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ENVIRONMENT, VEGETATION AND PHYTOGEOGRAPHY OF THE HIGH-ALTITUDE BOGS OF LESOTHO*

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Introduction

The high-altitude bogs of Lesotho or "Mokhoabo" are situated in the riverheads of the Orange River system in the eastern escarpment of Southern Africa (Fig. 1).

The mountain ranges of Lesotho, the Maluti Mts and the Drakensberg range (highest mountain Thabana-Ntlenyana 3484 m) are covered by up to 1500 m thick, early Jurassic, amygdaloidal basalts, in which the tributaries of the Orange River have cut deep valleys.

Climate and periglacial phenomena

The climate of the high mountains of Lesotho is alpine and seasonal in nature. According to Shand (1963) the interior uplands receive much less rain than the surrounding ridges. High rainfall especially occurs on the north-west face of the Malutis. This rain can come down in very heavy showers; e.g. from 16-19th February, 1972, 83 cm were registered near the Oxbow-site. The north-east and south-east slopes of the Drakensberg chain receive orographic rain from the humid maritime air coming from the Indian Ocean.

* Nomenclature of species is given in the tables.

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Rainfall in Lesotho varies greatly, with annual values up to over 1600 mm, with a summer maximum. This represents the highest precipitation in southern Africa, and is the major source of water to the vast semi-arid and arid surrounding regions. During the summer rains, atmospheric humidity is very high and the mountains are often covered in clouds during the day.

The temperature regime above 2500 m altitude is characterised by cool summers and cold winters with some snow, which can especially persist on southern slopes. The maximum temperatures in summer do not exceed 16 °C, while the nightly minimum-temperatures at soil level are below freezing point throughout the year. These diurnal changes in temperature are very pronounced, and the climate can, except for its seasonal changes, be compared with that of the high East African mountains.

Troll (1944) described soil features related to frost at altitudes above 3100 m in the Mt. aux Sources region in north-eastern Lesotho. The most common feature is needle ice which causes frost heaving of soil particles and stones (Van Zinderen Bakker, 1965). On flat surfaces this process leads to sorting of material and on slopes 'needle ice solifluction' (Kammeis-Solifluktion, Troll, 1944) is the consequence of repeated freezing and thawing. In the Drakensberg Troll (1944) also observed patterns of narrow parallel soil ridges caused by simultaneous frost action and wind. As a consequence of this frost regime, humid soil can be subjected to up-freezing every night and thawing every day. We have observed

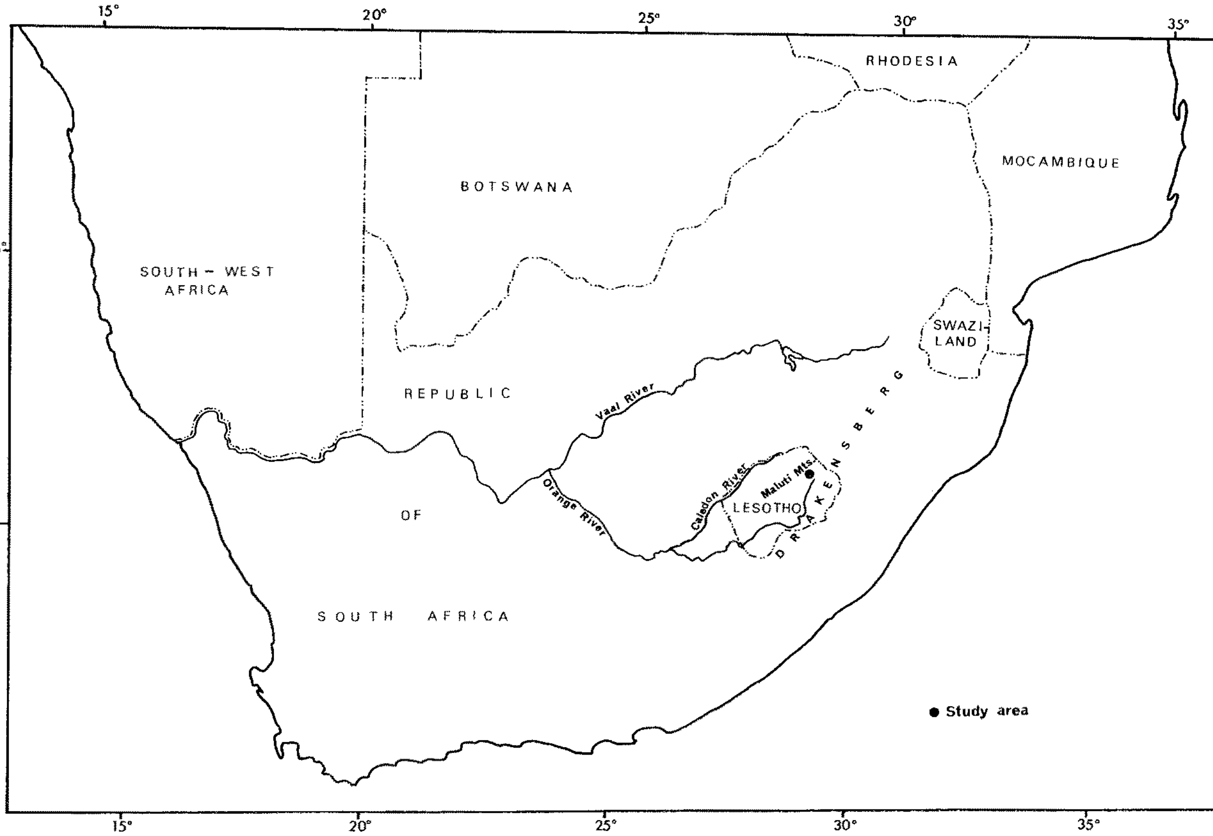

Fig. 1. Locality map.

that this process continues daily in mid-summer on exposed sites. As has been studied by Hedberg (1964) on Mt. Kenya, vegetation can hardly develop in such unstable soil. In the Lesotho mountains *Oxalis depressa* and *Gazania krebsiana* subsp. *serrulata* are the only pioneers which can establish on the many terracettes occurring on the mountain slopes.

Polygons caused by frost also occur in the Lesotho mountains, but these are rare and small as no permafrost is developed.

A very common feature in the bogs, however, are thufur or bog-hummocks which have a diameter of 50–70 cm and a height of about 20–30 cm (Fig. 2). These thufur, which were studied in detail by Van Zinderen Bakker in 1958, have been described for Lesotho by Jacot-Guillarmod (1962, 1963), Van Zinderen Bakker (1965), Harper (1969) and Marker & Whittington (1971). Bog-hummocks are known from many parts of the world and cover extensive flat, boggy areas on Iceland (Thorarinsson 1951), from where the name originates (singular thufa, plural thufur). The origin of thufur has been explained in different ways. They are often ascribed to local unevenness of ground and vegetation. Thicker vegetation protects the soil against frost, and patches with less vegetation become

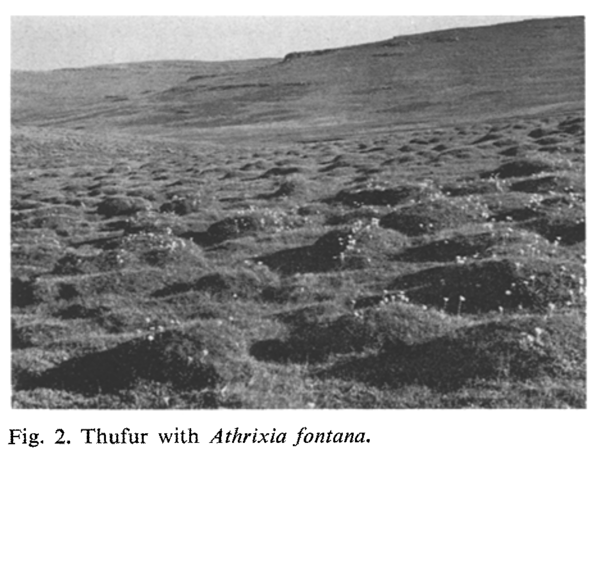

Fig. 2. Thufur with *Athrixia fontana*.

frozen first, which causes them to expand and squeeze earth towards the unfrozen parts. This results in the formation of small knobs. Vegetation in the hollows around and between these knobs is wet and is not as good an insulator as the thicker vegetation on the top of the knolls. Thus, the hollows are repeatedly frozen, while the knolls remain unfrozen or less frozen, resulting in hummocks (Beskow 1930, quoted in: Embleton & King 1968 and in Lundqvist 1969; Sharp 1942; Sigafoos & Hopkins 1951; Hopkins & Sigafoos 1954). Similar explanations have been suggested by Harper (1969) and Lundqvist (1969).

Thufa-like hummocks were described from the mountains of the southern island of New Zealand by Billings & Mark (1961). These authors regarded the forming of these hummocks as due to a combination of surfacial frost-sorting, wind erosion and deposition, and rill erosion by water. Killick (1963) mentioned the occurrence of thufur in the alpine belt of the Cathedral Peak area in the Natal Drakensberg, and assumed that they might be caused by animal activity. Also Lötschert (1969) regards animal activity as an important agent in the formation of thufur. Carbiener (1970) reported thufur from the Vosges in France, from areas that are well drained, windswept and carry only a relatively thin layer of snow in winter time. Together with a differentiation between the vegetation on the thufur and that in the depressions between them, Carbiener reported a differentiation in soil structure, particularly an enlarged porosity of the thufa soil. According to Carbiener, particularly the thufur are frozen deeply in winter, while the depressions which are snow-filled are only frozen superficially. He concluded that the forming of thufur in the Vosges is a result of active interplay of vegetation and frost action on the soil.

The undisturbed thufur of the Lesotho bogs are entirely covered with a short mat of vegetation. When they are damaged by animal action or otherwise, their surface is exposed to frost heaving. The result of the forming of needle ice is that hundreds of thufur may have the appearance of small craters covered with loose soil (Troll, 1944, p. 578). Lichens are the first pioneers which settle on the solid edges of such structures. The influence of the predominant West wind on the upfreezing is often clearly demonstrated as all the crater-like thufur are open on their western edge.

On exposed sites in the fjaeldmark, frost action of a similar kind destroys the edge of the grass mat continuously. Ice is formed here in the humus rich soil under the overhanging grass. After thawing of the needle ice at daytime and drying of the soil the loose soil is blown away by the strong wind, resulting in fragmentation of the grass cover. Similar processes have been described by Troll (1944).

General remarks on the vegetation

Above an altitude of about 2200 m the extensive mountain area of Lesotho is mainly treeless and might, according to the classical studies of the Alps, be named 'alpine belt'. For many reasons, which will be discussed later, the term 'Austro-afroalpine Belt' introduced by Coetzee (1967) is, however, to be preferred. The vegetation of this belt is in many ways unique for southern Africa and the area is of special economic interest. Strongly increased human activity in the highest regions of these mountains has recently caused considerable soil erosion and it is evident that this will have a profound impact on the regional ecology. Therefore a detailed knowledge of the ecology of the area seems of utmost importance. Such knowledge will also be of considerable phytogeographical and quaternary geological interest. Still, Lesotho has stayed virtually unknown ecologically. Some general ecological descriptions of the mountain area of Lesotho have been given by Bews (1917), Staples & Hudson (1938), Bawden & Carroll (1968), Killick (1963) and Jacot-Guillarmod (1971). Herbst & Roberts (1974a, b) discuss briefly some plant-habitat relationships of this area, and the relative importance of the various species.

The Austro-afroalpine Belt of Lesotho is covered mainly by two grassland types: the *Themeda* grassland zone (Seboku grassland) which occupies the lower regions, and the *Festuca-Merxmuellera* grassland zone (Letsiri grassland) which occurs on the southern slopes above ±2100 m. and the northern slopes above ±2700 m. Two types of bogs are found in this belt: one is formed in seepage areas on mountain slopes, where large tussock grasses and other plants grow; and another type occurs in the cirque-like riverheads, where rather extensive swampy areas are formed, covered by a low, dense mat of vegetation. The vegetation of this latter bog type, which shows a conspicuous regular patterned microrelief and is covered by thufur, will be dealt with in this study.

These bogs in the riverheads form the so-called sponges of the Orange River System, as they accumulate rainwater and seepage coming down the screes, which is released as a regular flow. Underground water often surfaces in springs, unless soil erosion has opened up channels from the surrounding slopes. Around the springs, peat is slowly deposited, sometimes forming remarkable flat terraces on which a number of tarns occur. Excess water flows through small stream channels to lower levels, but frequently during heavy rain a sheet flow of water develops following depressed areas without the formation of real channels.

In some cases, the bogs in the riverheads have originated in another way, viz. from a small lake which occupied a depression in the valley. In such instances a typical blue-green gley horizon is found at the bottom of the soil profile consisting of clay deposited in the former lake. This lake must have been overgrown by the bog vegetation which resulted in the formation of a clayey peat horizon (A_1). The ash-coloured A_2-horizon has been leached as a consequence of the rainy climate and the acid soil conditions. In the B-horizon, which overlies the G-layer, some black strata have developed in this podsol profile.

The bogs vary in size from about 1 ha to several km^2. Usually their outline is roughly triangular, with the base at the top end of the cirque-like riverhead and narrowing towards the lower end of the valley. The grasses and miniature bog plants are very important for the flocks of sheep and mohair goats, as well as the many horses and cows which concentrate here throughout the year. As a consequence of this intensive usage many of the bogs show signs of severe soil erosion. Deep channels have formed into the soft peaty soil up to the rock bottom. Some of these valuable bogs are practically completely washed away. These bogs should be better utilised to the benefit of the Basuto herdsmen, as otherwise their most valuable grazing areas will be destroyed in the foreseeable future. The destructive erosion is mainly caused by the trampling of cattle and horses which, through their body weight, damage the soil surface. Besides their value for grazing, the "sponges" are also of great importance for the regular flow of the rivers. They act as filters which produce crystal-clear water. It is therefore necessary that these bogs, including their surrounding slopes, are fenced in such a way that animals like horses are kept outside. Sheep and mohair goats, which form a very important source of income for the Basuto and which do not cause soil erosion, should be allowed to graze. This matter is of great urgency, as the destruction which has been initiated can otherwise no longer be stopped.

The alpine bogs of Lesotho are of Late- or Post-Glacial age. The oldest radiocarbon date which has been obtained so far is 8020 ± 80 BP. (Reg. nr. Pta – 751). The average thickness of the peat layer deposited per year is only about 0,25 mm which shows that the production of organic material is very limited under the cold alpine conditions prevailing at these high altitudes.

During the last glacial period, the climate at an altitude of over 3000 m must have been unfavourable for the development of swamp vegetation. Pollen analytical and geological evidence from Southern and East Africa indicate that the average annual temperature must have been at least 5 °C lower than at present (Van Zinderen Bakker & Butzer, 1973; Coetzee, 1967). From a study of fossil and present day periglacial phenomena in the Lesotho mountains, Harper (1969) came to the same conclusion. A decrease in temperature of this magnitude will have shortened the vegetation period considerably and will have increased the snow cover. Palaeoclimatic evidence further indicates that the climate of southern Africa was more humid during the glacial period and drier during post-glacial times. Alternations of rainy and drier climates must have caused changes in the bog profiles, the rainy periods being marked by gravel layers and the drier ones by deposition of peat and thick deposits of white diatomite. The first pollen analytical results indicate that the climate probably changed from a more humid to a drier type (Van Zinderen Bakker, 1955) during the deposition of the peat layers.

According to their hydrology, the bogs are of the ombrogenous-soligenous type. The water they receive is eutrophic as the basalt is rich in CaO, K_2O and P_2O_5 (Stockley, 1947) and has a pH of about 8. The bogs develop, however, into an oligotrophic direction with ultimate pH values between 4 and 5.

Phytosociology

Three of the alpine bogs, some 30 km NW of Mokhotlong, at an altitude of 3200 m, were surveyed in April 1972, November 1972 and January 1973. The three bogs are separated from one another by mountain ridges of approximately 300 to 400 m high, and the distances between them vary about two to ten km. Twenty-eight plots, representing the observed variation in vegetation and varying in size from 25 to 100 dm^2, were laid down so as to avoid obvious structural and environmental

Fig. 3. In the pool the Crassuletum natantis. Alongside the low thufur at both sides of the pool the Ranunculetum meyeri haplocarphetosum and on the thufur the Senecionetum cryptolanati inops.

heterogeneity within each plot. Thufur and hollows were sampled separately. Another fifteen plots, varying in size from 1 to 50 m^2, were sampled in the vegetation surrounding the bog, in order to establish the differences between the two types of vegetation. Complete species lists were recorded at each plot site, with cover-abundance and sociability values rated on the commonly used Braun-Blanquet scales. Phytosociological tables were prepared in the usual way (Ellenberg, 1956; Braun-Blanquet, 1964; Werger 1973, 1974; Westhoff & Van der Maarel, 1973).

In the tarns and pools, formed by a widening in the stream channels, where the water stagnates somewhat, we find the *Crassuletum natantis* ass. nov. (Table 1, Fig. 3) a water plant community for which the following species are characteristic: *Crassula natans*, *Lagarosiphon muscoides*, *Limosella capensis*, *Nitella sp.* and *Colpodium hedbergii*. *Lagarosiphon muscoides* and *Nitella sp.* are submerged plants, and such is the peculiar *Crassula natans* that has got clearly succulent characters. (There is also a terrestrial, miniature form of *Crassula natans*, recently described as a subspecies *filiformis*.) *Limosella capensis* roots under water, but usually sends some leaves and its flowers to the surface, where they are floating. The floating leaves differ considerably from the submerged ones. *Colpodium hedbergii*, also known from the East African mountains, is a floating grass.

Occasionally little peaty islands with nearly pure stands of *Deschampsia caespitosa* are found at the edge of tarns or pools, in which the *Crassuletum natantis* occurs. Whereas the pH of the water in tarns, streams and pools varied between 7,9 and 8,6 (measured on the 7th April, 1972 at 1600 S.A.S.T.), the pH of the oozy, peaty mud in the root zone of the *Crassuletum natantis* was 5,2.

The terrestrial communities of the Lesotho peat bogs are interwoven in a mosaic, which can be correlated with habitat features, but is more complex than the pattern described by Carbiener (1970) from the Vosges.

On areas where no real stream channels are formed, but a nearly permanent run-off as a sheet flow occurs, a species-poor community, the *Ranunculetum meyeri* ass. nov. is found. Character-species of this association is the creeping, mat-forming *Rananculus meyeri*, which reaches high cover-abundance values. Also of importance can be *Scirpus fluitans*, *Limosella longiflora*, *Agrostis subilifolia* and the bryophyte *Bryum erythrocarpoides* (Table 2). Two subassociations are distinguished.

Table 1

Crassuletum natantis

relevé no.	134	145	148	149	150	153	157	161
depth of water (dm)	2	6	3	3	3	5	3	6
total cover (%)	100	90	100	80	80	80	100	75
relevé area (dm^2)	100	100	100	100	100	100	100	100
total number of species	5	3	4	4	4	4	4	5
Crassula natans Thunb.	4.5	2.2	1.2	+.2	2.2	4.5	2.2	3.3
Lagarosiphon muscoides Harv.	+.2	5.5	5.5	3.4	2.3	3.3	4.4	3.4
Limosella capensis Thunb.	5.5		3.5	2.2	3.2	2.2	2.2	1.2
Nitella sp.		2.3		3.4			2.3	1.3
Colpodium hedbergii (Meld.) Tzuel.	+.2		+.2					1.2
green algae					2	+		
brown algae	1							

Table 2. Scirpo-limosellion longiflorae

	RANUNCULETUM MEYERI						SENECIONETUM CRYPTOLANATI													
	aponogeto-netosum		haplocarphetosum				inops						merxmuelleretosum							
relevé no.	135	136	146	152	142	147	137	138	158	159	139	140	144	141	154	156	160	155	143	162
total cover (%)	100	100	100	100	100	100	100	100	100	100	100	100	75	100	100	95	95	80	95	98
relevé area (dm^2)	100	100	100	100	100	100	25	25	25	25	100	100	56	25	25	100	100	100	100	50
height of vegetation (cm)	15	15	25	6	15	10	7	6	4	5	6	12	15	10	8	8	12	8	15	15
total number of species	5	7	5	7	7	5	12	9	9	9	11	11	16	16	16	19	17	14	16	12
<u>Character species of Ranunculetum meyeri</u>																				
Ranunculus meyeri Harv.	5.5	5.5	2.2	3.5	1.2	5.5	3.2	2.2			1.2	+.2			+.2					
<u>Differential species of aponogetonetosum</u>																				
Apogonetum junceus Lehm. ex Schlechtd.	1.1	1.1																		
<u>Differential species of haplocarphetosum</u>																				
Haplocarpha nervosa (Thunb.) Beauv.			5.2	5.2	5.5	4.2							+.2							
<u>Character and differential (d) species of Senecionetum cryptolanati</u>																				
(d) Koeleria cristata (L.) Pers.							3.2	2.2	+.2	+.2	1.2	1.2	3.2	2.2	+.2	1.2	1.2	1.2	4.2	2.2
Senecio cryptolanatus Killick							1.2	1.2	+.2	+.2	1.2	3.2	+.2	+.2	+.2	+.2	+.2	+.2	+.2	+.2
Cenia hispida Benth. & Hook.		3.2					+.2	+.2	2.2	2.2	2.2	1.2	3.2		+.2	2.2	+.2		3.2	
Helichrysum bellum Hilliard							+.2			+.2		+.2	1.2	+.2	2.2	2.3	+.2	1.2	+.2	1.2
Athrixia fontana MacOwen							+.2					+.2	+.2	+.2	2.2	2.2	1.2	1.2		+.2
Trifolium burchellianum Ser.					1.2						2.2	2.2		2.2	1.2	1.3				
<u>Differential species of merxmuelleretosum</u>																				
Merxmuellera disticha Nees													+.2	3.2	3.2	1.2	2.2			4.3
Thesium nigrum A.W.Hill											3.1		+.1	1.1	1.1	+.1	2.2	2.1	+.1	
Cerastium arabidis E.Mey. ex Fenzl.				+.2							+.2		2.2	1.3		+.2	+.2		+.2	
Bryum argenteum Hedw. & Br. capillare Hedw. & Br. muehlenbeckii B.S.G.													1	1	+	2		1	2	1
Carex flava L. (s.l.)																+.2	1.2	3.3	2.2	+.2
Ornithogalum paludosum Bak.													1.2		+.1		2.1			+.1
Sebaea marlothii Gilg													1.2			3.5	2.3			
Lobelia galpinii Schlechter															+.3		+.3	1.3		
Helichrysum flanaganii H.Bolus														+.2					+.2	+.3
Rhodohypoxis palustris Killick															1.2					+.2
<u>Character species of Scirpo-Limosellion longiflorae</u>																				
Scirpus fluitans L.	5.5	3.2	3.2	3.5	2.2	1.2	2.2	4.5	3.5	5.5	3.5	4.5		2.2	+.2	3.5	2.3	3.5	1.2	
Limosella longiflora O.Kuntze	3.2	3.2	2.2	3.2			3.2	3.2	+.2	3.2	5.5	3.2		3.2	4.2	4.5	3.2	2.2	2.2	
Agrostis subilifolia Stapf		3.2		1.2	2.2		2.2	2.2	1.2	+.2	1.2	1.2	+.2	+.2	1.2	+.2	2.2	+.2	2.2	
Bryum erythrocarpoides C. Muell. & Hamp.	+	3		4	+		5	5			+	1	1	1			3			
<u>Companion species</u>																				
Poa binata Nees		+.2			+.2		+.2		4.3	+.2				+.2		+.2	2.2	+.2	+.2	
Limosella capensis Thunb. forma									+.2				+.2						+.2	
Hesperantha baurii Bak.																+.1		+.1		
Aster uligonosus Wood & Evans													+.2						+.2	
Crassula galpinii Schonl.																+.3		+.3		
Festuca caprina Nees var. caprina														2.2						
Crassula natans Thnb. subsp. filiformis Tölken									1.3	2.3						+.2				
Helichrysum trilineatum DC.																				1.2
Helichrysum witbergense H.Bolus																				+.2
Lagarosiphon muscoides Harv.			+.2																	
Colpodium hedbergii						+.2														
Zygonemaceae 1351	2					2														
Nostoc sp.																			+	

Most common is the subassociation *haplocarphetosum* subass. nov. (Table 2), in which the differential species *Haplocarpha nervosa* is always very abundant. A photograph of the community from the Natal Drakensberg is shown by Killick (1963: plate 36), but he only describes it in general terms.

Immediately alongside stream channels and tarns, where the watertable is at or just above the surface, the subassociation *aponogetonetosum* subass. nov. occurs. Differential species for this subassociation is *Aponogeton junceus*, which is visible only part of the year. It is a widespread species in southern Africa and also occurs in temporary waterholes in the southern Kalahari (Leistner, 1967). *Ranunculus meyeri* and *Scirpus fluitans* usually reach very high cover-abundance values in the *aponogetonetosum* whereas *Haplocarpha nervosa* is absent. Examples of this subassociation are relevés 135 and 136 in Table 2.

In the remaining major part of the bogs, the vegetation mosaic is formed by two subassociations of the association *Senecionetum cryptolanati* ass. nov. Character-species for this association are the composite rosette plants *Senecio cryptolanatus, Cenia hispida, Helichrysum bellum* and *Athrixia fontana* and the mat-forming *Trifolium burchellianum.* Differential species of the *Senecionetum cryptolanati* against the *Ranunculetum meyeri* is the small tussock grass *Koeleria cristata*, which is abundant in the vegetation of the slopes and plateaux surrounding the bog.

On the thufur near tarns or in the areas with sheet flow, where the water table is at or just above the surface level of the hollows (rel. 137 and 138) and on thufur (rel. 158) and in hollows (rel. 139) further away from tarns, where the watertable is somewhat deeper, the subassociation *inops* subass. nov. of the *Senecionetum cryptolanati* occurs (for the epitheton "inops" we refer to Westhoff & Van der Maarel 1973). Still further away from the tarns, where the water table is further below the surface, this subassociation only occurs in the depressions (relevés 140 and 159), whereas on the thufur (rel. 141, 144 and 154) the subassociation *merxmuelleretosum* subass. nov. occurs.

The *merxmuelleretosum* is characterised by a number of differential species which also occur in other communities outside the bogs: the grass *Merxmuellera disticha*, the rather tenuous *Thesium nigrum*, the mat formers *Cerastium arabidis, Sebaea marlothii, Lobelia galpinii* and *Helichrysum flanaganii*, the graminoid *Carex flava* and possibly the bulbous *Ornithogalum paludosum* and *Rhodohypoxis palustris.* Also three bryophytes *Bryum argenteum, B. capillare* and *B. muehlenbeckii*, which have not been separated in the field, are differential for the *merxmuelleretosum.*

At the outer edge of the bogs, the water table is so far below the surface that the *Senecionetum cryptolanati merxmuelleretosum* occurs in the depressions as well (rel. 143, 155, 156 and 160), whereas on the thufur dwarf shrubs of the tussock grass and ericoid dwarf shrub vegetation, the general type of the austro-afro-alpine belt, start to occur. Rel. 162 is from such a thufa on the edge of the bogs. A number of species that commonly occur in the bog, such as *Scirpus fluitans* and *Limosella longiflora* are absent from this stand, whereas *Merxmuellera disticha* is very abundant, and the dwarf shrubs *Helichrysum trilineatum* and *Helichrysum witbergense* are present.

The *Senecionetum cryptolanati* and the *Ranunculetum meyeri* have a number of constant species in common, and are combined into one alliance, the *Scirpo-Limosellion longiflorae* all. nov. The following species are character-taxa for this alliance, and can reach high cover-abundance values in both associations (Table 2): *Scirpus fluitans, Limosella longiflora, Agrostis subilifolia* and *Bryum erythrocarpoides.*

The pH values of the soil with high water tables were found to vary between 5,2 and 5,7. Where the water table is lower, the pH of the soil of the thufur as well as of the depressions were recorded at between 4,2 and 4,5. Towards the edge of the bog the pH of the soil measured 5,2.

Table 3 summarises the pattern of plant communities in the bogs.

Carbiener (1970) could associate the vegetation pattern in a thufur area in the Vosges with porosity, or water capacity of the soil. In this study, no soil samples were analysed in detail. A more detailed soil analysis in the high-altitude bogs of Lesotho might show a correlation similar to the one shown for the Vosges.

The vegetation surrounding the bogs consists mainly of tussock grasses and ericoid dwarf shrubs and has been described by Killick (1963) under the name *Danthonia-Festuca-Pentaschistis* Grassland. Herbst & Roberts (1974a, b) briefly discuss some plant-habitat relationships in this vegetation zone.

Both communities often consist of two vegetation layers: a.) a layer of dwarfshrubs and taller grasses up to about 0,40 m rarely up to 0,70 m high, and with an aerial cover usually from 15–30%; and b.) a ground

Table 3

Mosaic of vegetation in bog

Water table	Depression	Thufur
at or above surfaces of depressions	Ranunculetum meyeri	Sen. crypt. inops
somewhat below surface	Senecionetum cryptolanati inops	Sen. crypt. inops
considerably below surface	Sen. crypt. inops	Sen. crypt. merxmuelleretosum
far below surface (edge of bog)	Sen. crypt. merxm.	Sen. crypt. merxm. with *Helichrysum* etc.

ayer of small grasses, creeping and mat-forming plants, less than 0,10 m in height and covering usually 75–90 % in the slope community, and about 35–50 % in the plateau community. Total aerial cover values for the phytocoenoses of the slope community are mostly 75–90 %. Gravel and rocks usually cover less than 20 % and bare ground less than 15 %. In the plateau community the total aerial cover values are somewhat lower, i.e. 40–60 %, exceptionally up to 85 %. Rock and gravel form often hamada-like surfaces here and can cover up to 60 % of the surface. This is in accordance with the strongly wind-swept character of the habitat of the plateau community. The rocks in both communities, but particularly so in the plateau community, show abundant growth of lichens in several colours (grey, green and orange). The taller grasses often grow under or through dwarfshrubs, thus finding some protection against the often strong winds. In the slope community terracettes are frequent, often consisting of virtually bare ground with a scant growth of narrow leaved rosettes of *Gazania krebsiana* subsp. *serrulata*.

The community of the slopes differs from the plateau community by the following positively differentiating species: the mat-forming *Geranium incanum* and *Helichrysum flanaganii*, the rosette plants *Cotula hispida*, *Silene burchelii*, *Helichrysum marginatum*, *Helichrysum*

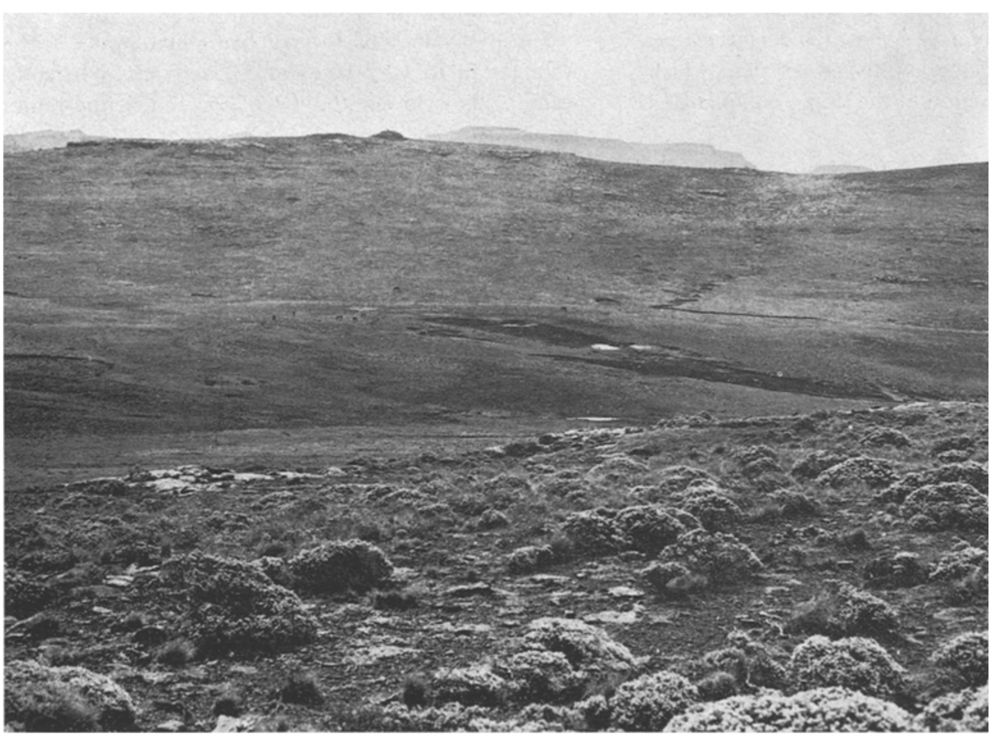

Fig. 4. Foreground: fjaeldmark. In distance "mokhoabo" with signs of erosion and exposed diatomite.

Table 4. Tussock grasses and dwarfshrub vegetation

	plateau community				community of the slopes						
relevé no.	14	9	6	5	15	13	12	8	7	4	151
total cover (%)	60	85	40	40	75	85	90	85	90	85	80
relevé area (m^2)	25	25	50	50	25	15	15	25	25	25	9
height of vegetation (cm)	25	25	40	40	60	70	40	20	30	25	60
number of strata	2	2	2	2	2	2	2	1	2	2	2
bare surface (%) (soil or gravel)	25	5	30	60	5	15	10	12	10	15	
rock covered surface (%)	15	10	30	3	20	0	1	3	1	0	
slope angle (°)	0	0	3	3	14	15	9	6	19	14	11
aspect	-	-	SW	E	W	W	W	NW	E	E	NW
total number of species	35	30	17	21	31	31	26	17	28	14	19
differential species plateau community											
Thesium nigrum A.W.Hill	+.1		1.2	+.2							
Psammotropha mucronata (Thunb.) Fenzl	2.3	+.3		2.3							
Moraea stricta Bak.	1.1		2.1	1.1							
Wahlenbergia montana A.DC.	+.2	1.3									
Orchidaceae sp.	+.1	1.1									
Zaluzianskya peduncularis Walp.	+.2		+.2								
differential species slope community											
Geraneum incanum Burm.f.		+.2			+.2	1.2	1.2	1.2	+.2	+.2	2.2
Helichrysum flanaganii H.Bolus						2.3	3.2	3.3	2.3	3.3	2.3
Cotula hispida (DC.) Harv.						1.2	1.2		+.2	+.2	+.2
Helichrysum trilineatum DC. var. trilineatum	+.2				2.2	1.2			+.2	2.2	+.2
Silene burchellii Otth.					+.2		+.2	+.2		+.2	+.2
Helichrysum marginatum DC.	+.2				1.2	+.2	+.2		+.2		
Helichrysum setigerum H.Bol.					1.2	1.2	1.2		+.2		
Eumorphia sericea Wood et Evans					+.2	1.2	1.2				2.2
Geum capense Thunb.		+.2				2.2	2.2	2.2			1.2
Manulea benthamiana Hiern				+.2				+.2	+.2	+.2	
other species											
Koeleria cristata (L.) Pers	2.2	1.2	3.2	2.2	2.2	2.2	2.2	4.2	3.2	3.2	2.2
Festuca caprina Nees var. caprina	1.2	1.2	+.2	1.2	2.2	1.2	2.2	1.2	1.2	1.2	2.2
Helichrysum trilineatum DC. var. tomentosum Harv.	+.2	2.2	2.2	2.2	+.2	1.2	2.2	+.2	1.2	+.2	+.2
Helichrysum stoloniferum (L.f.) Thunb.	2.3	4.4	+.3	2.3	1.3	1.2	+.2	+.3	2.3	2.3	
Poa binata Nees	+.2	1.2		+.2	+.2	1.2	1.2	+.2	2.2	1.2	1.2
Merxmuellera disticha (Nees) Conert	1.2	1.2	+.2	+.2	2.2	+.2	4.2		2.2		+.2
Crassula galpinii Schonl.	1.2	1.2	+.3	+.3	+.2	+.2	+.2		+.2		+.2
Aster uliginosus Wood et Evans	1.2	1.2	+.2	+.2	2.3	+.2	1.2		+.3		+.3
Delosperma cf. crassuloides L.Bol.		+.2	+.3	+.2	+.3	+.2	+.2		+.2	1.3	
Scabiosa columbaria L.	1.2	1.2	+.2	+.2	2.2	+.2	+.2		+.2		
Cerastium arabidis E.Mey. ex Fenzl	1.2	1.3	+.2		+.2	+.2		+.3	+.2		1.3
Senecio macrocephalus DC.	+.2	+.2			1.2	+.2	+.2		+.2	+.2	
Pentaschistus galpinii (Stapf) McClean	1.2	1.2	1.2	+.2		1.2	+.2		+.2		
Senecio cf. reptans Turcz.			1.2	+.1	1.2	+.2	+.2	+.2	1.2		
Hesperantha baurii Bak.	+.1			+.1	+.1	+.1		+.1	+.1		+.1
Luzula africana Drege ex Steud.		+.2	+.2	+.2	1.2	+.2	+.2				
Oxalis depressa Eckl. et Zeyh.	+.1	+.1					+.1	+.1	+.2		
Hebenstreitia cooperi Rolfe	+.2		+.2	+.2	+.2				+.2		
Bupleurum mundtii Cham. et Schlechtd.	+.2	1.2				+.2			+.2		
Carex flava L.(s.l.)		1.2			1.2	2.2					
Helichrysum subglomeratum Less.	1.2	+.2						+.2			
Sebaea marlothii Gilg	+.2	2.3			+.2						
Thesium imbricatum Thunb.	1.2	+.2			1.2						
Felicia drakensbergensis Wood et Evans	+.2					+.2	+.2				
Lotononis maximileana Schltr.	+.2								+.1		
Crassula setulosa Harv. var. curta (N.E.Br.) Schonl.				+.2				+.2			
Merxmuellera drakensbergensis (Schweick.) Conert					2.2	4.2					
Indigofera cardiophylla Harv.		+.2			2.3						
Helichrysum bellidiastrum Moeser		+.2					+.2				
Zaluzianskya dentata Walp.		+.2				+.2					
Helichrysum witbergense H.Bolus	2.2										+.2
Herniaria eckertii Hermann				+.2							+.2
lichenes	2	1	3	1			+	1			
bryophytes	+		+								

further occurring once: relevé 14: Euryops decumbens B.Nord.(1.2), Heliophila alpina Marais (+.2), Geranium canescens L'Herit (+.1), Ficinia filiformis Schrad. (2.2), Ursinia montana DC. subsp. montana (+.2); relevé 9: Alepidia galpinii Dümmer (+.2), Senecio tugelensis Wood et Evans (+.2); relevé 15: Erica frigida Bol. (1.2), Anthoxanthum ecklonii (Nees ex Trin.) Stapf (+.2), Heliophila minima (Stephens) Marais (+.1), Kobresia kunthiana (Kük) Koyama (1.2); relevé 13; Zaluzianskya alpestris Diels (+.2), Gladiolus longicollis Bak. var. platypetalis (Bak.) Oberm. (+.1); relevé 12: Trifolium burchellianum Ser. (r): relevé 8: Taraxacum officinale Weber (+.2); relevé 7: Alepidea thodei Dümmer (+.2), Felicia rosulata Yeo. (+.2); relevé 4: Gazania krebsiana Less. subsp. serrulata (DC.) Roessler (1.1); relevé 151: Senecio harveyanus MacOwen (+.2).

setigerum, *Geum capense* and *Manulea benthamiana* and the dwarfshrubs *Helichrysum trilineatum* var. *trilineatum* and *Eumorphia sericea*. In particular *Helichrysum flanaganii* is usually very abundant.

The plateau community is positively differentiated from the slope community by *Thesium nigrum*, the diminutive cushion plants *Psammotropha mucronata* and *Wahlenbergia montana*, the rosette plant *Zaluzianskya peduncularis*, the needle-leaved iridacious *Moraea stricta* and a small unnamed orchid.

The slope and plateau communities are floristically closely related and have many species in common. Most constant and abundant of these species are the grasses *Koeleria cristata*, *Festuca caprina* var. *caprina*, *Poa binata*, *Merxmuellera disticha* and *Pentaschistis galpinii*, the dwarfshrubs *Helichrysum trileatum* var. *tomentosum*, the cushion- or mat-forming plants *Helichrysum stoloniferum*, *Crassula galpinii*, *Aster uliginosus* and *Cerastium arabidis*, the rosette plants *Scabiosa columbaria*, *Senecio macrocephalus* and *Senecio* cf. *reptans* and the aizoaceous plant *Delosperma* cf. *crassuloides*.

Relevé no.	1
total cover (%)	7
relevé area (m^2)	50
height of vegetation (cm)	15
number of strata	2
bare surface (%)	85
rock covered surface %	7
total number of species	21
dwarfshrubs:	
Euryops decumbens B. Nord	1.3
Helichrysum trilineatum DC. var. tomentosum Harv.	1.2
Gnidia compacta (C.H.Wr.) J. H. Ross	+.2
Eumorphia sericans Wood & Evans	+.2
Glumicalix montanus Hiern	+.2
Senecio seminiveus Wood et Evans	+.2
grasses:	
Koeleria cristata (L.) Pers.	+.2
Pentaschistis galpinii (Stapf) McClean	1.2
others:	
Helichrysum stoloniferum (L.f.) Thunb.	1.3
Helichrysum subglomeratum Less.	+.2
Delosperma cf. crassuloides L. Bol.	1.3
Moraea stricta Bak.	2.1
Aster uliginosus Wood et Evans	+.2
Psammotropha mucronata (Thunb.) Fenzl	+.3
Crassula campestris (Eckl. et Zeyh.) Harv	+.2
Crassula setulosa Harv. var. curta (N.E.Br.) Schonl.	1.2
Crassula galpinii Schonl.	+.3
Senecio cf. reptans Turcz.	+.2
Gazania krebsiana Less. subsp. serrulata (DC.) Roessler	+.1
Cerastium arabidis E. Mey. ex Fenzl.	+.2
Zaluzianskya peduncularis Walp.	+.1
bryophotes	+
lichens	+

Locally, on some of the severely wind-swept, flat sloping plateaux and cols a fjaeldmark-like formation occurs. (Fig. 4). It consists of a community related to the plateau community, but nevertheless clearly distinct Total aerial cover of this fjaeldmark community is always low. Prominent are the cushionlike, slightly doming dwarfshrubs up to 0,15 m high of which *Euryops decumbens* is the most abundant. The low aerial cover is largely made up by a sparse ground layer, less than 0,05 m in height. A hamada-type of bare surface can occupy up to 85 %, showing everywhere the thready leaves of the iridaceous *Moraea stricta*. Rel. 1 gives an example of this community.

On a rather steep (12°) northwest sloping area, a few metres below the edge of the plateau, rel. 11 was recorded. The site is efficiently protected against wind from all sides, except from the North, to which it is entirely exposed. Large boulders and bare ground each cover about 15 per cent of the area. A layer of dwarfshrubs and grasses, up to 0,25 m high, covers 50 %, whereas the ground layer, less than 0,10 m in height, covers

relevé no.	11
total cover (%)	70
relevé area (m^2)	6
total number of species	13
dwarfshrubs:	
Euryops decumbens B. Nord.	3.3
Helichrysum trilineatum DC. var. tomentosum Harv.	+.2
grasses:	
Festuca caprina Nees var. caprina	2.2
Pentaschistis galpinii (Stapf) McClean	2.2
Koeleria cristata (L.) Pers	1.2
others:	
Ficinia filiformis Schrad.	2.2
Helichrysum stoloniferum (L.f.) Thunb.	+.3
Helichrysum argentissimum Medley-Wood	+.3
Crassula campestris (Eckl. et Zeyh) Harv.	+.2
Crassula galpinii Schonl.	+.3
Oxalis depressa Eckl. et Zeyh.	1.1
Zaluzianskya peduncularis Walp.	+.2
Lotononis maximileana Schltr.	+.2
lichens	1

35 %. This phytocoenosis has a position somewhat in between the fjaeldmark and the plateau communities, as can be seen from a comparison of the following list with rel. 1 and 14.

Almost bare surfaces of the hamada-type, interrupted here and there by sickle-shaped eroded tufts of *Pentaschistis galpinii*, exist on the level edges of the wind-swept plateaux. A species-poor pioneer community occurs here, which is illustrated by the following relevés:

relevé no.	2	3
total cover (%)	25	30
relevé area (m^2)	1	1
height of vegetation (cm)	2	2
number of strata	1	1
bare surface (%)	75	70
rock covered surface (%)	0	0
total number of species	6	5
Ranunculus baurii Mac Owan	1.2	3.2
Limosella capensis Thunb. forma	2.2	+.2
Crassula natans Thunb. subsp. filiformis Tölken	2.1	2.1
Crassula setulosa Harv. var. curta (N.E.Br.) Schonl.	+.2	+.2
Romulea thodei Schltr.	+.1	+.1
Pentaschistis galpinii (Stapf) McClean	+.2	

Phytogeography of the bog vegetation

Since Hauman (1956) proposed to recognise the flora of the high mountains in East Africa as an independent Afroalpine Region, this concept has been accepted generally and extended as to include the high mountain flora in southern Africa (Monod, 1957; White, 1971). Coetzee (1967) pointed out the considerable differences between alpine floras of East and southern Africa, and proposed to use the term Austro-afroalpine belt for the entire vegetation belt above the three-line in southern Africa. The striking differences between the two floras also become evident when comparing the southern African alpine flora with that of East Africa, as analysed by Hedberg (1965). Thus the designation of the southern African alpine flora as austro-afroalpine seems justified.

Using information from literature* and records of the Pretoria Herbarium, the flora of the Lesotho peat-bogs was analysed phytogeographically. The analysis included most of the character and differential species of the associations and subassociations described above.

Three phytogeographical groups can be distinguished:

1. The South African group, consisting of species restricted to the alpine zone of the South African mountains: *Haplocarpha nervosa, Senecio cryptolanatus, Athrixia fontana, Cenia hispida* and *Helichrysum bellum.*

2. The southern and eastern African group, comprising species occurring in southern Angola, South West Africa, South Africa, eastern central Africa and East Africa: *Lagarosiphon muscoides, Aponogeton junceus, Limosella capensis, Limosella longiflora, Crassula natans* and *Trifolium burchellianum.* These species are not restricted to the alpine zone, but also occur in the montane zone and even lower. It is remarkable that three of the four anthospermous character species of the *Crassuletum natantis* belong to this group.

3. The northern temperate group. The species of this group or their nearest allies have their main distribution area in the northern temperate zone, with a spur along the eastern African mountain ridges: *Agrostis subilifolia, Colpodium hedbergii, Koeleria cristata, Scirpus fluitans* and *Ranunculus meyeri.* In the more temperate regions of their distribution area, these species also occur outside the alpine zone, while within the tropics they are restricted to it.

* Engler & Prantl's "Die natürlichen Pflanzenfamilien", (1. and 2. ed.), "Prodromus einer Flora von Südwestafrika", "Conspectus Florae Angolensis", "Flora Zambesiaca", "Flora of Tropical East Africa", "Flora of Southern Africa", "Flore du Congo, du Rwanda et du Burundi", "Flora Europaea".

Summary

The geological and climatological setting of the high-altitude bogs occurring in the river heads of the Lesotho mountains is shortly described. The high summer rainfall and the diurnal climate are characteristic for this region. The daily "frost-thaw" regime at ground level causes up-freezing, small polygons, terracettes and the formation of thufur in the bogs.

The bogs have originated in post-glacial times around springs or from small alpine lakes. During the last glacial period, temperatures in the alpine region were too low for the growth of bog vegetation. The bogs are of great significance for the regular flow of clear water and for grazing. They are in the process of being eroded through animal trampling, and measures for protection are being proposed.

The remarkable mosaic of plant communities occurring at high-altitude on thufur and in depressions, in

the stream head bogs of Lesotho is analysed and described. The following syntaxa are newly described: association *Crassuletum natantis*, alliance *Scirpo-Limosellion longiflorae*, associations *Ranunculetum meyeri* with the subassociations *aponogetonetosum* and *haplocarphetosum*, and *Senecionetum cryptolanati*, with the subassociations *inops* and *merxmuelleretosum*. Their distribution pattern is linked with the variation in water table. Reference is made to literature on the origin of thufur and on a similar vegetation pattern described from the Vosges, France.

The bog vegetation is compared with the surrounding tussock grasses and dwarfshrub vegetation in the Lesotho mountains, and some of the communities belonging to that vegetation type are preliminary described.

Chorological analysis of the bog flora showed a pattern of three phytogeographical groups of species: a South African group, a southern and eastern African group and a northern temperate group.

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