

Glaciers of the Middle East and Africa—

GLACIERS OF TURKEY

By AJUN KURTER

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-G-1

The glaciers of Turkey have a total area of 22.9 km² and are located on three mountain ranges and three stratovolcanoes; documentation is provided by maps, aerial photographs, and Landsat images



CONTENTS

	Page
Abstract-----	G1
General introduction-----	1
Occurrence of glaciers-----	2
FIGURE 1. Index map to the mountain ranges, dormant stratovolcanoes, and the coverage by Landsat images of the glacierized regions discussed in the text-----	4
TABLE 1. Principal glaciers of Turkey -----	3
Observations of glaciers -----	6
Historical studies -----	6
Modern studies -----	6
Mapping of glaciers -----	7
The earliest maps of glaciers -----	7
Modern maps of glaciers -----	7
Imaging of glaciers-----	8
Aerial photography -----	8
Landsat imagery-----	9
Glaciers on Landsat images-----	9
FIGURE 2. Index map to the optimum Landsat 1, 2, and 3 images of the glaciers of Turkey-----	12
TABLE 2. Optimum Landsat 1, 2, and 3 images of the glaciers of Turkey-	10
Glaciers in coastal ranges along the Black Sea	13
Karagöl Dağı (Mount Karagöl), Giresun Dağları (Giresun Mountains) -----	13
Gavurdağları (Gavur Mountains) -----	13
Doğukaradeniz Dağları (Eastern Black Sea Mountains)--	13
FIGURE 3. A, A 1:1,000,000-scale Landsat MSS image (2211-07214, band 6; 21 August 1975; Path 186, Row 32) of north-central Turkey showing the areas of the annotated enlargements; B, An approximately 1:250,000-scale enlargement showing the Avliyana Glacier and other small mountain glaciers on Mount Aptalmusa in the Gavur Mountains; C, An approxi- mately 1:250,000-scale enlargement showing the Soğanlı Mountains with the highest peak, Mount At, and Varşanba Tepe (Mount Verçenik) and Mount Kaçkar with their small mountain glaciers -----	14
4. Photograph of Kaçkar I Glacier on the northwestern part of the summit of Mount Kaçkar in the Eastern Black Sea Mountains-----	16
Glaciers in the Toros Dağları (Taurus Mountains)-----	17
Orta Toroslar (Middle Taurus Mountains).....	17
Güneydoğu Toroslar (Southeastern Taurus Mountains) --	17
Kavuşşahap Dağları (Kavuşşahap Mountains)-----	19
FIGURE 5. A, Portion of a 1:1,000,000-scale Landsat MSS image (1146- 07525, band 7; 16 December 1972; Path 189, Row 34) of the Middle Taurus Mountains of south-central Turkey showing location of enlargements; B, An approximately 1:250,000-scale enlargement showing the Lolut Glacier (valley glacier) on the south flank of Demirkazık Peak in the Ala Mountains; C, An approximately 1:250,000-scale enlargement showing a mountain glacier on Medetsiz Peak in the Bolkar Mountains -----	18

	Page
FIGURE 6. A, A 1:1,000,000-scale Landsat MSS image (2189-07002, band 7; 30 July 1975; Path 182, Row 34) of southeastern Turkey showing the area of the annotated enlargement; B, An approximately 1:250,000-scale, band 5 enlargement showing the Buzul (Cilo) and Ikiyaka (Sat) Mountains and valley glaciers of the Southeastern Taurus Ranges -----	G20
7. Photograph of Uludoruk Glacier, the largest glacier on Uludoruk Peak, Southeastern Taurus Mountains -----	21
8. Annotated 1:1,000,000-scale Landsat MSS false-color composite image (2227-07104, bands 4, 5, and 7; 6 September 1975; Path 184, Row 33) including Mount Süphan, Lake Van, and Mount Hasanbeşir of the Kavuşşahap Mountains area of southeastern Turkey----	22
Glaciers on dormant stratovolcanoes	19
Glaciers on Erciyes Dağ (Mount Erciyes) -----	23
Glaciers on SüphanDağı (Mount Süphan)	25
The ice cap on Ağrı Dağ (Mount Ağrı, or Ararat) -----	25
FIGURE 9. Annotated 1:250,000-scale enlargement of part of a Landsat MSS image (2933-07110, band 7; 12 August 1977; Path 188, Row 33) showing glaciers on the flanks of Mount Erciyes, a dormant stratovolcano in central Turkey -----	23
10. Photograph of the valley glacier on the northwest slope of Mount Erciyes taken from 3,200 m -----	24
11. An approximately 1:250,000-scale annotated enlargement of part of a Landsat MSS image (2946-06414, band 7; 25 August 1977; Path 183, Row 33) showing mountain glaciers in the crater of the Mount Süphan stratovolcano north of Lake Van in southeastern Turkey	25
12. Annotated 1:250,000-scale enlargement of part of a Landsat MSS image (2586-06570, band 7; 30 August 1976; Path 183, Row 32) of the ice cap on Mount Ağrı, a dormant stratovolcano and Turkey's highest mountain	26
13. Annotated enlargement of part of a Landsat 3 RBV image (30950-06480-A; 10 October 1980; Path 182, Row 33) of Great Ararat and Little Ararat	27
14. An approximately 1:90,000-scale annotated enlargement of part of a Landsat 5 TM false-color composite image (50209-07140; bands 2, 4, and 7; September 1984; Path 170, Row 32) showing the prominent ice cap on Mount Ağrı-----	28
References cited	29

GLACIERS OF THE MIDDLE EAST AND AFRICA—

GLACIERS OF TURKEY

By **AJUN KURTER**¹

Abstract

Glaciers currently occur in Turkey in the higher elevations of the coastal ranges along the southeastern shore of the Black Sea, in the Middle and Southeastern Taurus Mountains, and on Mounts Erciyes, Süphan, and Ağrı. The total area of the glaciers is estimated to be 22.9 square kilometers, with the greatest concentration occurring in the Southeastern Taurus Mountains. Although a few early glacier studies were carried out just after 1900, modern scientific studies of the glaciers of Turkey did not begin until the 1930's. Precise, reliable modern topographic maps at scales of 1:100,000 and 1:25,000 have become available during the last 30 years. Complete aerial photographic coverage of Turkey has been acquired at 1:35,000 and 1:20,000 scales, but the photographs have limited usability for glacier research because they often contain too much snow cover and there is little repetitive coverage. Landsat imagery can be used for repetitive coverage of the glaciers of Turkey, but the spatial resolution restricts its use to the largest glaciers.

General Introduction

The areas of present glaciation in the Middle East are situated in the northern part of the region and include various types and sizes of glaciers in Turkey and Iran. The primary reasons for this distribution are (1) the decrease in the elevation of the snowline from south to north and (2) the presence of high mountains within these two countries that rise above the snowline altitude. In addition to the prevailing climatic conditions (for example, temperature, wind direction, precipitation), orographic factors, such as slope orientation and degree of landform dissection, are also favorable. By contrast, in the southern part of the Sinai Peninsula of Egypt, which also is a mountainous area, the snowline elevation lies above Mount Sinai (2,287 m), the highest peak in the region. Only during the Pleistocene was the snowline depressed enough to support glaciers in the southern Sinai Peninsula. Neither Syria nor Iraq has high enough mountains or climatic conditions suitable for formation of glaciers. In Lebanon, which is bordered on the west by the eastern Mediterranean Sea, a somewhat different situation exists. Elevations reach above 3,000 m in the Lebanon and Anti-Lebanon Mountains. Although the elevations are below the present snowline (about 3,700 m), there are occasional perennial snow patches at elevations that exceed 3,000 m. During the Würm glacial stage of the Pleistocene, even though the snowline dropped approximately 1,000 m to below 2,700 m, glaciation in this part of the Middle East was not fully developed because of orographic conditions and the degree of landform dissection (Klaer, 1957).

High mountain areas encompass parts of Turkey and Iran. The highest elevation in the Elburz Mountains in northern Iran is 5,670 m on

Manuscript approved for publication May 20, 1988.

¹ Institute of Marine Sciences and Geography, University of Istanbul, Istanbul, Turkey.

Damāvand. The summit of **Kūhhā-ye Sabālan**, approximately 135km east of Tabriz, Iran, has an elevation of **4,740** m. Here, the elevation of the snowline has been calculated to be about **4,500** m, so these high mountain systems support small glaciers. The eastern half of Turkey also is a suitable area for the development of glaciers of different sizes and types because of the climate and altitude. Information on the glaciers of Turkey will be given in this section. The glaciers of Iran will be discussed separately in the next section.

Occurrence of Glaciers

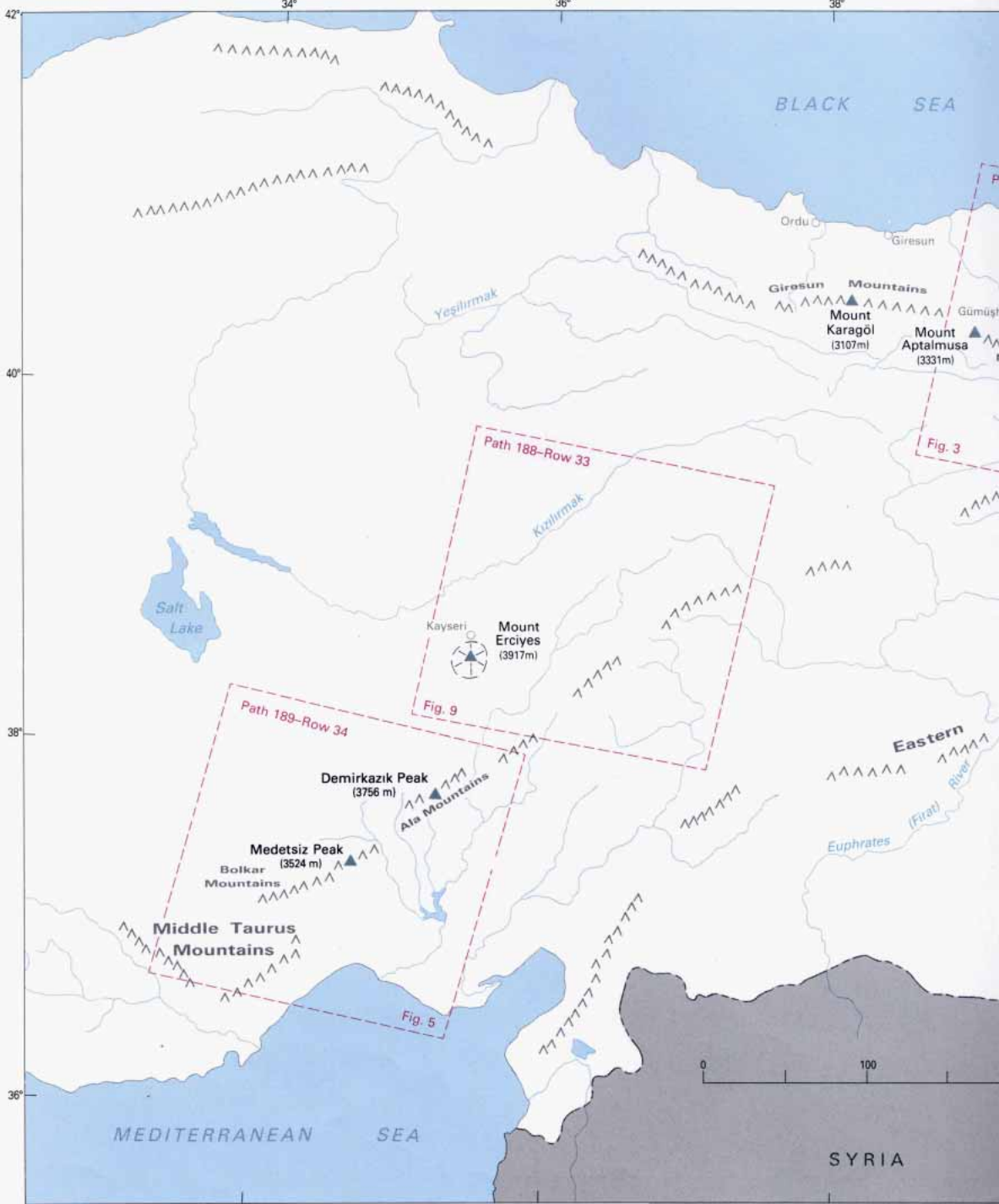
Turkey, located between latitudes **36°** and **42°** N., exhibits different topographic and climatic features from west to east as well as from the coastal to interior regions. For example, high mountain chains extending parallel to the northern and southern coasts prevent penetration of moist air masses to the interior plains and plateaus. Although the elevation of Turkey's interior is considerable, the highest terrain is located in the central and eastern parts, especially in association with the many extinct or dormant volcanoes. Toward the east, different mountain ranges converge to produce a region of increasing elevation. The highest extinct volcanoes are also located in this region. The degree of continentality increases with distance from the coast. Temperature rises toward the interior, while the simultaneous increase in continentality results in lower precipitation toward the east. On the other hand, humid air masses that move over the region during the winter months produce precipitation that exceeds **2** m in the higher elevations. There are a few glaciers on the summits of coastal mountains that have elevations above the snowline. Well-developed glacierization and long valley glaciers are nonexistent in these coastal ranges, however, because of the increased elevation of the snowline, high degree of erosional dissection, and small number of peaks that are above the snowline. Toward the eastern part of Turkey, the elevation of the snowline increases in association with continentality, so that the glaciation in this region seems to be less well developed. The southeastern part of the **Toros Dağları** (Taurus Mountains)² is the foremost glacierized area. Some valley glaciers in this region are **4** km in length (table 1). **Ağrı Dağı** (Mount Ağrı, or Mount Ararat), near the eastern border, has an elevation of 5,137 m. It is covered with an ice cap that has an area of 10.0 km², the largest single glacier in Turkey. Thus, one can say that glaciation in Turkey is developed for the most part in the eastern part of the country (fig. 1). Although no comprehensive studies on glaciation in Turkey have been carried out, in the limited studies that have been done, most scientists have reached similar conclusions. The studies have found some traces of evidence about glaciation in earlier glacial periods, especially Riss. It has also been concluded that extensive glaciation occurred at the beginning of the Würm. In fact, the snowline was at least 1,000 m lower than at present. As a result, valley glaciers developed, descending to an elevation of **2,000** m. Cirque glaciers and small valley glaciers formed on mountains that do not have glaciers today. However, this glaciation disappeared after the end of Würm II. In other words, the present glaciation cannot be considered to be a continuation of the Pleistocene glaciation. During the postglacial interval

² The geographic names used in this subchapter are from the Gazetteer of Turkey (U.S. Board on Geographic Names, **1984**), the New Atlas of Turkey (Harita Genel Müdürlüğü, 1977), and the author.

of warm temperatures, glaciers probably existed only on one or two of the highest mountains. Other glaciers regenerated within historic times (B.C. 2200-1800), and, during this period, the area covered with glaciers is estimated to have been twice the present one. Beginning with the second half of the 19th century, a glacier recession began. In conclusion, one can say that glaciers in Turkey have been subjected to many fluctuations in position of termini and areal extent since the end of the Pleistocene Epoch.

TABLE 1.—Principal glaciers of Turkey (after Kurter and Sungur, 1980)

Name of mountain range	Name of mountain or peak	Elevation of mountain or peak (m)	Location (latitude and longitude)	Named glacier(s) (informal names shown in quotation marks)	Type of glacier	Area of glacier(s) (km ²)	Mean length of glacier (km)
Giresun Mountains.	Mount Karagöl	3,107	40°30'-40°32'N. 38°08'-38°13'E.	"Northwest"	Mountain	0.08	0.4
Gavur Mountains	Mount Aptalmusa	3,331	40°22'-40°26'N. 39°02'-39°07'E.	Avliyana	Mountain	.045	.15
Eastern Black Sea Mountains.	Varşanba Peak (Mount Verçenik)	3,710	40°40'-40°46'N. 40°54'-41°05'E.	Sinançor and Varşanba Tepe	Valley	.14	.7
Eastern Black Sea Mountains.	Mount Kaçkar	3,932	40°50'-41°00'N. 41°08'-41°20'E.	Kaçkar I, II, III, and Krenek II	Valley	.06	.3
Middle Taurus Mountains.	Mount Medetsiz Bolkar Mountains	3,524	37°26'-37°33'N. 34°36'-34°50'E.	"North"	Mountain	.06	.3
Middle Taurus Mountains.	Mount Demirkazik Ala Mountains	3,756	37°41'-37°55'N. 35°02'-35°16'E.	Lolut	Valley	.5	1.0
Southeastern Taurus Mountains ...	Mount Uludoruk (Reşko)	4,135	37°26'-37°32'N. 43°56'-44°04'E.	Uludoruk and Mia Havara	Valley	8.0	4.0
Southeastern Taurus Mountains ...	Mount Dolampar İkiyaka (Sat) Mountains	3,794	37°18'-37°24'N. 44°10'-44°20'E.	Geverok	Valley	.8	1.0
Kavuşşahap Mountains	Mount Hasanbegir	3,503	38°12'-38°16'N. 42°48'-42°54'E.	"Northwest"	Mountain	.06	.3
	Mount Erciyes	3,917	38°31'-38°34'N. 35°24'-35°28'E.	"Northwest"	Valley	.11	.55
	Mount Süphan	4,058	38°53'-38°55'N. 42°47'-42°52'E.	"South"	Mountain (crater)	3.0	1.5
	Mount Ağrı	5,137	39°41'-39°44'N. 44°15'-44°19'E.		Ice cap	10.0	-
					Total:	22.9	



BLACK SEA

42°
40°
38°
36°

34° 36° 38°

Salt Lake

Yesilirmak

Kızılırmak

Euphrates (Fırat) River

MEDITERRANEAN SEA

SYRIA



Fig. 9

Mount Erciyes (3917m)

Demirkazık Peak (3756 m)

Medetsiz Peak (3524 m)

Middle Taurus Mountains

Bolkar Mountains

Ala Mountains

Giresun Mountains

Mount Karagöl (3107m)

Mount Aptalmusa (3331m)

Path 188-Row 33

Path 189-Row 34

Fig. 3

0 100

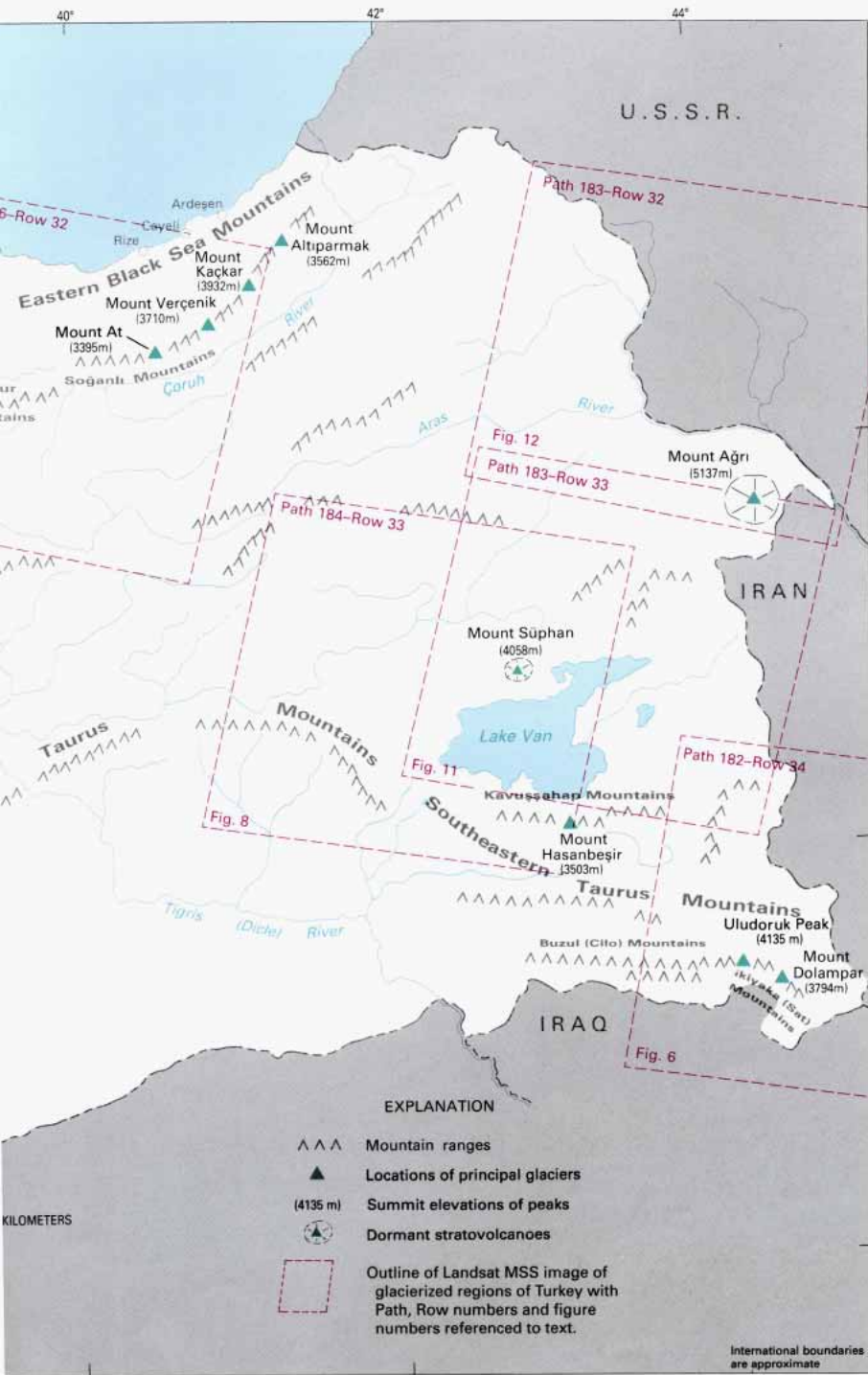


Figure 1.—Mountain ranges, dormant stratovolcanoes, and the coverage by Landsat images of the glacierized regions discussed in the text.

Observations of Glaciers

Historical Studies

From a historical viewpoint, published references to glaciers in Turkey are not very old or extensive. Although the presence of glaciers in the southeastern part of the Taurus Mountains was noted in 1842 (Ainsworth, 1842), and similar observations were made in the *Doğukaradeniz Dağları* (Eastern Black Sea Mountains) (Koch, 1846; Palgrave, 1872), the scientific study of the glaciers of Turkey did not begin until the 20th century. Maunsell (1901) studied glaciers in the Buzul Dağı (Buzul, or Cilo, Mountains) in the Güneydoğu Toroslar (Southeastern Taurus Mountains) in 1901; Penther (1905) studied glaciers on Erciyes Dağı (Mount Erciyes) in 1902. Penther's photograph of one of these glaciers is the oldest known photograph of a glacier in Turkey. Philippson (1906) published an article on this same glacier on Mount Erciyes. However, these initial studies were not followed by additional ones in other glacierized areas of the country. As a matter of fact, after these studies were completed, there was a lengthy hiatus before additional glacier studies were again carried out in Turkey.

Modern Studies

In a real sense, scientific studies on glaciers in Turkey began during the 1930's. During those years additional glacierized areas were discovered. In 1927, Künne (1928) visited the *Aladağ* (Ala Mountains). During the same year, Stratil-Sauer (1927) studied the Eastern Black Sea Mountains. However, the most remarkable studies in these regions were made by Krenek (1932) and Leutelt (1935). During that period Bartsch (1935) studied the Erciyes Glacier. At the beginning of World War II, Bobek (1940) made an exhaustive study of glaciers in the Buzul Mountains of the Southeastern Taurus Mountains that included good photographic documentation of the glaciers. Bobek's work was the first in which the glaciated areas of Turkey were studied in the context of the Pleistocene. No other detailed studies were made during World War II, with the exception of the general study by Louis (1944). In the years following World War II, Turkish geographers began to play a more active role in glacial studies. In particular, the research by Erinç is recognized as that of the pioneer Turkish glaciologist, with his very detailed studies of Turkey's glaciers (Erinç, 1949a,b, 1951, 1952b, 1953), including the discovery of glaciers on *Kaçkar Dağı* (Mount Kaçkar) (Erinç, 1949b) and on *Süphan Dağı* (Mount Süphan). He also made valuable contributions in his studies of variations in snowline altitudes (Erinç, 1952a). Glaciers in the Buzul Mountains were also studied by Izbirak (1951), another Turkish scientist, who was active at the same time. By the 1960's, foreign scientists became more and more interested in the glaciers discovered previously in Turkey. For example, Klaer (1962, 1965, 1969) studied glaciers on Mount Erciyes, Mount Süphan, the Ala Mountains, and the *Bolkar Dağları* (Bolkar Mountains). Wright (1962) investigated glaciers in the Buzul Mountains. Blumenthal (1938, 1952, 1954, 1955, 1956, 1958) studied glaciers in the Ala Mountains, on Mount Kaçkar, and on Mount *Ağrı*. Gall (1966) studied glaciers on *Varşanba Peak* (Mount Verçenik), or Dilek Peak, and Mount Kaçkar. Löffler (1970) investigated glaciers on Mount Verçenik, Mount Kaçkar, and in other parts of the Eastern Black Sea Mountains. Spreitzer (1939, 1956, 1958, 1959, 1971) carried out

studies of glaciers on Mount Süphan and in the Ala Mountains. Stratil-Sauer, who initially carried out investigations in the Eastern Black Sea Mountains (1927), continued his studies of Pleistocene glaciation and small modern glaciers in the western part of these ranges (1961, 1964, 1965). Imhof (1956), Ivan'kov (1959), and Arkel (1973) conducted studies of glaciers on Mount Ağrı. In addition, Louis (1938, 1944), Messerli (1964, 1967), and Birman (1968), made observations and published papers about the glacierized areas of Turkey. Birman (1968) also endeavored to conduct a reconnaissance survey of the glacial geology and glaciers of the entire country. Horvath (1975) reviewed the glaciers of Turkey as part of a discussion of the area including Turkey, Armenian S.S.R., and Iran.

Mapping of Glaciers

The Earliest Maps of Glaciers

During the 19th century, accurate large-scale or small-scale maps were not available for glacier studies in Turkey. For this reason, from the middle to the end of the 19th century, all of the scientists who carried out field studies in Turkey had to produce their own base maps. This situation prevailed until the beginning of the 20th century. In the years preceding World War I, maps, such as those made by the German cartographer Kiepert, in which relief features were shown by hachures, became available but were filled with numerous errors (Philippon, 1918). Maps made of the southeastern part of the country at a scale of 1:400,000 by German cartographers and at a scale of 1:250,000 by British mapmakers during this period were used by many explorers after World War I. For example, Bobek (1940) made use of these maps in his glacial studies in the Buzul Mountains and in the İkiyaka (Sat) Dağları (İkiyaka, or Sat, Mountains). However, there is no information about glaciers on the aforementioned maps.

In summary, for glacial geology and glacier studies in Turkey until the beginning of World War II, explorers had to use very small scale maps. These maps did not show any glaciers and also provided erroneous information about peaks, valleys, and landforms, in general. As a result, scientists made many errors on sketch maps of glaciers.

Modern Maps of Glaciers

In the years following World War II, as greater interest was shown in glaciological research, scientists involved in such studies were more fortunate because of the availability of more reliable topographic maps. A 1:200,000-scale topographical map series of Turkey in which contour intervals are shown at 50-m intervals was completed by this time. Unfortunately, topographic maps in this series do not contain correct information on either elevations or geographic place-names. Hence, scientists who used the 1:200,000-scale topographic maps noted that there were inconsistencies in place-names used by earlier explorers and place-names shown on more recently published maps (Gall, 1966; Löffler, 1970). In addition, glaciers are not delineated on this map series. Despite these obvious problems, the 1:200,000-scale maps have been used in almost all recent studies of glaciers. However, explorers made use of these maps only for orientation purposes and finding their locations.

Within glacierized regions each scientist had to draw a large-scale sketch map with an altimeter and a compass. However, errors do exist on these sketch maps because of the inaccurate base maps.

In recent years the situation has been altered considerably because of the availability of very precise topographic maps of Turkey at scales of 1:250,000, 1:100,000, and 1:25,000. When these maps are used, sketch maps drawn by explorers are more precise, especially with regards to delineation of the snowline. Also on recently published 1:25,000- and 1:100,000-scale topographic maps, contour lines on the larger glaciers are drawn in blue. Although the large-scale maps were primarily prepared to support military planning and operations and have some restrictions in their availability, in recent years scientists have been able to use them in their research. For example, Planhol and Bilgin (1964) and Kurter and Sungur (1980) based their research on these maps.

In summary, maps of the glacierized areas of Turkey since World War II have been compiled in the field because of lack of availability of large-scale topographic maps, but most such independently drawn maps contain errors. More recently, however, 1:25,000- and 1:100,000-scale maps have become available for modern field studies, and scientists have begun to make effective use of them.

Imaging of Glaciers

Aerial Photography

In Turkey, aerial photogrammetric methods were used extensively for the first time during the 1950's. The main impetus was to meet the objective of preparing a 1:25,000-scale topographic map series of Turkey. A military unit attached to the General Staff Headquarters was given the responsibility for acquiring complete aerial photographic coverage of Turkey. Vertical aerial photographs of the entire country were taken over a period of several years. The vertical aerial photographs can be used, with some restrictions, for all types of scientific studies, with the exception of mapmaking. Two scales, one at 1:35,000 and the other 1:20,000, are available. The 1:20,000-scale vertical aerial photographs are more suitable for studies of glaciers.

Although aerial photographs are available of the glacierized areas of Turkey, the anticipated increase in glacial and glacier studies in Turkey has not been realized, because the photographs were acquired for topographic mapmaking, not for scientific purposes. Thus, the photographs are generally only of average quality, often lacking in the detail needed to support precise scientific investigations. In addition, another negative factor in their use for glacier studies is the limited opportunity for repetitive coverage. Because the main purpose is for topographic mapmaking, only one or two flights are made over each area to be mapped. Once a usable set of aerial photographs is available for topographic mapmaking, no other survey flights of the area are scheduled. Thus, scientists are deprived of the availability of periodic aerial photographs necessary to determine the advance or retreat of a glacier. Also, because the aerial photographs have not been taken during the time of minimum snow cover, determination of the snowline on the glaciers is very difficult.

In recent years, aerial photographs have also been acquired for forest-management purposes, and 1:10,000- and 1:5,000-scale aerial photographs are available for such studies. However, because glacierized areas do not coincide with forested areas, these aerial photographs are not useful for glacier studies. Arrangements for photographing glacierized areas during a specific season and time can be made with the Harita Genel Müdürlüğü (General Maps Directorate), the only establishment in Turkey authorized to acquire aerial photographs, but the institution that needs the photographs must pay all costs.

Landsat Imagery

The limitations inherent in using aerial photographs of Turkey for glacier studies do not apply to Landsat imagery. In fact, glaciers could be analyzed during different years on Landsat images available for the period 1972–77 (table 2; figs. 1 and 2). Thus, advance or recession of glaciers could easily be determined. Also, acquisition of images at the end of the melt season increases the chance of having minimum snow cover. In this way, satellite images give some advantages that cannot be derived from aerial photographs. However, delineation of Turkey's glaciers on satellite images is difficult because of the glaciers' small areas and volumes. Although glaciers on the volcanic cones of Mount Erciyes, Mount Süphan, and Mount Ağrı can be seen quite easily on the 1:1,000,000-scale images, small features such as glacierets and firn patches cannot be detected in the mountain ranges, especially on high peaks and steep slopes, even on enlargements of the images. For this reason, only the major glaciers of Turkey could be studied on available Landsat multispectral scanner (MSS) and return beam vidicon (RBV) images, even though they are enlarged to a scale of 1:250,000 or larger. Also, some of the available Landsat MSS and RBV images contain too many clouds and (or) too much snow cover for optimum analysis (table 2).

In the following discussion of Turkey's glaciers, a combination of aerial photographs and Landsat images was used, even though each had its own limitations. Because the aerial photographs of Turkey were taken for other uses, primarily mapmaking, they were not acquired during the optimum time of year (end of the melt season) and do not provide repetitive coverage; therefore, they have only limited value for studies of glaciers. These shortcomings of the aerial photographs are overcome by use of the Landsat images; however, the spatial resolution of the Landsat MSS images restricts its value to studies of only the largest Turkish glaciers.

Glaciers on Landsat Images

In Turkey, various types of glaciers tend to cluster in specific areas, and, in fact, almost all of the glaciers are located in the eastern half of the country (fig. 1). The glaciers are classified as valley, mountain, and rock glaciers. The concentration of glaciers in specific areas presents an opportunity for recording several of them on the same image. However, since some glaciers have developed on the highest peaks in widely separated parts of Turkey, several satellite images must be used to cover all the glacierized regions of Turkey. Eight separate Landsat images are the minimum needed to provide complete coverage, although only seven are shown in figure 1 because of the lack of an adequate image for one region.

TABLE 2. – *Optimum Landsat 1, 2, and 3 images of the glaciers of Turkey*

[Explanation of symbols used in the "Code" column is provided on figure 2. The single occurrence of a half-filled circle indicates a fair to poor image]






















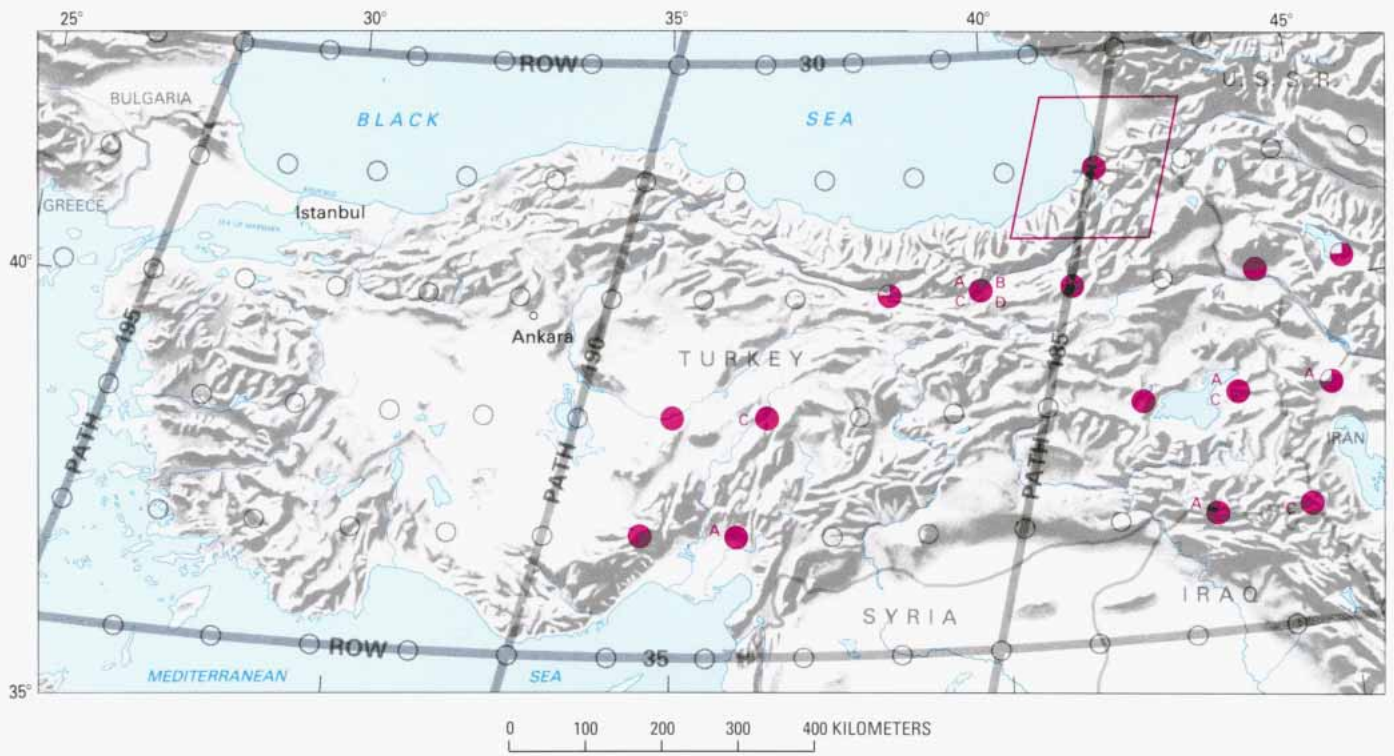
Path-Row	Nominal scene center (lat-long)	Landsat identification number	Date	Solar elevation angle (degrees)	Code	Cloud cover (in percent)	Remarks
18232	40°14'N. 45°34'E.	2603-06505	16 Sep 76	43		10	Mount Ağrı
182-33	38°49'N. 45°05'E.	2603-06512	16 Sep 76	44		10	Mount Ağrı
182-33	38°49'N. 45°05'E.	30950-06480-A	10 Oct 80	36		0	Mount Ağrı; Landsat 3 RBV; figure 13
182-34	37°24'N. 44°37'E.	2189-07002	30 Jul 75	56		0	Buzul and İkiyaka Mountains; figure 6
182-34	37°24'N. 44°37'E.	30950-06482-C	10 Oct 80	37		0	Buzul and İkiyaka Mountains; Landsat 3 RBV
183-32	40°14'N. 44°08'E.	2586-06570	30 Aug 76	47		10	Mount Ağrı; figure 12
183-32	40°14'N. 44°08'E.	2946-06411	25 Aug 77	46		0	Mount Ağrı; color composite available
183-33	38°49'N. 43°39'E.	2946-06414	25 Aug 77	47		0	Mount Süphan, Kavuşşahap Mountains; figure 11
183-33	38°49'N. 43°39'E.	2208-07050	18 Aug 75	52		10	Mount Süphan, Kavuşşahap Mountains
183-33	38°49'N. 43°39'E.	30915-06545-AC	05 Sep 80	46		0	Mount Süphan, Kavuşşahap Mountains; Landsat 3 RBV
183-34	37°24'N. 43°11'E.	2208-07053	18 Aug 75	53		0	Kavuşşahap and Buzul Mountains
183-34	37°24'N. 43°11'E.	30951-06540-A	11 Oct 80	37		0	Kavuşşahap Mountains; Landsat 3 RBV
184-33	38°49'N. 42°13'E.	2227-07104	06 Sep 75	48		0	Mount Süphan, Kavuşşahap Mountains; color composite available; figure 8
185-31	41°40'N. 41°46'E.	2210-07153	20 Aug 75	50		0	Mount Altıparmak area of Eastern Black Sea Mountains; color composite available
185-32	40°14'N. 41°16'E.	2084-07170	16 Apr 75	50		0	Mounts At and Kaçkar area of Eastern Black Sea Mountains; heavy snow cover; color composite available
186-32	40°14'N. 39°50'E.	2211-07214	21 Aug 75	51		0	Mounts Aptalmusa and Kaçkar areas; color composite available; figure 3
186-32	40°14'N. 39°50'E.	30954-07102-ABCD	14 Oct 80	34		0	Mount Aptalmusa and Varşanba Peak; Landsat 3 RBV
187-32	40°14'N. 38°24'E.	2248-07271	27 Sep 75	41		10	Mount Karagöl, Giresun Mountains; color composite available
188-33	38°49'N. 36°28'E.	2933-07110	12 Aug 77	49		0	Mount Erciyes; figure 9
188-33	38°49'N. 36°28'E.	2915-07120	25 Jul 77	52		0	Mount Erciyes; color composite available
188-33	38°49'N. 36°28'E.	30956-07220-C	16 Oct 80	34		0	Mount Erciyes; Landsat 3 RBV

TABLE 2.-Optimum Landsat 1, 2, and 3 images of the glaciers of Turkey—Continued

Path-Row	Nominal scene center (lat-long)	Landsat identification number	Date	Solar elevation angle (degrees)	Code	Cloud cover (in percent)	Remarks
188-34	37°24'N. 36°00'E.	2933-07113	12 Aug 77	50	●	0	Ala Mountains; some snow cover
188-34	37°24'N. 36°00'E.	30938-07231-A	28 Sep 80	41	◐	20	Ala Mountains; Landsat 3 RBV
189-33	38°49'N. 35°02'E.	2268-07390	17 Oct 75	36	●	0	Mount Erciyes; fine topographic detail
189-34	37°24'N. 34°34'E.	1146-07525	16 Dec 72	24	●	0	Ala and Bolkar Mountains; some snow cover; figure 5



EXPLANATION OF SYMBOLS

Evaluation of image usability for glaciologic, geologic, and cartographic applications. Symbols defined as follows:

- Excellent image (0 to ≤ 5 percent cloud cover)
- Good image (> 5 to ≤ 10 percent cloud cover)
- Usable Landsat 3 return beam vidicon (RBV) scenes
A, B, C, D refer to usable RBV subscenes
- Nominal scene center for a Landsat image outside the area of glaciers



Approximate size of area encompassed by nominal Landsat MSS image. Landsat 3 RBV subscenes encompass slightly more than one overlapping quadrant (A, NW; B, NE; C, SW; D, SE) of an MSS nominal scene.

Figure 2.—Optimum Landsat 1, 2, and 3 images of the glaciers of Turkey. The vertical lines represent nominal paths. The rows (horizontal lines) have been established to indicate the latitude at which the imagery has been acquired.

Glaciers in Coastal Ranges Along the Black Sea

A series of mountain ranges extends along the coastline parallel to the Black Sea. The snowline is lower on the north-facing than on south-facing slopes of these ranges because of the effect of humid air masses. The elevation of the snowline on the northern slopes is 3,100-3,400 m (Erinç, 1952b). The limited number of peaks that extend above the snowline has been a negative factor in the development of glaciers. Glaciers are located on Karagöl Dağı (Mount Karagöl) in the Giresun Dağları (Giresun Mountains), on Aptalmusa Dağı (Mount Aptalmusa) in the Gavurdağları (Gavur Mountains), and on Varşanba Peak and Mount Kaçkar in the extreme eastern part of the Eastern Black Sea Mountains.

Karagöl Dağı (Mount Karagöl), Giresun Dağları (Giresun Mountains)

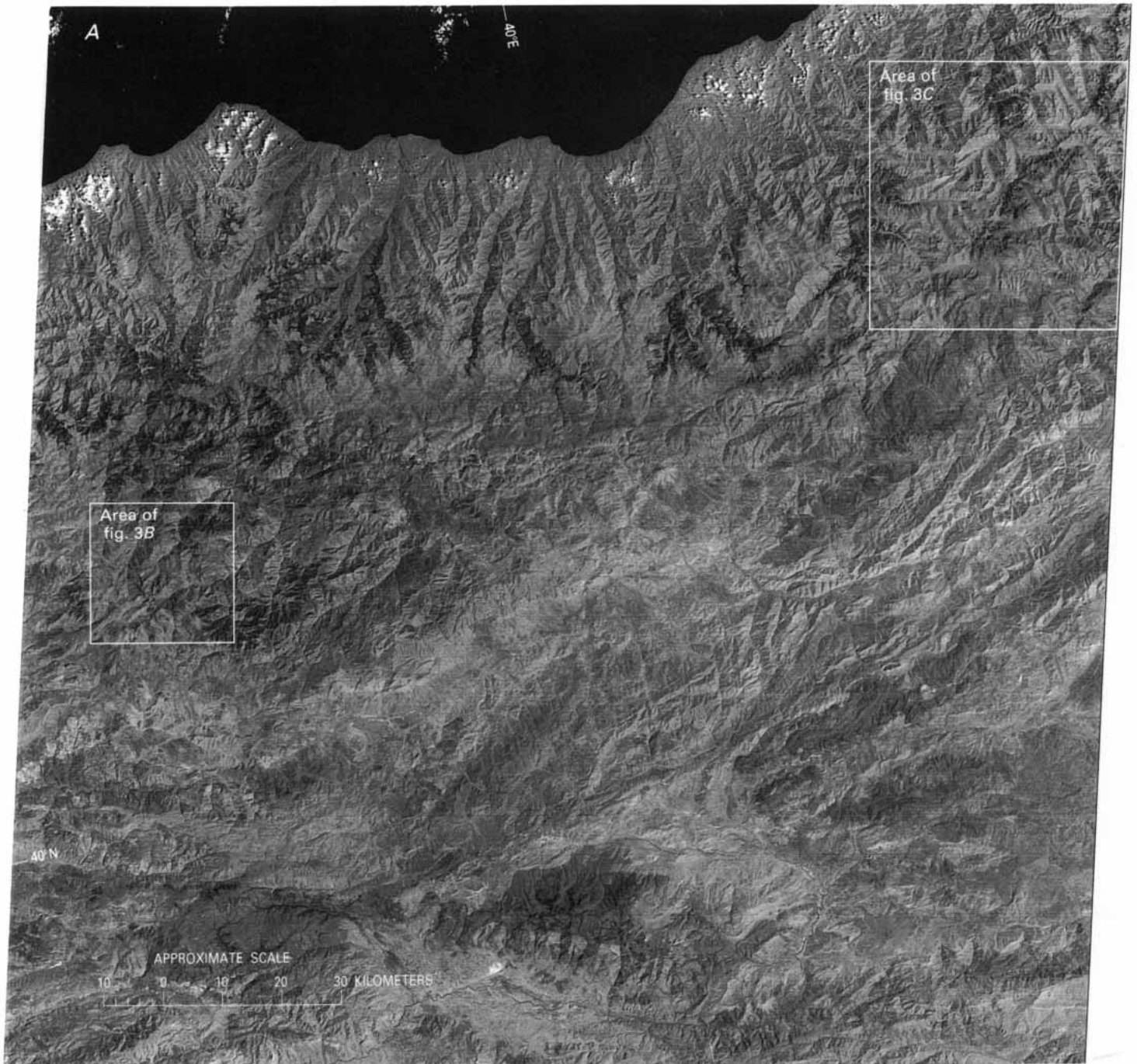
The Giresun Mountains are located just to the west of the Eastern Black Sea Mountains. The peaks extend between latitudes 40°30' and 40°32' N. and longitudes 38°08' and 38°13' E., reaching a maximum elevation of 3,107 m on Mount Karagöl. A small mountain glacier, about 0.08 km², exists within a cirque on the northwestern part of this mountain. Some glacierets are also present on north-facing slopes. The elevation of the snowline is at 2,900 m, which is lower than the snowline in the Eastern Black Sea Mountains because of cloudiness and nourishment differences (Planhol and Bilgin, 1964). Except for the largest glacier on the northwestern slope on Mount Karagöl, all of its glacierets are too small to be resolved by the Landsat MSS and cannot be seen on the images under normal conditions.

Gavurdağları (Gavur Mountains)

The southwestern part of the Eastern Black Sea Mountains is known as the Gavur Mountains. There are a few small glaciers on the highest peaks of these mountains, which are situated between latitudes 40°22' and 40°26' N. and longitudes 39°02' and 39°07' E. The area is located on the western edge of Landsat image 2211-07214, which was acquired on 21 August 1975, at a time of minimum snow cover. On the Landsat image several small mountain glaciers and old cirque lakes extending in a southwest to northeast direction immediately east of the summit of Aptalmusa Dağı (Mount Aptalmusa) (3,331 m) can be delineated (fig. 3). The largest of the mountain glaciers, the Avliyana Glacier, has a width of 300 m and a length of 150 m. It is contained within a cirque basin that has developed on the northern slope of Mount Aptalmusa. The Avliyana Glacier takes its name from a creek that flows nearby. The snowline elevation here is estimated to be at 3,100 m.

Doğukaradeniz Dağları (Eastern Black Sea Mountains)

This lofty part of the Eastern Black Sea Mountains is located to the south of the towns of Rize and Ardeşen and has its highest elevations in excess of 3,000 m. The western part of this mountain group is called the Soğanlı Dağları (Soğanlı Mountains), which lie between latitudes 40°25'



21AUG75 C N40-20/E039-56 N N40-20/E040-00 MSS 6 R SUN EL51 AZ127 191-2936-G-I-N-D-2L NASA ERTS E-2211-07214-6 01

Figure 3.—A, A 1:1,000,000-scale Landsat MSS image (2211-07214, band 6; 21 August 1975; Path 186, Row 32) of north-central Turkey showing the areas of the annotated enlargements. **B,** An approximately 1:250,000-scale enlargement of 3A showing the Avliyana Glacier and other small mountain glaciers on Mount Aptalmusa in the Gavur Mountains. **C,** An approximately 1:250,000-scale enlargement of 3A showing the Soğanlı Mountains with the highest peak, Mount At, and Varşanba Peak (Mount Verçenik) and Mount Kaçkar with their small mountain glaciers (see fig. 1).



and 40°45' N. and longitudes 40° and 40°52' E. The highest peak, **Atdağı** (Mount At), has an elevation of 3,395 m and is included within Landsat MSS image 2211-07214, acquired on 21 August 1975 (fig. 3). Although this is the region with the highest annual precipitation in Turkey, cloud cover on the image is negligible, making it very suitable for glacier studies. There are a few glacierets and rock glaciers on this high mountain group that await further investigation.

Toward the east, even higher peaks of the Eastern Black Sea Mountains are situated. **Varşamba Tepe** (Mount Verçenik) has an elevation of 3,710 m and is located between latitudes 40°40' and 40°46' N. and longitudes 40°52' and 41°05' E. On Landsat MSS image 2211-07214 (fig. 3), several rock glaciers northeast of the summit of Mount Verçenik and a mountain glacier near the Sinançor area can be delineated. The Sinançor Glacier is approximately 300 m in length and hangs down to the northeast. Dilek Tepe Glacier has a length of 700 m and is located on the north slope of Mount Verçenik. The elevation of the snowline in this area is about 3,500 m, and most of the cirques have developed at the 3,600-m elevation.

The highest part of the Eastern Black Sea Mountains, which includes Mount Kaçkar (3,932 m), is south of the town of **Ardesen** between latitudes 40°50' and 41° N. and longitudes 41°08' and 41°20' E. The area is partially covered by Landsat MSS image 2211-07214 of 21 August 1975 (fig. 3). The image includes only the northeast edge of the summit area of Mount Kaçkar. This mountainous region is the part of the Eastern Black Sea Mountains where glaciers are most highly developed. In fact, three valley glaciers are situated on the northern part of the summit of Mount Kaçkar. Kaçkar I Glacier extends 1.5 km in length (fig. 4); Kaçkar II Glacier is almost 1 km long, and Kaçkar III Glacier is slightly shorter. These three valley glaciers originate at an elevation of 3,650 m and terminate at 2,900 m, 2,990 m, and 3,130 m, respectively. The snowline elevation in this part of the range is at 3,400 m. A smaller glacier southwest of the summit, the Krenek II Glacier, extends to the northeast. It originates at an elevation of 3,760 m and terminates at 3,350 m. Kaçkar I and II Glaciers can be delineated clearly on the Landsat image (fig. 3). One other small glacier is situated in the **Altıparmak Dağları** (Altıparmak Mountains), a little farther east at an elevation of 3,562 m, but this area is outside of the area covered by figure 3.



Figure 4.-Kaçkar I Glacier on the north-western part of the summit of Mount Kaçkar in the Eastern Black Sea Mountains. Photograph taken at 3,000 m.

Glaciers in the Toros Dağları (Taurus Mountains)

The Taurus Mountains are a group of mountain ranges that extend from the west, running roughly parallel to the Mediterranean coast, in an arc to the east. Maritime air masses move to the north over the Taurus Mountains from the Mediterranean Sea on the south, and numerous glaciers have formed on the sheltered northern slopes of the system of mountain ranges. The **Güneydoğu Toroslar** (Southeastern Taurus Mountains) contain Turkey's greatest concentration of glaciers, with about two-thirds of the glaciers located in this mountain range. Although the precipitation is lower than in the area of the Eastern Black Sea Mountains, the higher degree of glacierization of the Taurus Mountains can be explained by greater erosion and lesser ablation (Erinç, 1952b). In the Taurus Mountains, glaciers tend to be concentrated in two areas: (1) the Orta Toroslar (Middle Taurus Mountains) and (2) the Güneydoğu Toroslar (Southeastern Taurus Mountains).

Orta Toroslar (Middle Taurus Mountains)

The Middle Taurus Mountains form the part of the Taurus Mountains that extends parallel to the Mediterranean coast. Unfortunately, the available Landsat MSS images of this area generally contain too much cloud and (or) snow cover. The most suitable Landsat MSS images for analysis are Landsat MSS images 2933–07113 of 12 August 1977 (table 2) and 1146–07525 of 16 December 1972 (fig. 5). In the Bolkar Mountains, which are located between latitudes 37°26' and 37°33' N. and longitudes 34°36' and 34°50' E., a mountain glacier about 300 m in length has developed at an altitude of 3,000 to 3,350 m on Medetsiz Tepe (Medetsiz Peak) (3,524 m); its tongue extends to the north down to an elevation of 2,950 m. The snowline in this area is at 3,450 m. The fact that the glacier on Mount Medetsiz has developed below the snowline can be explained only by unique local climatological and physiographic conditions (Klaer, 1962; Messerli, 1967; Kurter and Sungur, 1980). Glacierization in the Ala Mountains is even more extensive. A number of mountain glaciers have developed on the northern slopes of Demirkazik Tepe (Demirkazik Peak) (3,756 m). There are also several glaciers on the southern flank, including the Lolut Glacier. The Lolut Glacier has a length of 1 km and can be classified as a valley glacier. Demirkazik Peak is situated between latitudes 37°41' and 37°55' N. and longitudes 35°02' and 35°16' E.

Güneydoğu Toroslar (Southeastern Taurus Mountains)

The Southeastern Taurus Mountains are the most important glacierized region in Turkey. More than 20 glaciers have been identified in this range (Erinç, 1952b). The glaciers are especially well developed on two mountain groups, the first of which is the Buzul Mountains. The Buzul Mountains extend between latitudes 37°26' and 37°32' N. and longitudes 43°56' and 44°04' E. Glaciers can be delineated on Landsat MSS images 2208-07053 of 18 August 1975 (table 2) and on 2189–07002 of 30 July 1975 (fig. 6). Both images are cloud free and have minimum snow cover. The valley glacier, Uludoruk Glacier, on the north side of Uludoruk Tepe (Uludoruk Peak) (4,135 m), also known as Reşko Tepe (Reşko Peak), can be delineated easily (fig. 6). The Uludoruk Glacier has a length of almost

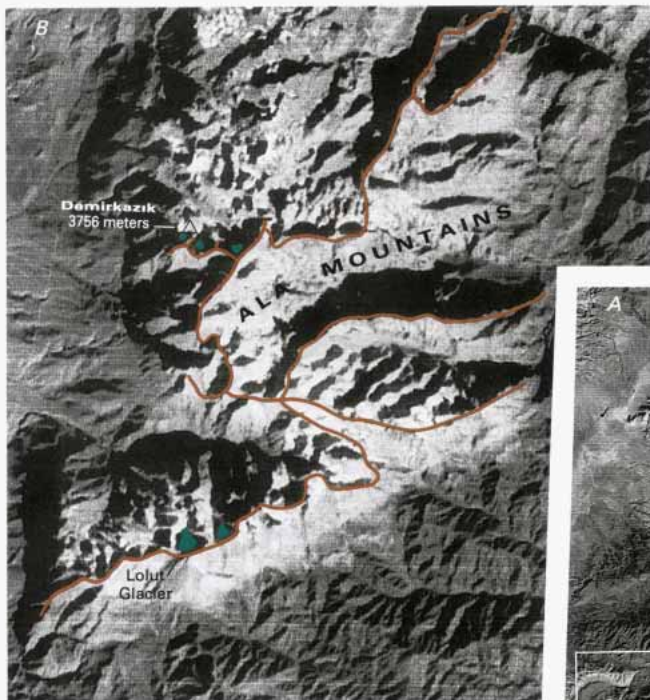
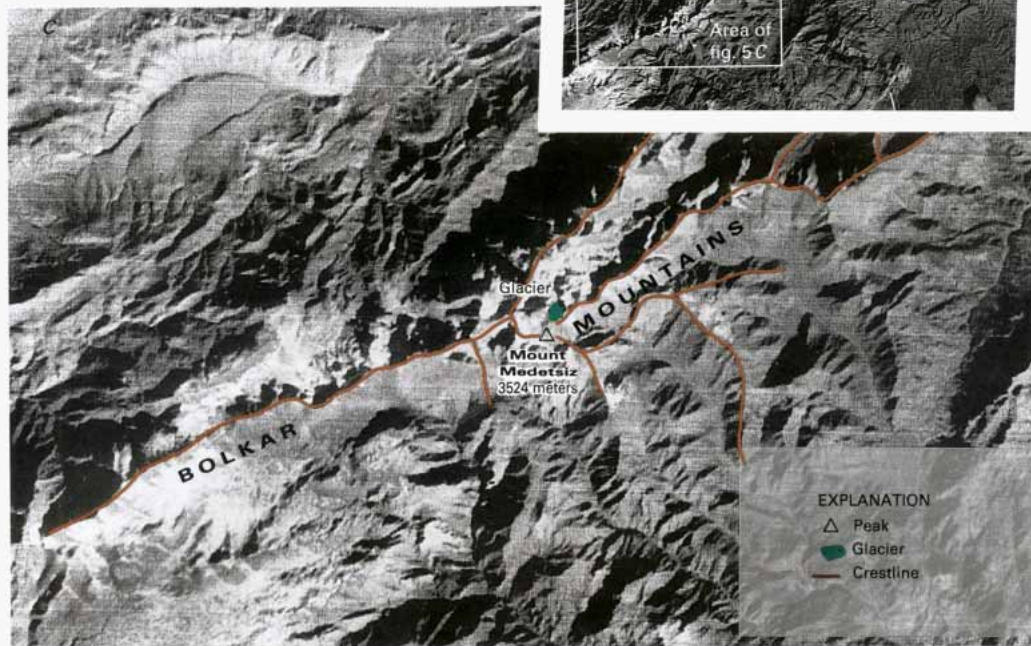


Figure 5.—A. Portion of a 1:1,000,000-scale Landsat MSS image (1146-07525, band 7; 16 December 1972; Path 189, Row 34) of the Middle Taurus Mountains of south-central Turkey showing location of annotated enlargements. B, An approximately 1:250,000-scale enlargement showing the Lolui Glacier (valley glacier) on the south flank of Demirkazik Peak in the Ala Mountains. C, An approximately 1:250,000-scale enlargement showing a mountain glacier on Medetsiz Peak in the Bolkar Mountains.



4 km and extends down to an elevation of 3,000 m (fig. 7). The elevation of the snowline in this mountain group is approximately 3,600 m (Erinç, 1952b). One other glacier, Mia Havara, has advanced to the east and down to the 2,800-m elevation (fig. 6). Lesser numbers of glaciers exist in the İkiyaka (Sat) Mountains, which are situated between latitudes 37°18' and 37°24' N. and longitudes 44°10' and 44°20' E. and can be seen easily on figure 6. The Geverok Glacier on Dolampar Dağı (Mount Dolampar) (3,794 m) extends in a northwesterly direction and has a length of about 1 km. The elevation of the snowline in this area is 3,500 m.

Kavuşşahap Dağları (Kavuşşahap Mountains)

Glaciers in the Kavuşşahap Mountains, which are located south of Van Gölü (Lake Van) (see fig. 1), have been discovered only recently (Klaer, 1965; Schweizer, 1972, 1975). The Kavuşşahap Mountains, which are situated between latitudes 38°12' and 38°16' N. and longitudes 42°48' and 42°54' E. include Hasanbeşir Dağı (Mount Hasanbeşir) (3,503 m), the highest peak in the area. Several Landsat MSS images cover the area, but Landsat MSS image 2208-07053 of 18 August 1975 provides good coverage. Landsat MSS false-color composite image 2227-07104 of 6 September 1975 (fig. 8) and Landsat image 2946-06414 of 25 August 1977 are also suitable for analysis. Glacier features on the northern slopes of Mount Hasanbeşir at an elevation of 3,300 m can be delineated on all these images. The mountain glacier on the northwest slope of Mount Hasanbeşir has a length of 300 m and a width of 200 m and is too small to be delineated on the Landsat image. The mean elevation of the snowline in this area is 3,400 m, so that the existing glaciers are the result of unusual local climatological and physiographic conditions.

Glaciers on Dormant Stratovolcanoes

Glaciers have also developed on three dormant stratovolcanoes that are located in the interior parts of Turkey. Although the elevation of the snowline is higher in the interior of the country than on coastal mountain ranges, these volcanoes have sufficient elevation to support the formation of glaciers: Erciyes Dağı (Mount Erciyes) (3,917 m), Süphan Dağı (Mount Süphan) (4,058 m), and Ağrı Dağı (Mount Ağrı) (5,137 m). All three stratovolcanoes are considered by Simkin and others (1981) to have been active during the Holocene; Mount Erciyes, on the basis of anthropological evidence, is considered to have erupted in prehistoric times.

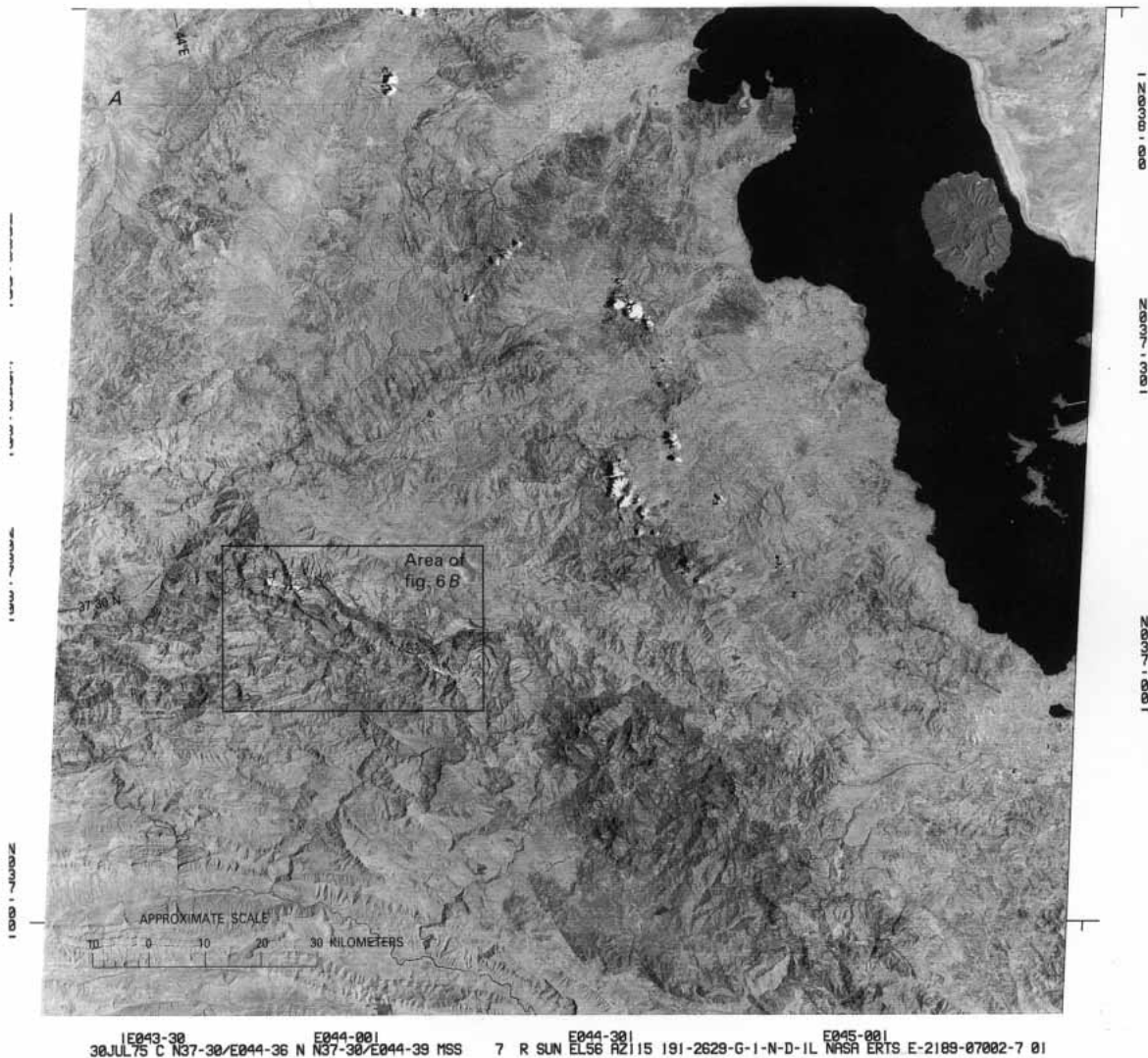


Figure 6.—A, A 1:1,000,000-scale Landsat MSS image (2189-07002, band 7; 30 July 1975; Path 182, Row 34) of southeastern Turkey showing the area of the annotated enlargement. **B,** An approximately 1:250,000-scale, band 5 enlargement showing the Buzul (Cilo) and Ikiyaka (Sat) Mountains and valley glaciers of the Southeastern Taurus Ranges (see fig. 1). Uludoruk Glacier and Mia Havara Glacier on Uludoruk (Reşko) Peak and the Geverok Glacier on Mount Dolampar can be delineated easily.

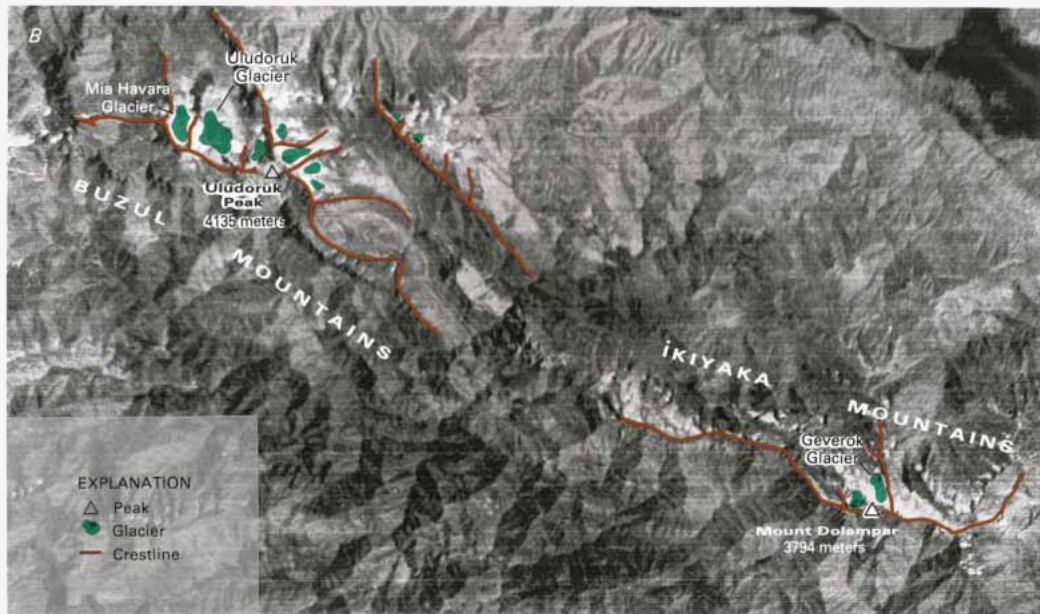
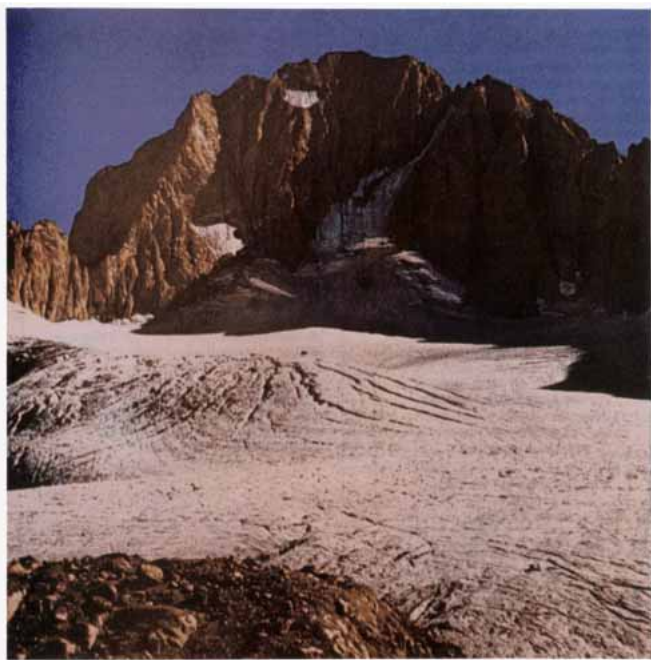


Figure 7.—Uludoruk Glacier, the largest glacier on Uludoruk Peak, Southeastern Taurus Mountains (photographed by M. Somuncu).





E041-30 | N038-001 | E042-00 | E042-301
 06SEP75 C N38-48/E042-13 N N38-48/E042-19 MSS 5 7 R SUN EL48 RZ132 191-3159-R-1-N-D-2L NPSR ERTS E-2227-07104-3 01

Figure 8.—Annotated 1:1,000,000-scale Landsat MSS false-color composite image (2227-07104, bands 4, 5, and 7; 6 September 1975; Path 184, Row 33) including Mount Süphan, Lake Van, and Mount Hasanbeşi of the Kavuşşahap Mountains area of south-eastern Turkey (see fig. 1).

Glaciers on Erciyes Dağı (Mount Erciyes)

A glacier has developed on the northern part of the dormant volcanic cone of Mount Erciyes, which is located south of the city of Kayseri between latitudes 38°31' and 38°34' N and longitudes 35°24' and 35°28' E. Two useful Landsat MSS images of Mount Erciyes were analyzed. Landsat MSS image 2268-07390 (17 October 1975) (table 2) shows the fine topographic detail of the stratovolcano, while Landsat MSS image 2933-07110 of 12 August 1977 more clearly delineates the glaciers (fig. 9). Of the several glaciers on Mount Erciyes, the one that extends to the northwest has been the most studied (Penther, 1905; Bartsch, 1935; Blumenthal, 1938; Erinoç, 1951; Klaer, 1962; Messerli, 1964). The northwest glacier is classified as a valley glacier and extends from 3,800 to 3,400 m (fig. 10). The second glacier, which is also clearly seen on the two Landsat images, extends to the east from a large cirque and appears to be a rock glacier at an elevation of 3,100 m (Güner and Emre, 1983). Various values have been given for the mean elevation of the snowline on Mount Erciyes, but the best estimate is about 3,600 m.

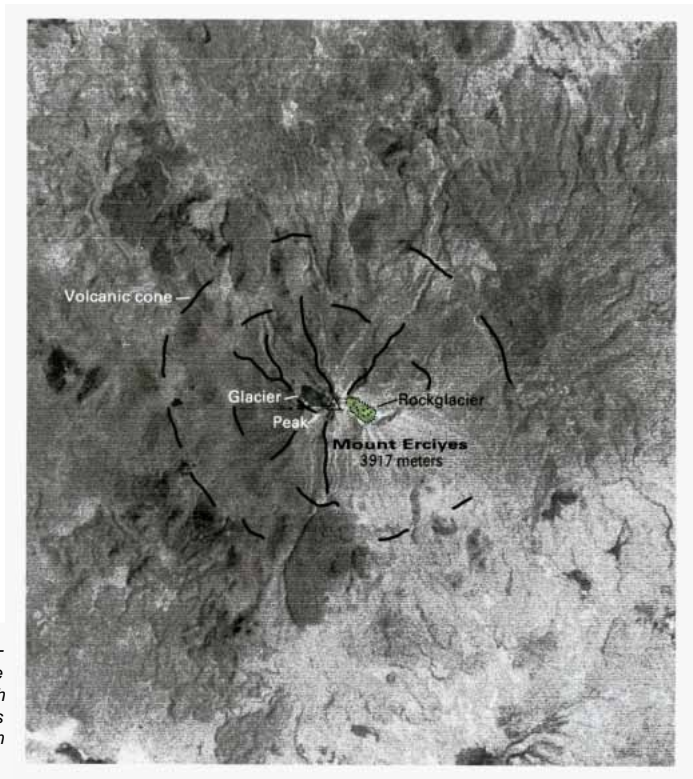


Figure 9. —Annotated 1:250,000-scale enlargement of part of a Landsat MSS image (2933-07110, band 7; 12 August 1977; Path 188, Row 33) showing glaciers on the flanks of Mount Erciyes, a dormant stratovolcano in central Turkey (see fig. 1).



Figure 10.—The valley glacier on the north-west slope of Mount Erciyes viewed from 3,200 m (photographed by M. Somuncu).

Glaciers on Süphan Dağı (Mount Süphan)

Mount Süphan is located to the north of Lake Van in southeastern Turkey, has a summit elevation of 4,058 m, and also is a dormant stratovolcano (fig. 8). The crater of this volcano, which contains several glaciers, lies between latitudes 38°53' and 38°58' N. and longitudes 42°47' and 42°52' E. Detailed analyses can be made from two Landsat MSS images, 2208–07050 of 18 August 1975, and 2946–06414 of 25 August 1977 (fig. 11). The best developed glacier, located on the north-facing slope of the crater, has a width of 2 km, has a length of 1.5 km, and extends in a southerly direction. There are also several other smaller glaciers on the northern slope of the crater. The elevation of the snowline on Mount Süphan is around 3,700–4,000 m, with the mean elevation about 3,900 m.

The Ice Cap on Ağrı Dağı (Mount Ağrı, or Ararat)

Mount Ağrı, a dormant stratovolcano, is the highest mountain in Turkey, with the elevation of Büyük Ağrı Dağı (Great Ararat), the highest of its two peaks, at 5,137 m (the other peak, Küçük Ağrı Dağı (Little Ararat), reaches 3,927 m). It is located in the easternmost part of the country near the border with Iran between latitudes 39°41' and 39°44' N. and longitudes 44°15' and 44°19' E. The summit region of Mount Ağrı is covered by an ice cap (Imhof, 1956). Landsat MSS image **2586-06570** of 30 August 1976 (fig. 12) corresponded to a time of minimum snow cover. Cloudiness is also negligible, although there are small clusters of clouds on the northern slopes that do not affect the analysis of the image. As is evident on the Landsat images, the ice cap is most prominent in a northwesterly direction (figs. 12–14). In the northwest, the ice cap extends down to an altitude of 4,100 m and encompasses an area of 10 km² (Kurter and Sungur, 1980). The elevation of the snowline on Mount Ağrı is estimated to be at 4,300 m (Klaer, 1965; Kurter and Sungur, 1980).

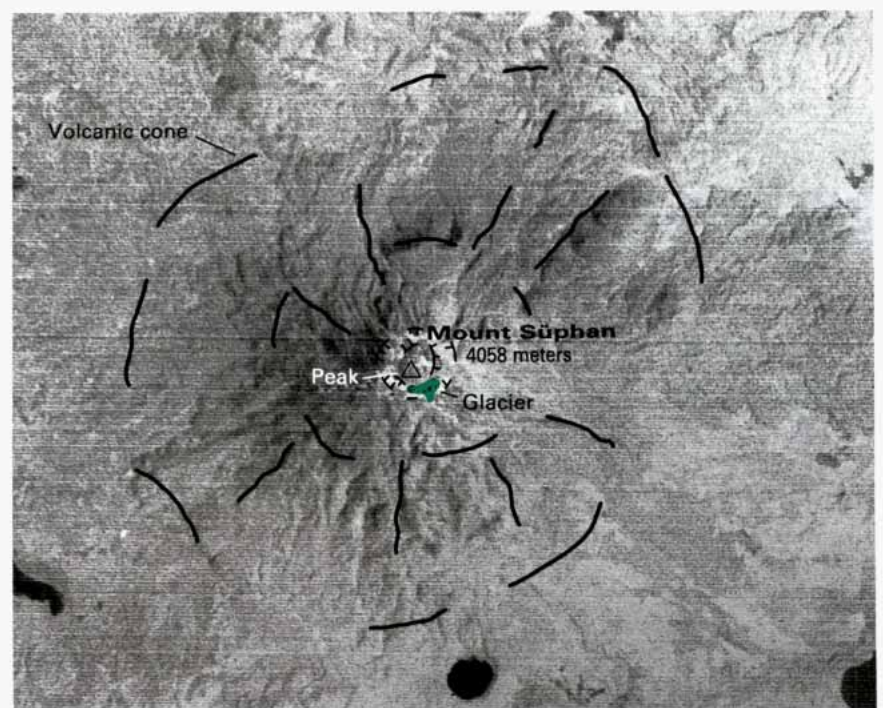


Figure 11.—An approximately 1:250,000-scale enlargement of part of a Landsat MSS image (2946-06414, band 7; 25 August 1977; Path 183, Row 33) showing mountain glaciers in the crater of the Mount Süphan stratovolcano north of Lake Van in southeastern Turkey (see figs. 1 and 8).

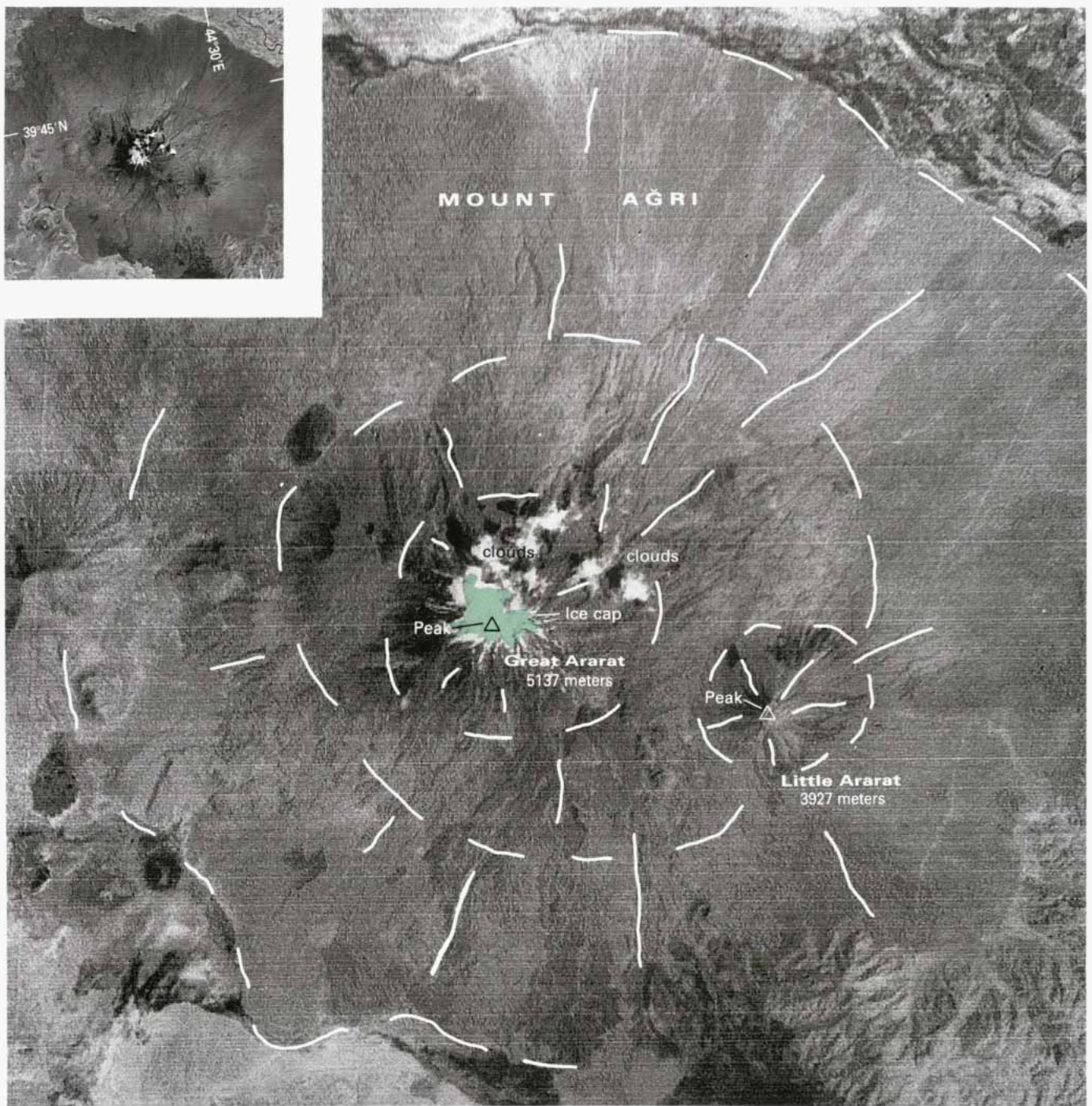


Figure 12.—Annotated 1:250,000-scale enlargement of part of a Landsat MSS image (2586-06570, band 7: 30 August 1976: Path 183, Row 32) of the ice cap on Mount Agri, a dormant stratovolcano and Turkey's highest mountain (5,137 m) (see fig. 1). Inset shows Mount Agri at 1:1,000,000 scale.

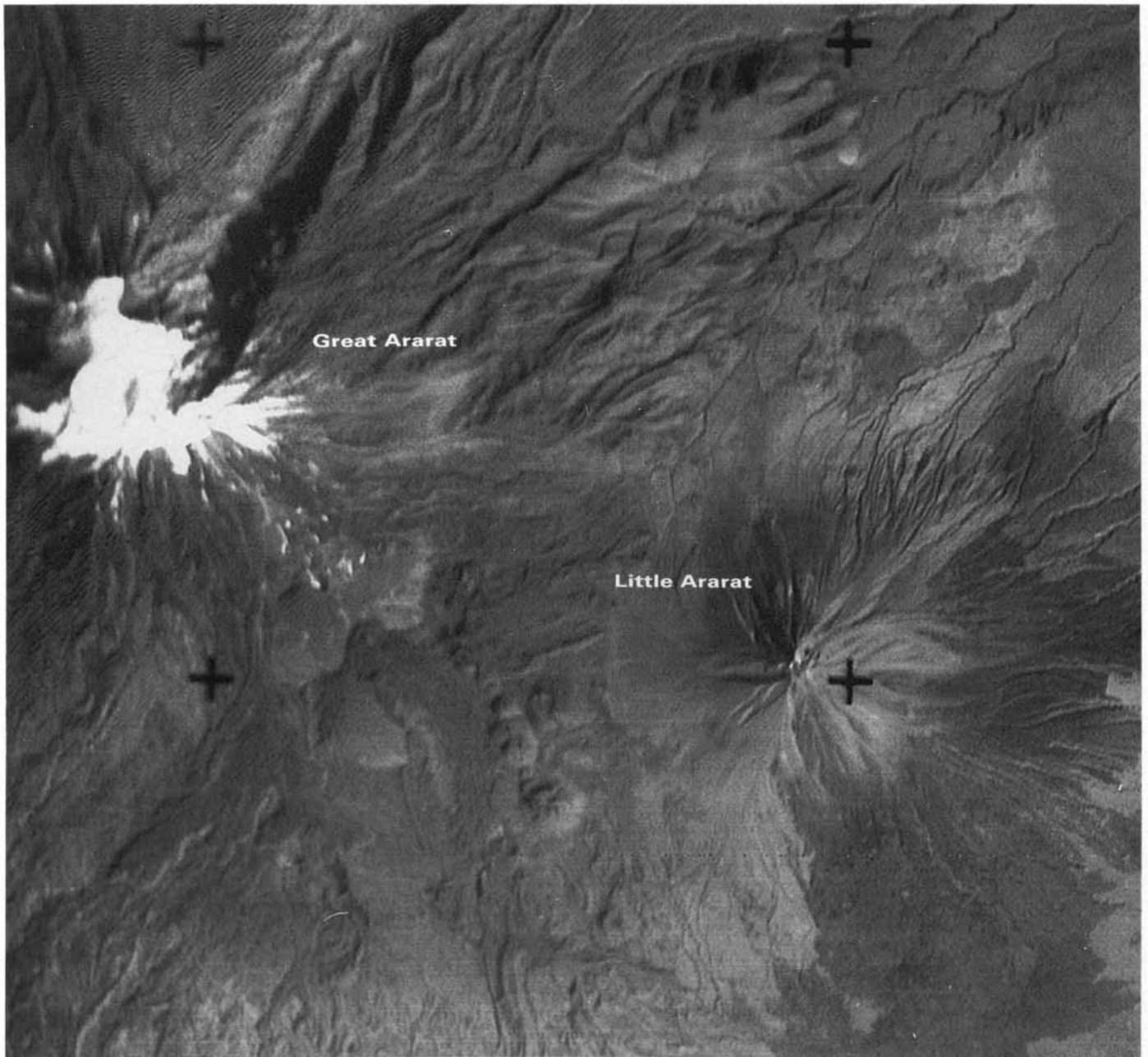


Figure 13.—Annotated enlargement of part of a Landsat 3 RBV image (3095046480–A; 10 October 1980; Path 182, Row 33) of Great Ararat and Little Ararat. Approximate scale is 1:100,000.



Figure 14.—An approximately 1:90,000-scale annotated enlargement of part of a Landsat 5 TM false-color composite image (50209–07140; bands 2, 4, and 7; 26 September 1984; Path 170, Row 32) showing the prominent ice cap on Mount Ağrı. On the image, white clouds partially obscure the upper part of the bluish ice cap. The spatial resolution of the TM image is approximately equivalent to that of a Landsat 3 RBV image (compare figs. 13 and 14). Image courtesy of Nicholas M. Short, National Aeronautics and Space Administration, Goddard Space Flight Center.

References Cited

- Ainsworth, W.F., 1842, Travels and researches in Asia Minor, Mesopotamia, Chaldea and Armenia: London, J.W. Parker, v. 1, 364 p.; v. 2, 399 p.
- Arkel, N.A. van, 1973, Die gegenwärtige Vergletscherung des Ararat [The present-day glaciation of Ararat]: Zeitschrift für Gletscherkunde und Glazialgeologie, v. 9, no. 1–2, p. 89–103.
- Bartsch, G., 1935, Das Gebiet des Erdschias Dağı und die Stadt Kayseri in Mittel-Anatolien [The region around Mount Erciyes and the city of Kayseri in central Anatolia]: Jahrbuch der Geographischen Gesellschaft zu Hannover für 1934 und 1935, p. 87–202.
- Birman, J.H., 1968, Glacial reconnaissance in Turkey: Geological Society of America Bulletin, v. 79, no. 8, p. 1009–1026.
- Blumenthal, M.M., 1938, Der Erdschias-Dagh, 3916 m [Mount Erciyes, 3,916 m]: Die Alpen, v. 14, no. 3, p. 82–87.
- 1952, Das taurische Hochgebirge des Aladağ, neuere Forschungen zu seiner Geographie, Stratigraphie und Tektonik [The Taurus Mountains of the Ala Mountains, new investigations of its geography, stratigraphy, and tectonics]: Ankara, Maden Tetkik ve Arama Enstitüsü Yayınlarından-Veröffentlichungen des Institutes für Lagerstättenforschung der Türkei, ser. D, no. 6, 136 p.
- 1954, Im südostanatolischen Hochland zwischen dem Van-See und den Cilo-Ketten [In the southeastern Anatolian highlands between Lake Van and Mount Cilo]: Die Alpen, v. 30, p. 223–240.
- 1955, Geologie des Hohen Bolkaradağ, seiner nördlichen Randgebirge und westlichen Ausläufer (Südanatolischer Taurus) [Geology of the Bolkar Mountains, their northern border region and western extension (southern Anatolian Taurus Mountains)]: Ankara, Maden Tetkik ve Arama Enstitüsü Yayınlarından-Veröffentlichungen des Institutes für Lagerstättenforschung der Türkei, ser. D, no. 7, 169 p.
- 1956, Die Vergletscherung des Ararat (Nordöstliche Türkei) [The glaciation of Mount Ararat (northeastern Turkey)]: Geographica Helvetica, v. 11, no. 4, p. 263–264.
- 1958, Vom Ağrı Dag (Ararat) zum Kaçkar Dag. Bergfahrten in nordostanatolischen Grenzlanden [From Mount Ararat to Mount Kaçkar. Mountain trip in the frontier region of northeastern Anatolia]: Die Alpen, v. 34, p. 125–137.
- Bobek, H., 1940, Die gegenwärtige und eiszeitliche Vergletscherung im Zentralkurdischen Hochgebirge [The present and Pleistocene glaciation in the central Kurdistan Mountains]: Zeitschrift für Gletscherkunde, v. 27, no. 1–2, p. 50–87.
- Erinç, S., 1949a, Eiszeitliche Formen und gegenwärtige Vergletscherung im nordostanatolischen Randgebirge [Pleistocene landforms and present glaciation in the northeastern Anatolian border mountains]: Geologische Rundschau, v. 37, p. 75–83.
- 1949b, Kaçkaradağı grubunda diluvial ve bugünkü glasyasyon. Eiszeitliche und gegenwärtige Vergletscherung in der Kaçkaradağ-Gruppe [Pleistocene and recent glaciation in the Kaçkar mountain group]: İstanbul Üniversitesi Fen Fakültesi Mecmuası (Revue de la Faculté des Sciences de l'Université d'Istanbul), ser. B, v. 14, no. 3, p. 243–246.
- 1951, Glasiyal ve post glasiyal safhada Erciyes glasiyesi [The glacier of Erciyes in Pleistocene and Post-glacial epochs]: İstanbul Üniversitesi Coğrafya Enstitüsü Dergisi (Review of the Geographical Institute of the University of Istanbul): v. 1, no. 2, p. 82–90.
- 1952a, Glacial evidences of the climatic variations in Turkey: Geografiska Annaler, v. 34, no. 1–2, p. 89–98.
- 1952b, The present glaciation in Turkey: General Assembly and Seventeenth International Congress of the International Geographical Union, 8th Proceedings, Washington, D.C., August 8–15, 1952, p. 326–330.
- 1953, Van'dan Cilo Dağlarına [From Lake Van to Mount Cilo]: İstanbul Üniversitesi Coğrafya Enstitüsü Dergisi [Review of the Geographical Institute of the University of Istanbul]: v. 2, no. 3, p. 84–106.
- Gall, H., 1966, Gletscherkundliche Beobachtungen im Hochgebirge von Lasistan (Nordostanatolischen Randgebirge) [Glaciological observations in the high mountains of Lasistan (northeastern Anatolian border mountains)]: Mitteilungen der Österreichischen Geographischen Gesellschaft, v. 108, no. 2, 3, p. 261–286.
- Giüner, Y., and Emre, O., 1983, Erciyes Dağında Pleistosen Buzullaması ve Volkanizma ile ilişkisi [Pleistocene glaciation on Mount Erciyes and its relation to volcanism]: Ankara, Jeomorfoloji Dergisi [Bulletin of Geomorphology], no. 11, p. 23–34.
- Harita Genel Müdürlüğü, 1977, Yeni Türkiye Atlası [New Turkish Atlas]: Ankara, M.S.B., Harita Genel Müdürlüğü.
- Horvath, E., 1975, Glaciers of Turkey, Armenian S.S.R. and Iran, in Field, W.O., ed., Mountain glaciers of the Northern Hemisphere, pt. III Glaciers of Southern Asia: Hanover, N.H., U.S. Army Cold Regions Research and Engineering Laboratory, p. 343359.
- Imhof, E., 1956, Der Ararat [Ararat]: Die Alpen, v. 32, no. 1, p. 1–14.
- Ivan'kov, P.A., 1959, Sovremennoe oledenenie Malogo Kavkaza i Armianskogo Nagor'ia [Present-day glaciation of the Lesser Caucasus and the Armenian highlands]: Izvestia Akademii Nauk Armianskoi SSR, Seriya Geologiceskoi i Geograficeskoi Nauki, v. 12, no. 2, p. 47–50.
- İzbrak, R., 1951, Cilo dağı v Hakkâri ile Vangölü çevresinde coğrafya araştırmaları [Geographical research in Lake Van and in the Hakkari and Cilo Mountains]: Ankara Üniversitesi, Dil ve Tarih-Coğrafya Fakültesi yayımları, no. 67, Coğrafya Enstitüsü (yayımları), no. 4, 149 p.
- Klaer, W., 1957, Beobachtungen zur rezenten Schnee- und Strukturbodengrenze im Hochlibanon [Observations on the Holocene snow line and limit of patterned ground in the Lebanon Mountains]: Zeitschrift für Geomorphologie, neue Folge, v. 1, no. 1, p. 57–70.
- 1962, Untersuchungen sur klimagenetischen Geomorphologie in den Hochgebirgen Vorderasiens [Investigations on the climatogenetic geomorphology of the mountains of the Asian front]: Heidelberger Geographische Arbeiten, no. 11, 135 p.
- 1965, Geomorphologische Untersuchungen in den Randgebirgen des Van-See (Ostanatolien) [Geomorphological investigations in the border mountains of Lake Van (eastern Anatolia)]: Zeitschrift für Geomorphologie, neue Folge, v. 9, no. 3, p. 346–355.
- 1969, Glazialmorphologische Probleme in den Hochgebirgen Vorderasiens [Glaciomorphological problem in the border mountains of the Asian front]: Erdkunde, v. 23, no. 3, p. 192–200.
- Koch, K.H.E., 1846, Reise im pontische Gebirge [Trip in the Pontic Mountains]: Weimar.
- Krenek, L., 1932, Gletscher im Pontischen Gebirge (Lasistan) [Glacier in the Pontic Mountains (Lasistan)]: Zeitschrift für Gletscherkunde, v. 20, no. 1–3, p. 129–131.
- Künne, G., 1928, Die deutsche alpine Taurus-Expedition 1927 (Ala Dagh in Zilizien) [The German alpine expedition to the Taurus Mountains in 1927 (Ala Mountains in Cilicia)]: Petermanns Mitteilungen, v. 74, no. 9–10, p. 273–276.
- Kurter, A., and Sungur, K., 1980, Present glaciation in Turkey, in World Glacier Inventory, Proceedings of the workshop at Riederalp, Switzerland, 17–22 September 1978: International Association of Hydrological Sciences, Publication 126, p. 155–160.
- Leutelt, R., 1935, Glazialgeologische Beobachtungen im Lasistanischen Hochgebirge [Glacial geology observations in the mountains of Lasistan]: Zeitschrift für Gletscherkunde, v. 23, no. 1–3, p. 67–80.
- Löffler, E., 1970, Untersuchungen zum eiszeitlichen und rezenten klimagenetischen Formenschatz in den Gebirgen Nordostanatoliens [Investigations of Pleistocene and Holocene climatogenetic relict landforms in the northeastern Anatolian Mountains]: Heidelberger Geographische Arbeiten, no. 27, 162 p.
- Louis, H., 1938, Eiszeitliche Seen in Anatolien [Pleistocene lakes in Anatolia]: Zeitschrift der Gesellschaft für Erdkunde zu Berlin, v. 73, no. 7–8, p. 267–285.

- 1944, Die Spuren eiszeitlicher Vergletscherung in Anatolien [The evidence for Pleistocene glaciation in Anatolia]: *Geologische Rundschau*, v. 34, no. 7–8, p. 447–481.
- Maunsell, F.R., 1901, Central Kurdistan: *Geographical Journal*, v. 18, no. 2, p. 121–144.
- Messerli, B., 1964, Der Gletscher am Erciyas Dag und das Problem der rezenten Schneegrenze im anatolischen und mediterranen Raum [The glacier on Mount Erciyes and the problem of the Holocene snow line in the Anatolian and Mediterranean region]: *Geographica Helvetica*, v. 19, no. 1, p. 19–34.
- 1967, Die eiszeitliche und die gegenwärtige Vergletscherung im Mittelmeerraum [The Pleistocene and the Holocene glaciation in the Mediterranean region]: *Geographica Helvetica*, v. 22, no. 3, p. 105–228.
- Palgrave, W.G., 1872, Vestiges of the glacial period in north-eastern Anatolia: *Nature*, v. 5 (April 1872), p. 444–445.
- Penther, A., 1905, Eine Reise in das Gebiet des Erdschias-Dagh (Kleinasien), 1902 [A trip to the Mount Erciyes region (Asia Minor) in 1902]: *Abhandlungen der K. K. Geographischen Gesellschaft in Wien*, v. 6, no. 1, 48 p.
- Philippson, A., 1906, Ein Gletscher am Erdschias-Dagh (Argaeus) in Kleinasien [A glacier on Mount Erciyes (Argaeus) in Asia Minor]: *Zeitschrift für Gletscherkunde*, v. 1, no. 1, p. 66–68.
- 1918, Kleinasien. Handbuch der regionale Geologie [Asia Minor. Handbook of regional geology]: Heidelberg, C. Winters Universitätsbuchhandlung, v. 5, no. 2 (no. 22), 183 p.
- Planhol, X. de, and Bilgin, T., 1964, Glaciaire et périglaciaire quaternaires et actuels dans le massif du Karagöl (Chaînes pontiques-Turquie) [Quaternary and present glacial and periglacial (landforms) in the Karagöl massif (Pontic Mountains of Turkey)]: *Revue de Geographie Alpine*, v. 52, no. 3, p. 497–512.
- Schweizer, G., 1972, Klimatisch bedingte geomorphologische und glaziologische Züge der Hochregion vorderasiatischer Gebirge (Iran und Ostanatolien) [Climatically based geomorphological and glaciological characteristics of the high-altitude regions of Near Eastern mountain areas (Iran and eastern Anatolia)], *in* *Geocology of the high-mountain regions of Eurasia: Erdwissenschaftliche Forschung*, v. 4, p. 221–236.
- 1975, Untersuchungen zur Physiogeographie von Ostanatolien und Nordwestiran [Investigations of the physical geography of eastern Anatolia and northwestern Iran]: *Tübinger Geographische Studien*, v. 60, Special Issue 9, 145 p.
- Simkin, T., Siebert, L., McClelland, L., Bridge, D., Newhall, C., and Latter, J.H., 1981, *Volcanoes of the world*: New York, Van Nostrand Reinhold, 232 p.
- Spreitzer, H., 1939, Bergfahrten und Forschungen im Ala Dag (Südostanatolien). *Deutsche Taurus-Bergfahrt 1938 des Zweiges Klagenfurt*. Die Kundfahrt und ihre Ergebnisse [Mountain trip and investigations in the Ala Mountains (southeastern Anatolia). German expedition to the Taurus Mountains in 1938 of the Zweiges Klagenfurt. The scientific expedition and its results]: *Zeitschrift des Deutschen Alpenvereins*, v. 70, p. 50–52.
- 1956, Untersuchungen im Kilikischen Ala Dag im Taurus [Investigations on Kilik, Ala Mountains of the Taurus Mountains]: *Mitteilungen des Österreichischen Geographischen Gesellschaft*, v. 98, no. 1, p. 57–64.
- 1958, Frührezente und rezente Hochstände der Gletscher des Kilikischen Ala Dag im Taurus [Pre-Holocene and Holocene positions of the glacier on Kilik, Ala Mountains of the Taurus Mountains]: Innsbruck, Universitätsverlag Wagner, *Geographische Forschungen (Festschrift zum 60. Geburtstag von Hans Kinzl)*, no. 190, p. 265–281.
- 1959, Fussflächen am Kilikischen Ala Dag im Taurus [Base level of Kilik, Ala Mountains of the Taurus Mountains]: *Mitteilungen des Österreichischen Geographischen Gesellschaft*, v. 101, no. 2, p. 183–201.
- 1971, Rezente und eiszeitliche Grenzen der glazialen und periglazialen Hohenstufen im Zentralen Taurus (vornehmlich am Beispiel des Kilikischen Ala Dag) [Holocene and Pleistocene limits of the glacial and periglacial elevation levels in the Middle Taurus Mountains (particularly the example on Kilik, Ala Mountains)]: *Mitteilungen des Naturwissenschaftlichen Vereines für Steiermark*, v. 101, p. 139–162.
- Stratil-Sauer, G., 1927, Der östliche Pontus [The eastern Pontic Mountains]: *Geographische Zeitschrift*, v. 33, no. 9, p. 497–519.
- 1961, Beobachtungen im Ostpontischen Gebirge unter besonderer Berücksichtigung der Kaltzeitformen [Observations in the eastern Pontic Mountains, with particular reference to Pleistocene landforms]: *Mitteilungen des Österreichischen Geographischen Gesellschaft*, v. 103, no. 1, p. 1–24.
- 1964, Beobachtungen im Ostpontischen Gebirge unter besonderer Berücksichtigung der Kaltzeitformen. Teil II [Observations in the eastern Pontic Mountains, with particular reference to Pleistocene landforms. Part 2]: *Mitteilungen des Österreichischen Geographischen Gesellschaft*, v. 106, no. 1, p. 16–44.
- 1965, Beobachtungen im Ostpontischen Gebirge unter besonderer Berücksichtigung der Kaltzeitformen (Teil III) [Observations in the eastern Pontic Mountains, with particular reference to Pleistocene landforms (Part 3)]: *Mitteilungen des Österreichischen Geographischen Gesellschaft*, v. 107, no. 1–2, p. 20–44.
- U.S. Board on Geographic Names, 1984, *Gazetteer of Turkey*: Defense Mapping Agency, Washington, D.C., 1,502 p.
- Wright, H.E., 1962, Pleistocene glaciation in Kurdistan: *Eiszeitalter und Gegenwart*, v. 12, p. 131–164.