Glaciers of Asia—

GLACIERS OF NEPAL—Glacier Distribution in the Nepal Himalaya with Comparisons to the Karakoram Range

By Keiji Higuchi, Okitsugu Watanabe, Hiroji Fushimi, Shuhei Takenaka, *and* Akio Nagoshi

SATELLITE IMAGE ATLAS OF GLACIERS OF THE WORLD

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Introduction

The Nepal Himalaya and the Karakoram Range are the highest mountainous regions on Earth, with many peaks higher than 6,000–8,000 m in elevation. As a result, attempts to study glaciers in these ranges using field and airborne surveys have presented many difficulties historically. The availability of Landsat images in the 1970s, however, offered the opportunity to study the distribution and morphological characteristics of glaciers in the Nepal Himalaya, and to compare them to characteristics of glaciers in the Karakoram Range. The images were particularly valuable because no large-scale official maps were available. Additionally, a series of field investigations of the Nepal Himalaya glaciers, organized by Nagoya and Kyoto Universities, Japan, and conducted over six years (1973–1978), provided ground truth which could be used in resolving inherent Landsat image interpretation issues. This was the first attempt at glacier surveys in these two regions using Landsat images.

The Himalaya dominates the central and northern portions of Nepal (figs. 1 and 2). The Karakoram Range lies in northern India and Pakistan, along the border with China (figs. 1 and 3). Although these ranges are geographically near one another, they are separated by the Indus, Gilgit, and Shyok Rivers and by approximately 150 km of lower elevation terrain.

Use of Landsat Images in Glacier Studies

Because of the many logistical problems in conducting field and airborne surveys, Landsat images are more effective tools for obtaining preliminary information about glaciers in relatively unexplored areas such as the Nepal Himalaya and the Karakoram Range. However, there are several problems in the application of Landsat images to glaciological studies. First, the resolution

[1]This section was written in the early 1980s, and describes the glaciers of Nepal during the 1970s, the baseline period for the Satellite Image Atlas of Glaciers of the World, U.S. Geological Survey Professional Paper 1386. Because there was a delay in publication, a supplement by Yuteka Ageta has been added at the end of this section to describe more recent research.

[2]The authors were with the Water Research Institute, Nagoya University, when this section was written.

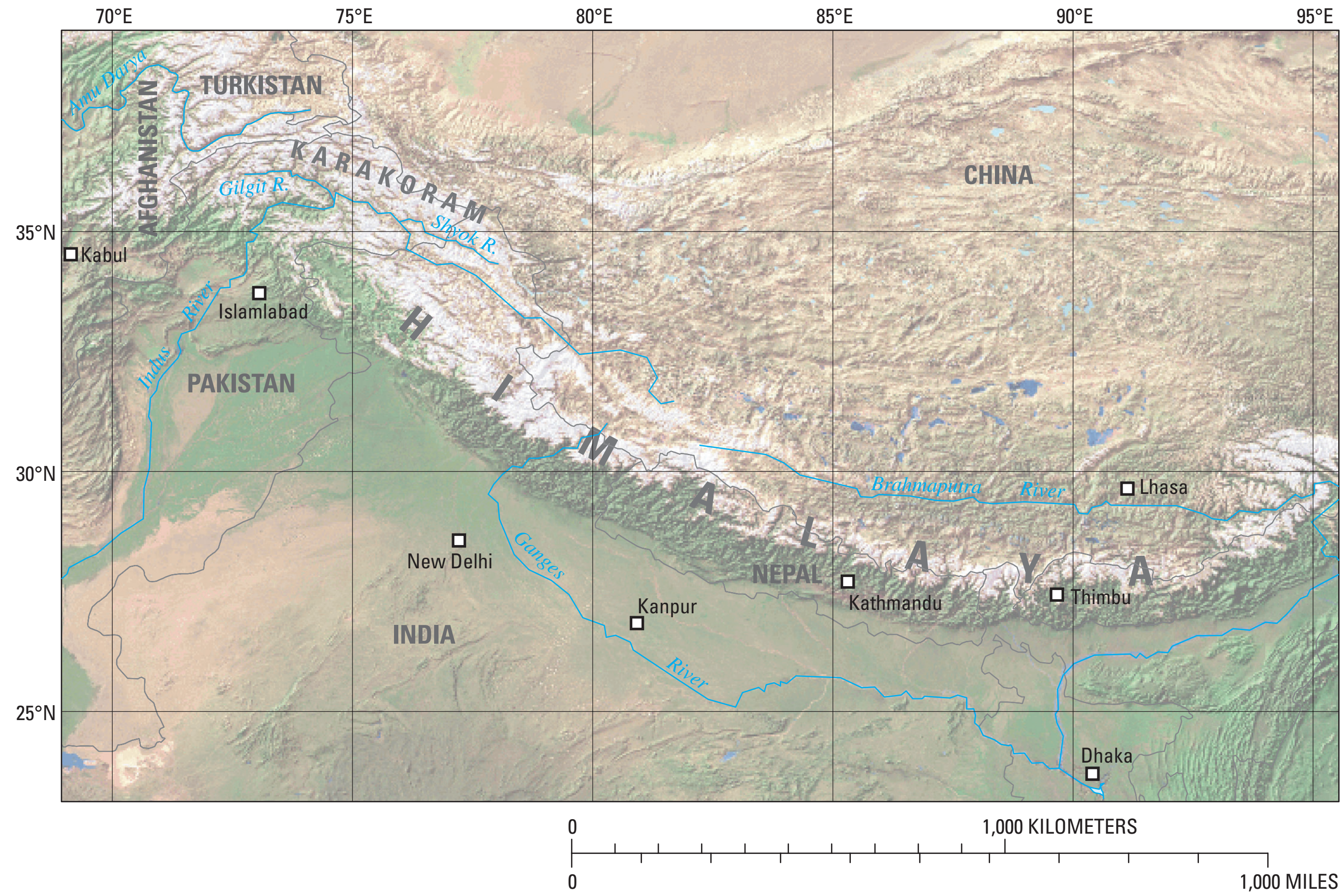


Figure 1.*— Location of the Nepal Himalaya and Karokoram Range in Southern Asia.*

of the image may not be adequate to identify smaller glaciers. For example, small cirque glaciers (less than 100 m in width) are difficult to recognize on Landsat multispectral scanner (MSS) images (Higuchi, 1975). Second, some glacier surfaces are covered by a combination of materials such as soil, ice, and rock that are not only hard to see but difficult to differentiate, so that snow facies and glacier structures are not distinguishable in the images. Third, observations with sensors in the visible part of the spectrum are impossible to make during the monsoon season, and are difficult at other times of the year (particularly in the afternoon) because of cloud cover. In addition, the orbital parameters of the Landsat satellite result in the images for this area being acquired in the morning hours which makes it difficult to see details on the western slopes of mountain ridges because of shadows. Therefore, results of the ground investigations conducted during the same period as this study provided a means of checking questionable Landsat interpretations.

In this paper, the results of a preliminary application of Landsat images to the analysis of glaciological characteristics in the Nepal Himalaya and the Karakoram Range are presented. Ground investigation results from detailed studies in the Dudh Kosi region of Nepal Himalaya (Higuchi and others, 1978, 1980) were used to improve the Landsat interpretations.

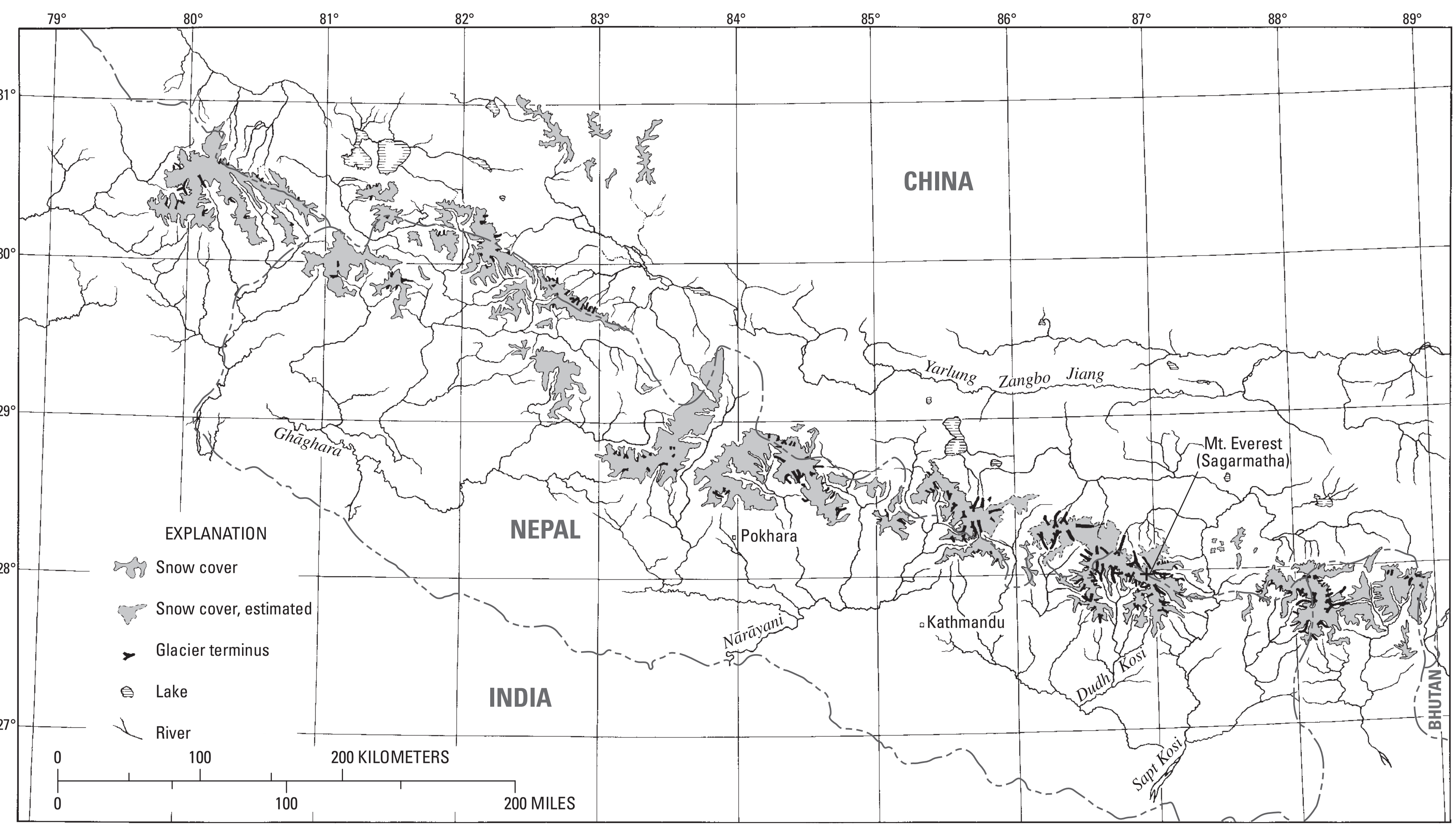


Figure 2.— *Glacier distribution of the Nepal Himalaya and its surrounding regions. Some political boundaries are uncertain.*

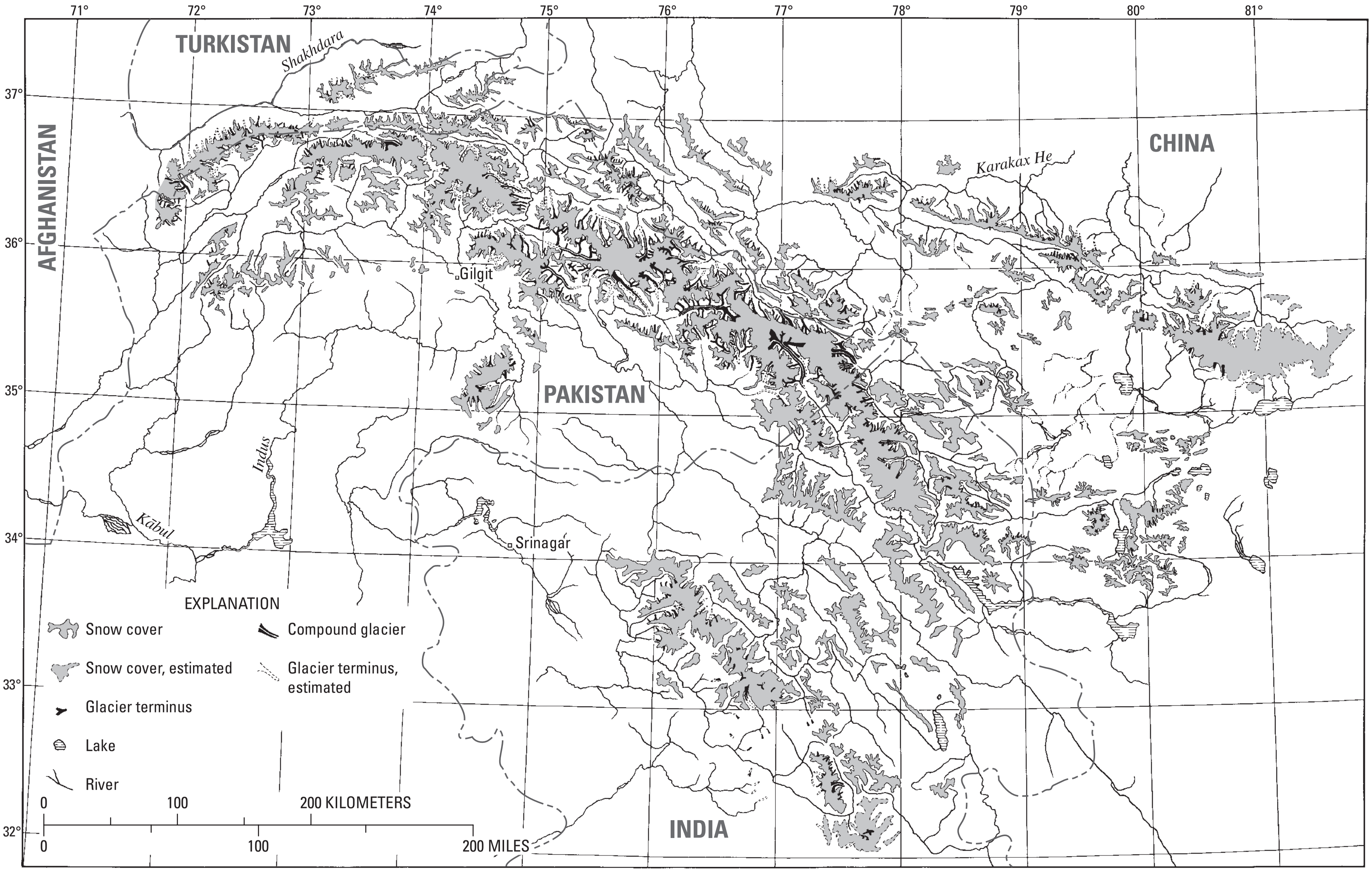


Figure 3.— *Glacier distribution of the Karakoram Range. Some political boundaries are uncertain.*

A Brief History of Glacier Investigations

Since 1949, foreign mountaineers and scientists have repeatedly visited the Nepal Himalaya. The first glaciologist to visit Nepal was Fritz Müller who was a participant in the Swiss Everest Expedition of 1956. He studied the Khumbu Glacier, East Nepal (Müller, 1958). During the following years, the number of mountaineering and scientific expeditions has gradually increased, improving our knowledge of the Nepal Himalayan region and glaciers.

The *Takpu Glacier,*[3] situated in the northwesternmost part of the Nepal Himalaya, was visited by a Japanese expedition in 1963. After additional Japanese glaciological work in 1965 on the *Gustang Glacier* in central Nepal, Watanabe (1976) classified the glaciers of the Nepal Himalaya into two types, based on climatic characteristics of glacierization and surface morphological features: (1) Nepal-type glaciers and, (2) Tibet-type glaciers. The former type has relatively wet-maritime characteristics and the latter type has relatively dry-continental characteristics.

In 1963, Miller and others (1965), as scientific members of the American Everest Expedition, did glaciological studies on the Khumbu Glacier of eastern Nepal. They studied the accumulation processes in the Khumbu Glacier by tritium dating ice layers above the equilibrium line in the *West Cwm*, at the head of the Khumbu Glacier. An inventory of glaciers in the Mt. Everest (Sagarmatha) region was first attempted by Müller (1970) during the International Hydrological Decade (IHD) as a pilot study for the Himalayan glacier inventory.

The concept of using a representative glacier as an index of the regional characteristics of the Nepal Himalayan glaciers was proposed by Watanabe (1976). He selected 80 glaciers from the entire region encompassed by the Nepal Himalaya, and described their topographical features from the perspective of the regional characteristics of glaciers. His study is useful for monitoring long-term change in glaciers.

The first systematic investigation of the Nepal Himalayan glaciers was organized by Nagoya and Kyoto Universities, Japan. The Glaciological Expedition of Nepal (GEN), led by Higuchi (1976, 1977, 1978, 1980), carried out a series of field studies in the Khumbu, *Shorong, Hink,* and *Hunk* regions in eastern Nepal, and the Mukut Himal region in central Nepal from 1973 to 1978. Year-round meteorological observations were made at *Lhajung* Station (4,420 m), Khumbu region, East Nepal, which operated from 1973 to 1976. Also, precise inventory work was performed on the glaciers in the Dudh Kosi region, East Nepal, as part of this research program (Higuchi and others, 1978, 1980). Detailed results of this work are described in this report.

Although the Karakoram glaciers are much larger than those of the Nepal Himalaya, fewer glaciological studies have been performed there. For a discussion of some of the earlier work on the Karakoram glaciers, see the section in this chapter on the Glaciers of Pakistan, as well as the work of Visser (1928), Untersteiner (1955), and von Wissmann (1959).

[3]U.S. Government publications require that official geographic place-names for foreign countries be used to the greatest extent possible. In the Glaciers of Nepal section, the use of geographic place-names is based on the U.S. Board on Geographic Names (BGN) Website *http://earth-info.nga.mil/gns/html/index.html*. Names not listed on the BGN Website are shown in italics.

Procedures for Mapping Glacier Distribution from Landsat Images

Landsat images are available for most of the Nepal Himalaya and Karakoram Range. Images acquired between 17 September 1972 and 6 December 1976, were used for the analysis of the Nepal Himalaya glaciers (fig. 4); images acquired between 19 September 1973 and 27 September 1977, were used for the analysis of the Karakoram Range glaciers (fig. 5). The optimum Landsat 1, 2, and 3 images for glacier studies in the 1970s time frame are shown in table 1. An accompanying index map is shown in figure 6.

Landsat image analysis is the most effective remote sensing technique available for analyzing the seasonal and secular variations of cryospheric phenomena. The areal distribution of glaciers and seasonal snow cover are easily discernible on the images. However, it is difficult to map the glaciers using Landsat MSS images because of the low spatial resolution.

Other problems include how to ascertain the extent of individual glaciers and how to distinguish the firn limit from the temporal snow cover in the upper part of the glacier. In the ablation area, drawing a clear boundary between the area of the supraglacial debris cover and that of the moraine field on glaciated ground is also a serious problem in analyzing the images. These difficulties in interpretation directly affect the accuracy of maps made from the images.

To solve these problems, comparison studies were conducted using objective criteria from ground observations to validate the interpretations from the images. The following procedures were used in making the maps.

1. An area was selected where ground survey and aerial photography data were available and much data had been collected on the glaciers.

2. Ground observations were plotted and image data related to the glacial features on a geographic base map of these areas.

3. Glacier features were classified, and compared to information from Landsat images and ground observations.

4. Criteria were established for determining the areal extent of a glacier and its morphological surface characteristics.

After some trial and error, the following criteria were established.

1. All snow and/or ice surface areas above the firn limit would be included in the "cryospheric zone." However, there were severe difficulties in deciding whether these features were glacierized or not. The limit of perennial snow/ice cover becomes clear just before the summer monsoon season, April or May in the Himalaya, so a satellite image taken during that time period should be used, if available.

2. According to results obtained from preliminary studies in the area, it was not difficult to distinguish between the areas of supraglacial debris cover and the areas of moraine which had no subsurface ice body (at the image scale). This was because, after comparing Landsat images with ground observations, the supraglacial debris-covered area did not make much difference in the determination of the glacier extent.

These criteria can only be applied to glaciers larger than a certain limit—approximately several kilometers in length and several hundred meters in width. Therefore, glaciers smaller than this limit were not mapped as individual glaciers but were included in the total cryospheric area. It should be noted that debris-covered areas with stagnant and/or fossil ice, being remnants of past expansion, were not mapped as active glacier areas.

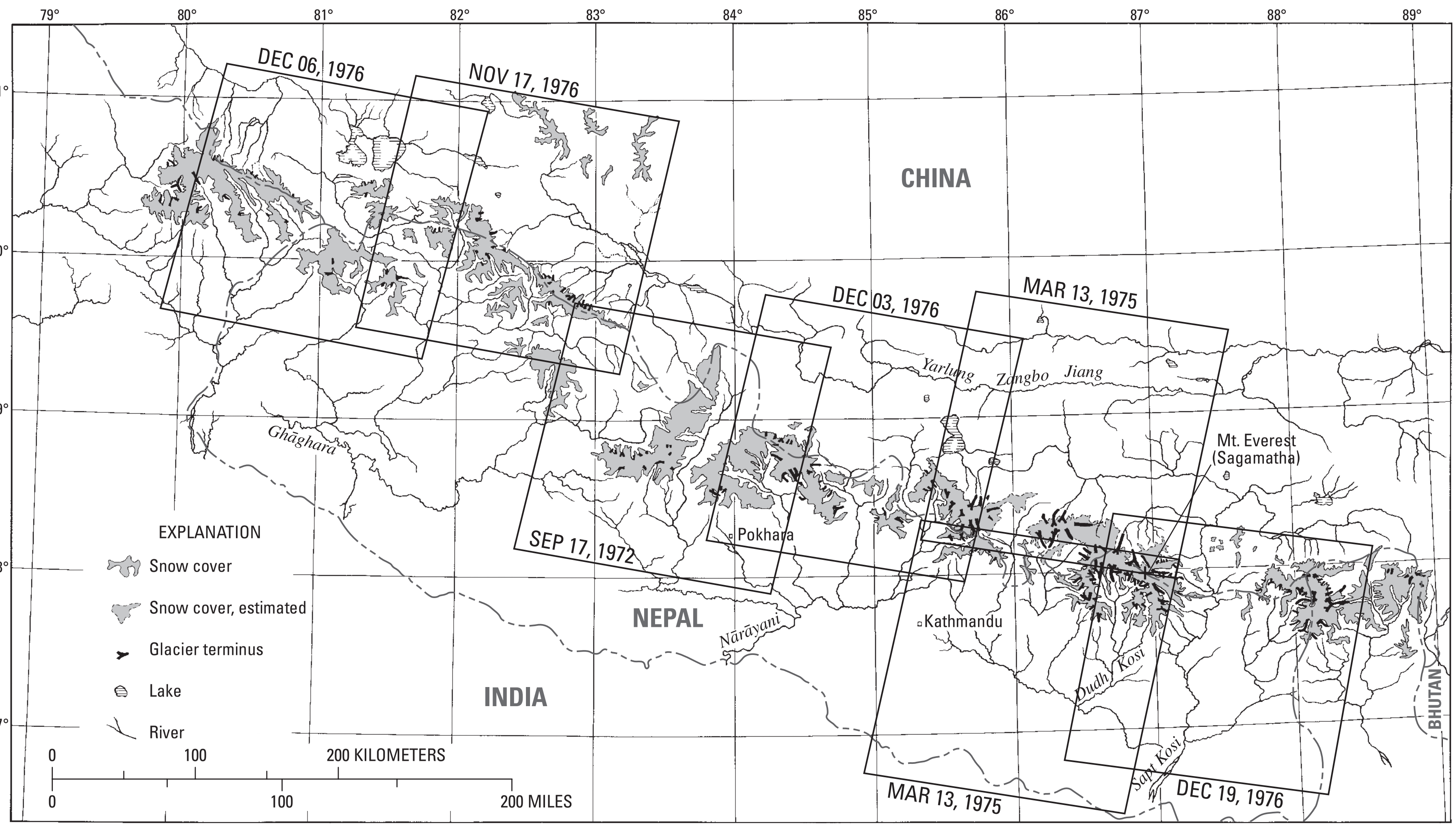


Figure 4.— *Index map of the glaciers of Nepal showing coverage by Landsat 1, 2, and 3 MSS images.*

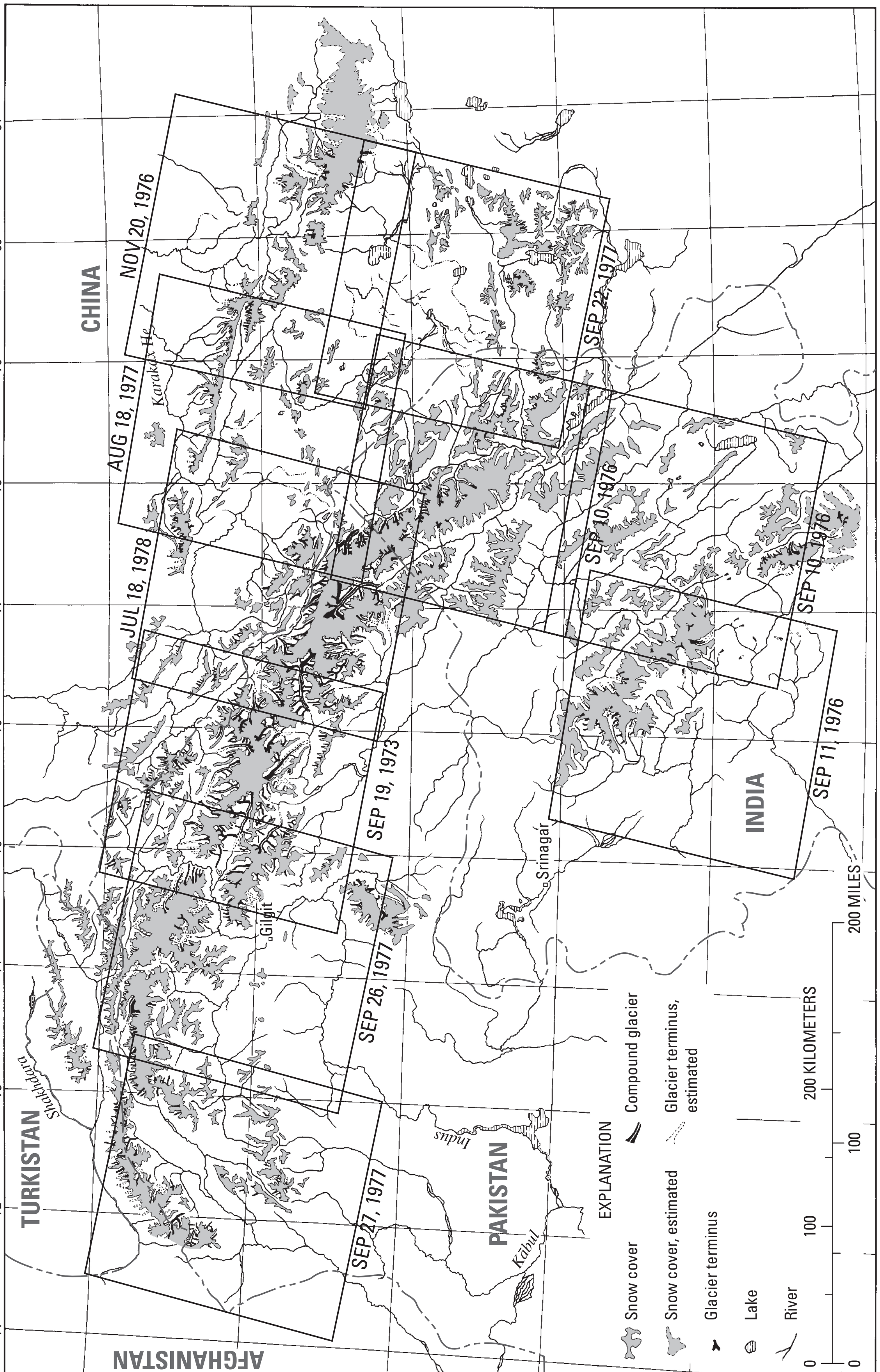


Figure 5.— Index map of the glaciers of the Karkoram Range showing coverage by Landsat 1, 2, and 3 MSS images.

Table 1.—*Optimum Landsat 1, 2, and 3 MSS images of the glaciers of Nepal*

Path-Row	Nominal scene center latitude and longitude		Landsat identification number	Solar elevation angle (degrees)	Date	Code	Cloud cover (percent)	Remarks
150–41	27°23′N.	87°31′E.	2150041007635490	28	19 Dec 76	●	5	Dudh-Kosi, Mt. Everest region
151–40	28°49′N.	86°29′E.	2151040007507290	43	13 Mar 75	◕	10	
151–40	28°49′N.	86°29′E.	2151040007635590	27	20 Dec 76	●	5	
151–41	27°23′N.	86°05′E.	2151041007507290	44	13 Mar 75	●	5	
151–41	27°23′N.	86°05′E.	2151041007635590	28	20 Dec 76	◕	10	
152–40	28°49′N.	85°03′E.	215204007633890	30	03 Dec 76	●	5	
153–40	28°49′N.	83°37′E.	1153040007226190	~45	17 Sep 72	◑	20	Line drops
153–40	28°49′N.	83°37′E.	2153040007700990	27	09 Jan 77	◕	10	
154–39	30°15′N.	82°35′E.	2154039007632290	32	17 Nov 76	◕	10	
154–40	28°49′N.	82°11′E.	2154040007632290	33	17 Nov 76	◑	30	
155–39	30°15′N.	81°09′E.	2155039007634190	28	06 Dec 76	●	5	

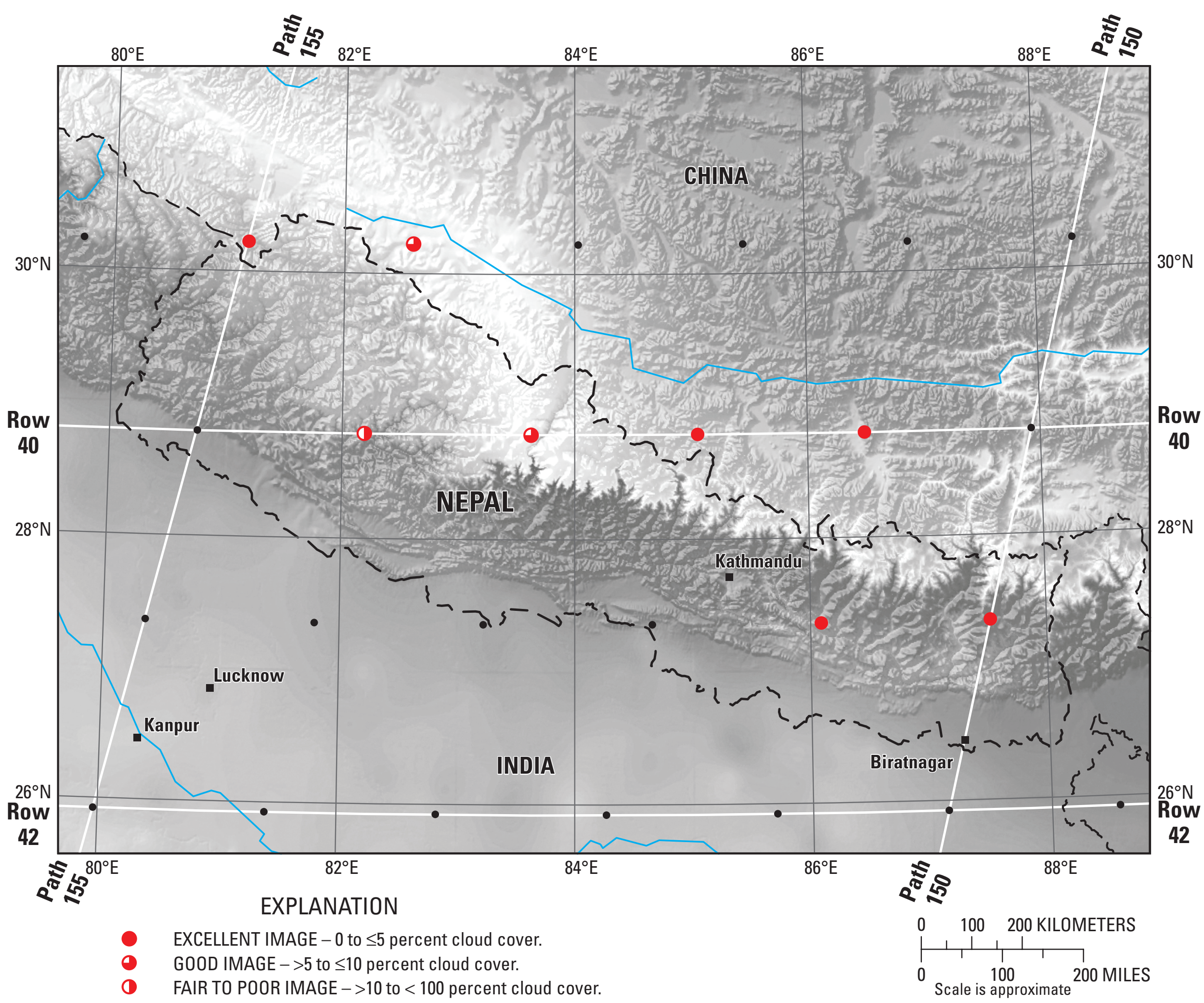


***Figure 6.**—Index map of optimum Landsat 1, 2, and 3 MSS images of the glaciers of Nepal.*

Glaciers in the Nepal Himalaya and the Karakoram Range

Based on the Landsat image analysis, a glacier inventory was developed for the Nepal Himalaya and the Karakoram, and the glacier distribution and characteristics were compared between the two areas. A ground survey of glaciers in the Dudh Kosi region of Nepal was conducted and results were compared to results from a Landsat image analysis by Müller (1970). A comprehensive comparison of results from Landsat image and ground investigations was conducted on the Khumbu Glacier, in Nepal.

Glacier Inventory Based on a Map Compiled from Landsat Images

Tables 2 and 3 list the glaciers which were identified using Landsat images, based on the established criteria, for the Nepal Himalaya and Karakoram Range, respectively. The locations of these glaciers are shown on figures 7 and 8. Italicized glacier names in the tables are tentative designations assigned for practical convenience, because official geographic place-names have not yet been established for many of the glaciers in these two regions. The elevation of the terminus and the length and width of each glacier in horizontal projection are estimated from various published papers and maps, and from direct measurements on the Landsat images.

The "Description" column in tables 2 and 3 includes specific surface features and other characteristics of the glacier that were identified directly from the images. Surface conditions of a glacier, such as the distribution of supraglacial debris and the occurrence of medial moraines, glacier lakes, and other glacial features were easily recognized using Landsat images. This information contributed effectively to our knowledge of the present conditions of individual glaciers. Additionally, the monitoring of glacier lake conditions and surge-type glaciers by means of satellite images appears to be an effective means of obtaining advanced warning of potential glaciological catastrophes.

TABLE 2.—*Glaciers in the Nepal Himalaya and surrounding regions*

[Description: D, debris-covered glacier; S, lateral moraine; C, clean glacier; M, medial moraine; Dp, partly debris-covered glacier; P, pond; L, lake around glacier; ?, unknown whether it is covered by snow or debris. References: 1, Higuchi and others (1978, 1980); 2, Schneider (1963); 3, Yoshizawa (1977). Units: m, meter; km, kilometer]

Glacier number	Glacier name	Location latitude and longitude		Lowest glacier elevation (m), when known	Length/width (km), when known	Description	Reference
ALAKNANDA BASIN							
001	*Bagani Bank*	30°45′N.	80°00′E.			D, S	3
002	*Dunagiri Bank*	30°45′N.	80°00′E.			D	3
003	*Uttari Rishi*	30°30′N.	80°00′E.			C, S	3
004	*Uttari Nanda Devi*	30°30′N.	80°00′E.			D, S	3
005	*Dakkhni Nanda Devi*	30°30′N.	80°00′E.			D	3
006	*South Rishi*	30°30′N.	80°00′E.			D, S	3
007	*Trisal*	30°30′N.	79°45′E.			D, S	3
KALI BASIN							
101	*Shalang*	30°15′N.	80°15′E.			D, M, S	3
102	Milam	30°30′N.	80°15′E.			D, M, S	3
103	*Kalabaland*	30°30′N.	80°30′E.			C, S	3
104	*Ngalaphu*	30°15′N.	80°30′E.			D, M, S	3

Table 2.—*Glaciers in the Nepal Himalaya and surrounding regions*—Continued

[Description: D, debris-covered glacier; S, lateral moraine; C, clean glacier; M, medial moraine; Dp, partly debris-covered glacier; P, pond; L, lake around glacier; ?, unknown whether it is covered by snow or debris. References: 1, Higuchi and others (1978, 1980); 2, Schneider (1963); 3, Yoshizawa (1977). Units: m, meter; km, kilometer]

Glacier number	Glacier name	Location latitude and longitude		Lowest glacier elevation (m), when known	Length/width (km), when known	Description	Reference
105	*Rama*	30°15′N.	80°45′E.			D	3
106		30°15′N.	80°45′E.			Dp	
KARNALI BASIN							
201		30°00′N.	81°00′E.	4,298	6.8/0.7	D, M	3
202		30°00′N.	81°00′E.	4,480	4.9/0.7	D	3
203	*Saipal*	30°00′N.	81°30′E.	3,721	5.0/0.4	Dp, S	3
204	*Ghat*	30°00′N.	81°30′E.	4,419	1.6/	D, S	3
205		30°00′N.	81°30′E.	3,505	7.0/1.4	D, S	3
206	*N. Saipal*	30°00′N.	81°30′E.	4,282	7.6/0.4	Dp, M	3
207		30°30′N.	80°45′E.			C, S	
208		30°30′N.	81°15′E.			C	
209		30°30′N.	81°15′E.			D, M, S	
210		30°15′N.	81°15′E.			Dp	
211		30°15′N.	81°45′E.			C, S	
212		30°15′N.	81°45′E.			C	
213		30°15′N.	82°15′E.			D, S	
214		30°00′N.	82°15′E.			Dp, S	
215		30°00′N.	82°15′E.	4,267	5.1/0.6	D, M, P	3
216		30°00′N.	82°15′E.			Dp, S	
217		29°45′N.	82°45′E.			Dp, S	
218		29°45′N.	82°45′E.	5,029		Dp, M, S	3
219		28°45′N.	83°15′E.	4,115	4.6/0.4	?	3
220		28°45′N.	83°15′E.	4,892	4.3/	?	3
221		28°45′N.	83°15′E.	4,304	5.4/0.4	?	3
222		28°45′N.	83°15′E.	4,877	10.0/0.6	D, S	3
223		28°45′N.	83°15′E.	5,264	4.7/0.3	?	3
224		28°45′N.	83°15′E.	4,724	3.7/0.7	D, S	3
225		28°45′N.	83°15′E.	4,816	5.2/0.3	?	3
226	*Kaphe*	28°45′N.	83°15′E.	4,206	8.3/0.5	?	3
KALI GANDAKI BASIN							
301	*Konabon*	28°45′N.	83°30′E.	4,389	8.5/	?	3
302	*Chhonbarban*	28°45′N.	83°30′E.	3,770	14.6/0.4	?, S	3
303		28°45′N.	83°30′E.	4,282	4.8	?	
304		28°45′N.	83°30′E.	5,014	3.8/0.4	?	3
305		28°45′N.	83°30′E.	5,608	3.2/	?	3
306		28°45′N.	83°30′E.	5,303	4.8/0.6	?	3
307	*S. Annapurna*	28°30′N.	84°00′E.	3,566	13.7/0.5	D, S	3
308	*W. Annapurna*	28°45′N.	84°00′E.	3,789	7.8/0.3	D	3
309	*E. Annapurna*	28°30′N.	84°00′E.		6.9/0.3	D	3
310		28°45′N.	84°15′E.			D	
311		28°45′N.	84°15′E.			D, S, P	
312		28°45′N.	84°30′E.			D, S	
313		28°45′N.	84°30′E.			D, M, S, P	
314		28°45′N.	84°30′E.			D, M, S, P	
315		28°45′N.	84°30′E.			D, M, S, P	
316		28°30′N.	84°30′E.			D, P	
317	*Tulangi*	28°30′N.	84°30′E.	4,023	12.4/0.4	D, P	3
318	*Chuling*	28°30′N.	84°45′E.	3,017	14.0/0.7	D, M, S	3
319	*Lidanda*	28°30′N.	84°30′E.	3,139	14.0/0.9	D, S	3
320	*Pungeu*	28°30′N.	84°30′E.	3,840	10.2/0.7	D, S	3
321	*Manaslu*	28°30′N.	84°30′E.	3,597	7.5/0.4	Dp	3

Table 2.—*Glaciers in the Nepal Himalaya and surrounding regions*—Continued

[Description: D, debris-covered glacier; S, lateral moraine; C, clean glacier; M, medial moraine; Dp, partly debris-covered glacier; P, pond; L, lake around glacier; ?, unknown whether it is covered by snow or debris. References: 1, Higuchi and others (1978, 1980); 2, Schneider (1963); 3, Yoshizawa (1977). Units: m, meter; km, kilometer]

Glacier number	Glacier name	Location latitude and longitude		Lowest glacier elevation (m), when known	Length/width (km), when known	Description	Reference
322		28°45′N.	84°30′E.	4,602	6.1/0.5	D	3
323	*Jarkya*	28°45′N.	84°30′E.	4,419	12.4/0.7	Dp, S	3
324		28°45′N.	84°30′E.			?	
325	*Torogompa*	28°30′N.	85°00′E.			D, S	3
326		28°30′N.	85°00′E.			D, S	
327	*Sangjing*	28°30′N.	85°15′E.			D, S	3
328		28°45′N.	85°30′E.			D, S	
329		28°45′N.	85°30′E.			D, S	
330		28°45′N.	85°30′E.			?	
331		28°45′N.	85°30′E.			D, S	
332	*Chinkyong*	28°45′N.	85°30′E.			D, S	3
333	*Lalaga*	28°30′N.	85°30′E.			D, S	3
334	*Phurephu*	28°30′N.	85°30′E.			D, S	3
335	*Chasmudo*	28°15′N.	85°30′E.			D, S	3
336	*Lirang*	28°15′N.	85°30′E.	3,962		D, S	3
337	*Shalbachum*	28°15′N.	85°30′E.	4,114		D	3
338		28°15′N.	85°45′E.	4,663		D, S	3
339	*Langtang*	28°15′N.	85°45′E.	4,550		D, S	3
SAPT KOSI BASIN							
401		28°15′N.	85°45′E.	4,267	4.6/0.6	D	3
402		28°15′N.	85°45′E.	4,115	5.5/0.6	D, S	3
403	*Phurbi Cha Chu*	28°15′N.	85°45′E.	3,840	7.8/0.4	D, S	3
404		28°15′N.	85°45′E.	3,846	4.8/0.4	D, S	3
405	*Nyanamphu*	28°30′N.	85°45′E.			?	
406		28°30′N.	85°45′E.			D, S	
407		28°30′N.	85°45′E.			?	
408		28°30′N.	86°15′E.			?	
409		28°15′N.	86°15′E.			?	
410		28°15′N.	86°15′E.			?	
411		28°15′N.	86°30′E.			?	
412		28°00′N.	86°30′E.			D, S, P	
413		28°00′N.	86°30′E.			D	
414		28°00′N.	86°30′E.			D, P	
415		28°00′N.	86°30′E.			D, M, S, P	
416	*Drogpa Nagtsang*	28°00′N.	86°30′E.		10.5/0.8	D, M, S, P	2
417	*Ripimu*	28°00′N.	86°30′E.		10.5/0.7	D, S	2
418	*Tolambau (Drolambao)*	28°00′N.	86°30′E.		14.5/0.8	D, P	2, 3
419	*(Likhu Nup)*	27°45′N.	86°30′E.		4.2/0.5	D	2
420	*(Zurmoche)*	27°45′N.	86°30′E.		7.3/0.5	D, S	2
421	*Dudh Kund*	27°45′N.	86°30′E.	4,400	6.6/0.5	D, S	1, 3
422	*Lumding*	27°45′N.	86°30′E.	4,800	5.3/0.5	D, M, P	1, 3
423	*Thengpo*	28°00′N.	86°30′E.	4,300	2.2/0.3	D	1, 3
424	*Chhule*	28°00′N.	86°30′E.	4,680	4.7/0.4	D, S	1, 3
425	*Dingjung*	28°00′N.	86°30′E.	4,600	7.8/0.7	D, S, P	1, 3
426	*Pangbug*	28°00′N.	86°30′E.	4,880	8.6/0.7	D, S, P	1, 3
427	*Lunak*	28°00′N.	86°30′E.	4,600	18.2/0.8	D, S	1, 3
428	*Nangpa*	28°00′N.	86°30′E.	4,600	18.2/0.8	D, S	1, 3
429	*Sumna*	28°00′N.	86°30′E.	4,880	9.4/0.7	D, S, P	1, 3
430	*Ngojumba*	28°00′N.	86°45′E.	4,680	22.4/1.2	D, S, P	1, 3
431	*Gyubanare*	28°00′N.	86°45′E.	4,680	22.4/1.2	D, S, P	1, 3
432	*Changri (Nup)*	28°00′N.	86°45′E.	5,180	7.2/0.6	D	1, 2, 3

Table 2.—*Glaciers in the Nepal Himalaya and surrounding regions*—Continued

[Description: D, debris-covered glacier; S, lateral moraine; C, clean glacier; M, medial moraine; Dp, partly debris-covered glacier; P, pond; L, lake around glacier; ?, unknown whether it is covered by snow or debris. References: 1, Higuchi and others (1978, 1980); 2, Schneider (1963); 3, Yoshizawa (1977). Units: m, meter; km, kilometer]

Glacier number	Glacier name	Location latitude and longitude		Lowest glacier elevation (m), when known	Length/width (km), when known	Description	Reference
433	*East Changri (Changri Shar)*	28°00′N.	86°45′E.	5,180	5.2/0.7	D	1, 2, 3
434	Khumbu	28°00′N.	87°00′E.	4,920	16.5/0.7	D, M, S, P	1, 3
435	*West Cwm*	28°00′N.	87°00′E.	4,920	16.5/0.7	D, M, S, P	1, 3
436	*Nuptse*	28°00′N.	87°00′E.	4,960	6.3/0.4	D, S	1, 3
437	*West Lhotse (Lotse Nup)*	28°00′N.	87°00′E.	4,980	4.2/0.6	D, M, S	1, 2, 3
438	*Lhotse*	28°00′N.	87°00′E.	4,960	6.4/1.1	D, S	1, 3
439	*Imja*	28°00′N.	87°00′E.	5,030	9.8/0.7	D, M, S, P	1, 3
440	*Ama Dablam*	28°00′N.	87°00′E.	4,850	4.8/0.5	D, S	1, 3
441	*Hink (Shar Nup)*	27°45′N.	87°00′E.		7.5/0.4	D, S	2, 3
442	*(Hink Teng)*	27°45′N.	87°15′E.		5.0/1.0	D, P	2
443	*Hongu*	27°45′N.	87°00′E.	5,580	1.0/	D, P	1, 3
444	*Iswa*	27°45′N.	87°00′E.			D, S	3
445	*Lower Barun*	27°45′N.	87°00′E.		14.5/0.9	D, S, L	3
446	*Barun*	27°45′N.	87°00′E.		15.5/0.5	D, L	2, 3
447		27°45′N.	87°15′E.			D, S	
448	*Sakyetong*	28°00′N.	87°15′E.			D, S	
449	*Kangdoshung*	28°00′N.	87°00′E.			D, S	
450	*Chomo Lonzo*	28°00′N.	87°00′E.		6.0/0.5	D	2, 3
451	*Kangshung*	28°00′N.	87°00′E.		16.5/1.3	D, M, S, P	2, 3
452		28°00′N.	87°15′E.			D	
453		28°00′N.	87°00′E.			?	
454		28°00′N.	87°00′E.			?	
455		28°00′N.	87°00′E.			?	
456	*Kharta*	28°00′N.	87°00′E.			?	3
457	*East Rongbuk (Ronphu Shar)*	28°00′N.	86°45′E.			?	2, 3
458	*Rongbuk (Ronphu)*	28°00′N.	86°45′E.		15/1.1	?	2, 3
459	*Rongta*	28°15′N.	86°45′E.			?	3
	Gyachung	28°15′N.	86°45′E.			?	3
460		28°15′N.	86°30′E.			?	
461	*Kyetrak (Gyabrag)*	28°15′N.	86°30′E.			?	2, 3
462		28°30′N.	86°30′E.			?	
463		28°30′N.	86°15′E.			?	
464		28°30′N.	86°15′E.			?	
465		28°30′N.	85°45′E.			?	
466		28°30′N.	85°45′E.			D	
467	*Lashar*	28°00′N.	88°00′E.			D, M, S	3
468	*Lashar*	28°00′N.	88°00′E.			D, M, S	3
469		28°00′N.	87°45′E.			?, S, P	
470		28°00′N.	87°45′E.			?	
471		28°00′N.	87°45′E.			?	
472	*Hidden*	28°00′N.	87°45′E.			?, S	3
473	*Phuchong*	27°45′N.	88°00′E.			?, S	3
474	*Pamdro*	27°45′N.	88°00′E.			?, S	3
475	*Tsisima*	27°45′N.	88°00′E.			?, S	3
476	*Broken*	27°45′N.	88°00′E.			?	3
477	*Kangchenjanga*	27°45′N.	88°00′E.			?, S	3
478	*Ramtang*	27°45′N.	88°00′E.			?, S	3
479	*Jannu*	27°45′N.	88°00′E.			?	3
480	*Yomatari*	27°30′N.	88°00′E.			Dp, S	3
481	Yalung	27°30′N.	88°00′E.			D, S	3
482	Yalung	27°30′N.	88°00′E.			D, S	3

Table 2.—*Glaciers in the Nepal Himalaya and surrounding regions*—Continued

[Description: D, debris-covered glacier; S, lateral moraine; C, clean glacier; M, medial moraine; Dp, partly debris-covered glacier; P, pond; L, lake around glacier; ?, unknown whether it is covered by snow or debris. References: 1, Higuchi and others (1978, 1980); 2, Schneider (1963); 3, Yoshizawa (1977). Units: m, meter; km, kilometer]

Glacier number	Glacier name	Location latitude and longitude	Lowest glacier elevation (m), when known	Length/width (km), when known	Description	Reference
TISTA BASIN						
501		27°30′N. 88°15′E.			D	
502		27°30′N. 88°15′E.			D, M	
503		27°45′N. 88°15′E.			?, S	
504		27°45′N. 88°15′E.			D, S, P	
505		27°45′N. 88°15′E.			D, M, S	
506		27°45′N. 88°15′E.			D, S, P	
507		27°45′N. 88°15′E.			D, S, P	
508	*Jongsan*	28°00′N. 88°00′E.			D, S, P	3
509	*Lhonak*	28°00′N. 88°00′E.			D, M, S	3
510		28°00′N. 88°45′E.			D	
511		28°00′N. 88°45′E.			D	
512		28°00′N. 88°45′E.			D	
513		28°00′N. 88°45′E.			?	
514		27°45′N. 89°00′E.			?	
515		27°45′N. 89°00′E.			D	
YARLUNG ZANGBO JIANG						
601		28°30′N. 85°45′E.			D, M, S	
602		29°00′N. 84°30′E.			?	
603		29°00′N. 84°30′E.			?	
604		29°00′N. 84°30′E.			?	
605		29°00′N. 84°30′E.			?	
606		29°00′N. 84°15′E.			?	
607		29°00′N. 84°15′E.			?	
608		29°45′N. 83°00′E.			C, P	
609		29°45′N. 83°00′E.			C, S	
610		29°45′N. 83°00′E.			C, S	
611		29°45′N. 82°45′E.			C	
612		29°45′N. 82°45′E.			C	
613		29°45′N. 82°45′E.			C, S	
614		29°45′N. 82°45′E.			C	
615		29°45′N. 82°45′E.			C, P	
616		30°00′N. 82°45′E.			?	
617		30°00′N. 82°45′E.			C, S	
618		30°00′N. 82°45′E.			C, P	
619		30°00′N. 82°45′E.			C, S	
620		30°00′N. 82°45′E.			C, L	
621		30°00′N. 82°45′E.			C, P	
622		30°15′N. 82°15′E.			C, S, P	
623		30°15′N. 82°15′E.			C, S	
624		30°15′N. 82°15′E.			C	
625		30°15′N. 82°15′E.			C, S, L	
SUTLEJ BASIN						
701		30°30′N. 81°15′E.			C, S	
702		30°30′N. 80°30′E.			Dp	
703		30°30′N. 80°30′E.			Dp, S	
704		30°30′N. 80°15′E.			Dp, S	
705		30°30′N. 80°15′E.			Dp, S	
706		30°30′N. 80°15′E.			?	

TABLE 3.—*Glaciers in the Karakoram Range*

[Description: Dp, partly debris-covered glacier; M, medial moraine; C, clean glacier; D, debris-covered glacier; S, lateral moraine; L, lake around glacier; ?, unknown whether it is covered by snow or debris. Unit: km, kilometer]

Glacier number	Glacier name	Location latitude and longitude		Length (km)	Number of constituent glaciers	Description
1	Upper Tirich	36°26′N.	71°51′E.	17	17	Dp, M
2	Atark	36°30′N.	72°00′E.	16	3	C
3	Niroghi	36°30′N.	72°10′E.	12	2	D
4	Chiantar	36°50′N.	73°40′E.	30	4	Dp, S, M
5	Yashkuk Yaz	36°45′N.	74°20′E.	16	3	Dp, M
6	Batura	36°30′N.	74°40′E.	51	4	Dp, S, M
7	*Pasu*	36°30′N.	74°45′E.	21	1	Dp, S
8	*Ghulkin*	36°25′N.	74°50′E.	16	1	D
9	*Gulmit*	36°25′N.	74°50′E.	8	1	Dp, M
10	*Lupghur Yaz*	36°25′N.	75°00′E.	13	1	D
11	Momhil	36°25′N.	75°05′E.	20	1	Dp, S, M
12	Mulungutti	36°25′N.	75°15′E.	16	1	Dp, S, M
13	Yazghil	36°20′N.	75°25′E.	26	2	C, S
14	Khurdopin	36°15′N.	75°30′E.	35	2	Dp, S, M
15	Virjerab	36°15′N.	75°40′E.	37	2	Dp, M
16	Braldu	36°10′N.	75°50′E.	31	1	D, M
17	*Skamri*	36°05′N.	76°10′E.	35	3	Dp, S, M
18	*Sarpo Laggo*	35°55′N.	76°20′E.	27	3	Dp, S, M
19	K2	36°00′N.	76°30′E.	19	2	D, S, M
20	*Gasherbrum*	35°50′N.	76°40′E.	23	2	C, S, M
21	*Urdok*	35°45′N.	76°45′E.	21	2	D, M
22	*Staghar*	35°45′N.	76°50′E.	16	1	C, S
23	*Singhi*	35°40′N.	77°00′E.	?	2	Dp, S, M, L
24	*Kyagar*	35°35′N.	77°15′E.	17	3	C, S, M, L
25	Rimo	35°25′N.	77°30′E.	38	2	Dp, S, L
26	*S. Rimo*	35°20′N.	77°30′E.	23	2	Dp, L
27	*N. Shukpa Kunchang*	34°50′N.	77°50′E.	?	3	C, S, M
28	*S. Shukpa Kunchang*	34°40′N.	77°50′E.	?	3	D, S, M
29	*S. Terong*	35°10′N.	77°25′E.	24	2	D
30	*Teram Shehr*	35°30′N.	77°10′E.	28	1	Dp, S, M, L
31	Siachen	35°25′N.	77°05′E.	70	4	Dp, S, M
32	Bilafond	35°20′N.	76°55′E.	20	2	Dp, S, M
33	*Sherpi Gang*	35°20′N.	76°45′E.	16	1	Dp, S
34	Kaberi	35°30′N.	76°35′E.	25	2	Dp, S, M
35	*Chogolisa*	35°25′N.	76°30′E.	17	2	D, L
36	*Ghondokoro*	35°35′N.	76°25′E.	17	2	Dp, S, M
37	Godwin Austin	35°50′N.	76°35′E.	23	2	Dp, S, M
38	Baltoro	35°45′N.	76°20′E.	61	11	Dp, S, M, L
39	*Panmah*	35°55′N.	76°00′E.	41	4	Dp, S M
40	Biafo	35°50′N.	75°45′E.	52	3	D, S, M
41	*Kero Lungma*	36°00′N.	75°15′E.	15	3	D
42	Chogo Lungma	35°55′N.	75°10′E.	42	5	Dp, S, M
43	*Khotia*	35°50′N.	75°00′E.	12	3	D, S
44	*Mani*	35°55′N.	74°55′E.	14	2	D
45	Bualtar	36°10′N.	74°45′E.	19	2	D, M
46	Barpu	36°10′N.	74°50′E.	22	2	Dp, S
47	*Kham Basa*	36°10′N.	75°25′E.	13	2	D, S, M
48	*Julmau*	36°10′N.	75°20′E.	15	3	D, S, M
49	*Khingyang*	36°15′N.	75°10′E.	20	3	D, S
50	Hispar	36°05′N.	75°20′E.	47	4	D, S, M, L
51	*Triror (Gharesa)*	36°15′N.	74°55′E.	20	2	Dp, S

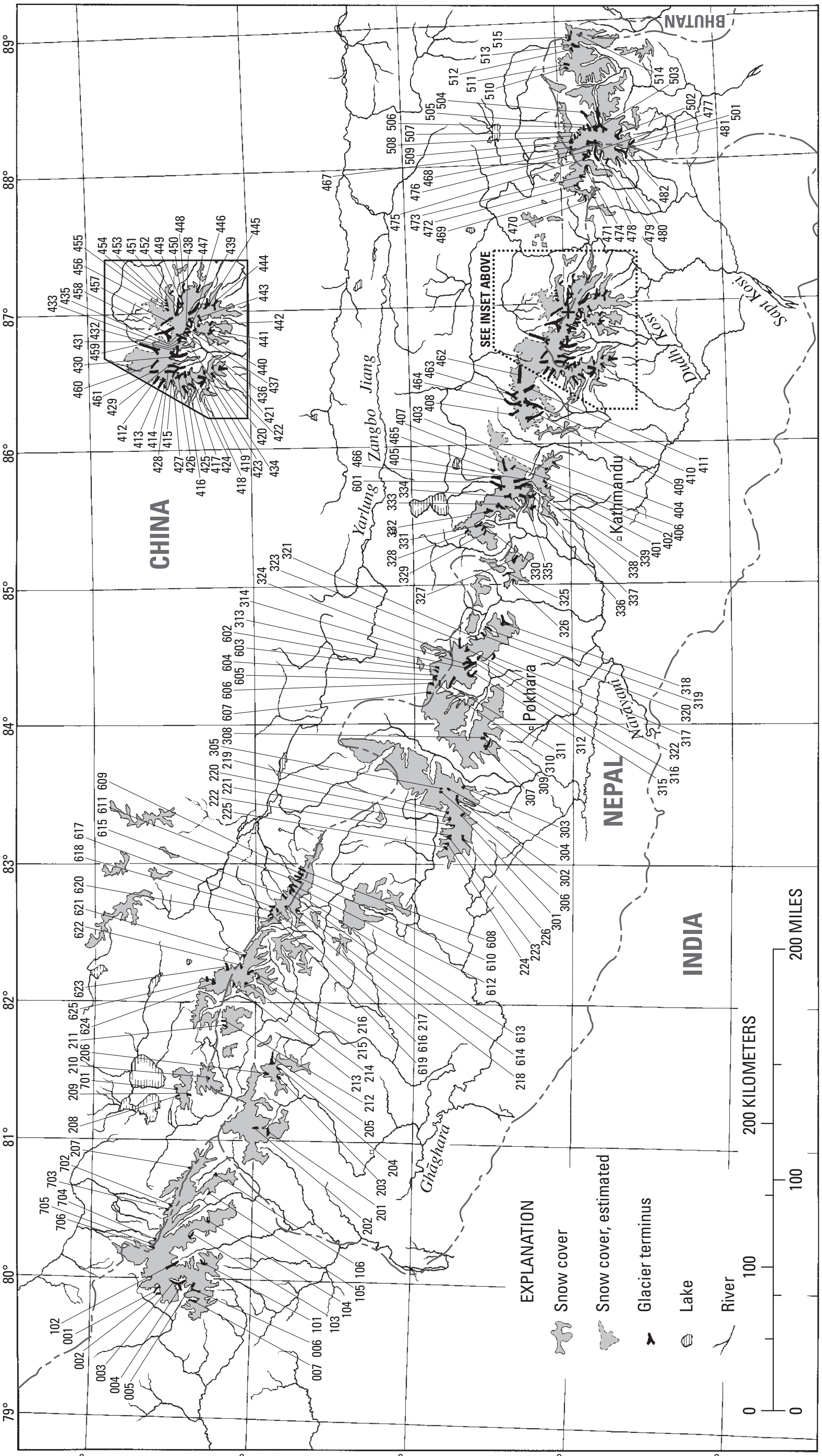


Figure 7.— Location of individual glaciers in the Nepal Himalaya and its surrounding regions, identified by glacier number (see table 2).

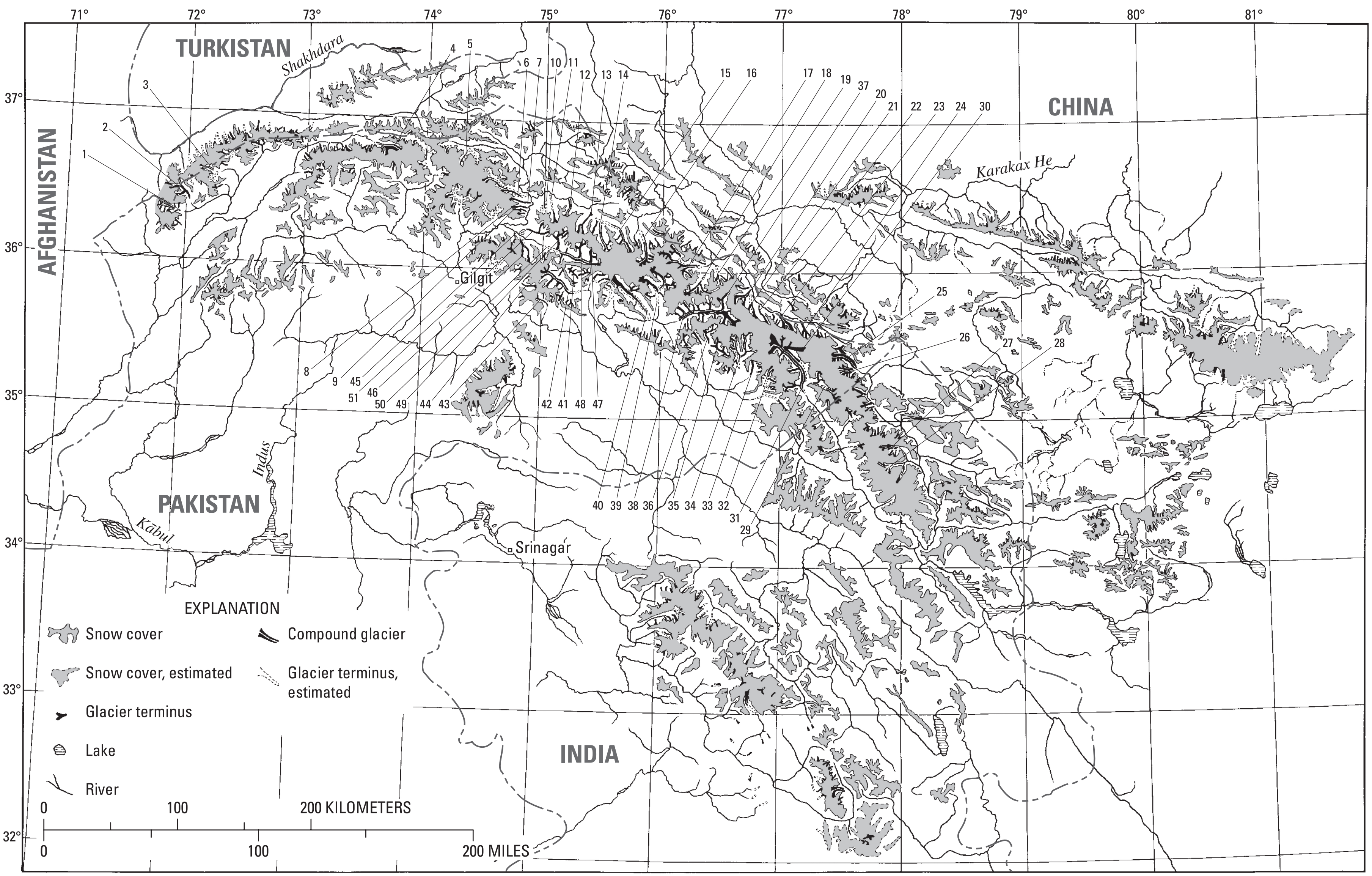


Figure 8.*— Location of individual glaciers in the Karakoram Range identified by glacier number (see table 3).*

Comparison of Nepal Himalaya and Karakoram Range Glacier Distribution

The Nepal Himalaya extend from about 80° to 87°E. in longitude and from about 27.5° to 30.5°N. in latitude (fig. 2). The central region of the Karakoram Range extends from 72° to 79°E. and from 34° to 37°N. (fig. 3). Both of these regions are nearly equivalent in areal extent (7 degrees of longitude and 3 degrees of latitude), and both have a northwest-southeast trending crest with several mountains over 8,000 m in elevation.

The topographical and climatic characteristics of these two regions are very different, however, and because of this, the distribution and features of the glaciers in these two regions are very different. The glacierized area of the Karakoram is much larger than that of the Nepal Himalaya in horizontal scale and is distributed as large, connected, glacier systems, whereas that of the Nepal Himalaya is distributed as individual glaciers.

Figures 2 and 3 show that the obvious contrast in cryospheric area between the Nepal Himalaya and the Karakoram is also reflected in the shapes and sizes of the individual glaciers. The total area of the glacierized region and the average length of glaciers of both mountain ranges, and the mean elevation of glacier termini for the Nepal Himalaya, are shown in table 4. In general, the accumulation basins of the Karakoram glaciers tend to concentrate the ice, and the river system is well controlled by the regional geological structure, so that compound glaciers with long lengths are well developed. In regard to the geomorphology, mountains in the Karakoram Range are massive, and the rivers are wholly parallel to the northwest/southeast crest line. Conversely, the Nepal Himalaya are composed of mountain ranges that are more separated; and although the mountains have a northwest-southeast trend, rivers cut the main range perpendicularly in a north-south direction. Additionally, climatic influence of the summer monsoon is different between regions — the Karakoram Range is less influenced by the summer monsoon than the Nepal Himalaya.

TABLE 4.—*List of glaciological characteristics of the Nepal Himalaya and the Karakoram Range*

[Abbreviations: km, kilometer; m, meter; ?, unknown]

Characteristic	Nepal Himalaya and surrounding regions	Karakoram Range
Total area of the glacierized region including snow cover	24,900 km^2	65,300 km^2
Average length of glacier	All glaciers: 8.1 km Karnāli Basin: 5.6 km Kāli Gandaki Basin: 9.0 km Sapt Kosi Basin: 9.6 km	25.4 km
Mean elevation of glacier terminus	All glaciers: 4,480 m Karnāli Basin: 4,450 m Kāli Gandaki Basin: 4,190 m Sapt Kosi Basin: 4,710 m	?

Glacier Inventory from Ground Surveys in the Dudh Kosi Region, Nepal, and Comparison with Landsat Image Analyses

Detailed studies on glaciers in the Dudh Kosi region, Khumbu Himal, were carried out from 1973 to 1978 as part of the Glaciological Expedition of Nepal (GEN) by Japanese scientists. The *Lhajung* station, located near *Periche* village where the upper *Imja Khola* joins the tributary originating from the Khumbu Glacier, was operated for three and a half years to collect meteorological data and to make glaciological observations on many glaciers of various sizes.

As a result of these ground studies, a glacier inventory was prepared for the Dudh Kosi region, using data from ground surveys and aerial photographs (Higuchi and others, 1978). In the glacier inventory, glaciers were divided into several categories according to the surface topography: (1) ice body, (2) ice body covered by debris, (3) estimated ice body, and (4) rock glacier. The glacier distributions were plotted on the "Mount Everest Regions" 1:100,000-scale map of the Royal Geographical Society (1975), and glaciers were denoted with numbers according to the above-mentioned categories.

The Dudh Kosi region was divided into several sub-basins identified by the letters AX to HX, and each glacier was assigned a three-digit number. Glacier numbers from Müller's pilot study (Müller, 1970) were shown as well as glacier names that were collected from various other sources. In the Dudh Kosi region, there are 664 glaciers recorded in this ground surveyed glacier inventory by GEN; Müller (1970) identified 166 glaciers in the *Nagpo Tsaugpo* and *Imja Khola* basins of the northernmost Dudh Kosi region.

Figure 9*A* is a Landsat MSS image of the Dudh Kosi region. The glacier distribution in this region as determined from the GEN ground survey is shown in figure 9*B*, and the glacier distribution based on the Landsat images is shown in figure 9*C*. When using the Landsat multispectral scanner (MSS) images, the minimum width and length of glaciers that are discernable is 0.3 km and 1.0 km, respectively; these can be seen without difficulty by simple visual analyses.

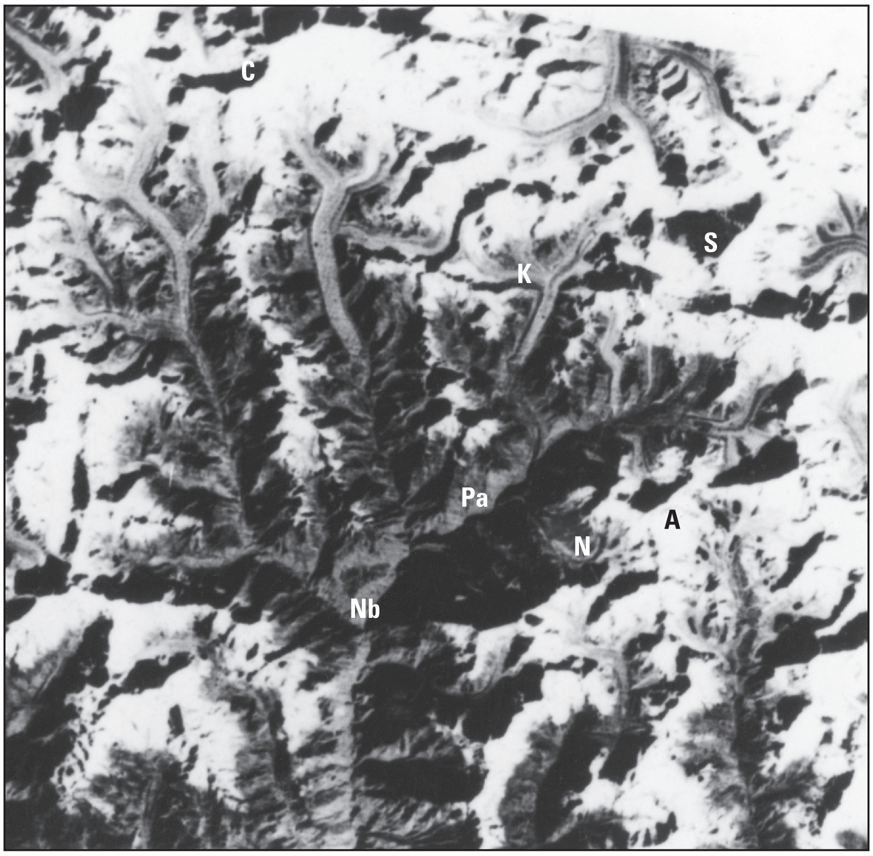
The smaller glaciers are considered as perennial ice-and-snow areas when analyzing glacier distribution on the Landsat image. It is possible to discern the smaller glaciers from the images only when meteorological conditions are good, and it is necessary for them to be checked by ground surveys.

Comparison of Results for the Khumbu Glacier, Nepal, from Landsat Image Analysis and Ground Surveys

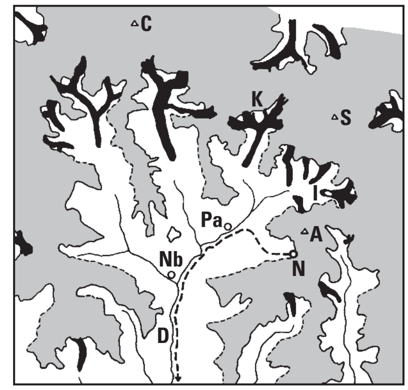
The Khumbu Glacier (fig. 10) is one of the best studied glaciers in the Nepal Himalaya. The glacier is composed of an upper part, the *Western Cwm*, that has an accumulation area that receives ice from the steep cliff of Sagarmatha (Mount Everest, 8,848 m) and an ice fall ranging from 5,400 to 6,000 m, and an ablation area with rich supraglacial debris in its lower part. The equilibrium line altitude is estimated to be at about 5,600 m and the terminus is at 4,920 m.

Below the ice fall, there are longitudinal rows of ice pinnacles which disappear in the lower part where the supraglacial debris occurs. Based on the flow measurements and surface topography, the present active terminus is thought to be located where the *Changri Glacier* joins from the west (fig. 11*A*). Below the present active terminus, it was thought there was stagnant ice and fossil ice from past glacier expansion that occurred in the 16th century (Fushimi, 1978). [Editors' note: However, it was later found that most of the glacier was active and flow velocities were measured (Nakawo and others, 1999).]

A



C



EXPLANATION

- Snow cover
- Path of outburst flood
- **A** *Mt. Ama Dablam*
- **C** Cho Oyu peak, (8,153 meters above sea level)
- **D** Dudh Kosi River
- **I** *Imja Glacier*
- **K** Khumbu Glacier
- **Nb** Namche settlement
- **N** *Nare Glacier Lake*
- **Pa** Pangboche
- **S** Sagarmatha peak (Mt. Everest, 8,848 meters above sea level)

B

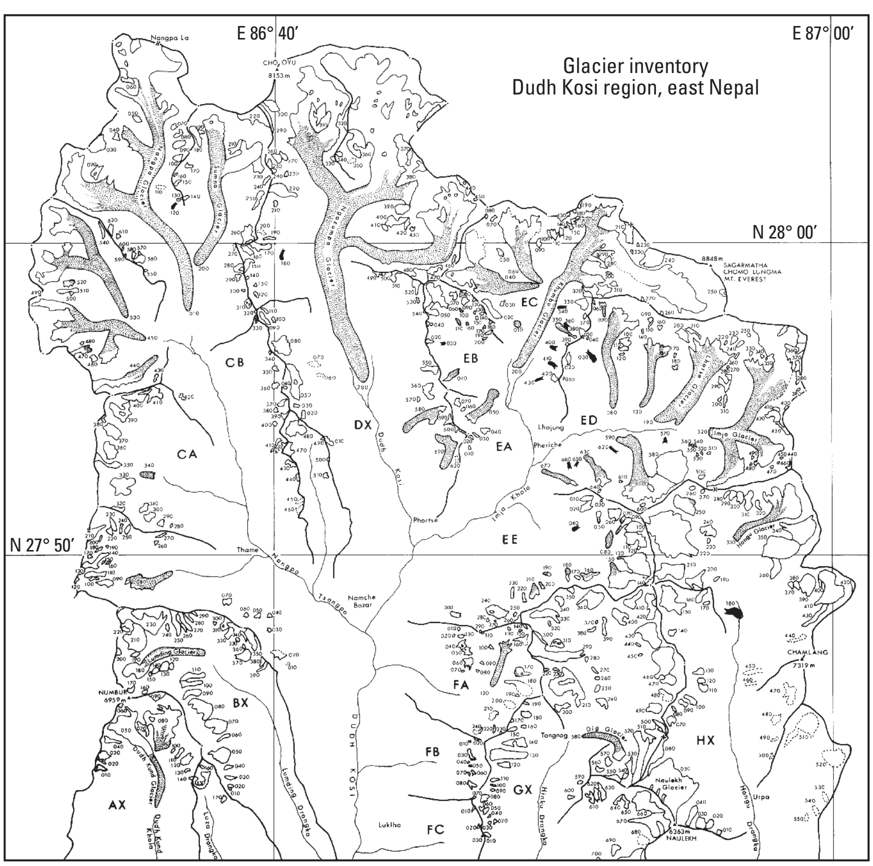


Figure 9.— **A**, *Landsat image;* **B**, *glacier inventory based on ground surveys; and* **C**, *glacier distribution mapped from Landsat image, in the Dudh Kosi region, east Nepal.*

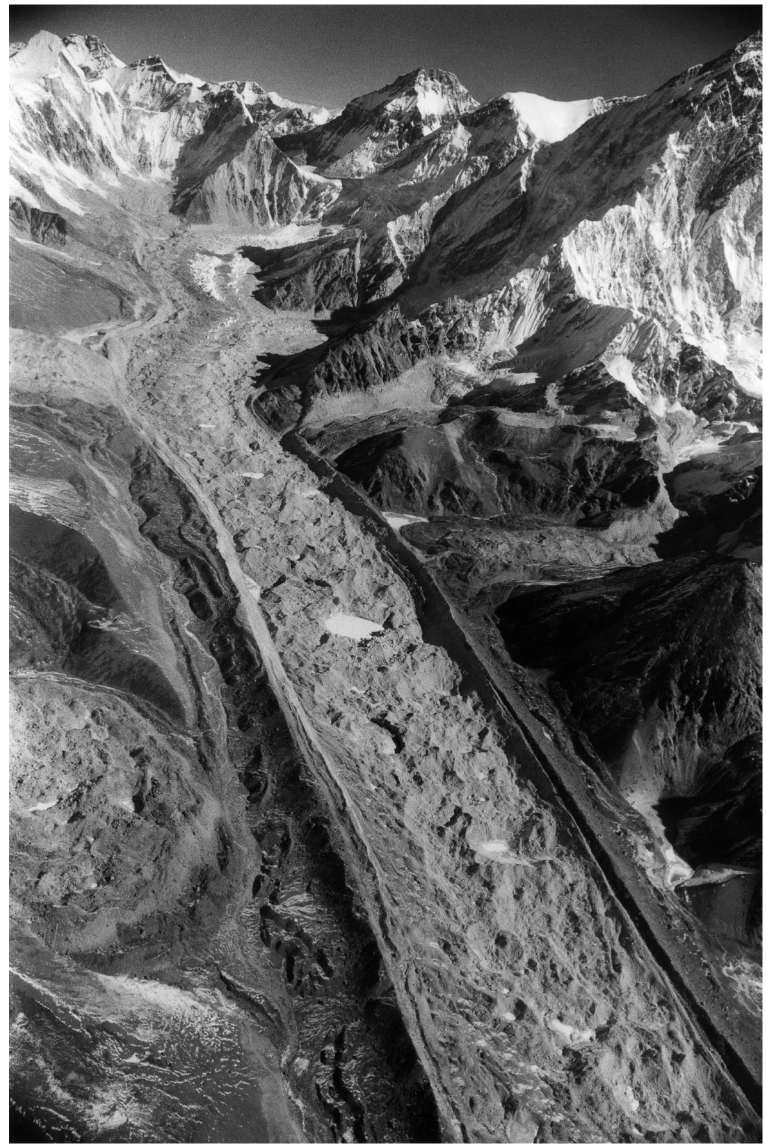


Figure 10.— *Oblique aerial photograph of the Khumbu Glacier, Khumbu region, east Nepal, taken on 11 December 1978.*

Thus, the Khumbu Glacier is broadly divided into a debris-free area and a debris-covered area, with ice pinnacles along its boundary. There are two types of rock in the supraglacial debris: dark-colored metasediments of generally black schists and hornfels, and light-colored plutonic rocks such as granite and diorite. Both types come from weathering of bedrock in the upper basins. The distribution of supraglacial debris gives information about the flow and ablation processes of compound glaciers.

Detailed topographical surveys and ground investigations of the debris-cover in the ablation area of Khumbu Glacier were carried out in 1978 to clarify the origin of the debris-cover, the heat balance characteristics, and the effects of debris cover on the glacier variations (Watanabe and others, 1980; Iwata and others, 1980; Fushimi and others, 1980; Inoue and Yoshida, 1980). As a result, a map of the debris-covered area was completed (fig. 11*B*). The map shows the ablation area of the glacier up to 5.5 km from the terminus, and contains 125-m grid squares which identify the coverage of debris-covered ridges, ice cliffs, lakes, and streams in each square.

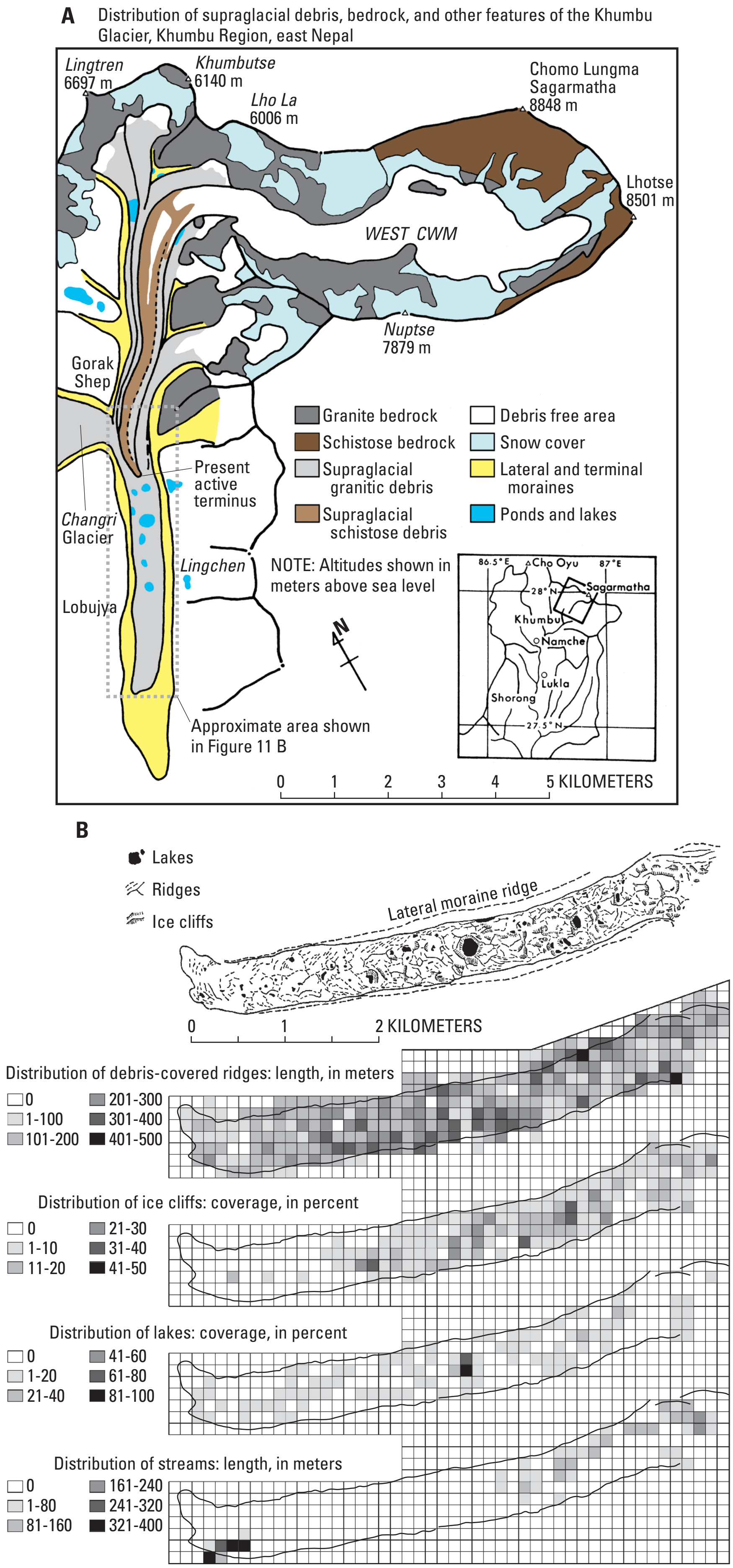


Figure 11.— **A**, *Distribution of supraglacial debris, bedrock, and other features of the Khumbu Glacier, Khumbu region, east Nepal.* **B**, *Surface characteristics of a 5.5 km length of the ablation area of the Khumbu Glacier, mapped in 125 m grid squares.*

During the same period, Rundquist and Samson (1980) examined the Khumbu Glacier using digital Landsat images. The aim of their study was to evaluate the utility of digital Landsat data for the analysis of alpine glaciers. They assumed the following six land-cover classes and analyzed their distribution from digital data: (1) water body (lakes, ponds, and streams), (2) barren rock, (3) moraine (unconsolidated deposits such as lateral and terminal moraines), (4) supraglacial moraine (light deposits termed "debris covered ice"), (5) clean ice, and (6) firn and snow. They concluded that their method provided a relatively accurate assessment of the surface characteristics of the Nepalese glacier.

Results of these simultaneous studies, the digital analysis of the Landsat image, and ground surveys of the surface features and topography in the ablation area of the Khumbu Glacier, were compared. Though the comparison indicated discrepancies in the interpretation of granitic debris and bare ice, generally good agreement was obtained between the surveyed topography and the map compiled from digital analysis of Landsat images. Fundamental topographic features such as the area of the active glacier, debris-covered area, the moraine distribution, and structures of the compound glacier flow are almost identical.

Landsat Image Analysis for Monitoring Glacier Disasters

Two types of glacier disaster may occur in Nepal— the extraordinary advances of surge-type glaciers and glacier outburst floods (GLOFs) (jökulhlaups) caused by collapse of moraine- or ice-dammed proglacial lakes. These happen simultaneously in some cases and independently in others. In the Khumbu region, it is still a controversial point whether glacier surges happened in the past or not; however, there are oral traditions among local people that advances of glaciers destroyed pastures, farm lands, and mountain paths of the Great Himalayas in the past.

In September 1977, an outburst flood occurred south of *Mt. Ama Dablam* (6,856 m) when the morainic dam of the *Nare Glacier* lake collapsed and caused a flood along the Dudh Kosi river. The flood destroyed river-side houses, camping tents, and killed several people.

This outburst flood was caused by rapid drainage from the ice-cored, moraine-dammed lake. The size of the lake before the flood was 200×300 m, and its depth was 25 m. The flood level reached up to 10 m, and flood sediments were deposited along the Dudh Kosi river. The location of the *Nare Glacier* lake, the course of the flood, and the affected areas are indicated by a dotted line on figure 9*C*.

It is difficult to predict glacier disasters, but it is possible, as a future application of repeated analysis of sequential Landsat images, to observe the expansion or partial drainage of glacier lakes, and extraordinary glacier advance (surge-type glaciers) by periodic monitoring for many years. Figure 12 shows the supraglacial lake of the *Imja Glacier* (fig. 7) which should be monitored in the Khumbu region.

It is clear from published maps and photographs that the supraglacial lake of Imja Glacier did not show any indication of expansion in the 1960s. However, in the 1970s, the area covered by the glacial lake was estimated from various sources and showed a large expansion in total area.

[Editors' note: Several recent studies have been published about the glacier hazards in Nepal. See, for example, the following supplement by Ageta, publications by Young, 1993; Young and Neupane, 1996; Upreti, 2000; Mool

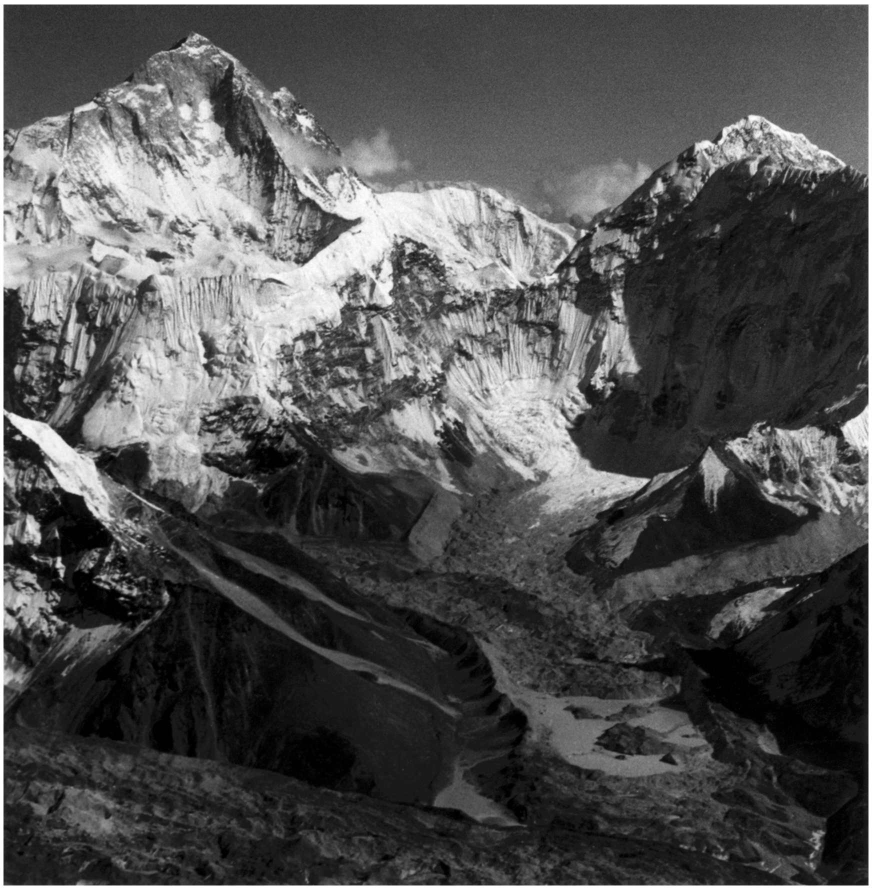


Figure 12.*— Oblique aerial photograph of the supraglacial lake of the* Imja Glacier, *Khumbu region, east Nepal taken on 30 November 1975. Mt. Makalu (8,481 m) is seen in the background.*

and others, 2001; the Nepal Case Study from the NAPA (National Adaption Program of Action) Workshop, Thimphu, Bhutan, September 2003, and the website of the International Centre for Integrated Mountain Development (ICIMOD), *http://www.icimod.org*]

Conclusions

It is clear that Landsat and other high-resolution satellite images are an invaluable tool for glaciological studies in Nepal. In comparisons with glacial distribution and features identified from ground investigations, Landsat images revealed many of the same features. Also, the distribution and features of the glaciers in the Nepal Himalaya and Karakoram Range could be compared using Landsat images. These images can be used for inventory, monitoring, mapping, and hazard prediction and detection. Perhaps the most important use is the latter — to help mitigate the disasters caused by potential glacial lake outburst floods. The images can be used to determine changes in water supply, to monitor lake size and flood threat potential, to monitor glacier termini positions which may indicate increased glacial melt, and to show other vegetation and land cover changes that may signal climate change.

Supplement to "Glaciers of Nepal"

By Yutaka Ageta[4]

Introduction

The preceding section, "Glaciers of Nepal" by Higuchi and others, was prepared in the early 1980s to describe the status of glaciers during the 1970s as analyzed by Landsat images and localized ground investigations. Here I briefly note supplementary information acquired after that time.

Glaciers in Nepal have been observed mainly by Japanese glaciologists since the 1970s. Their studies were reported by Higuchi (1993), Nakawo and others (1997), and Ageta and others (2001). Studies of Khumbu Glacier and other debris-covered glaciers which related to analyses in the preceding section were published by Seko and others (1998) and Nakawo and others (2000); glacier lakes and their outburst floods in Nepal were reported by Yamada (1998).

Another publication describing the glaciers of the Nepal Himalaya is a review of glacier distribution, characteristics, and glacier inventories in Asia by Tsvetkov and others (1998). Also, recently, Karma and others (2003) analyzed the distribution of the highest and lowest glaciers, and estimated equilibrium line altitudes of glaciers over most of the Himalayan Range, based on several glacier inventories.

Higuchi and others, in table 4 of the preceding section, calculated the total area of glaciers in Nepal to be 24,900 km^2. Their value is much larger than later results because they included the regions surrounding Nepal and the area of temporal snow cover. When referring to their work, it is also important to know that for several glaciers in the glacier list of table 2, one glacier was counted as two glaciers (for example, glacier numbers 430 and 431, 434 and 435). After their analysis, further estimates were made. The total glacierized surface area in Nepal was estimated at 6,000 km^2 from a preliminary glacier inventory based on Landsat image maps (Haeberli and others, 1989). [Editors' note: A map compiled by Qin Dahe and others (1999) reported a total of 3,466 glaciers in Nepal covering an area of 7,929 km^2 based on an analysis of 1975–78 Landsat MSS images.] An updated glacier inventory of Nepal was compiled by Mool and others (2001), utilizing Landsat images and other sources. They calculated the area of glaciers in Nepal to be 5,324 km^2.

[Editors' note: In addition to the excellent glaciological studies made by Japanese scientists in Nepal, other scientists from Nepal, the U.S., the U.K., Switzerland, Russia, and Germany, among others, have also made valuable contributions to all aspects of the glaciological research in Nepal in the last few decades.]

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Vertical aerial photographs were taken in 1992 and 1996 by the Survey Department of the Nepalese Government in cooperation with the Government of Finland. In the last several years, a topographical map series at 1:50,000 scale has been produced based on the photographs. Compilation of a more detailed and accurate glacier inventory of the whole country of Nepal using these aerial photographs and maps is now possible. Some work has already been done using these materials to analyze glacier variations by comparison with other earlier maps, photographs and satellite images and more is expected (Asahi, 2001).

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