S. Hastenrath and J. Wilkinson***

A CONTRIBUTION TO THE PERIGLACIAL MORPHOLOGY OF LESOTHO, SOUTHERN AFRICA

Abstract

During April-May 1971, a field survey was carried out in the mountains of Lesotho, at elevations between 1,800 m and 3,485 m, the summit of Tabana Ntlenyana. A variety of active periglacial forming processes was observed, such as pipkrake, turf exfoliation, terracette formation, and thufurs, mainly above about 2,800 m, and downslope sludging of individual stones, stone sortings, polygon soils, and tilting of stone plates abovo 3100 m. The destructive effect of needle ice is seemingly aided by the intensive grazing of mountain slopes, which began at the turn of the century. Fossil solifluctional mantles reach down to at least about 2,700 m, and solifluctionally shaped cirque morphology is found at elevations around 2,900–3,100 m. Available climatological observations are presented in relation to the observed altitudinal zonation of geomorphic phenomena.

INTRODUCTION

The mountains of Lesotho and the Natal Drakensberge hold a key role in an assessment of large-scale altitudinal zonation, inasmuch as they represent the highest elevations in Southern Africa as a whole. The high mountain environment reacts most sensitively to climatic change, which manifests itself in a spectrum of glacial and periglacial forming processes. The mountains of Lesotho are not high enough to reach a modern snow line. Fossil periglacial phenomena have been reported by Alexandre (1962) and by Sparrow (1964, 1967), who noted the difficulty in interpretation arising from the absence of a modern glaciation. To Troll (1944) we owe early observations on some recent periglacial phenomena in the Mont-Aux-Sources region of the Drakensberge. More recent observations are due to Harper (1969). In relation to a prospective assessment of modern and pleistocene altitudinal zonation, a systematic field survey of recent periglacial phenomena appeared appropriate.

On field trips in April and May of 1971, two regions of Lesotho were visited (Fig. 1): (a) the mountains of the Northeast, in a triangle described

* University of Wisconsin.

** University of the Witwatersrand.

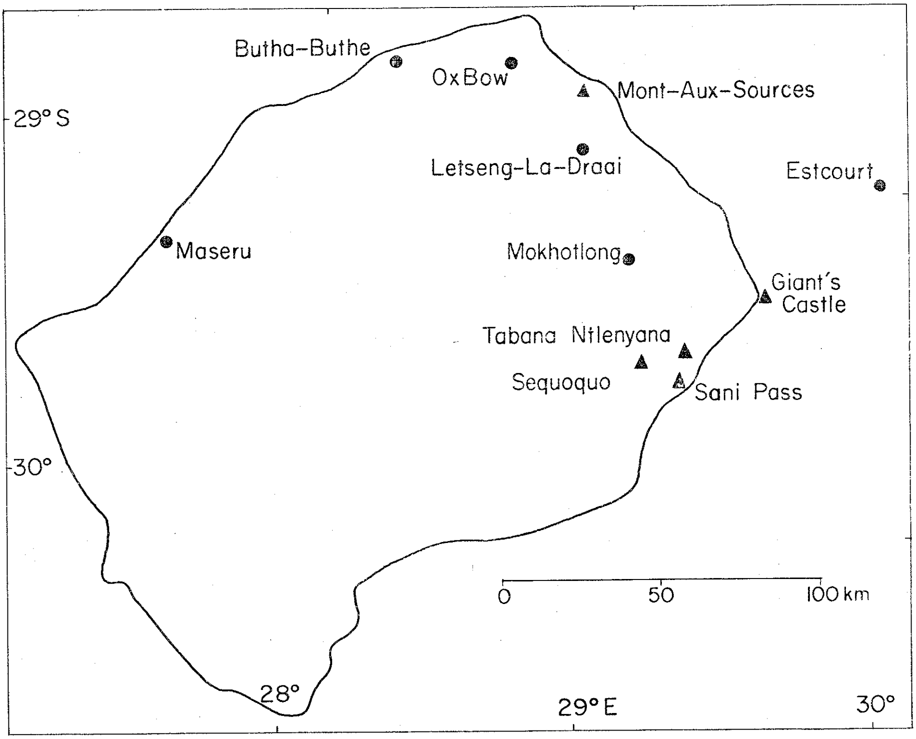


Fig. 1. Orientation map of survey areas

by Butha-Buthe, Mont-Aux-Sources, and Letseng-La-Draai, and (b) the area of Sani Pass, Tabana Ntlenyana, and Sequoquo, in the Southeast.

Basalt of the Stormberg series (Upper Karroo), partly in a plate-like development, forms the major bedrock throughout the higher parts of Lesotho, above about 1,800 m. It is underlain towards lower elevations by less mighty layers of Cave Sandstone and the sandstones and shales of the Red Beds, both belonging to the Stormberg series (Du Toit, 1939).

Areas surveyed ranged between 1,800 m and 3,485 m, the highest peak of Southern Africa, Tabana Ntlenyana (Fig. 1). A particular effort was made at an adequate photographic documentation of observed phenomena. For an accurate determination of the elevation of observed geomorphic phenomena, the available 1 : 50,000 and 1 : 250,000 maps (Directorate of Overseas Surveys, 1961–63, 1969) were used in conjunction with two aneroid altimeters. Altimeter readings were corrected on the basis of the 12 Z radio soundings of the same days at Durban and Bloemfontein (courtesy of South African Weather Bureau, Pretoria), thus ensuring adequate accuracy.

RECENT PERIGLACIAL FORMS

A wealth of active periglacial processes was found, many of which displayed a distinct pattern of vertical distribution.

Needle ice (pipkrake) was found in better development and more commonly at elevations above 2,800 m. Ice needles of an asbestos-like structure and a height of about 1–3 cm lift crumbs of fine earth off the subsoil. The sunshine of the morning hours melts the ice needles and the fine material sinks back to the surface. A marked stripe-like arrangement of the fine material is generally observed with an approximate ENE-WSW direction (Pl. 1). The exact orientation is very sensitive to obstructions of the horizon, in such a way that stripes point in the direction of local sunrise. It is recalled that Troll (1944) considered the striping to be due to the effect of strong winds.

An attempt was made to study the stripe formation experimentally: near the camp site at 3,020 m, a fine earth surface of about one square meter was smoothed out by hand in the evening, and was checked the subsequent morning. Night temperatures dropped below freezing and there was an abundance of frozen soil and puddles. However, a striping of the fine earth material could not be recognized, and it appears that this pattern develops more gradually in the course of a larger number of diurnal cycles.

On gentle slopes above 3,000 m, circular growth of plants was found (Pl. 2). This is considered a common phenomenon in the low latitude high mountain environment, and has been observed by the writer in the High Atlas of Morocco, the Central American Cordilleras, and the Peruvian Altiplano.

Terrassette formation in the vegetation cover occurs from elevations of less than 2,000 m to more than 3,300 m (Pl. 3). Especially at lower elevations, one has the impression that grazing cattle and sheep play a major role in the origin of these terrassettes. From about 3,000 m upward, needle ice has been observed to be an important agent in breaking up the vegetation cover (Pl. 4), thus contributing to the origin of scars and terrassettes. However, even at higher elevations the destructive frost action is seemingly aided by the intensive grazing, which is known to have reached extreme proportions since the turn of the century, in wide areas of Lesotho.

Little vegetation-covered mounds of about 20–50 cm height (thufur) are characteristic of sites with abundant soil moisture, at elevations between about 2,900 and more than 3,100 m. A clear tendency was observed for the vegetation cover to break up on the northward facing side of the mounds (Pl. 5). On steep slopes, the mounds show some asymmetry, with a deformation following the gradient. A cross-section was cut through some of these mounds. The vegetation is limited to a relatively thin superficial coat, and the interior of the mound is made up of a dark, heavy clay-like material.

An active solifluctional downslope slipping of individual rocks within a soft and muddy subsoil could be observed at some places near 3,200 m (Pl. 6).

Sorting of stone material in a variety of forms was found at elevations above about 3,100 m.

Large boulders, with typical diameters of 20–50 cm, scattered through an area of coarse soil were in their immediate vicinity surrounded by smaller stones of the size of 1–5 cm (Pl. 7). The smaller stones appeared to be packed tightly against the big boulder and showed indications of being arranged vertically.

An excellent development of polygon soil was discovered in an extended area near Ox Bow at an elevation of 3,300 m. The location is a pan-shaped depression, about 100 m in diameter. Marks on boulders and the vegetation distribution indicate that, at least episodically, this depression is filled with water. Experience in the Alps has shown that such conditions are particularly favorable for the formation of frost structure soils.

The mesh width of the polygon soil was about 20 cm, and the size of individual stones up to about 2 cm (Pl. 8). For an inspection of the vertical structure, a trench was dug across several stone rings (Pl. 9), down to a depth of about 20 cm, where the bedrock was encountered. This digging was done with bare hand and a small pocket knife, which provided for an optimal sensitivity to the size and quality of the material. The ring arrangement of larger stones is limited to the immediate surface. However, down to a depth of about 1 cm a distinct sorting was still noticed, in such a way that coarser material with intermixed stone grains of a few mm in size occurred in the ring portion, much in contrast to the soft, stone-free, cheese-like clay material in the center. The surface enclosed by a stone ring is slightly convexly curved.

In the region of Tabana Ntlenyana and Kotisephola, in the southeastern part of Lesotho, stone sorting of a somewhat different appearance was found at elevations above 3,200 m. The material consisted of little stones with a typical grain size of 1–10 mm. A soil in the proper sense was absent. Within this fine gravel material, a net-like sorting was commonly observed (Pl. 10), with a typical mesh width of about 5–10 cm. The sorting appeared to extend downward only to a few mm.

The two net patterns just described differ in the following respects: the larger nets with a mesh width of about 20 cm (Pls. 8 and 9) consist of comparatively large stones embedded in very fine soil material whereas the smaller nets with a mesh width of about 5–10 cm (Pl. 10) are made up of small stone grains rather uniform in size. This differing behavior is interesting in relation to Corte's (1963, 1966) laboratory experiments.

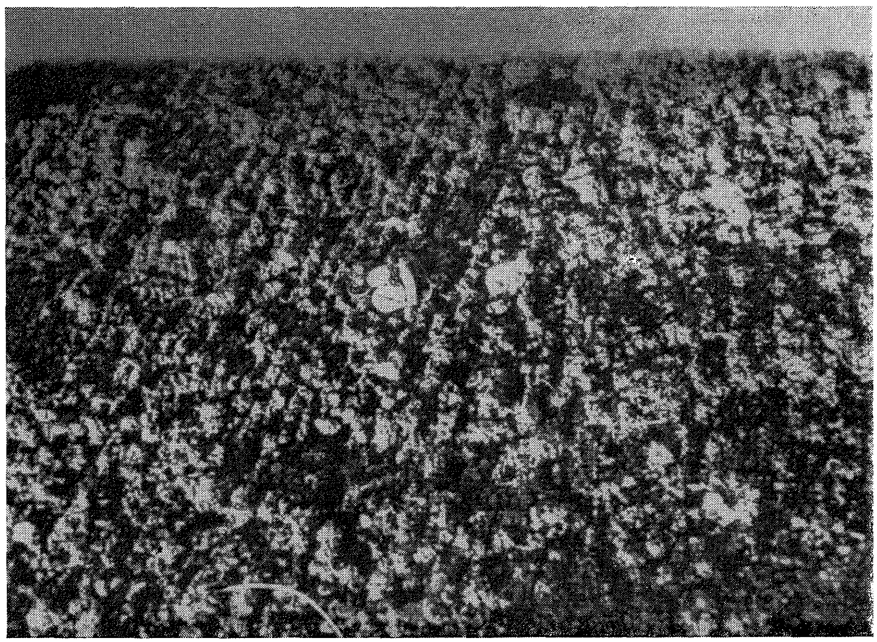


Photo by S. Hastenrath, 23 April 1971

Pl. 1. Pipkrake in ENE-WSW orientation at 3,300 m, region of Ox Bow

Compass has side length of 5 cm; note orientation of compass needle

Photo by S. Hastenrath, 23 April 1971

Pl. 2. Circular growth of plants at 3,200 m, region of Ox Bow

Pocket knife as scale is 9 cm long

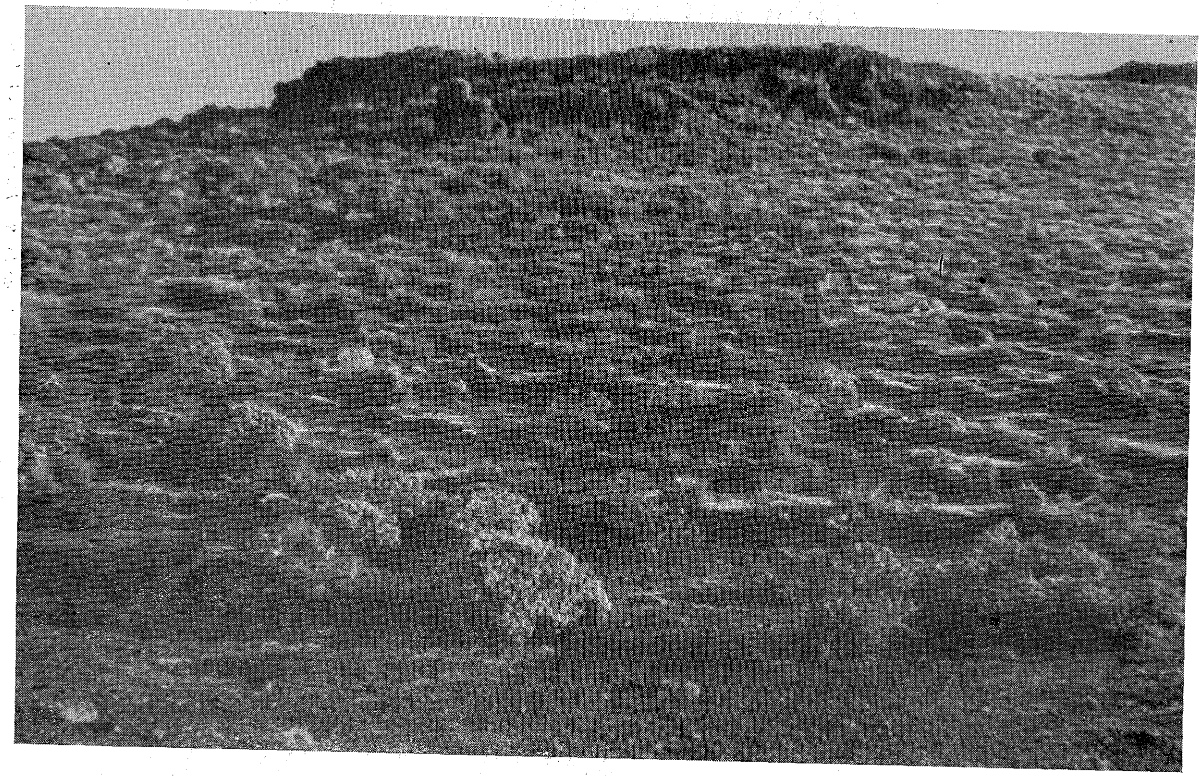


Photo by S. Hastenrath, 23 April 1971

Pl. 3. Terrassette formation on mountain slope at 3,350 m, region of Ox Bow

Photo by S. Hastenrath, 24 April 1971

Pl. 4. Destruction of vegetation cover through needle ice, 3,170 m, region of Ox Bow

Photo by S. Hastenrath, 24 April 1971

Pl. 5. Thufur with breaking up of vegetation on northern face, 3,020 m, region of Letseng-
-La-Draai

Compass and pocket knife as scale

Photo by S. Hastenrath, 25 April 1971

Pl. 6. Downslope sludging of individual rock on muddy subsoil, 3,220 m, region of Mahlasela Hill, Ox Bow

Altimeter as scale has diameter of 7 cm

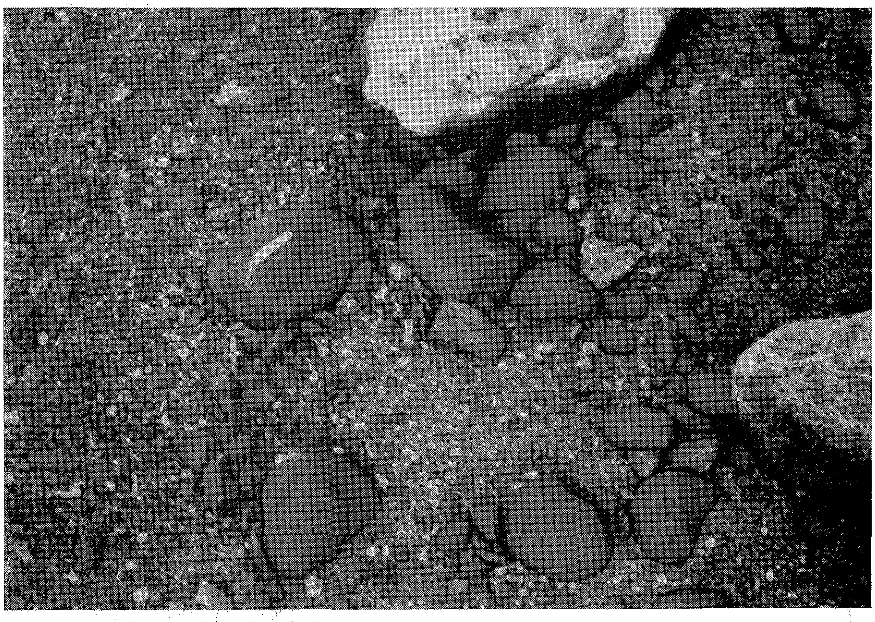


Photo by S. Hastenrath, 23 April 1971

Pl. 7. Packing of smaller stones around large boulder, 3,300 m, region of Ox Bow

Pocket knife as scale

Photo by S. Hastenrath, 23 April 1971

Pl. 8. Polygon soil at 3,300 m, region of Ox Bow

Pocket knife as scale

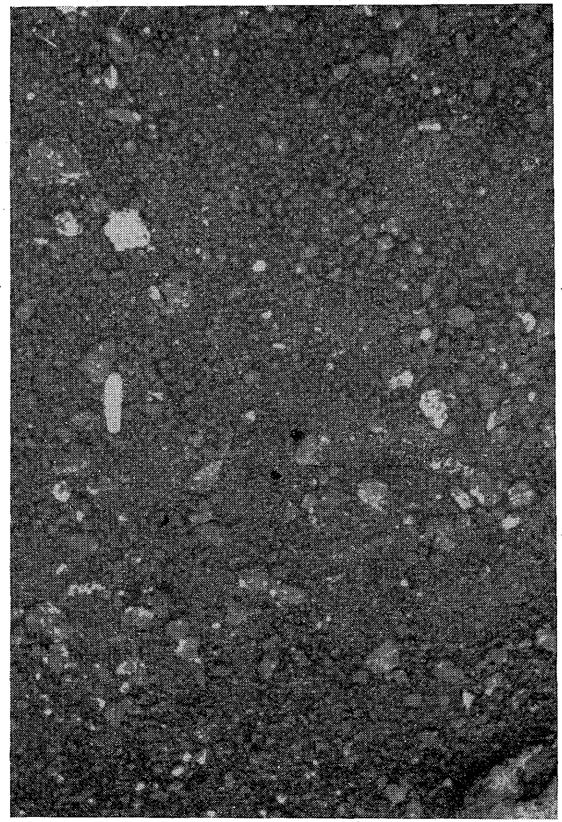


Photo by S. Hastenrath, 23 April 1971

Pl. 9. Polygon soil, cross section, at 3,300 m, region of Ox Bow

Pocket knife as scale

Photo by S. Hastenrath, 1 May 1971

Pl. 10. Polygon soil at 3,280 m, region of Kotisephola–Tabana Ntlenyana

Pocket knife as scale

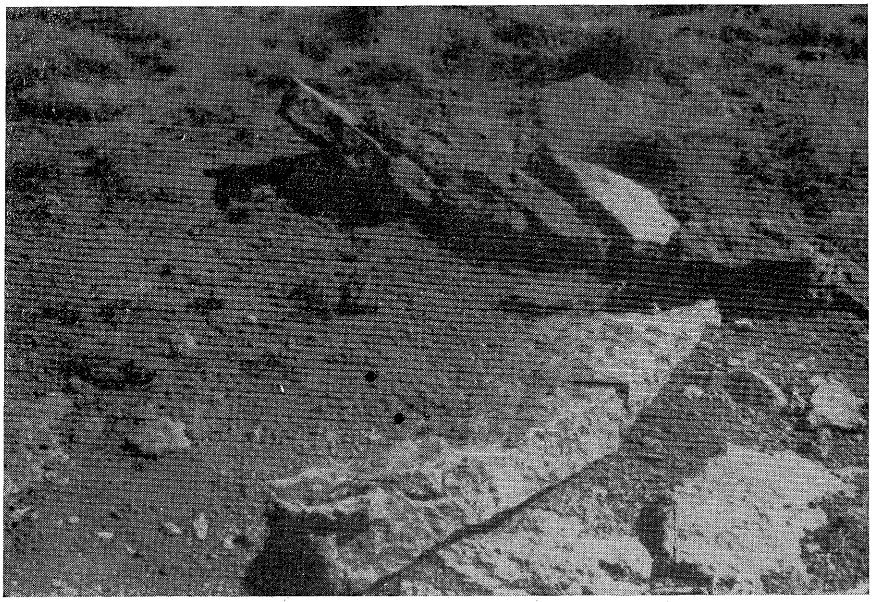
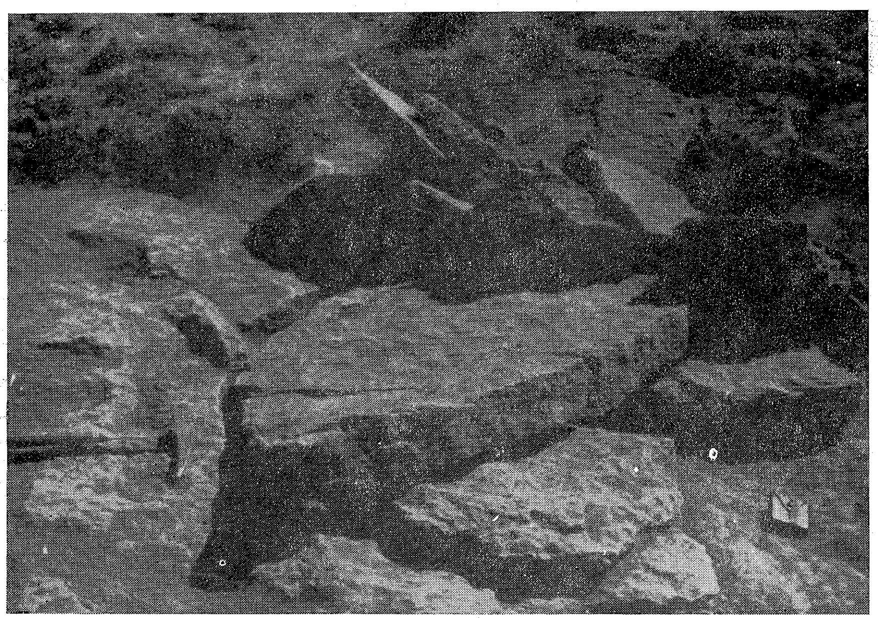


Photo by S. Hastenrath, 24 April 1971

Pl. 11. Packing of tilted basalt plates, 3,100 m, region of Letseng-La-Draai

Compass case as scale has side length of 7 cm



Pl. 12. Same as Pl. 11, after excavation

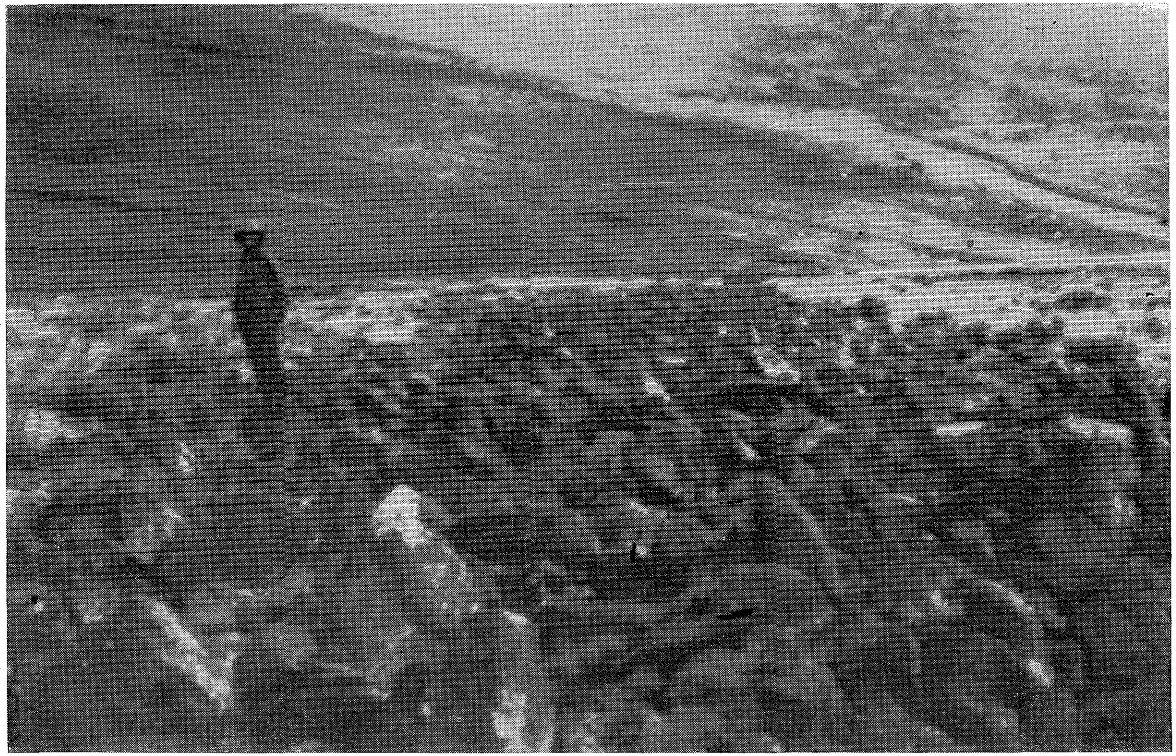


Photo by S. Hastenrath, 2 May 1971

Pl. 13. Block stream on SE-ward facing slope, 3,180–2,960 m, 1,25 km long, region of Tabana Ntlenyana

A more unusual arrangement of rocks presumably also due to frost action was found in the area of Letseng-La-Draai (Fig. 1), on a slightly sloping plateau at 3,100 m. The basalt rock in this location has a plate-like structure. Basalt plates were found tilted nearly vertically, sticking out of the ground (Pl. 11). This stone arrangement was carefully excavated in various steps documented by photography (Pl. 12).

In the surrounding ground basalt plates were found to be layered almost horizontally. Close inspection revealed that several segments of some plate--like layers had been dislocated and pushed on top of each other, with some tilting. Dislocation and horizontal displacement at this site was found to have taken place in a counterlockwise turning. The strongly tilted plates apparent at the surface could be traced to nearly horizontal plate-like layers in the ground, from where they had been dislocated. Vegetation in the area is scarce and can be discarded as a cause for dislocation of rocks of this magnitude. Finer soil material is available in the surroundings of this stone arrangement and in the spaces between the individual plate segments. Change of frost is extremely frequent at these altitudes, as will be seen further below. It is suggested that change of frost is the mechanism for the observed dislocation and tilting of basalt plates.

Frost is recognized as a morphogenetically important agent in the high mountain regions of Lesotho. In particular, needle ice damages the vegetation cover, provides a preparation of fine material, thus contributing to an active erosion process. The effectiveness of needle ice is seemingly aided by the intensive grazing of slopes especially in the northeastern part of the high mountains of Lesotho since the turn of the century.

FOSSIL MORPHOLOGY

Apart from the presently active periglacial processes, a variety of dead forms was found.

Mountain slopes and valley ends in the high mountain parts of Lesotho generally have a smoothed or camouflaged appearance, suggestive of a solifluctional overforming; a fluviatile incision may in turn be imposed on this. At appropriate places where a profile of the subsoil is accessible, fossil solifluctional mantles could be identified. These were observed down to elevations of about 2,700 m, in fair agreement with Alexandre's (1962) findings.

Numerous block streams were observed in both study areas at elevations between 2,700 and 3,200 m (Pl. 13), mostly on slopes facing towards southerly directions. As a rule, they did not seem to be in the process of formation at present.

Most remarkable are certain smooth concave forms and spoon-shaped valley ends commonly encountered with the bottoms of the depressions at elevations around 2,900–3,100 m. In their form and regularity of elevation, these features are extremely suggestive of fossil cirques. In general, these cirque-like concave forms have an aged appearance, as that resulting from a subsequent solifluctional forming. It is recalled that Sparrow (1964, 1967) indeed proposed the occurrence of pleistocene cirques in the area of Sani Pass and Giant's Castle at elevations of about 2,400 m.

ON MODERN AND PLEISTOCENE ALTITUDINAL ZONATION

The distinct pattern of vertical distribution of recent periglacial phenomena, as presented in Section 2 (p. 159), should be viewed in perspective with the climatic altitudinal zonation as borne out by the several years' meteorological observations at stations of different elevations. Data are only partly available in published form (Jackson, 1961; South African Weather Bureau, 1958–64, 1963–69), and unpublished records were obtained through the courtesy of the South African Weather Bureau, Pretoria.

Table I lists the selected stations, along with geographical coordinates, elevation, and period of record.

Table I

Meteorological surface stations

station	elevation	latitude	longitude	period of record (*cf.* Table II and Fig. 2)
Letseng–La–Draai	3,073 m	28°58′S	28°52′E	1966–70
Ox Bow	2,591 m	28°43′S	28°37′E	1958–62
Mokhotlong	2,375 m	29°17′S	29°05′E	1958–62
Butha-Buthe	1,768 m	28°46′S	28°15′E	1958–62
Estcourt	1,181 m	29°01′S	29°52′E	1958–62

For the rainfall distribution over Southern Africa reference can be made to Jackson's (1961) atlas: annual totals decrease from more than 1,400 mm in the mountains of eastern Lesotho and along the Natal Drakensberg Escarpment, to less than 600 mm in the valleys of central Lesotho, with an increase westward to about 700–900 mm in the western part of the country.

Table II offers an orientation on the vertical distribution of the thermal regime. The daily mean temperature for the year as a whole stays far above freezing at all elevations, but approaches it for the winter half-year at the highest stations. Consistent with the radiation conditions, the daily temperature range is largest during winter. Mean minimum temperatures for the winter half-year as a whole are below 0°C at stations above 2,300 m, which implies

Table II

Temperature regime in its vertical distribution

	November-April					May-October					Year			
	$\overline{T}$	$\overline{T}_x$	$\overline{T}_n$	$T_{x\ abs}$	$T_{n\ abs}$	$\overline{T}$	$\overline{T}_x$	$\overline{T}_n$	$T_{x\ abs}$	$T_{n\ abs}$	$\overline{T}$	$\overline{T}_x$	$\overline{T}_n$	N
Letseng-La-Draai				20.9	–9.0				20.8	–20.4				146
Ox Bow	10.5	16.2	4.8	23.0	–14.0	4.3	11.1	–2.5	23.0	–14.0	7.4	13.6	1.2	137
Mokhotlong	15.0	22.6	7.3	31.3	1.0	8.7	18.4	–0.9	30.4	–12.2	11.8	20.5	3.2	104
Butha-Buthe	17.7	24.5	10.9	33.0	4.8	10.8	19.5	2.1	32.2	–7.9	14.2	22.0	6.5	62
Estcourt	19.8	25.9	13.7	35.4	4.4	14.1	21.9	6.2	35.6	–3.7	16.9	23.9	9.9	6

Number of days with change of frost N, absolute maximum $T_{x\ abs}$, absolute minimum $T_{n\ abs}$, mean maximum $\overline{T}_x$, mean minimum $\overline{T}_n$, and daily mean temparature $\overline{T}$.

a large number of days with frost. As is seen from the vertical distribution of absolute minimum temperatures, at least occasional frosts occur at all stations during the winter half-year, whereas in summer they are limited to the highest elevations.

Changes of frost, rather than consistently low temperatures, are considered relevant in periglacial forming processes. Supplementing the information on altitudinal zonation of the thermal regime offered in Table II, Fig. 2 shows the seasonal march in the frequency of frost-free days, ice days, and days with change of frost, at five stations well distributed in the vertical. Fig. 2 illustrates the concertration of frost-free days during the summer season, an increase of frost change days with height, and ice days occurring during the two winter months at the highest station only. The annual frequency of days with change of frost at the two highest stations, Ox Bow and Letseng-La-Draai, is as large as 137 and 146, respectively. While it is recognized that the vertical distribution of patterned ground does not simply follow that of frost change frequency (Hastenrath, 1960) Fig. 2 does provide climatological background pertinent to the altitudinal distribution of soil frost phenomena.

The temperature field in the free atmosphere outside the high mountain region can be derived from the available radiosonde stations (U. S. Weather Bureau, 1958–63). The large-scale meridional variation in the elevation of the 0°C mean annual isotherm over Southern Africa along approximately 30°E is graphically depicted in Fig. 3. The corresponding elevations during the winter (May–October) and summer (November–April) half-years are also entered as broken lines. The upper-air stations Bloemfontein and Durban are regarded as representative of the latitude of the Lesotho mountains. The elevation of the 0°C mean annual isotherm at 30°S is read from Fig. 3 to be about 4,200 m, which is well above the highest peaks of the Lesotho mountains. This supplements the information on the temperature field provided by the mountain stations.

The approximate lower limits of fossil periglacial and of more common and well-developed recent periglacial phenomena is also entered in Fig. 3. It should be noted that the elevation ranges entered in Fig. 3 refer to the geomorphic phenomena observed during the April–May 1971 field trips, as described in Sections 2 and 3 (p. 159-162). It will be recalled that Sparrow (1967) reported periglacial landforms down to 1,800 m. Also, he suggested the existence of pleistocene cirques at about 2,400 m, which is at notably lower elevations than the fossil cirque morphology described in Section 3 (p. 162). The exact age of this cirque morphology is not known, but the seemingly fossil periglacial overforming would suggest that they do not belong to the last glaciation.

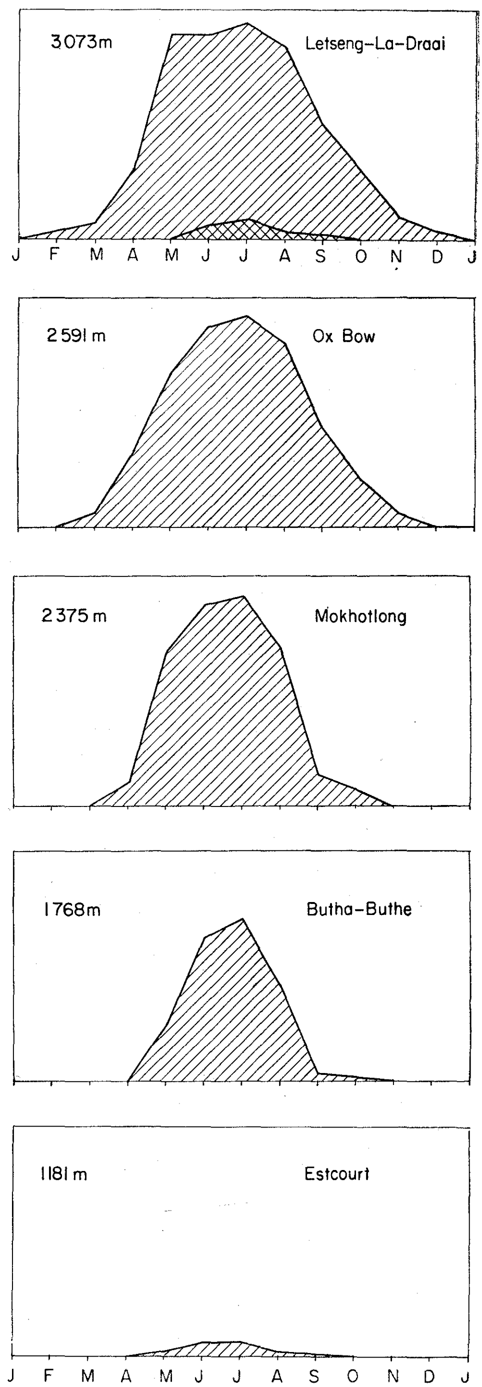


Fig. 2. Frequency of frost-free days, blank, ice days, dark shading; and days with change of frost, light shading. Stations Estcourt, Butha-Buthe, Mokhotlong, Ox Bow, period 1958–62; and Letseng-La-Draai, period 1966–70

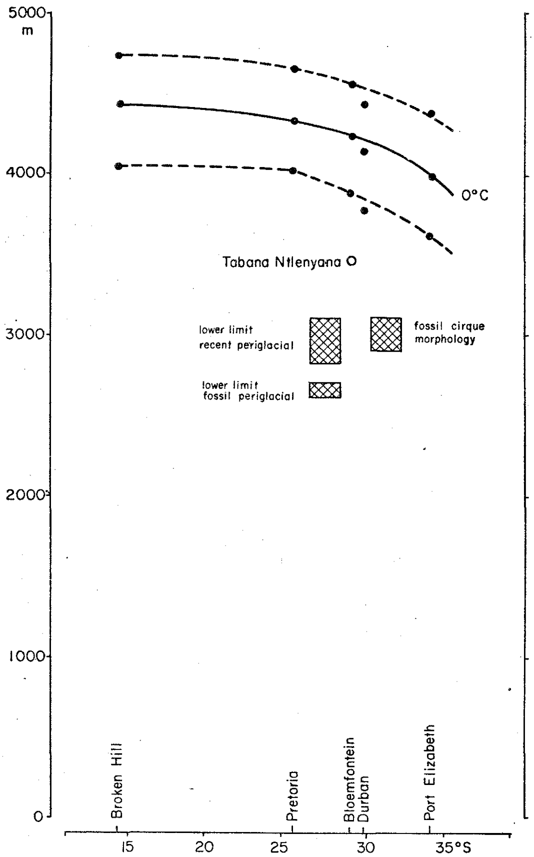


Fig. 3. Climato-geomorphic altitudinal zonation

O°C mean annual isotherm, solid line; elevations during the winter (May–October) and summer (November–April) half-years, broken (period 1958–62, source: U. S. Weather Bureau, 1958–63); lower limit of fossil periglacial and of more common and well developed recent periglacial phenomena, and elevation range of fossil cirque morphology, shaded bands

The absence of a modern glaciation and the limited meridional extent of high mountains hampers the interpretation of fossil periglacial and glacial phenomena; a systematic comparison with the less problematic situation in other sectors of the Southern Hemisphere is called for. It is hoped that the present survey of periglacial morphology may contribute to a better understanding of climato-geomorphic altitudinal zonation in Southern Africa.

ACKNOWLEDGEMENTS

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