ROCK GLACIERS IN GEYİK DAĞI AREA, CENTRAL TAURUS

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ABSTRACT. — Various glacial features are widespread in Geyik Dağı area, Central Taurus. Moderately well-preserved glacial troughs, moraines, rock glaciers and many empty cirques occur over a large area above 2050 meters altitude. Among them rock glaciers are particularly well developed. The mountains in the area consist of limestone. Limestone being a very suitable source rock for rock glaciers is mainly responsible for their widespread occurrence. Two different periods of rock glacier development have been identified. Several data show that rock glaciers in the region are no longer moving.

INTRODUCTION

In Geyik Dağı area effects of glaciation are displayed by empty cirques, glacial troughs, moraines and rock glaciers. Rock glaciers form the major subject of the present investigation. The area studied is shown in Figure 1.

MAJOR FEATURES OF MOUNTAIN GLACIATION IN THE REGION

Geyik Dağı,[1] Palaz Dağı, Tekelik Dağı, Ürküten Dağı and Manoğlu Dağı lodge several glacial features. These northwestward trending ridges have crests 2400-2875 meters in altitude.

Many empty cirques lie on northest flanks of these mountains (Fig. 2, 3 and PI. II A). Only a few are situated on flanks facing other directions. All of the cirques are developed in limestone terrane.[2]

Glacial troughs strongly modified by fluvial processes are the other widely occurring features in the region. These troughs are shown in Figure 2.

Cirque glaciers have been developed, in some of the cirques (PI. I). Features related to cirque glaciers are usually well preserved.

Moraines are rather rare. Small masses of cirque moraines are easily recognized. Greatly modified lateral and end moraines are also detectable in places (PI. II A and II B).

Rock glaciers which are rather well developed in the region will be studied in the present paper.

ROCK GLACIERS

Moraine-like deposits were encountered over wide areas. These have been identified as rock glaciers through study of their various characteristics.

[1] «Dağ (ı)» is the Turkish word for «mountain».

[2] Geology of an area covering part of the area under investigation has been discussed by Necdet Özgül in «The importance of block movement in structural evolution of the northern part of Central Taurus. Bull. Geol. Soc. Turkey, v. 14, pp. 85-101, 1.971.

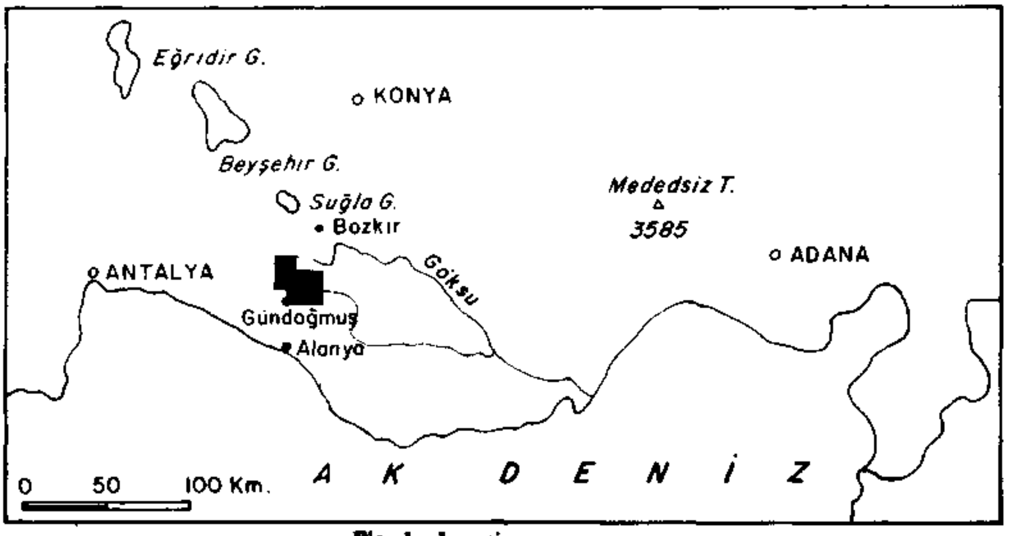

Fig. 1 - Location map.

The descriptions and photographs in Blumenthal's works on Taurus Ranges leave no doubt that similar deposits are widespread in Taurus Ranges. Deposits similar to rock glaciers are shown in Blumenthal's publications (1952 and 1956) on Bolkar Dağı and Aladağ areas. Blumenthal (1947) interpreted similar formations as debris deposited by floods generated by exceptionally heavy rains.

Distribution and dimensions of rock glaciers

Areas covered by rock glaciers extend parallel to cirques line, as it can be seen in Figure 2. Rock glaciers in this area occur in a zone between 2050 and 2500 meters in altitude. Numerous rock glaciers interfering each other and highly dissected by running water cover large areas (PI. III).

Well-preserved rock glaciers are spatulate in shape. They are a few hundred meters to a little more than 2 km long in the direction of flow. Their average width is about 800 m. Thickness up to 50 meters has been measured in places, but it rarely exceeds 30 meters.

The wide sheet formed by interfering rock glaciers has an average surface slope of about 2-3°. Rock glaciers with rather well-preserved shape have surface slope of about 6-7°. The front at their down-valley end slopes at an angle ranging between 15 to 20°. Angle between the front and the upper surface of them is not sharp, the front merging gradually with the upper surface.

Relationship between rock glaciers and other glacial features of the region

Most of the rock glaciers are connected in their upper end by a cirque. A bedrock surface relatively free of debris usually takes places between cirques and the heads of rock glaciers. Rock glaciers follow preexisting valleys in some places, and in places they are bound by moraine ridges formed by previous glacial activity (PI. II B and Fig. 4).

Surficial features of the rock glaciers

The area covered by rock glaciers gives impression of a karst morphology formed of numerous sinkholes (PI. III and Fig. 3). Lineations approximately perpendicular to the direction of flow, generally bowed down-valley, are exhibited by the disposition of sinkhole-like features. In well-preserved rock glaciers these lineations correspond to transverse ridges and furrows.

Another type of relief that seems to be related to rock glaciers are the longitudinal ridges somewhat higher than rock glacier proper and bordering it laterally. These, probably, are lateral moraines deposited by a valley glacier (PI. II B and III).

A quite large number of depressions occur over rock glaciers. Relatively bigger depressions take place in the upper parts of the rock glaciers (PI. III). Some of these depressions are occupied by seasonal ponds (PI. III).

Most of the rock glaciers are more or less dissected by running water. In places gullies have been developed in rock glaciers. Some of these gullies debouch to an aluvial fan in their lower end (PI. II and Fig. 4).

Composition of the rock glaciers

Rock glaciers are made almost entirely of subrounded limestone fragments of low sphericity (Fig. 5). Most common length size is 10 to 30 cm; but some blocks are more than 1 m and 1 cm long pebbles make a good part of the bulk. Clay and silt size materials are exposed only in a few places. They might have been sifted to lower levels. Clay and silt constitute the main materials of the plains adjacent to area covered by rock glaciers.

Limestone blocks of rock glaciers have many cracks. Profound solution has taken place along the cracks. No striations due to transport by ice are detectable on the blocks.

The debris making rock glaciers comes almost solely from the cliffs at the heads of the rock glaciers. These cliffs are developed in massive limestone showing slight bedding. Karstic features are largely developed in this limestone. Due to developed jointing and the presence of many cracks the limestone weathers by frost action into blocks.

Rock glaciers have only a very restricted amount of material taken from the floor. This material transported only a short distance consists of blocks of conglomerate and limestone.

MOTION OF THE ROCK GLACIERS

Rock glaciers have been reported from several places throughout the world. Wahrhaftig and Cox (1959) cite some of them.

Papers on rock glaciers are rather few in number. Early descriptions of rock glaciers are by Spencer (1900), Howe (1909), Capps (1910) and Tyrrell (1910). The subject is discussed in detail by Ives (1940), by Wahrhaftig and Cox (1959).

Numerous mechanisms are suggested for their origin. It is generally accepted that rock glaciers move down-slope by the flow of ice filling large interconnected interstices. Clear ice was observed in interstices of several active rock glaciers throughout the world. The ice in rock glacier could have been formed by the freezing of water derived from melting snow or from rain or of ground water that rises beneath the talus that feeds the rock glacier.

The interstitial ice solidly cementing debris of rock glaciers decreases the intergranular friction and plastic flow and movement along shear planes of the ice itself under high overburden pressure provides the mechanism for rock glacier motion.

It is concluded that rock glaciers in the area under investigation are inactive. Observations which lead to this conclusion will be discussed in the next chapter. Though they are inactive some of them having escaped severe erosion are suitable for the investigation of several characteristics of rock glaciers.

Most of the rock glaciers of the region are connected with cirques not containing perennial snow, thus not providing neve. It is clear that these cirques had cirque glaciers prior to the development of rock glaciers. A well-preserved cirque glacier moraine is seen in Plate I. Several remnants of cirque glacier masses stand in area covered by rock glaciers. Good examples of them are shown in Plate III. This type of moraines have not been able to conserve their primary shape. Some have been deformed, others have been completely destroyed by moving rock glaciers. However rarely some moraines, while they are situated in rock glacier area have been able to conserve their primary shape. Two moraine ridges marked in Plate II B are good examples of this situation. These two ridges were developed as lateral moraines of a small valley glacier. Between these two ridges is lodged a rock glacier. Conservation of their initial position despite their occurrence in rock glacier area is probably related to the lack of rock glacier in their outer sides. Outer sides being in direct contact with air might have not been able to retain water necessary for ice formation and this might have prevented the moraine ridges to participate in the movement of the rock glaciers. The place between these two ridges must have formed a channel for a rock glacier.

These observations suggest that stage of rock glacier development followed, and was the continuation of, a period of formation of numerous cirque glaciers and few small valley glaciers. Glacial troughs of larger size must have been formed during a still older period. These valleys do not exhibit traces of glacial abrasion neither any remnant of their moraines is present.

Widespread occurrence in high areas of a rock type which gives blocky debris upon alteration, existence of fault caused cliffs which favor rapid wasting of materials and probably existence of a suitable climate during the past must have been the causes of the extensive development of rock glaciers.

Discussion on the movement of rock glacier of the region

Through the examination of several active rock glaciers throughout the world the motion of rock glaciers has been found to be in laminar flow, the velocity increasing gradually upward from the bottom. The fronts of active rock glaciers are completely devoid of vegetation, while their upper surface is more or less covered by low herbaceous plants and lichens. These fronts slope at an angle that is near the angle of repose of their constituent debris, and the angle at the top of each front where it joins the upper surface is sharp. These characteristics match very well with laminar type of flow.

The rock glaciers of the region under investigation are thought to be inactive for their front angles are gentler than the angle of repose of their constituent debris, their tops are gently rounded and the fronts as well as the upper surfaces are covered with lichens showing a long-time stability. Other evidences for the inactivity of the rock glaciers of the region are the development of debris cones at the lower ends of rock glaciers wherever the setting is suitable (PI. II B and Fig. 4) and the presence of a rather old avalanche deposit resting undeformed on the head of a rock glacier.

RELATIVE AGES OF THE ROCK GLACIERS OF THE REGION

One of the rock glaciers of the region seems to be older than the others. Surface of that rock glacier has ridges more rounded and wider and the vegetation cover over it is somewhat more developed than that on the other rock glaciers (PI. II A and Fig. 6). A period of immobility must have existed between two stages of rock glacier development. It is clearly seen that one of the younger rock glaciers has been developed by the reactivation of part of the older one (PI. II A).

It seems probable that the younger rock glaciers have been developed at the end of the last (neoglaciation) glaciation phase.

NEED FOR FURTHER INVESTIGATION OF ROCK GLACIERS IN TAURUS RANGES

It is known that Quaternary glaciation was effective in Taurus Ranges (Blumenthal, 1947, 1952, 1956; Planhol, 1953; Planhol and İnandık, 1958; Onde, 1954; Spreitzer, 1956, 1958).

Indirect manifestations of Quaternary glaciation in Taurus Ranges are seen at river and lake terraces occurring in large number in the region: Erol (1969) has pointed out terraces of Tuz Gölü in Central Anatolia being developed in accordance with Quaternary glaciation. Also known to be related to Quaternary glacial activity are terraces of Burdur Lake in the district of lakes in Southwest Anatolia.

Terraces and other features of Taurus Ranges indirectly related to glaciation would be more fruitfully interpreted if data on the effectiveness of glacial cycles there are obtained.

The presence of rock glaciers at various stages of development offers a promising area to study mechanism of rock glacier formation.

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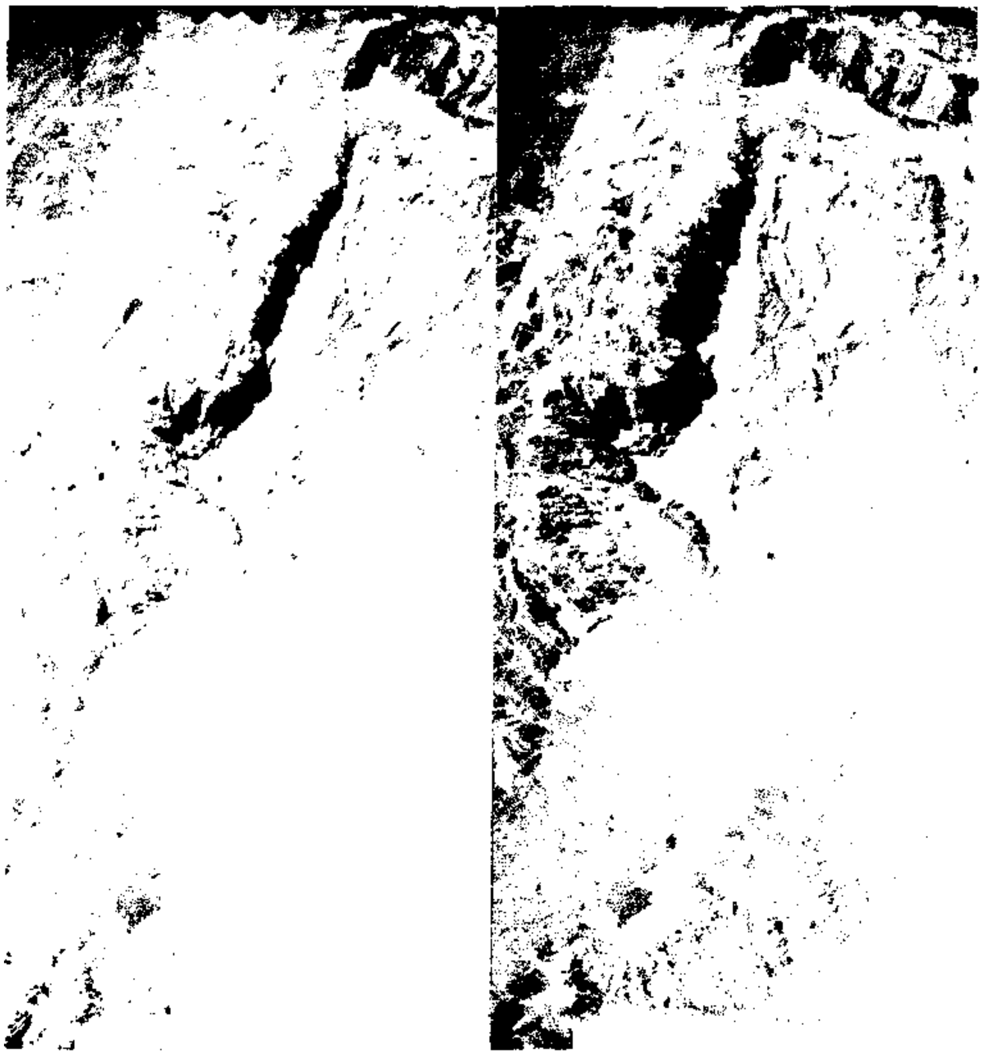


A well-preserved cirque glacier moraine. Rock glacier mechanism must have possibly been effective in the development of the light-colored formation seen in the depression once filled by cirque glacier.

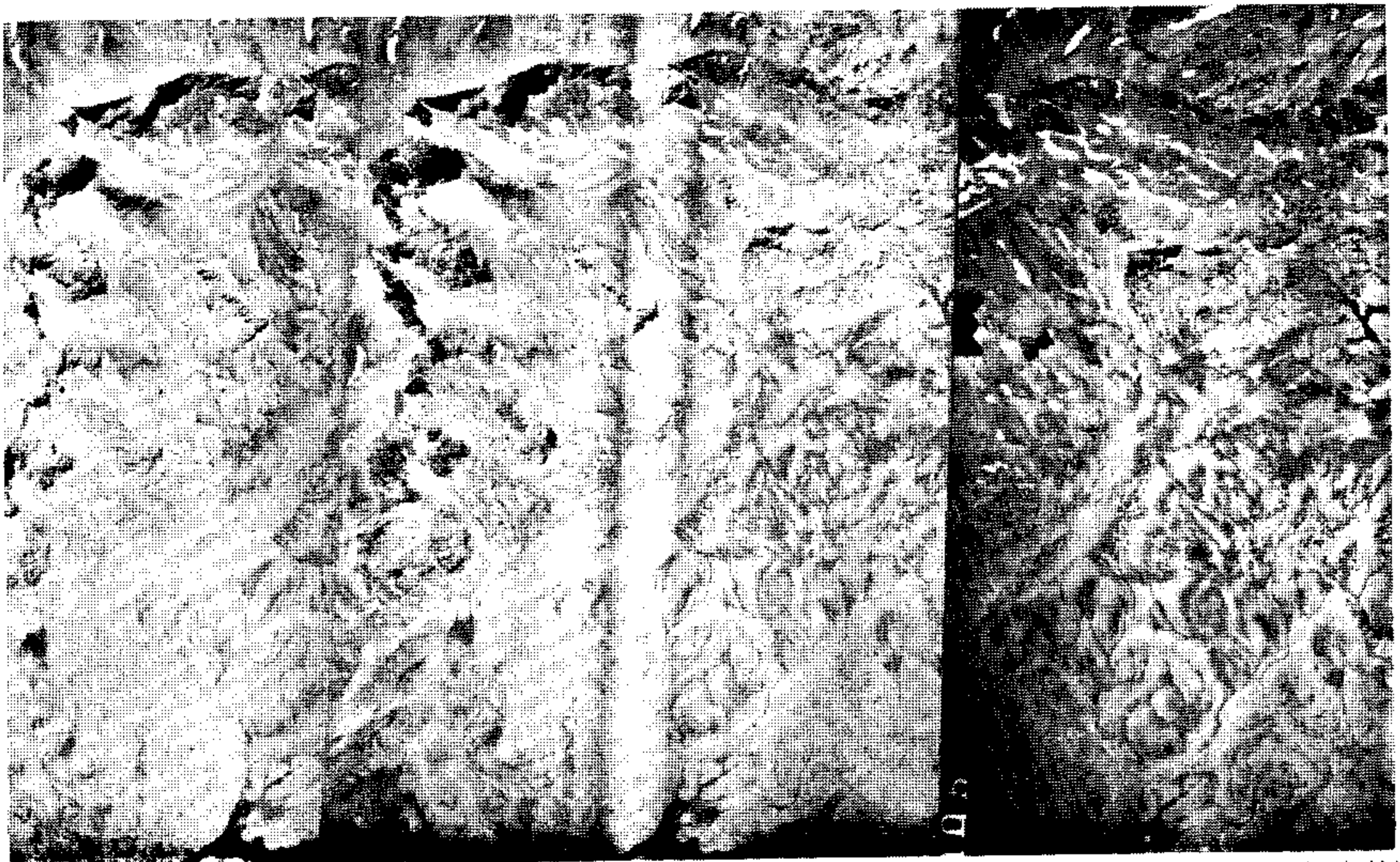
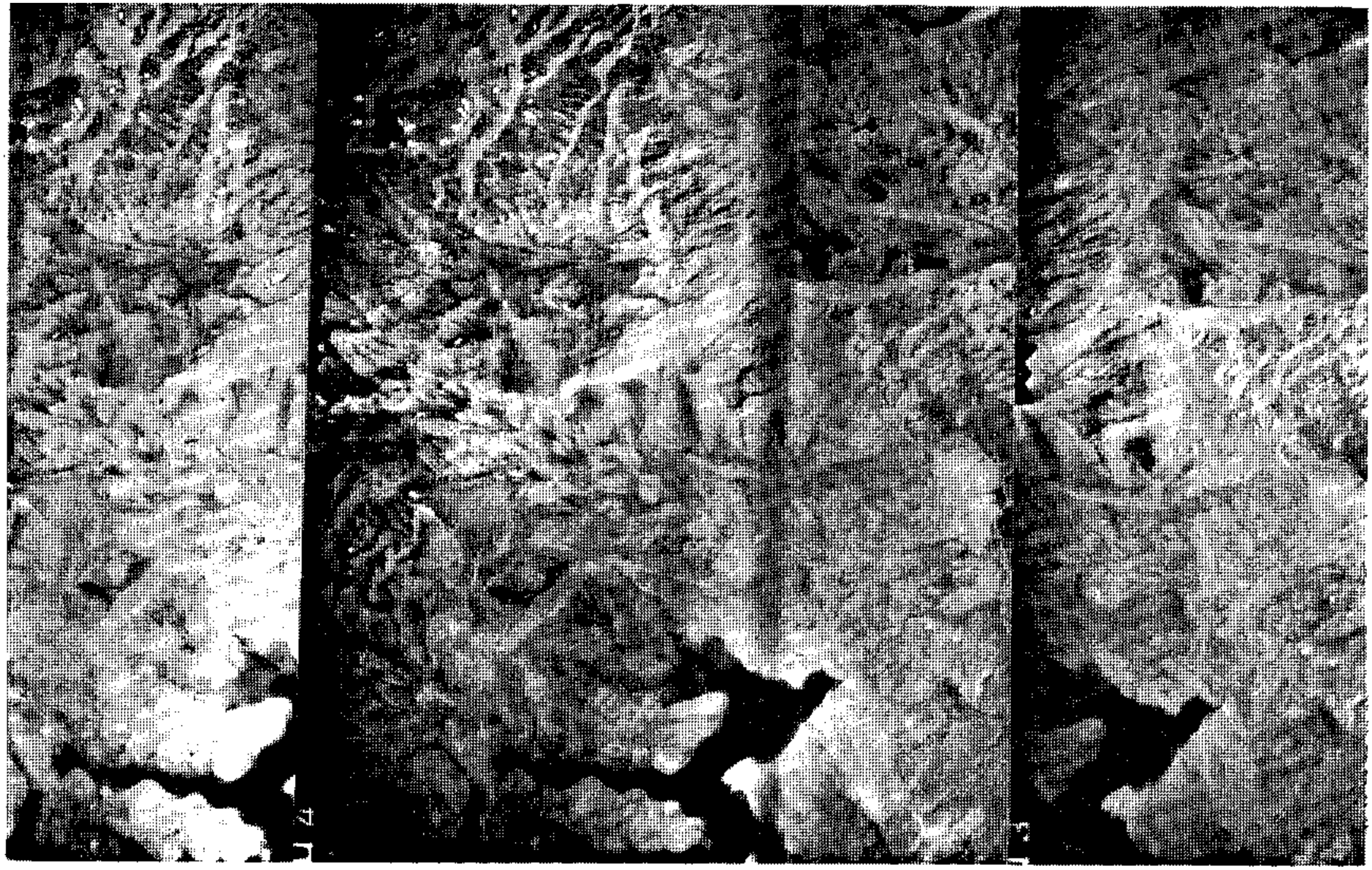
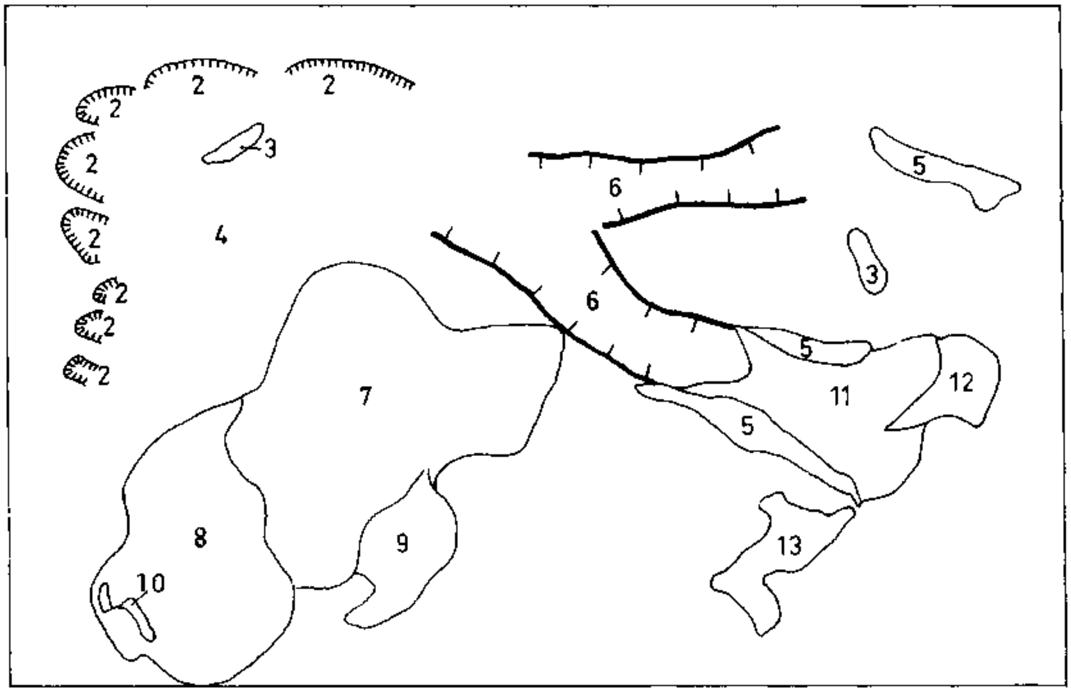


Plate II B is the continuation of this plate. Explanations for these plates are on the page following Plate II B. Flight is southward (left-hand side).



This plate is the continuation of Plate II A. Explanations are on the next page. Flight is southerly (left-hand side).



Explanation of Plates II A and II B.

1 - Summit of Geyikdağı.

2 - Numerous cirques developed on northeast flank of Geyik Dağı.

3 - Remnant of a cirque glacier.

4 - Barren surface between cirques and rock glaciers.

5 - Lateral moraines of a valley glacier which preceded formation of rock glaciers.

6 - Bed rock denuded by valley glacier.

7 - Remnant of an older rock glacier. Differentiated from the younger ones by its broader ridges and by its somewhat more developed vegetation cover which reflects in photos as a darker tone.

8 - A younger rock glacier. Convex ridges and furrows are well seen.

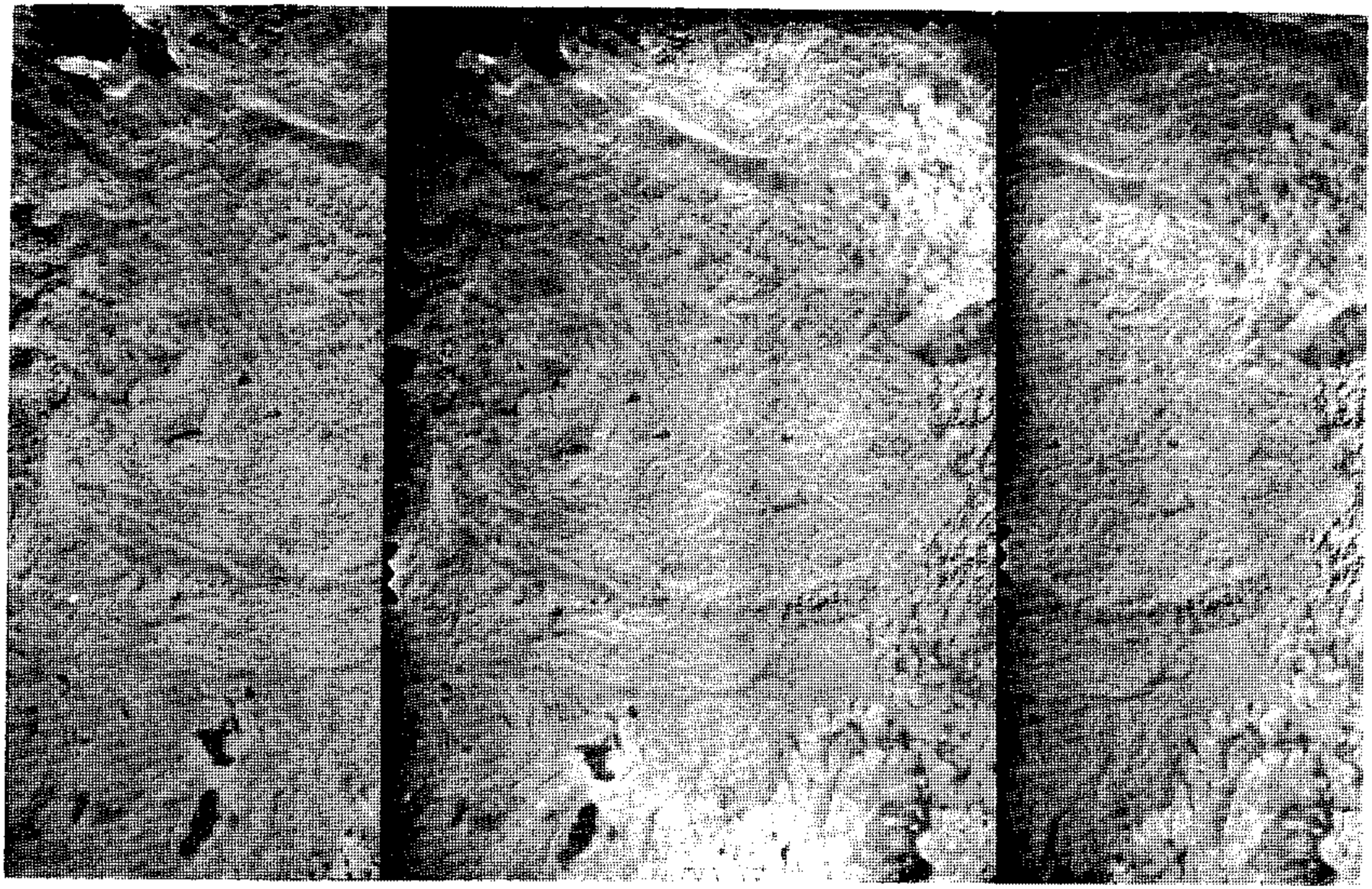
9 - A younger rock glacier. Possibly developed by reactivation of an older rock glacier. ,

10 - Possibly a moraine ridge completely lost its primary attitude due to the rock glacier invasion.

11 - A rock glacier which has used an older glacial trough and has been developed of the ground maraines.

12 - Debris cone consisting of materials transported from the rock glaciers by running water.

13 - A pond formed by obstruction by rock glaciers.

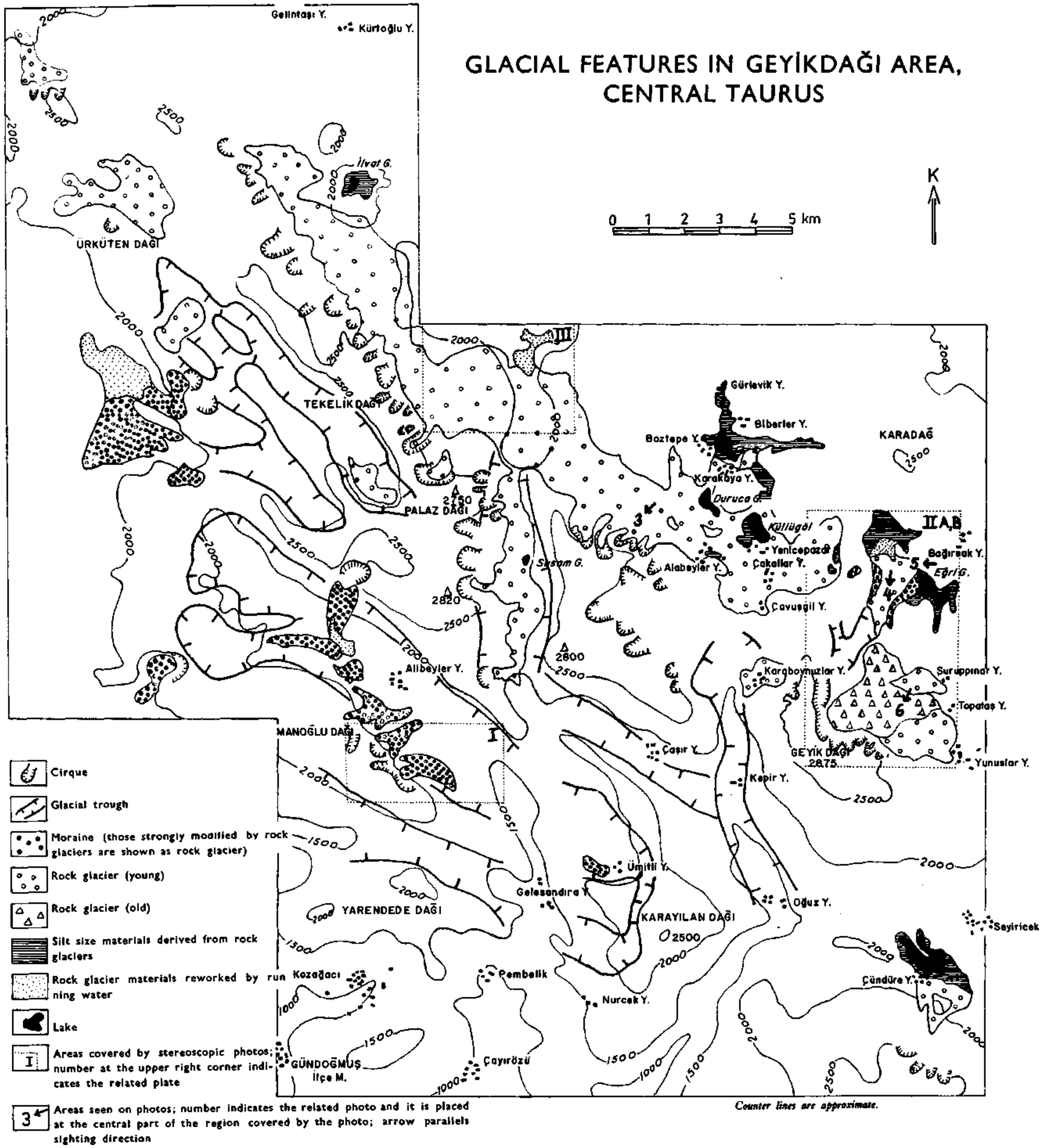


Explanation is on the next page. The flight is northerly (right-hand side).

Explanation of Plate III

A rock glacier mass showing various characteristic features. It is formed by material derived from the cirques, ends of which are seen at southwest corner. Solubility of limestone is also responsible for the higher irregularity of the upper surface. Ridges and furrows convex downslope are nicely displayed. A large depression once filled by ice takes place between rock glacier and cirques. The long ridges standing somewhat higher than the rock glacier surface are suggested to be remnants of cirques glacier moraines, displaced by rock glaciers. Material consisting of very big blocks, and covering a part of a long ridge at SW corner probably belong to a quite young event, an avalanche.

Material covering eastern portion of the Plate could be recessional end moraines of a small valley glacier. Glacial trough extending south, beyond the limits of the photo (seen in Figure 2) must have belonged to the valley glacier which has deposited these moraines. Although derived from similar lithology, due to longer transport and friction, materials of these moraines are finer than that making the rock glaciers. Their darker appearance on photos and their impermeability inferred from the presence of several lakes are probably due to the abundance of fine-size material.



GLACIAL FEATURES IN GEYİKDAĞI AREA, CENTRAL TAURUS
0 1 2 3 4 5 km
K
Cirque
Glacial trough
Moraine (those strongly modified by rock glaciers are shown as rock glacier)
Rock glacier (young)
Rock glacier (old)
Silt size materials derived from rock glaciers
Rock glacier materials reworked by running water
Lake
Areas covered by stereoscopic photos; number at the upper right corner indicates the related plate
Areas seen on photos; number indicates the related photo and it is placed at the central part of the region covered by the photo; arrow parallels sighting direction
Counter lines are approximate.
ÜRKÜTEN DAĞI
TEKELİK DAĞI
PALAZ DAĞI
MANOĞLU DAĞI
YARENDEDE DAĞI
KARAYILAN DAĞI
KARADAĞ
GEYİK DAĞI
2875
GÜNDOĞMUŞ
İlçe M.
Gelintaşı Y.
Kürtoğlu Y.
İlvat G.
Gürlevik Y.
Biberler Y.
Boztepe Y.
Karakaya Y.
Duruca G.
Küllügöl
Yenicepazar
Çakallar Y.
Alabeyler Y.
Çavuşgil Y.
Bağırsak Y.
Eğri G.
Susam G.
Alibeyler Y.
Karaboynuzlar Y.
Suruppınar Y.
Topalaş Y.
Yunuslar Y.
Çaşır Y.
Kepir Y.
Ümitli Y.
Gelesandıra Y.
Oğuz Y.
Seyiricek
Kozağacı
Pembelik
Nurcek Y.
Çündüre Y.
Çayırözü

Fig. 2

Fig. 3 - Empty cirques developed in limestone and hummocky upper surface of rock glaciers. SW of Boztepe Yaylası, NE of the mapped area.

Fig. 4 - Lateral moraine ridges bounding a rock glacier from two sides. Many cirques developed on the northern flank of Geyik Dağı are seen in background. At the right-hand-bottom corner is seen a debris cone developed by flood water carrying materials from rock glaciers.

Fig. 5 - Close up of the materials forming rock glaciers. This ridge forms the flank of a newly developed valley. The slope angle has been increased by hydraulic action of the creek. Near NW of Eğrigöl (NE section of the investigated area).

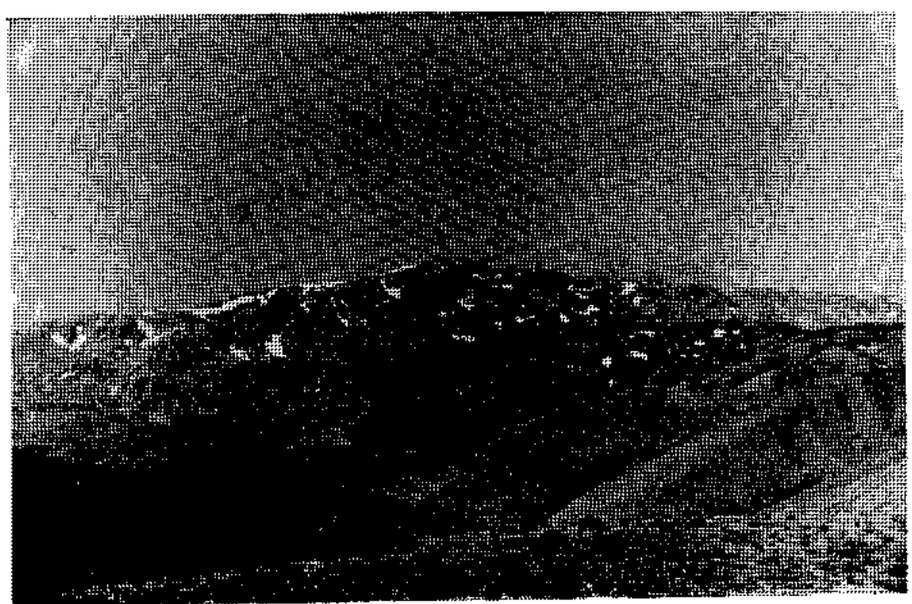


Fig. 6 - Rock glaciers developed at the NE foot of Geyik Dağı. At the right half of the picture is seen an older rock glacier with rounded ridges and with its more developed vegetation cover. Younger rock glaciers at the left-hand side are easily distinguished by their different surface texture.