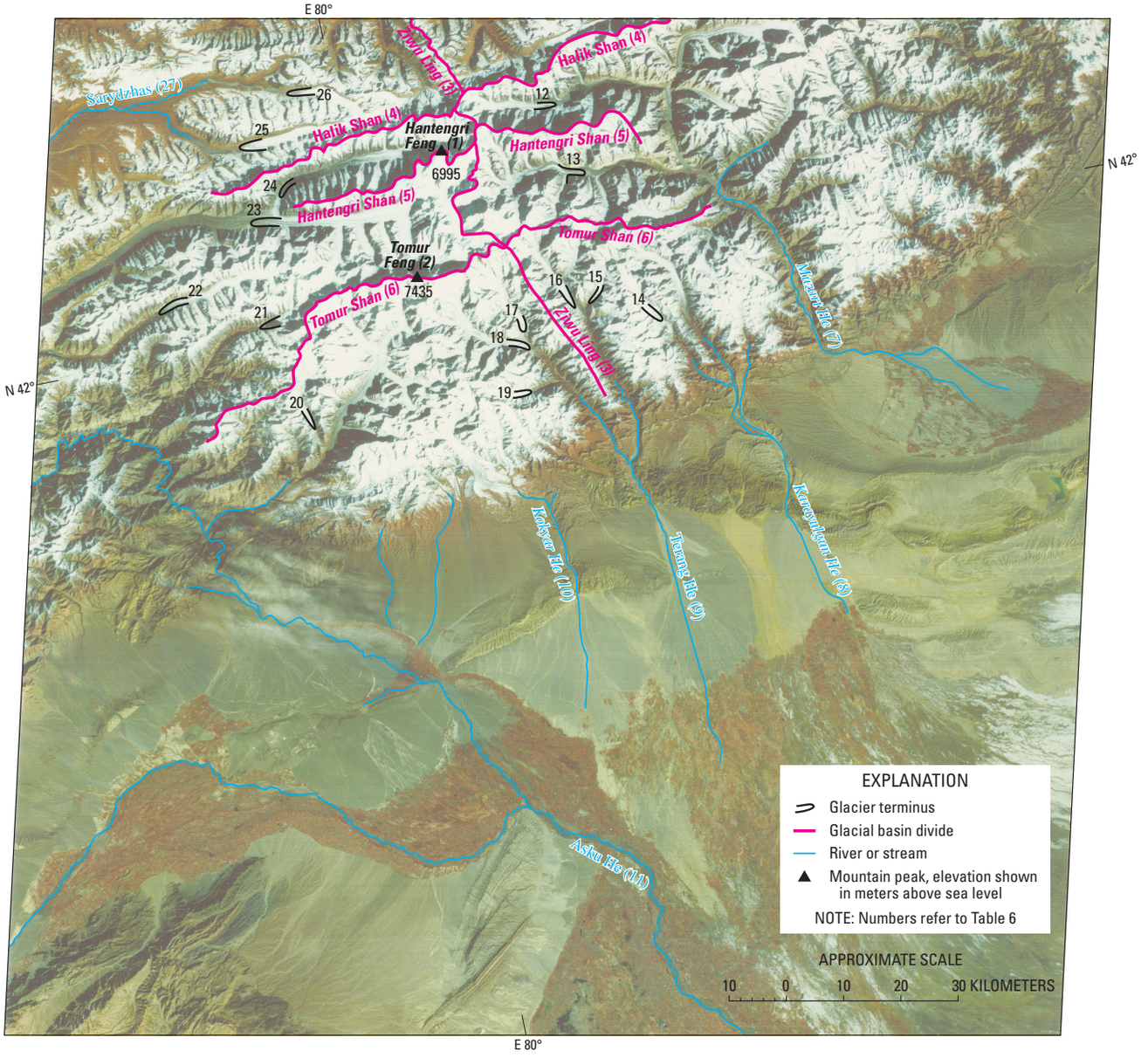


Figure 3.—*Annotated Landsat 2 MSS false-color composite image of the western part of the Chinese Tian Shan region, including the* Hantengri Feng -Tomur Feng *area. Drainage divides between glacierized basins shown in red; selected rivers shown in blue; elevations of selected peaks shown in meters; selected positions of glacier termini shown in black; numbers indicate place-names of geographic features that are keyed to table 6. Landsat 2 MSS image (2633–04315, bands 4, 5, 7; 16 October 1976; Path 158–Row 31) from the U.S. Geological Survey, EROS Data Center, Sioux Falls, S. Dak.*

TABLE 6.—*Selected place-names of glaciers and other geographic features of the western part of the Chinese Tian Shan region, including the* Hantengri Feng *and* Tomur Feng *regions*

[See figure 3 for number locations of the place-names on a Landsat image of the region]

Place-name of glacier or other geographic feature	Latitude	Longitude
Hantengri Feng (1)	42°14′N.	80°10′E.
Tomur Feng (2)	42°02′N.	80°05′E.
Ziwu Ling (3)(Meridianal ridge)	41°48′N.–42°23′N.	80°15′E.–80°20′E.
Halik Shan (4)	42°15′N.–42°26′N.	79°45′E.–80°42′E.
Hantengri Shan (5)	42°11′N.–42°17′N.	79°40′E.–80°42′E.
Tomur Shan (6)	41°51′N.–42°03′N.	79°36′E.–80°46′E.
Muzart He (7)	41°49′N.	80°54′E.
Karayulgun He (8)	41°40′N.	80°43′E.
Terang He (9)	41°41′N.	80°28′E.
Kokyar He (10)	41°38′N.	80°15′E.
Aksu He (11)	41°09′N.	80°11′E.
Karagul Bingchuan (12)	42°16′N.	80°27′E.
Tugbeliqi Bingchuan(13)	42°09′N.	80°29′E.
Kiqikkuzbay Bingchuan (14)	41°54′N.	80°36′E.
Ajen Bingchuan (15)	41°58′N.	80°27′E.
Kiqikterang Bingchuan (16)	41°57′N.	80°25′E.
East Qongterang Bingchuan (17)	41°46′N.	80°17′E.
West Qongterang Bingchuan (18)	41°44′N.	80°17′E.
Saysepil Bingchuan (19)	41°49′N.	80°15′E.
Aylonsu Bingchuan (20)	41°49′N.	79°49′E.
Telekiqi Bingchuan (21)	42°01′N.	79°34′E.
Kayind Bingchuan (22)	42°04′N.	79°33′E.
South Lednik Engil'chek (23)	42°21′N.	79°48′E.
North Lednik Engil'chek (24)	42°13′N.	79°52′E.
Lednik Mushketova (25)	42°18′N.	79°49′E.
Lednik Semënova (26)	42°21′N.	79°54′E.
Sarydzhas (river) (27)	42°23′N.	79°30′E.

which advanced 62 m a^{-1} between 1942 and 1976; the *Aylonsu Bingchuan* (20), which advanced 53 m a^{-1} between 1964 and 1976; and the *Kayind Bingchuan* (22), which advanced 38 m a^{-1} between 1942 and 1976 (Su and Wang, 1985). Lednik Mushketova (25) advanced about +4,500 m in 1956 and 1957; this was likely a surge (Bakov, 1975).

Generally, glaciers in the western part of the region are stable or advancing, while those in the south are retreating. In the last few years, the snowline elevation has been increasing and as a consequence, retreat has quickened.

Western Qilian Shan Region

A Landsat 2 MSS false-color composite image (fig. 4, table 7) includes an area of the western Qilian Shan located in the boundary district between Gansu and Qinghai Provinces. Elevations range from 2,000 m in the broad valley in the northwest corner of the image to peaks of 5,600 m.

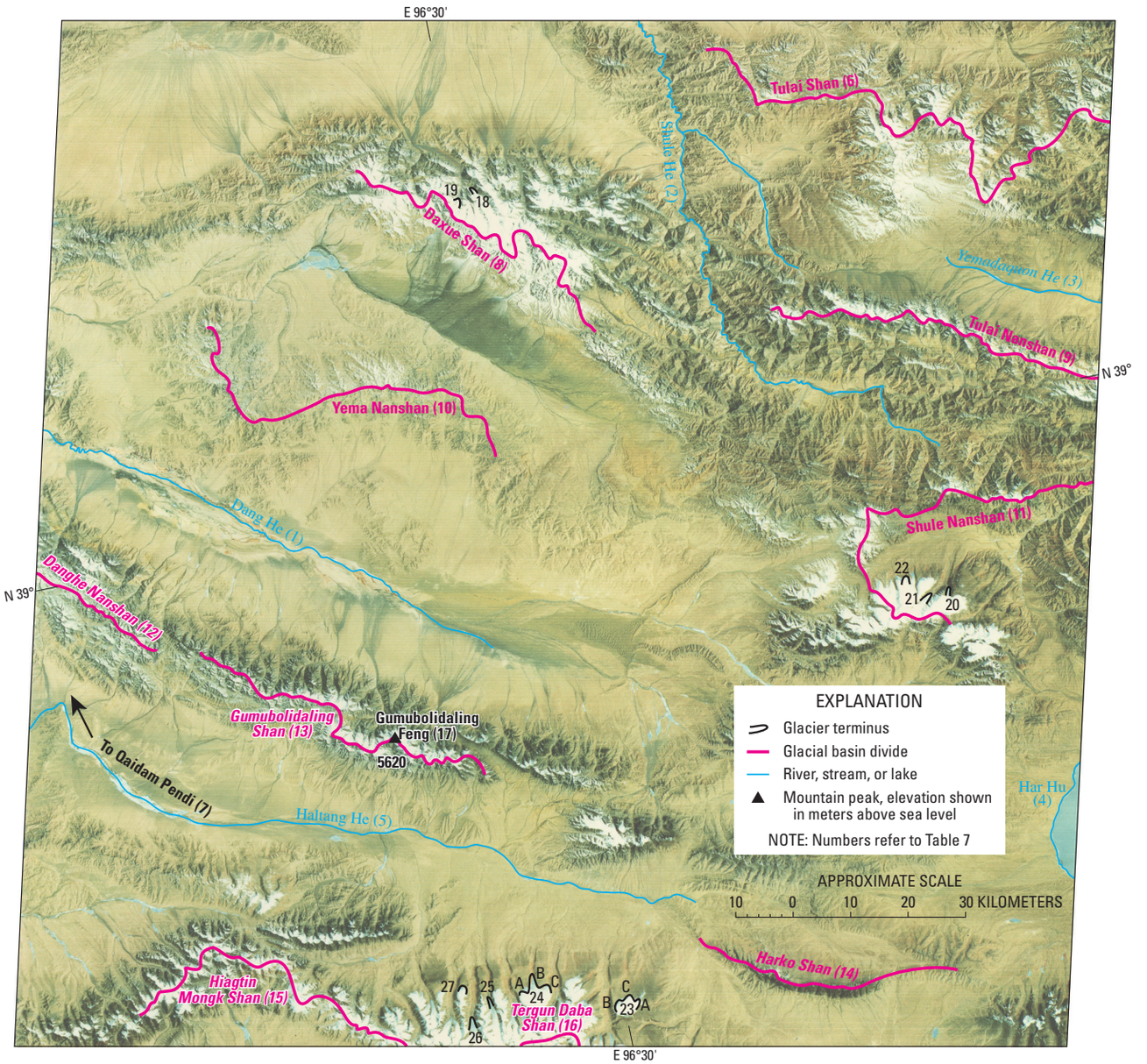


Figure 4.—*Annotated Landsat 2 MSS false-color composite image of the western Qilian Shan region. Drainage divides between glacierized basins shown in red; selected rivers shown in blue; elevations of selected peaks shown in meters; selected positions of glacier termini shown in black; numbers indicate place-names of geographic features that are keyed to table 7. Landsat 2 MSS image (2819–03160, bands 4, 5, 7; 20 April 1977; Path 146–Row 33) from U.S. Geological Survey, EROS Data Center, Sioux Falls, S. Dak.*

TABLE 7.—*Selected place-names of glaciers and other geographic features of the western Qilian Shan region*

[See figure 4 for number locations of the place-names on a Landsat image of the region]

Place-name of glacier or other geographic feature	Latitude	Longitude
Dang He (1)	39°00′N.	96°00′E.
Shule He (2)	39°30′N.	97°00′E.
Yemadaquon He (3)	39°09′N.	97°36′E.
Har Hu (4)	38°18′N.	97°32′E.
Haltang He (5)	38°33′N.	96°00′E.
Tulai Shan (6)	39°30′N.	97°29′E.
Qaidam Pendi (7)	37°00′N.	93°00′E.
Daxue Shan (8)	39°24′N.	96°36′E.
Tulai Nanshan (9)	39°08′N.	97°23′E.
Yema Nanshan (10)	39°15′N.	96°13′E.
Shule Nanshan (11)	38°53′N.	97°16′E.
Danghe Nanshan (12)	39°00′N.	95°36′E.
Gumubolidaling Shan (13)	38°42′N.	96°00′E.
Harko Shan (14)	38°11′N.	96°52′E.
Hiagtin Mongk Shan (15)	38°15′N.	95°53′E.
Tergun Daba Shan (16)	38°08′N.	96°21′E.
Gumubolidaling Feng (17)	38°38′N.	96°08′E.
Laohugou No. 12 Bingchuan (18)	39°29′N.	96°31′E.
Laohugou No. 18 Bingchuan (19)	39°28′N.	96°29′E.
Zahelung Bingchuan (20)	38°45′N.	97°13′E.
Lungno'odang Bingchuan (21)	38°45′N.	97°15′E.
Yematan No. 2 Bingchuan (22)	38°48′N.	97°18′E.
Ih Xahalgou Gol No. 1 Bingchuan (23)	38°09′N.	96°30′E.
Mohalxalge Bingchuan (24)	38°12′N.	96°19′E.
Gurban Gol No. 1 Bingchuan (25)	38°12′N.	96°13′E.
Horbaxahige No. 10 Bingchuan (26)	38°10′N.	96°11′E.
Horbaxahige No. 13 Bingchuan (27)	38°13′N.	96°10′E.

Under conditions of continental climate, many large continental glaciers exist and are an important water resource for the *Hexi Zoulang* (Corridor) of Gansu Province and the Qaidam Pendi (7) of Qinghai Province. The drainage systems shown on the Landsat 2 MSS image (fig. 4, table 7) include the Dang He (1), the Shule He (2), and the *Yemadaquon He* (3), a tributary to the Beida He; all drain inland and eventually northward into the *Hexi Zoulang* (Corridor). The Har Hu (4) is an independent inland drainage. The Haltang He (5) flows into the Qaidam Pendi (7).

The mountain ranges from north to south are the Tulai Shan (6), the Daxue Shan (8), Tulai Nanshan (9), Yema Nanshan (10), Shule Nanshan (11), Danghe Nanshan (12), the *Gumubolidaling Shan* (13) the *Harko Shan* (14), the *Hiagtin Mongk Shan* (15), and the Tergun Daba Shan (16); the highest peak is *Gumubolidaling Feng* (17) at an elevation of 5,620 m.

The glaciers are concentrated in the Daxue Shan (8), the Shule Nanshan (11), the *Gumubolidaling Shan* (13), the *Hiagtin Mongk Shan* (15), and the Tergun Daba Shan (16). Most of the glaciers of the Qilian Shan retreated between 1966 and 1977. Glaciers in the *Hiagtin Mongk Shan*, however, generally advanced during that period.

Most Chinese glaciologic research has been done on the glaciers of the Daxue Shan (8). The *Laohugou No. 12 Bingchuan* (18), in the Daxue Shan, is 10.1 km long, the longest in the Qilian Shan. It is a typical continental type glacier with sub-freezing ice temperatures and a clean surface. Field surveys indicate that this glacier retreated –72 m (–5m a^{-1}) from May 1962 to August 1976. The *Laohugou No. 18 Bingchuan* (19) has a snowline at an elevation of 4,710 m and a terminus at 4,440 m; field surveys show a retreat of –30 m (–2 m a^{-1}) from May 1962 to August 1976. For the period 1957 through 1973, the *Laohugou No. 12 and 18 Bingchuan* retreated –150 m and –76 m, respectively, and exhibited a much greater rate of retreat during the late 1950s and early 1960s than later.

Three major glaciers in the Shule Nanshan all retreated between 1966 and 1977, as determined from 1966 aerial photographs and a Landsat image acquired on 20 April 1977 (fig. 4). The flat-topped *Zahelung Bingchuan* (20), with a snowline at 4,840 m and terminus at 4,540 m, retreated –250 m; the *Lungo'odang Bingchuan* (21), which heads in a 5,472 m peak, and has its snowline at 5,075 m and its terminus at 4,500 m, retreated –150 m; and the sloping *Yematan No. 2 Bingchuan* (22), with a terminus at 4,550 m, retreated –70 m.

Several termini position changes were also seen in the *Hiagtin Mongk Shan (15)* between 1966 and 1977. The *Ih Xahalgou Gol No. 1 Bingchuan* (23) has a flat accumulation zone with three advancing ice tongues (A, B, and C): A advanced +1,000 m, B advanced +100 m, and C advanced +100 m. The lowest terminus is at an elevation of 4,700 m. The *Mohalxalge Bingchuan* (24) also has three ice tongues which are at 4,470 m or above; the glacier's snowline elevation is 4,810 m. A advanced +100 m, B advanced +200 m, and C experienced a minor retreat. The *Gurban Gol No. 1 Bingchuan* (25) advanced +1,300 m, the *Horbaxahige No.10 Bingchuan* (26) was stable, and the *Horbaxahige No. 13 Bingchuan* (27), with its head at an elevation of 5,361 m and its terminus at 4,845 m, advanced +100 m.

Qogir Feng (K2) of the Karakorum Shan Region

The northern two-thirds of a Landsat 3 MSS false-color composite image (fig. 5, table 8) shows the Chinese Xinjiang Region; to the south is the Kashmir of Pakistan and India. Physiographically, the area includes the western Kunlun Shan (19) and eastern Karakorum Shan (20). Precipitation south of the Karakorum Shan is much greater than north of the range, and, accordingly, glaciers are larger on the southern slopes. Because of the extremely high elevation, including Qogir Feng (K2) (18) at 8,611 m, many large glaciers have developed: the *Yengisogat Bingchuan* (1), *Yulin Bingchuan* (2), *Qogir Bingchuan* (3), *Skyang Bingchuan* (4), *Gasherbrum Bingchuan* (5), *Urdok Bingchuan* (6), *Sitager Bingchuan* (7), *Teram Kangri Bingchuan* (8), *Kyagar Bingchuan* (9), *North,* Central, and *South* Rimo Glaciers (10, 11, 12), Siachen Glacier (13), Baltoro Glacier (14), *Tatrugou Bingchuan* (15), *Sudikuwadigou Bingchuan* (16), and *Qiadijileg Bingchuan* (17).

Recent changes in many of these glaciers were determined using maps, aerial photographs, and Landsat images. The *Yengisogat Bingchuan* (1) is the longest glacier in China. It is 42 km long, has a snowline elevation of about 5,450 m, and terminus at 4,000 m. Based on a map by Shipton (1938), a 1968 map, and Landsat images of 1973, the glacier was stable and the terminus did not move. From 1973 to 1978, the terminus position still did not change, but the clean ice zone moved 500 m downglacier (Shipton, 1938; Zhang, 1980).

From 1937 to 1968, the *Qogir Bingchuan* (3) retreated –1,700 m, and the *Skyang Bingchuan* (4) retreated –4,200 m. From 1973 to 1978, the *Skyang Bingchuan* retreated an additional –1,000 m. From 1973 to 1978, the western part of the *Teram Kangri Bingchuan* (8) retreated –300 m, while the eastern part advanced +300 m.

In 1926, the *Kyagar Bingchuan* (9) dammed the *Shaksgam He* (25) (Mason, 1930). An ice-dammed lake again formed between 1976 and 1978 (Hewitt, 1979), suggesting that a recession occurred between 1926 and 1976; but since 1976 the *Kyagar Bingchuan* has advanced. Between 3 September 1961 and 6 September 1978, repeated failures of the ice dam generated multiple jökulhlaups; the maximum flood discharges were 6,270 $m^3 s^{-1}$ and 4,700 $m^3 s^{-1}$ respectively (Zhang and others, 1990). Other glaciers have also recently advanced; from 1968 to 1978, the *Tatrugou Bingchuan* (15), *Sudikuwadigou Bingchuan* (16), and *Qiadijileg Bingchuan* (17) advanced +705 m, +500 m, and +60 m, respectively. In general, the glaciers of the Karakorum Shan region of China have been advancing. During the recent warming, however, recession of the glaciers has occurred.

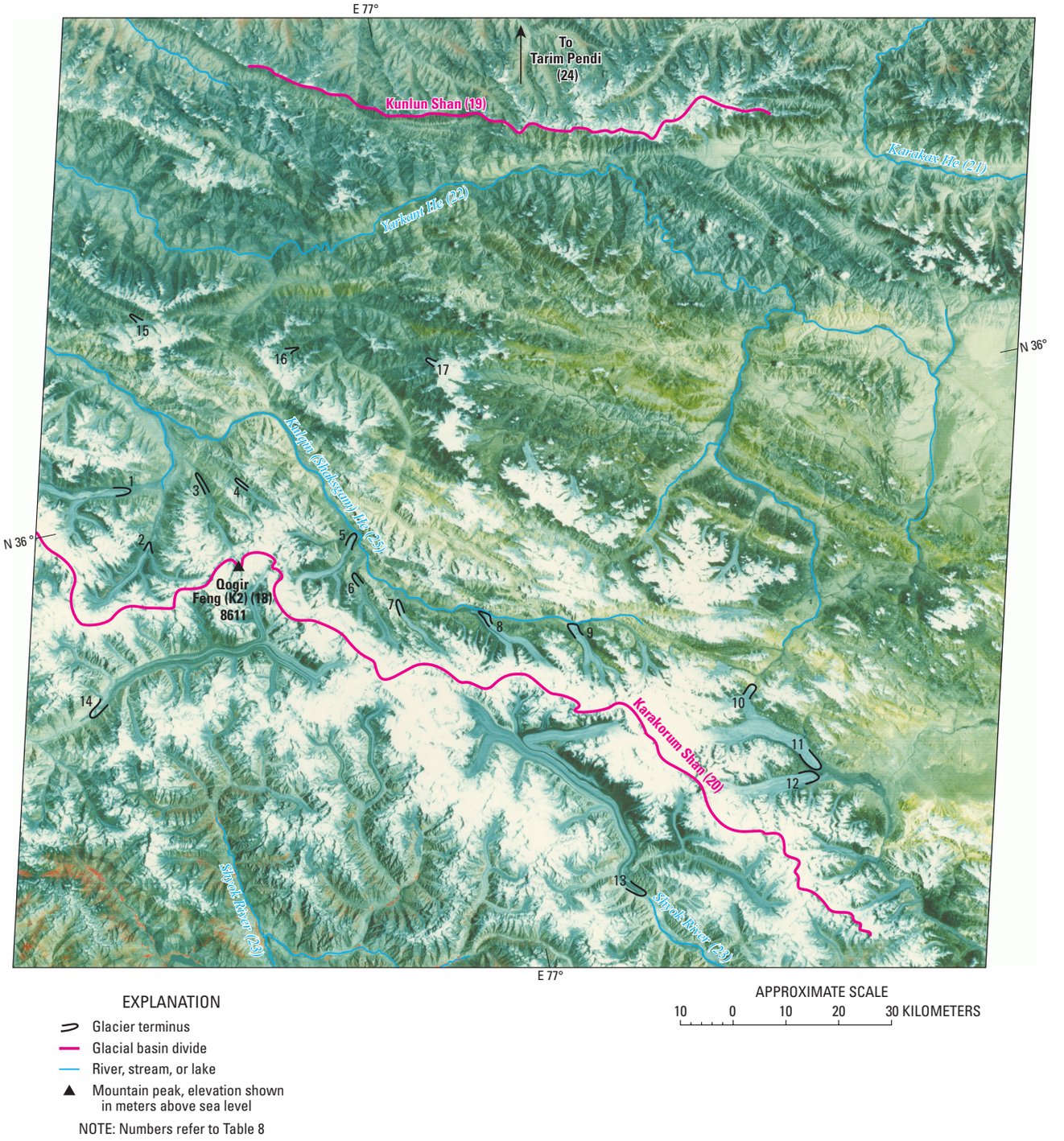


Figure 5.—*Annotated Landsat 3 MSS false-color composite image of the Qogir Feng (K2) area of the Karakorum Shan region. Drainage divides between glacierized basins shown in red; selected rivers shown in blue; elevations of selected peaks shown in meters; selected positions of glacier termini shown in black; numbers indicate place-names of geographic features that are keyed to table 8. Landsat 3 MSS image (30135–04492; bands 4, 5, 7; 18 July 1978; Path 159–Row 35) from U.S. Geological Survey, EROS Data Center, Sioux Falls, S. Dak.*

TABLE 8.—*Selected place-names of glaciers and other geographic features of the Qogir Feng (K2) of the Karakorum Shan region*

[See figure 5 for number locations of the place-names on a Landsat image of the region]

Place-name of glacier or other geographic feature	Latitude	Longitude
Yengisogat Bingchuan (1)	36°03′N.	76°17′E.
Yulin Bingchuan (2)	35°58′N.	76°21′E.
Qogir Bingchuan (3)	36°04′N.	76°29′E.
Skyang Bingchuan (4)	36°02′N.	76°32′E.
Gasherbrum Bingchuan (5)	35°55′N.	76°46′E.
Urdok Bingchuan (6)	35°51′N.	76°45′E.
Sitager Bingchuan (7)	35°47′N.	76°49′E.
Teram Kangri Bingchuan (8)	35°46′N.	76°59′E.
Kyagar Bingchuan (9)	35°43′N.	77°11′E.
North Rimo Glacier (10)	35°32′N.	77°32′E.
Central Rimo Glacier (11)	36°22′N.	77°38′E.
South Rimo Glacier (12)	35°21′N.	77°37′E.
Siachen Glacier (13)	35°13′N.	77°10′E.
Baltoro Glacier (14)	35°42′N.	76°11′E.
Tatrugou Bingchuan (15)	36°20′N.	76°24′E.
Sudikuwadigou Bingchuan (16)	36°10′N.	76°40′E.
Qiadijileg Bingchuan (17)	36°11′N.	76°59′E.
Qogir Feng (K2) (18)	35°55′N.	76°30′E.
Kunlun Shan (19)	36°33′N.	77°13′E.
Karakorum Shan (20)	35°39′N.	76°46′E.
Karakax He (21)	36°22′N.	78°03′E.
Yarkant He (22)	36°25′N.	77°15′E.
Shyok River (23)	35°09′N.–35°15′N.	77°16′E.–76°24′E.
Tarim Pendi (24)	39°30′N.	83°30′E.
Kulqin (Shaksgam) He (25)	36°09′N.	76°24′E.

Western Kunlun Shan Region

A Landsat 2 MSS image (fig. 6, table 9) shows glaciers concentrated in the lower third of the image, in the western Kunlun Shan region (1) on the border of Xinjiang Uygur Zizhiqu and Xizang Zizhiqu (Tibet Autonomous Region). These glaciers comprise about 8,000 km² of snow and ice — the largest glacier concentration in China. *Kunlun Feng* (2), at 7,167 m, is the highest peak in the area; the valley floors in the south are at an elevation of 5,000 m, and the northern desert is at 1,500 m. The *Guliya Binggai* (ice cap) (9) is the largest (200 km²), highest (6,700 m), and coldest (–19 °C at 10 m depth) glacier in Central Asia.

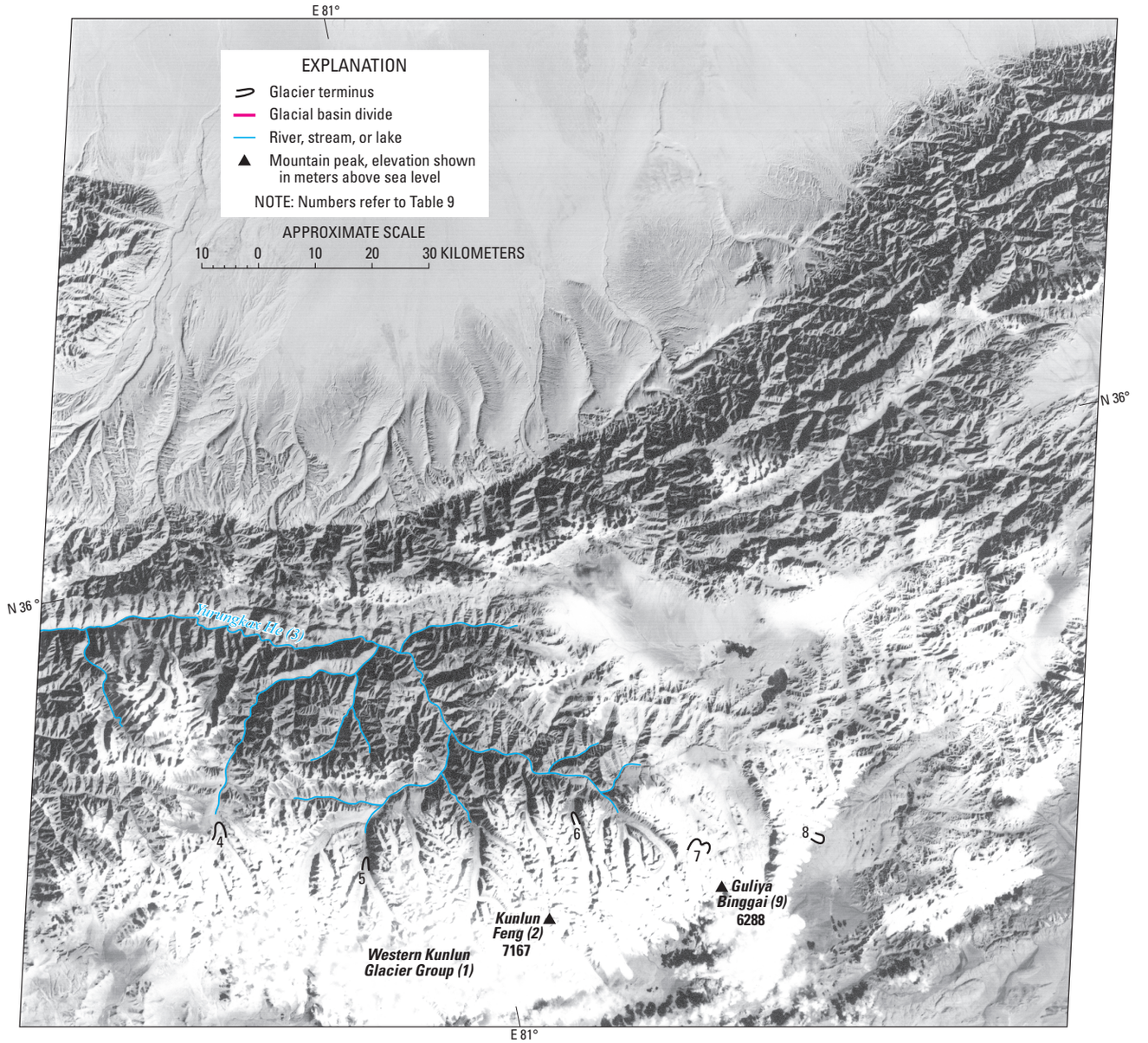


Figure 6.—*Annotated Landsat 2 MSS image of the western Kunlun Shan region. Selected rivers shown in blue; elevations of selected peaks shown in meters; selected positions of glacier termini shown in black; numbers indicate place-names of geographic features that are keyed to table 9. Landsat 2 MSS image (2667–04204, band 7; 19 November 1976; Path 156–Row 35) from U.S. Geological Survey, EROS Data Center, Sioux Falls, S. Dak.*

TABLE 9.—*Selected place-names of glaciers and other geographic features of the western Kunlun Shan region*

[See figure 6 for number locations of the place-names on a Landsat image of the region]

Place-name of glacier or other geographic feature	Latitude	Longitude
West Kunlun Glacier Group (1)	35°26′N.–35°13′N.	80°07′E.–81°40′E.
Kunlun Feng (2)	35°21′N.	81°05′E.
Yurungkax He (3)	35°57′N.	80°28′E.
Yurungkax He Source South No. 51 Bingchuan (4)	35°35′N.	80°29′E.
Kunlun Bingchuan (5)	35°29′N.	80°51′E.
Upper Yurungkax He No. 20 Bingchuan (6)	35°30′N.	81°11′E.
Yakabaktak He No. 10 Bingchuan (7)	35°26′N.	81°21′E.
Atedimu No. 13 Bingchuan (8)	35°24′N.	81°38′E.
Guliya Binggai (9)	35°17′N.	81°29′E.

The climate of this region is dry; annual precipitation is about 300 mm, of which the total on the southern slope is higher than that on the northern. The glacier meltwater from the southern slopes flows into the *Guozha Co* and the Tianshuihai basin, while that on the northern slopes empties mainly into the Yurungkax He (3).

The change over time in the positions of termini of several glaciers was determined using maps compiled from 1968–71 data and the 19 November 1976 Landsat 2 MSS image (fig. 6). The *Yurungkax He Source South No. 51 Bingchuan* (4) retreated –160 m between 1968–76. Its snowline elevation is at 5,800 m, and its terminus is at 5,125 m. The *Kunlun Bingchuan* (5) is a dendritic valley glacier with its snowline elevation at 5,920 m and its terminus at 4,880 m. The terminus is covered with debris. From 1970–76, the *Kunlun Bingchuan* advanced +400 m. The *Yakabaktak He No. 10 Bingchuan* (7) has its snowline at an elevation of 6,000 m; its head is at 6,288 m, and its terminus is at 5,510 m. It advanced +100 m between 1970–76. The *Atedimu No. 13 Bingchuan* (8) has a piedmont terminus at 5,610 m and a snowline elevation at 6,070 m. It retreated –90 m between 1971and 1976.

Typically, the northern slopes in this area are steep, making field investigations quite difficult; however, the southern slopes are gentle. This glacier group is an important water source for the *Hetun* region of the southern Xinjiang Region (fig. 1) (Li, 1975).

Tanggula Shan Region

A Landsat 1 MSS image (fig. 7, table 10) includes the area lying on the boundary between Xizang Zizhiqu (Tibet Autonomous Region) and Qinghai Sheng (Province) in China. This region includes the western section of the Tanggula Shan (15). The major glacier group of the region, the Geladaindong, is the source of the largest river in China, the Chang Jiang (Yangtze River). Subranges of the Tanggula Shan are seen at the northern and southern fringes of the Landsat image; the Jurhen Ul Shan (13) and *Gyotangmaryo Shan* (14), respectively.

Elevations in this region range from 3,000 m to over 6,000 m. The highest peak is Geladaindong (6) at 6,621 m. According to the data obtained from weather stations at an elevation of 4,900 m in an adjacent area, the average

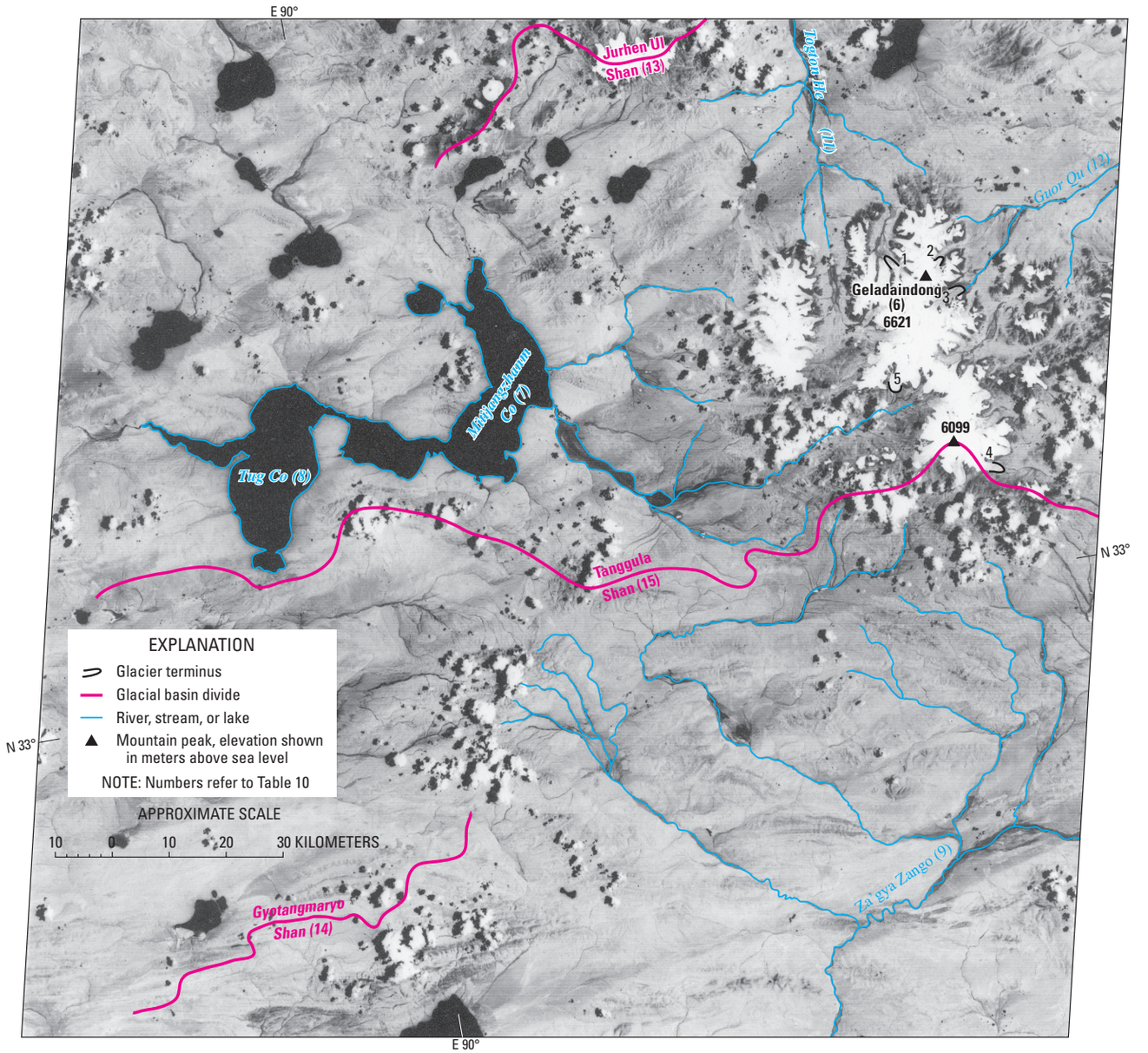


Figure 7.—*Annotated Landsat 1 MSS image of the Tanggula Shan region. Drainage divides between glacierized basins shown in red; selected rivers shown in blue; elevations of selected peaks shown in meters; selected positions of glacier termini shown in black; numbers indicate place-names of geographic features that are keyed to table 10. Landsat 1 MSS image (1358–04040, band 7; 16 July 1973; Path 149–Row 37) from U.S. Geological Survey, EROS Data Center, Sioux Falls, S. Dak.*

TABLE 10.—*Selected place-names of glaciers and other geographic features of the Tanggula Shan region*

[See figure 7 for number locations of the place-names on a Landsat image of the region]

Place-name of glacier or other geographic feature	Latitude	Longitude
Sumeiqu Bingchuan (1)	33°32′N.	91°03′E.
Guoriqu Bingchuan (2)	33°31′N.	91°09′E.
Gangjiaquba Bingchuan (3)	33°28′N.	91°10′E.
Goluqu Bingchuan (4)	33°09′N.	91°10′E.
Ganaqinmaqu Bingchuan (5)	33°20′N.	91°02′E.
Geladaindong (6)	33°29′N.	91°13′E.
Mitijangzhanm Co (7)	33°24′N.	90°19′E.
Tug Co (8)	33°23′N.	89°50′E.
Za'gya Zangbo (9)	32°33′N.	90°58′E.
Siling Co (south of the image)	31°50′N.	89°00′E.
Togton He (11)	33°49′N.	90°57′E.
Guor Qu (12)	33°34′N.	91°20′E.
Jurhen Ul Shan (13)	33°55′N.	90°37′E.
Gyotangmaryo Shan (14)	32°37′N.	89°47′E.
Tanggula Shan (15)	33°10′N.	90°20′E.

annual air temperature is –5.5 °C; the monthly average air temperature in January is –16 °C and the maximum monthly temperature (5.5 °C.) is in July. The duration of the sub 0 °C period is as long as 8 months. As a result, a deep layer of permafrost has developed in this region. Meteorological satellite data show that warm and moist air from the Bay of Bengal frequently moves northward and affects this area during summer. Therefore, 80 to 90 percent of the annual precipitation (about 550–650 mm) is concentrated in June, July, August, and September. The Landsat image was acquired on 16 July 1973 (fig. 7), early in the rainy season, so the ground surface was rather wet.

The lakes shown on the Landsat image are the *Mitijangzhanm Co* (7) and *Tug Co* (8). Glaciers drain southward into Za'gya Zangbo (9) and Siling Co (south of the image), westward into *Mitijangzhanm Co* (7), and northward into the *Togton He* (11) and eastward to the *Guor Qu* (12), two sources of the Chang Jiang.

The glaciers on Geladaindong (6) have a total area of 74.94 km^2 (Glacier Inventory Basin No. 5Z213B16). These glaciers are typical continental type, and are developed on a planation surface in the shape of small ice caps with flow radiating from a central accumulation area. The glacier surfaces are very clean, because there are no higher sources of rock debris. Most of the glaciers in the Geladaindong are currently advancing. In comparing November 1969 aerial photographs with the 16 July 1973 Landsat image (fig. 7), several changes in glacier position can be observed. The *Sumeiqu Bingchuan* (1) terminates at 5,360 m, and has a snowline elevation of 5,770 m — its terminus retreated about 260 m (–69 m a^{-1}) for this period. The *Guoriqu Bingchuan* (2) advanced 190 m (about +50 m a^{-1}). The *Goluqu Bingchuan* (4) advanced 160 m (about +43 m a^{-1}). The *Ganaqinmaqu Bingchuan* (5) advanced 140 m (about +37 m a^{-1}).

Western Nyainqêntanglha Shan Region

A Landsat 2 MSS image (fig. 8, table 11) features the western Nyainqêntanglha Shan (2) and Nam Co (1) in the Xizang Zizhiqu (Tibet Autonomous Region). The *Bopuri Shan* (3) and the Nyainqêntanglha Shan form the divide between the inland-lake system to the north and the Indian Ocean to the south. The larger rivers of the inland-lake system are the *Bo Qu* (4), which drains into Nam Co, the *Tarma Zangbo* (5), and *Yougzhu Zangbo* (19), which drain into *Muggen Co* (13), and the Chumbu Zangbo (6) which drains into *Yoqia Co*. Other lakes are *Sen Co* (9), *Quru Co* (10), *Ringco Ogma* (11), *Ringco Kungma* (12), *Muggen Co* (13), and Gomang Co (14). The rivers of the inland

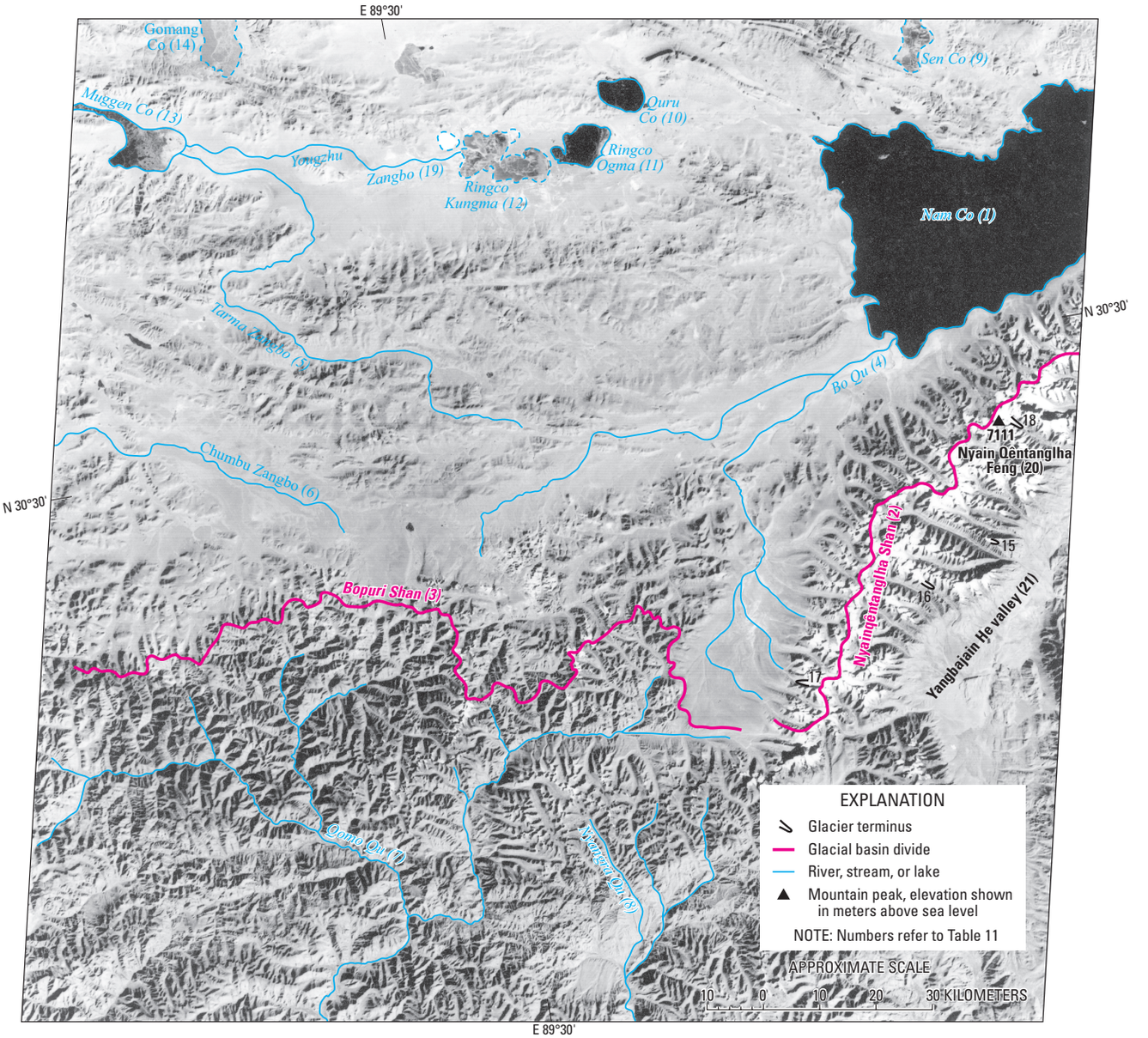


Figure 8.—*Annotated Landsat 2 MSS image of the western Nyainqêntanglha Shan region. Drainage divides between glacierized basins shown in red; selected rivers shown in blue; elevations of selected peaks shown in meters; selected positions of glacier termini shown in black; numbers indicate place-names of geographic features that are keyed to table 11. Landsat 2 MSS image (2696–03410, band 7; 18 December 1976; Path 149–Row 39) from U.S. Geological Survey, EROS Data Center, Sioux Falls, S. Dak.*

TABLE 11.—*Selected place-names of glaciers and other geographic features of the western Nyainqêntanglha Shan region*

[See figure 8 for number locations of the place-names on a Landsat image of the region]

Place-name of glacier or other geographic feature	Latitude	Longitude
Nam Co (1)	30°45′N.	90°30′E.
Nyainqêntanglha Shan (2)	30°18′N.	90°19′E.
Bopuri Shan (3)	30°13′N.	89°15′E.
Bo Qu (4)	30°29′N.	90°15′E.
Tarma Zangbo (5)	30°46′N.	89°26′E.
Chumbu Zangbo (6)	30°30′N.	89°02′E.
Qomo Qu (7)	29°45′N.	89°15′E.
Nyangra Qu (8)	29°37′N.	89°38′E.
Sen Co (9)	31°00′N.	90°28′E.
Quru Co (10)	30°59′N.	89°53′E.
Ringco Ogma (11)	30°55′N.	89°50′E.
Ringco Kungma (12)	30°56′N.	89°39′E.
Muggen Co (13)	31°02′N.	89°00′E.
Gomang Co (14)	31°11′N.	89°10′E.
Botang Bingchuan (15)	30°10′N.	90°29′E.
Linggong Bingchuan (16)	30°06′N.	90°18′E.
Tarqongqu Bingchuan (17)	30°00′N.	90°03′E.
Pagnuqu Bingchuan (18)	30°20′N.	90°33′E.
Yougzhu Zangbo (19)	30°58′N.	89°24′E.
Nyainqêntanglha Feng (20)	30°20′N.	90°31′E.
Yangbajain He valley (21)	30°05′N.	90°30′E.

regions have low erosive power. As a result, the surrounding areas have gentle relief and excellent highland pastures; the mean elevation is 5,200 m. The major rivers flowing to the Indian Ocean are the *Qomo Qu* (7) and the *Nyangra Qu* (8). Both are tributaries of the Yarlung Zangbo Jiang.

Under the influence of the Indian Ocean monsoon, the annual precipitation is 380 mm in a valley east of the Nyainqêntanglha Shan at 4,300 m; 79 percent of the precipitation occurs in June, July, and August. The mean annual temperature is 2.5 °C. The mean annual temperature at the snowline (5,700 m) is estimated to be –7.5 °C.

The major glaciers are concentrated around Nyainqêntanglha Feng (20) (7,111); most are small cirque or valley glaciers, 4 to 5 km long. A comparison of 1970 maps with the 18 December 1976 Landsat 2 MSS image (fig. 8) indicates that the *Botang Bingchuan* (15) advanced +80 m, the *Linggong Bingchuan* (16) retreated –100 m, and the *Tarqongqu* (17) and *Pagnuqu* (18) *Bingchuan* were stable.

Moraines of past Quaternary glaciation can be easily seen on the Landsat image (fig. 8). Evidence of a major prehistoric ice tongue can be seen north of the *Bopuri Shan* (3); a small lake now occurs in a depression near the terminus of the former glacier. Piedmont glaciers extended to the west and into the present Nam Co from the Nyainqêntanglha Shan, and, to the southeast, glaciers from straight valleys terminated at the edge of the Yangbajain He valley (21).

Eastern Nyainqêntanglha Shan Region

A Landsat 2 MSS false-color composite image (fig. 9, table 12) includes the area at the junction of the *Kangri Garbo Shan* (1) in the eastern Nyainqêntanglha Shan region of the Xizang Zizhiqu (Tibet Autonomous Region) and *Subola Ling* (Mountains) (2) in the Hengduan Shan. Peaks in this region rise to 6,600 m and valleys generally are at about 2,000 m, thus relief is extreme and vertical zonality of environment is very distinct.

This area is strongly affected by the southwestern monsoon (Indian Ocean monsoon); monsoonal precipitation is extremely high, and clouds and fog are common. The major rivers are the Zayü Qu (13) and its tributary, the *Gomrigarbu Qu* (3); the *Dalung Qu* (4) which joins the Yarlung Zangbo Jiang (8); the Parlung Zangbo (5); and the Sang Qu (6), a tributary of the Zayü Qu (13).

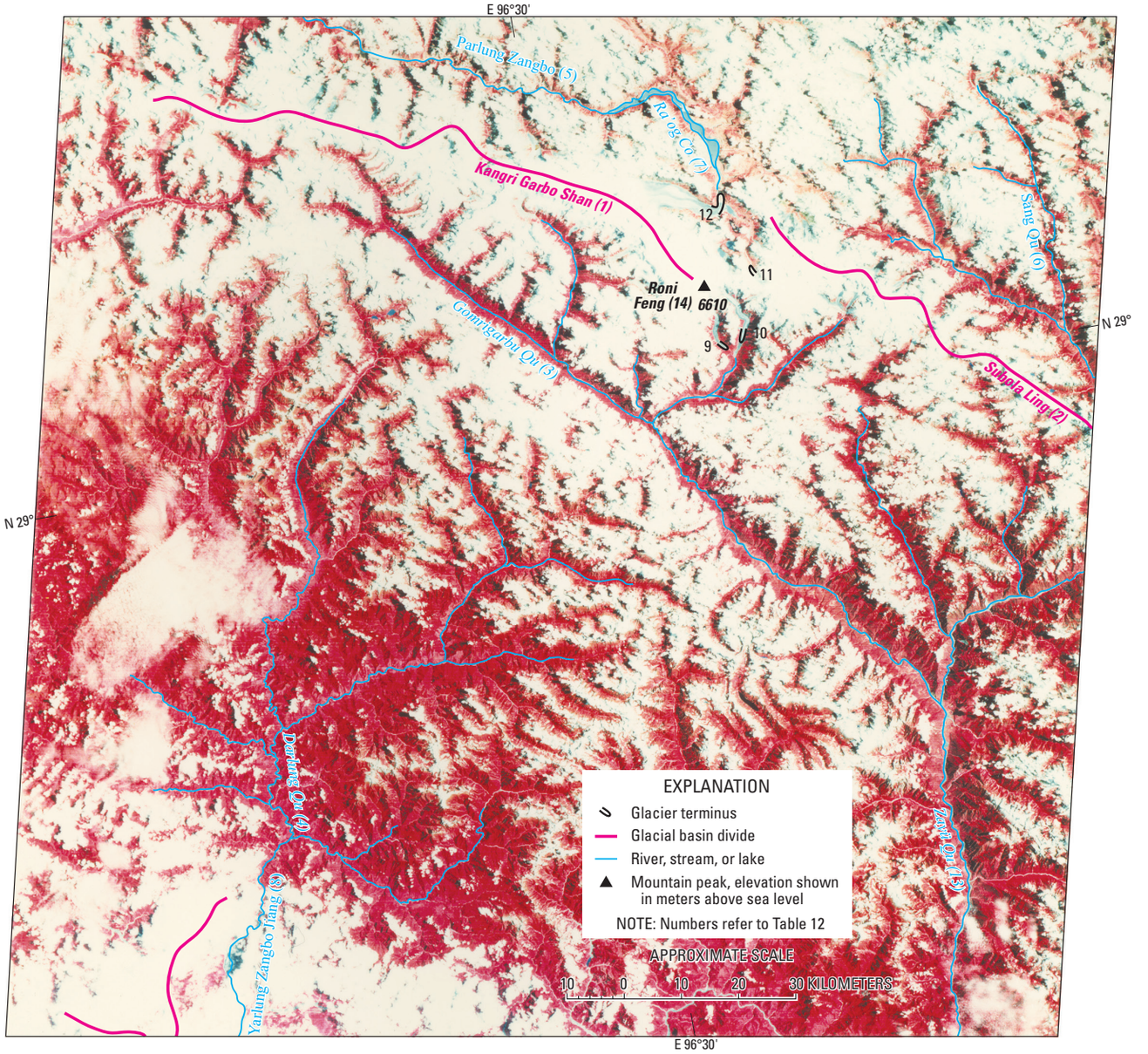


Figure 9.—*Annotated Landsat 2 MSS false-color composite image of the eastern Nyainqêntanglha Shan region. Drainage divides between glacierized basins shown in red; selected rivers shown in blue; elevations of selected peaks shown in meters; selected positions of glacier termini shown in black; numbers indicate place-names of geographic features that are keyed to table 12. Landsat 2 MSS image (2925–03020, bands 4, 5, 7; 4 August 1977; Path 144–Row 40) from U.S. Geological Survey, EROS Data Center, Sioux Falls, S. Dak.*

TABLE 12.—*Selected place-names of glaciers and other geographic features of the eastern Nyainqêntanglha Shan region*

[See figure 9 for number locations of the place-names on a Landsat image of the region]

Place-name of glacier or other geographic feature	Latitude	Longitude
Kangri Garbo Shan (1)	29°25′N.	96°26′E.
Subola Ling (2)	29°04′N.	97°10′E.
Gomrigarbu Qu (3)	28°53′N.	96°48′E.
Dalung Qu (4)	28°30′N.	95°50′E.
Parlung Zangbo (5)	29°37′N.	96°18′E.
Sang Qu (6)	29°05′N.	97°22′E.
Ra'og Co (7)	29°30′N.	96°45′E.
Yarlung Zangbo Jiang (8)	28°00′N.	95°42′E.
Roni Bingchuan (9)	29°08′N.	96°45′E.
Abzha Bingchuan (10)	29°07′N.	96°47′E.
Zoqupu Bingchuan (11)	29°10′N.	96°52′E.
Yagnung Bingchuan (12)	29°19′N.	96°42′E.
Zayü Qu (13)	28°21′N.	97°00′E.
Roni Feng (14)	29°09′N.	96°45′E.

Major maritime glaciers have developed in this area, and are characterized by temperate ice, intensive ablation, and high mass-exchange rate. It is estimated that average annual precipitation near the snowline is 2.5–3.0 m and average annual temperature is –2 to –4 °C (Li and Zheng, 1981). Annual ablation is the highest in China, 6.5–8.0 m of water equivalent. The largest glacier in the area *Kyaggen Bingchuan* (30°31′N., 94°42′E.) is located west of figure 9. It is 35.3 km long and has an area of 206.7 km^2. The snowline is at 4,900 m and the terminus at 3,900 m. It has a very broad accumulation area of about 165 km^2 (Li and others, 1986). The second largest glacier in the area is shown on figure 9 and is the *Yagnung Bingchuan* (12); it is 32.5 km long, with the snowline at 5,040 m, the terminus at 3,960 m, and an area of 191.45 km^2 (Shi and others, 2005). The 60 km^2 ablation area has three slightly contorted medial moraines, suggesting that it may have a surge history.

Because of the frequent cloud cover, aerial observations of these glaciers are rare. Landsat images from 1973 and 1977 show that the *Yagnung Bingchuan* (12) advanced +230 m over that period. In the early 1930s, the *Abzha* (10) and *Roni* (9) *Bingchuan* were joined (Kingdon-Ward, 1934). The 4 August 1977 Landsat MSS image (fig. 9) shows a separation between these two glaciers of 1,350 m, indicating major recession of the *Roni Bingchuan*. *Roni Feng* (14) (6,610 m) is at the head of the *Abzha Bingchuan* (10); the snowline elevation is 4,600 m and its terminus lies at 2,550 m. Observations by a local resident suggest that the *Abzha Bingchuan* has receded –700 m in the last 50 years, and observations from 1973–1977 showed a –193 m recession (Li and Zheng, 1981). Field work in 1976, however, indicated that the glacier was thickening, and by 1978 the *Abzha Bingchuan* had advanced +200 m. A small glacier, the *Zoqupu Bingchuan* (11), near the *Abzha Bingchuan,* advanced +350 m from 1973 to 1977.

Central Himalaya Region

A Landsat 2 MSS false-color composite image (fig. 10, table 13) includes the area of Qomolangma Feng (Mount Everest) (1) (8,848 m), in the southeast corner, and Xixabangma Feng (5) (8,012 m), in the southwest corner; both are in the central part of the Himalaya. Other major peaks are *Lhotse Feng* (2) (8,501 m), *Makalu Shan* (3) (8,470 m), and Cho Oyu (4) (8,153 m), all located near Mount Everest. Topographically, the northern slope tends to be gentle and the southern slope steep. Climatically, the northern slope of Himalaya is cold and dry, and the southern slope is warm and moist, indicating a general decrease, from south to north, in precipitation and temperature.

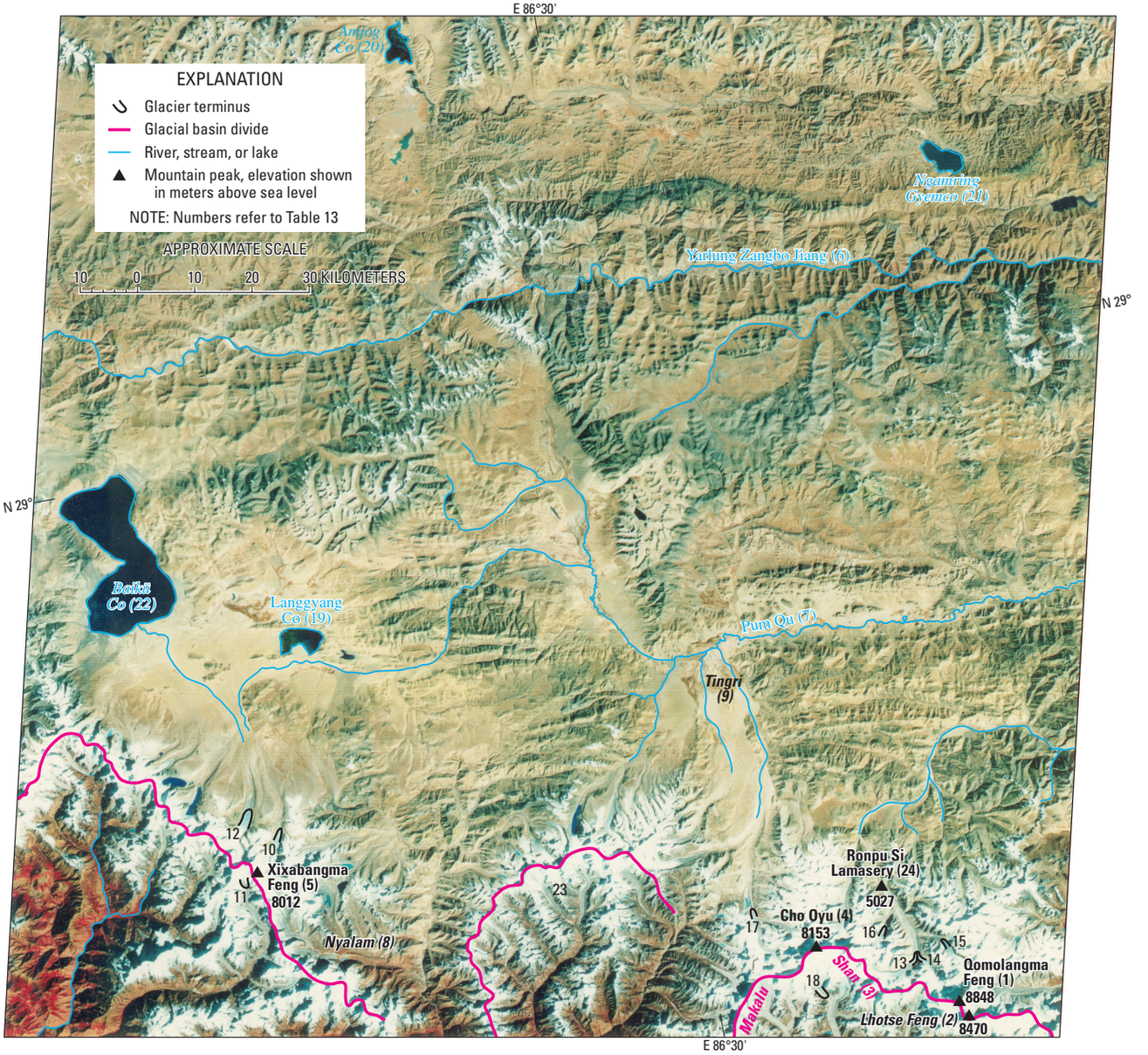


Figure 10.—*Annotated Landsat 2 MSS false-color composite image of the central Himalaya. Drainage divides between glacierized basins shown in red; selected rivers shown in blue; elevations of selected peaks shown in meters; selected positions of glacier termini shown in black; numbers indicate place-names of geographic features that are keyed to table 13. Landsat 2 MSS image (2662–03542, bands 4, 5, 7; 14 November 1976; Path 151–Row 40) from U.S. Geological Survey, EROS Data Center, Sioux Falls, S. Dak.*

TABLE 13.—*Selected place-names of glaciers and other geographic features of the central Himalaya region*

[See figure 10 for number locations of the place-names on a Landsat image of the region]

Place-name of glacier or other geographic feature	Latitude	Longitude
Qomolangma Feng (1)	27°58′N.	86°54′E.
Lhotse Feng (2)	27°56′N.	86°56′E.
Makalu Shan (3)	27°56′N.	87°04′E.
Cho Oyu (peak) (4)	28°05′N.	86°42′E.
Xixabangma Feng (5)	28°21′N.	85°47′E.
Yarlung Zangbo Jiang (6)	29°13′N.	86°31′E.
Pum Qu (7)	28°34′N.	86°35′E.
Nyalam (8)	28°10′N.	85°58′E.
Tingri (9)	28°34′N.	86°35′E.
Yebokangjiale (Dasapu) Bingchuan (10)	28°24′N.	85°47′E.
West Kangboqen Bingchuan (11)	28°18′N.	85°41′E.
North Kangboqen Bingchuan (12)	28°25′N.	85°42′E.
West Rongpu Bingchuan (13)	28°02′N.	86°50′E.
Central Rongpu Bingchuan (14)	28°03′N.	86°52′E.
East Rongpu Bingchuan (15)	28°03′N.	86°55′E.
Juda Bingchuan (16)	28°05′N.	86°50′E.
Gyachungkang Bingchuan (17)	28°09′N.	86°36′E.
Gyarag Bingchuan (18)	28°01′N.	86°42′E.
Langgyang Co (19)	28°43′N.	85°53′E.
Amjog Co (20)	29°37′N.	86°13′E.
Ngamring Gyemco (21)	29°18′N.	87°11′E.
Baikü Co (22)	28°53′N..	85°38′E.
Rongxar Region (23)	28°15′N.	86°15′E.
Rongpu Si Lamasery (24)	28°09′N.	86°49′E.

Precipitation in both areas is concentrated in summer. For example, annual precipitation at *Nyalam* (8) (3,800 m), southeast of Xixabangma Feng (5), is 422 mm; at the Rongpu Si Lamasery (24) (5,027 m), on the north side of Qomolangma Feng, annual precipitation is 335 mm, with 84 percent concentrated July through September; and further north at Tingri (9) (4,300 m), annual precipitation is 243 mm, with 97 percent occurring from July through September. Moreover, because of the dry climate, low latitude, and high elevation, this region has the most abundant solar radiation in China. Annual global radiation may reach 199.9 Kcal cm^{-2} at the Rongpu Si Lamasery and annual radiation balance is 80–90 Kcal cm^{-2} (Zeng and Kou, 1975).

The major drainage basins of this region are the Yarlung Zangbo Jiang (6) (the upper Brahmaputra River), and the Pum Qu (7) (the upper Arun River); the Pum Qu joins the Sun Kosi southeast of Qomolangma Feng (1). The lakes are all internal (closed) drainage basins: the Langgyang Co (19), *Amjog Co* (20), *Ngamring Gyemco* (21), and *Baikü Co* (22). The glacier area shown on the Landsat 2 MSS image (fig. 10) amounts to about 2,000 km^2 and is concentrated in the areas of Qomolangma Feng (1), Rongxar (23), and Xixabangma

Feng (5). Glacier termini range from 4,400 to 5,200 m, and snowline elevations from 5,500 to 6,200 m (fig. 1). Because of the intense solar radiation, ice pyramids are well developed on many of the glacier termini.

Glaciers in the area of Xixabangma Feng (5) are retreating, and the glaciers of the southern slopes in this region are retreating two or three times faster than those on the northern slope. For example, the lowest limit of clear ice of the *Yebokangjiale (Dasupu) Bingchuan* (10), on the northern slope of Xixabangma Feng (5), retreated –160 m from 1974 to 1976, while for the same period the *West* (11) and *North Kangboqen* (12) *Bingchuan* retreated –460 m and –350 m, respectively.

In the Qomolangma Feng area, the clean ice of the *West Rongpu Bingchuan* (13) advanced +300 m from 1966 to 1976. During the same period, the *Central Rongpu Bingchuan* (14) and *East Rongpu Bingchuan* (15) retreated –60 m and –200 m, respectively. In the same area, the *Juda Bingchuan* (16) advanced +150 m from 1969 to 1976; the *Gyachungkang Bingchuan* (17) retreated –1,340 m during the period from 1969 to 1976; and the *Gyarag Bingchuan* (18) retreated –870 m from 1957 to 1976.

Optimum Landsat 1, 2, and 3 Images of the Glacierized Regions of China

The preceding sections discuss the use of selected Landsat images to describe glacierized areas of China. Table 14 and figure 11 list optimum Landsat 1, 2, and 3 images that cover all the glacierized areas of China.

TABLE 14.—*Optimum Landsat 1, 2, and 3 images of the glaciers of China*
[Code column indicates usability for glacier studies; see figure 11 for explanation]

Path–Row	Nominal scene center latitude and longitude		Landsat identification number	Date	Code	Cloud cover (percent)	Remarks
ALTAY SHAN							
152–27	47°20′N.	91°19′E.	2152027007718890	07 Jul 77	◕	10	
153–27	47°20′N.	89°53′E.	2153027007722590	13 Aug 77	◕	10	
154–26	48°44′N.	89°04′E.	2154026007719090	09 Jul 77	◑	15	
154–27	47°20′N.	88°27′E.	2154027007719090	09 Jul 77	◑	50	
155–26	48°44′N.	87°38′E.	2155026007720990	28 Jul 77	◑	50	
156–26	48°44′N.	86°12′E.	2156026007719290	11 Jul 77	◑	25	
TIAN SHAN							
152–30	43°05′N.	89°38′E.	2152030007726090	17 Sep 77	◕	10	
153–29	44°30′N.	88°44′E.	2153029007722590	13 Aug 77	●	0	
153–30	43°05′N.	88°12′E.	2153030007722590	13 Aug 77	●	0	
154–30	43°05′N.	86°46′E.	2154030007625090	06 Sep 76	●	0	
154–30	43°05′N.	86°46′E.	2154030007726290	19 Sep 77	●	0	Image used for fig. 2
155–30	43°05′N.	85°20′E.	1155030007224590	01 Sep 72	◑	50	
155–30	43°05′N.	85°20′E.	2155030007628790	13 Oct 76	◑	15	
155–31	41°40′N.	84°48′E.	2155031007722790	15 Aug 77	◕	10	
156–29	44°30′N.	84°26′E.	1156029007226490	20 Sep 72	●	0	
156–29	44°30′N.	84°26′E.	2156029007719290	11 Jul 77	◑	25	
156–30	43°05′N.	83°54′E.	2156030007228290	08 Oct 72	●	5	

TABLE 14.—*Optimum Landsat 1, 2, and 3 images of the glaciers of China*—Continued

[Code column indicates usability for glacier studies; see figure 11 for explanation]

Path–Row	Nominal scene center latitude and longitude		Landsat identification number	Date	Code	Cloud cover (percent)	Remarks
156–30	43°05′N.	83°54′E.	2156030007726490	21 Sep 77	◑	70	
157–29	44°30′N.	83°00′E.	2157029007724790	04 Sep 77	●	0	
157–30	43°05′N.	82°27′E.	2157030007722990	17 Aug 77	●	5	
157–31	41°40′N.	81°56′E.	2157031007722990	17 Aug 77	●	0	
158–29	44°30′N.	81°34′E.	2158029007723090	18 Aug 77	◑	15	
158–30	43°05′N.	81°01′E.	2158030007723090	18 Aug 77	●	0	
158–31	41°40′N.	80°30′E.	2158031007723090	18 Aug 77	●	5	Image used for fig. 3
159–29	44°30′N.	80°08′E.	2159029007522490	12 Aug 75	◕	10	
QILIAN SHAN							
141–34	37°24′N.	103°25′E.	2141034007527890	05 Oct 75	●	5	
142–34	37°24′N.	101°59′E.	2142034007517190	20 Jun 75	◑	40	
143–33	38°49′N.	101°01′E.	2143033007719790	16 Jul 77	●	0	
143–34	37°24′N.	100°33′E.	2143034007719790	16 Jul 77	◕	10	
144–33	38°49′N.	99°35′E.	2144033007618690	04 Jul 76	◑	50	
144–34	37°24′N.	99°07′E.	2144034007718090	29 Jun 77	◕	10	
145–33	38°49′N.	98°09′E.	1145033007330190	28 Oct 73	◕	10	
146–33	38°49′N.	96°43′E.	2146033007711090	20 Apr 77	●	0	Image used for fig. 4
146–34	37°24′N.	96°15′E.	2146034007711090	20 Apr 77	●	0	
147–33	38°49′N.	95°17′E.	2147033007712990	09 May 77	●	0	
PAMIR							
161–33	38°49′N.	75°12′E.	1161033007225190	07 Sep 72	◕	10	
KARAKORUM SHAN							
159–35	35°58′N.	77°08′E.	3159035007819990	18 Jul 78	◕	10	Image used for fig. 5
160–34	37°24′N.	76°10′E.	2160034007723290	20 Aug 77	●	0	
160–35	35°58′N.	75°42′E.	2160035007721490	02 Aug 77	●	5	
KUNLUN SHAN							
143–35	35°58′N.	100°05′E.	2143035007719790	16 Jul 77	◑	30	
143–36	34°32′N.	99°39′E.	2143036007719790	16 Jul 77	◑	30	
144–35	35°58′N.	98°39′E.	2144035007723490	22 Aug 77	◑	70	
145–35	35°58′N.	97°13′E.	2145035007710990	19 Apr 77	◕	10	
146–35	35°58′N.	95°47′E.	2146035007611190	25 Apr 76	●	5	
147–35	35°58′N.	94°21′E.	2147035007727390	30 Sep 77	◑	20	
148–35	35°58′N.	92°55′E.	2148035007713090	10 May 77	◑	20	
149–34	37°24′N.	91°57′E.	1149034007323390	21 Aug 73	●	0	
149–35	35°58′N.	91°29′E.	1149035007319790	16 Jul 73	◑	15	
150–34	37°24′N.	90°30′E.	1150034007227690	02 Oct 72	●	0	
150–35	35°58′N.	90°03′E.	2150035007635490	19 Dec 76	●	0	
151–34	37°24′N.	89°04′E.	2151034007715190	31 May 77	●	0	
152–34	37°24′N.	87°38′E.	1152034007325490	11 Sep 73	●	0	
152–35	35°58′N.	87°11′E.	1152035007235090	15 Dec 72	●	0	

TABLE 14.—*Optimum Landsat 1, 2, and 3 images of the glaciers of China*—Continued

[Code column indicates usability for glacier studies; see figure 11 for explanation]

Path–Row	Nominal scene center latitude and longitude		Landsat identification number	Date	Code	Cloud cover (percent)	Remarks
153–34	37°24′N.	86°12′E.	2153034007726190	18 Sep 77	●	5	
153–35	35°58′N.	85°45′E.	2153035007724390	31 Aug 77	●	5	
154–34	37°24′N.	84°46′E.	2154034007724490	01 Sep 77	●	0	
154–35	35°58′N.	84°19′E.	2154035007724490	01 Sep 77	●	0	
155–35	35°58′N.	82°53′E.	2155035007726390	20 Sep 77	◑	30	
155–36	34°32′N.	82°26′E.	2155036007706590	06 Mar 77	●	0	
156–35	35°58′N.	81°27′E.	2156035007632490	19 Nov 76	◑	30	Image used for fig. 6
156–35	35°58′N.	81°27′E	2156035007721090	29 Jul 77	◑	20	
156–36	34°32′N.	81°00′E.	2156036007704890	17 Feb 77	◕	10	
157–35	35°58′N.	80°00′E.	2157035007632590	20 Nov 76	●	5	
158–35	35°58′N.	78°34′E.	2158035007719490	13 Jul 77	◕	10	
159–34	37°24′N.	77°36′E.	1159034007326190	18 Sep 73	●	0	
TANGGULA SHAN							
145–38	31°41′N.	95°55′E.	2145038007721790	05 Aug 77	◑	40	
146–38	31°41′N.	94°29′E.	3146038008129690	23 Oct 81	●	5	Partial scene
147–37	33°07′N.	93°28′E.	2147037007705790	26 Feb 77	●	5	
148–37	33°07′N.	92°02′E.	2148037007635290	17 Dec 76	●	5	Geladaindong
149–36	34°32′N.	91°03′E.	2149036007631790	12 Nov 76	●	0	
149–37	33°07′N.	90°36′E.	2149037007705990	28 Feb 77	◕	10	Geladaindong. Image used for fig. 7
150–36	34°32′N.	89°36′E.	2150036007635490	19 Dec 76	●	0	
150–37	33°07′N.	89°10′E.	2150037007635490	19 Dec 76	●	0	
NYAINQÊNTANGLHA SHAN							
144–39	30°15′N.	96°56′E.	2144039007634890	13 Dec 76	●	0	
144–39	30°15′N.	96°56′E.	3144039008129490	21 Oct 81	●	0	Partial scene
144–40	28°49′N.	96°31′E.	2144040007634890	13 Dec 76	●	0	
144–40	28°49′N.	96°31′E.	2144040007721690	04 Aug 77	◑	50	Image used for fig. 9
145–39	30°15′N.	95°30′E.	2145039007634990	14 Dec 76	◑	30	
146–39	30°15′N.	94°04′E.	2146039007635090	15 Dec 76	●	5	
147–38	31°41′N.	93°03′E.	2147038007635190	16 Dec 76	●	0	
147–39	30°15′N.	92°38′E.	2147039007635190	16 Dec 76	●	0	
148–39	30°15′N.	91°12′E.	2148039007635290	17 Dec 76	●	0	
149–39	30°15′N.	89°46′E.	2149039007635390	18 Dec 76	●	0	Image used for fig. 8
GANGDISÊ SHAN							
151–39	30°15′N.	86°54′E.	2151039007633790	02 Dec 76	●	0	
152–39	30°15′N.	85°28′E.	2152039007633890	03 Dec 76	●	0	
153–38	31°41′N.	84°27′E.	2153038007632190	16 Nov 76	●	0	
153–39	30°15′N.	84°01′E.	2153039007700990	09 Jan 77	●	0	
154–38	31°41′N.	83°01′E.	2154038007632290	17 Nov 76	●	0	
154–39	30°15′N.	82°35′E.	2154039007632290	17 Nov 76	◕	10	
155–38	31°41′N.	81°35′E.	2155038007628790	13 Oct 76	●	5	

TABLE 14.—*Optimum Landsat 1, 2, and 3 images of the glaciers of China*—Continued

[Code column indicates usability for glacier studies; see figure 11 for explanation]

Path–Row	Nominal scene center latitude and longitude		Landsat identification number	Date	Code	Cloud cover (percent)	Remarks
155–39	30°15′N.	81°09′E.	2155039007634190	06 Dec 76	●	5	
156–37	33°07′N.	80°34′E.	2156037007632490	19 Nov 76	●	5	
156–38	31°41′N.	80°09′E.	2156038007632490	19 Nov 76	●	0	
HIMALAYA							
144–40	28°49′N.	96°31′E.	2144040007631290	07 Nov 76	◕	10	
144–40	28°49′N.	96°31′E.	2144040007721690	04 Aug 77	●	0	
145–39	30°15′N.	95°30′E.	2145039007634990	14 Dec 76	◑	30	
145–40	28°49′N.	95°95′E.	1145040007335590	21 Dec 73	◕	10	
146–40	28°49′N.	93°39′E	2146040007635090	15 Dec 76	◕	10	
147–40	28°49′N.	92°13′E.	2147040007635190	16 Dec 76	●	5	
147–41	27°23′N.	91°49′E.	2147041007700390	03 Jan 77	◑	20	
148–40	28°49′N.	90°47′E.	2148040007635290	17 Dec 76	●	5	
148–41	27°23′N.	90°23′E.	2148041007635290	17 Dec 76	◕	10	
149–41	27°23N.	88°57′E.	2149041007635390	18 Dec 76	◑	15	
150–40	28°49′N.	87°55′E.	2150040007635490	19 Dec 76	●	0	
150–41	27°23′N.	87°31′E.	2150041007635490	19 Dec 76	●	5	
151–40	28°49′N.	86°29′E.	2151040007631990	14 Nov 76	●	0	Image used for fig. 10
151–40	28°49′N.	86°29′E.	2151040007635590	20 Dec 76	●	5	
151–41	27°23′N.	86°05′E.	2151041007635590	20 Dec 76	●	10	
152–40	28°49′N.	85°03′E.	2152040007633890	03 Dec 76	●	5	
153–39	30°15′N.	84°01′E.	2153039007700990	09 Jan 77	●	0	
153–40	28°49′N.	83°37′E.	2153040007700990	09 Jan 77	◕	10	
154–39	30°15′N.	82°35′E.	2154039007632290	17 Nov 76	◕	10	
155–39	30°15′N.	81°09′E.	2155039007634190	06 Dec 76	●	5	
156–38	31°41′N.	80°09′E.	2156038007632490	19 Nov 76	●	0	
156–39	30°15′N.	79°43′E.	2156039007632490	19 Nov 76	●	0	
157–38	31°41′N.	78°42′E.	2157038007632590	20 Nov 76	●	0	
HENGDUAN SHAN							
140–39	30°15′N.	102°40′E.	1140039007400390	03 Jan 74	◕	10	
140–40	28°49′N.	102°16′E.	1140040007402190	21 Jan 74	●	0	
140–41	27°23′N.	101°52′E.	1140041007400390	03 Jan 74	●	0	
141–39	30°15′N.	101°14′E.	1141039007400490	04 Jan 74	●	0	
141–40	28°49′N.	100°50′E.	11410400074000490	04 Jan 74	●	0	
141–41	27°23′N.	100°26′E.	11410410074000490	04 Jan 74	◕	10	
142–39	30°15′N.	99°48′E.	11420390074000590	05 Jan 74	●	0	
142–40	28°49′N.	99°24′E.	11420400074000590	05 Jan 74	●	0	
142–41	27°23′N.	99°00′E.	11420410074000590	05 Jan 74	●	0	
143–39	30°15′N.	98°22′E.	2143039007631190	06 Nov 76	●	0	
143–40	28°49′N.	97°57′E.	2143040007631190	06 Nov 76	●	0	

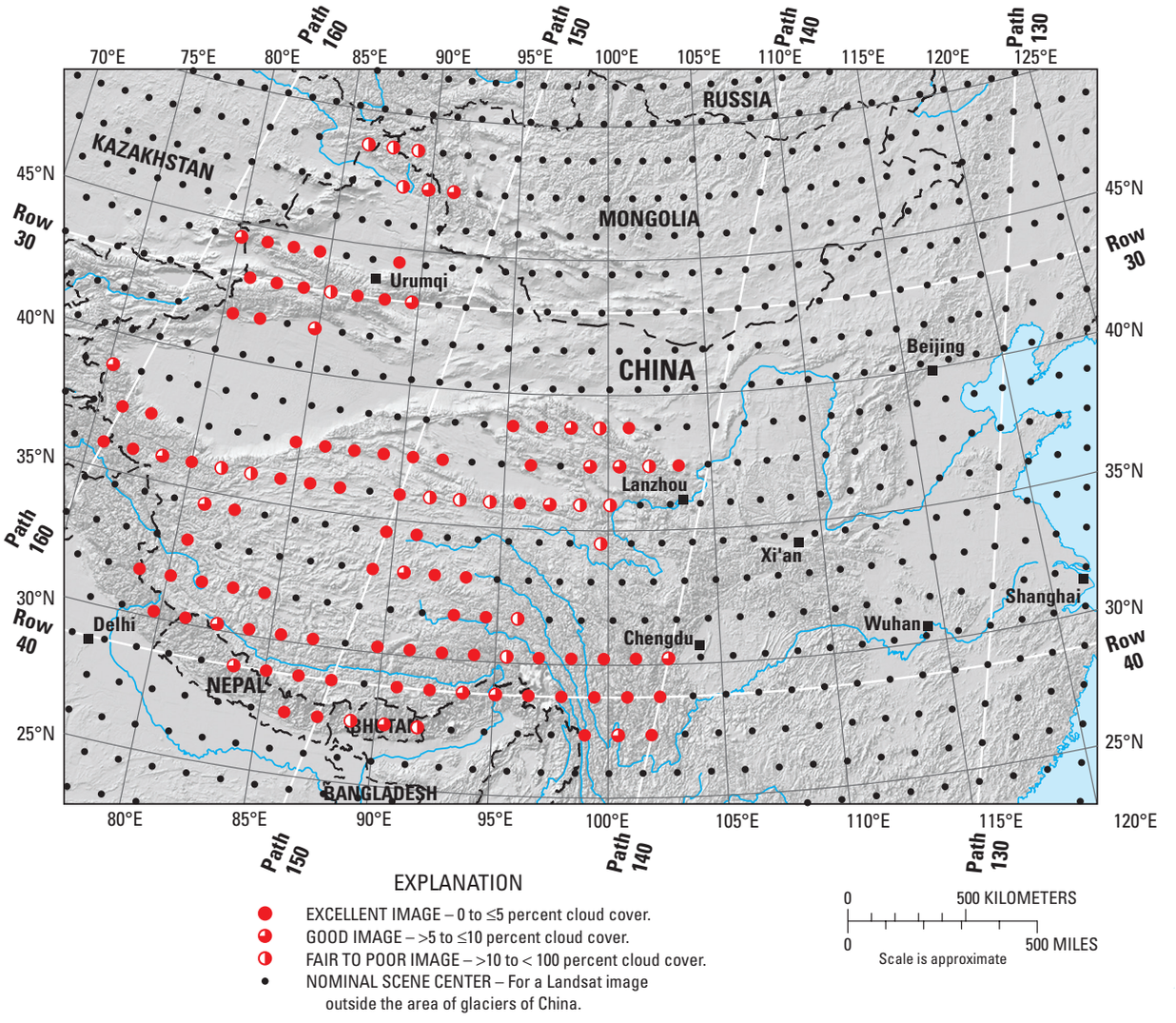


Figure 11.—*Index map of optimum Landsat 1, 2, and 3 images of the glacierized areas of China.*

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