Pleistocene 'periglacial' phenomena in southern Africa

KARL W. BUTZER

Butzer, Karl W.: Pleistocene 'periglacial' phenomena in southern Africa. *Boreas*, Vol. 2, pp. 1–11. Oslo, 1st March, 1973.

True 'periglacial' forms and deposits of late (and middle ?) Pleistocene age can be recognized in the Drakensberg and the adjacent parts of the Cape Province in the latitudinal zone 28° 30′–31°20′ S; lower limits in the eastern Cape and Natal appear to lie near 1500–1800 m, rising from southwest to northeast, and at 2600 m in Lesotho. Significant nivation in the Drakensberg is also indicated, but at higher elevations. Alleged 'periglacial' phenomena in Rhodesia, the Transvaal, the Cape Folded Ranges and their coastal margin are not acceptable as such and include no evidence for cryonival or geliflual processes. Nonetheless, there is bonafide evidence for several phases of accelerated Pleistocene frost-weathering, including sections of the Cape Coast that experience next to no frost today and would require a winter temperature depression of at least 10° C. It cannot be disputed that southern Africa has experienced cold, glacial-age climates, but there is a serious problem about many of the geomorphological observations or their interpretation.

Karl W. Butzer, Departments of Anthropology and of Geography, The University of Chicago, Chicago 60637, U. S. A., 7th December, 1972.

Recognition of Pleistocene 'periglacial' phenomena in subtropical areas has long provided fuel for geomorphological controversy. In some areas the impact of Pleistocene cold climates has remained ignored or overlooked by geomorphologists unfamiliar with their surface or sedimentary expression. In other regions a whole array of slope microforms and detrital accumulations has been incorrectly related to cold-climate processes by geomorphologists unfamiliar with the peculiarities of weathering, mass-movements, and fluvial activity in lower latitudes. Add to this the continuing confusion of concepts such as periglacial versus permafrost, frost-weathering versus complex mechanical weathering, geliflual transport versus miscellaneous mass-movements with or without the assistance of frost-induced transfers, cryoturbation versus torrential interbeds or shearing mass-movements in clayey residuals, and we have serious difficulty in evaluating the published record of Pleistocene cold-climate phenomena in lower latitudes.

Southern Africa is a typical example of an area where 'periglacial' phenomena – used here with specific reference to those features inventoried by Troll (1944), Tricart & Cailleux (1967), Embleton & King (1968), and Butzer (1971b: 113 ff.) – were to begin with not recognized. However, Troll (1944), and subsequently Alexandre (1962), described contemporary 'periglacial' features from the Drakensberg, while both Ellenberger (1960) and Alexandre (1962) hinted at the presence of fossil Pleistocene forms as well. Since then a number of papers have appeared with the implication that Pleistocene cold-climate processes have left a striking legacy not only in the high mountains of southern Africa but also at lower elevations. The present paper attempts a critical evaluation of the published claims, on the basis of three wide-ranging field seasons (1969–1971) in South Africa devoted to a study of Pleistocene landscape evolution, although not specifically to highland 'periglacial' features. Strictly speaking, a negative critique would require a point-by-point field re-examination to be conclusive. Nonetheless we feel that we have intensively studied a sufficiently broad range of comparable deposits and features to warrant a more conservative counter-argument for all but those phenomena described from the high Drakensberg.

Recent 'periglacial' phenomena

A variety of contemporary cold-climate features have been recognized on the high Drakensberg (28° 30′–31° S) by Troll (1944), Alexandre (1962), van Zinderen Bakker (1965), Harper (1969), and Hastenrath & Wilkinson (1972). These include downslope sludging of individual stones, patterned ground (including stone rings and polygons), and ablation of fines by meltwaters (above (3100 m); pip-krakes, turf exfoliation and thufur (above 2800 m); crescentic vegetation-tears (above 2000–2500 m), and terracettes of more questionable origin on south-facing slopes (above about 1800 m). Harper (1969) also refers to 'ice wedges', but the vague description suggests that he probably means frost-cracks. In detail, these features presumably reflect a combination of factors, including macro- and microclimate, exposure, soil depth and type, slope, and above all, vegetation cover and recent overgrazing (see Hastenrath 1960; Hastenrath & Wilkinson 1972). As a composite they fit current concepts of high mountain phenomena from other continents at similar elevations and latitudes.

Fossil 'periglacial' phenomena in the Drakensberg

The Drakensberg of the Natal-Lesotho border and the eastern Cape Province has crest elevations above 3000 m, with the highest peak (29° 30′ S, 29° 9′ E) attaining 3484 m.

G. W. A. Sparrow (1971, 1967a, 1967b, 1964), while working for the Geological Survey of South Africa, identified over 30 'nivation cirques' with southerly exposure, some with headwalls of 150–400 m relief, and a few having cirquelike dimensions (relief as much as to 915 m). These are associated with large quantities of crude, poorly-sorted screes of 'head' and their floor elevations rise along a SW to NE gradient from a minimum of 1600 m to 2100 m. Masses of slumped materials occupy the base or footslopes of many such basin forms, and are reworked into cones at the mouth of others. Sparrow (1967a) further notes a broad area of undulating swells (with swamps and lakes) and flat ridges in the uppermost Orange drainage at a maximum of 2440 m elevation. The basalt cover is eroded here, the joint-structure accentuated, and the soil cover minimal. Although striations are absent, the action of a thin ice mass or of compacted snow is considered. Altogether Sparrow (1967a) suggests a Pleistocene snowline of about 2450 m; it is implied that the climate was too dry to allow for typical glaciation.

On the other hand, G. Harper (1969), who accepts the presence of nivation niches but without description or illustrations, limits them to features of appropriately small size (up to 50 m in width) and infers a Pleistocene snowline at 3300 m or so (Harper 1969, Pl. 8). He does, however, identify two areas of snow-cap erosion around the highest summits, at 3300 m, attributing undulating surfaces to planation by radially moving snow. Finally, Hastenrath & Wilkinson (1972) describe cirque-like forms at 2900–3100 m elevation but emphasize that the concavities in question have been remodelled by solifluction and suggest considerable age. For easternmost Lesotho, where these sets of discordant observations coincide areally, minimum elevations of the forms in question are variously estimated at 2100 m, 2900 m and 3300 m.

It is impossible to interrelate these observations with full satisfaction, but (a) the higher observations of Harper & Hastenrath refer to the western, Lesotho slopes of the Drakensberg, while Sparrow's come from the eastern or southern, windward Natal slopes, and (b) different features, probably of differing ages, are alluded to. On the basis of additional photographic documentation (Hastenrath, pers. comm.), the writer feels that 2900–3100 m is a plausible elevation range for large nivational niches on the lee slopes. Lower elevations on the windward slopes are a reasonable assumption and Sparrow's features further include a broad range of elevations (2100–2400 m) and, possibly, phenomena of different ages or origins. In particular, his large cirque-like forms are difficult to accept without reservations, and a later paper of his (Sparrow 1971) makes no mention of true glacial forms or Pleistocene snowlines. Clearly, further work is warranted, both on the nature of the 'cirques' and on the intriguing planation features on the summit of the Drakensberg.

The matter of other 'periglacial' features in the Drakensberg is less ambiguous. In addition to the slump masses referred to in connection with nivation niches, Sparrow (1967a, 1971) emphasizes: (1) oversteepened south-facing cliff faces; (2) irregular solifluction lobes, up to 50 m in width, showing slump roll structures and locally contorted material; (3) extensive blockfields mantling basalt and sandstone slopes, becoming almost ubiquitous on the Lesotho plateau, and above 1600 m lacking evidence of edge-erosion by chemical weathering; and (4) waterworn boulders up to 10 m diameter found in colluvial valley terraces. Sparrow (1967a, Fig. 6) sets the lower limit of these inactive and dissected cold-climate phenomena at 1500 m in the south-west, rising to 1700 m in the northeast.

Harper (1969) essentially confirms these observations with valuable complementary information. For example, the blockfield materials are attributed to three generations of frost-shattering as argued by edge-corrosion and lichen studies, whereby the recent effects of frost-weathering are almost restricted to elevations above 3450 m. The oversteepened south-facing slopes are linked with 'basalt steps' — hillslope facets with a relief of as much as 6 m, accentuated by selective frost-weathering of resistant stratoid flows. Such steps conform with widely-held concepts of 'periglacial' slope evolution (see Tricart & Cailleux 1967:349 ff.) and are typical on the Natal slopes of the Drakensberg above 2100–2350 m. Harper (1969) recognizes two generations of basalt steps, the younger of which is poorly developed and restricted to elevations above 2600–2900 m. Similar elevation ranges are assigned to the two generations of thick boulder and gravel terraces of colluvial disposition, and attributed to geliflual transfer. Less apparent is the 'periglacial' significance of entrenched meanders and stream knickpoints.

It is evident that despite the compatibility of these convincing cold-climate phenomena variously described by Sparrow and Harper, there are again differences as to vertical zonation. Harper (1969), however, worked in Lesotho where his observations find support in the less detailed reports of Alexandre (1962) and Hastenrath & Wilkinson (1972), while Sparrow (1967a) was able to make many of his divergent observations in the eastern Cape Province. The writer can confirm that Sparrow's zonation does apply to the Stormberge and Witteberge, north of Queenstown (31° 20′–30° 40′ S), where a marked change of topography is conspicuous above 1700–1800 m: (1) south-facing cliff faces are oversteepened, with striking basalt steps and crude scree slopes below; (2) occasional mid-slope inflections resemble nivational niches and such hollows are invariably mantled with massive, dissected screes; (3) smoothly rounded footslopes, partly erosional and partly buried in dissected colluvium, provide a notable contrast to angular concave changes of slope at lower elevations However, the colluvial footslope deposits invariably grade into broad valley-floor alluvia that are commonplace at lower elevations, too, as well as elsewhere on the Interior Plateau (see Butzer 1971a).

In sum, the initial indications of extensive 'periglacial' sculpture reported by Ellenberger (1960) and Alexandre (1962) do appear to be amply confirmed and extended by the work of Sparrow and Harper. Harper (1969) calculates a 9.0 °C annual temperature depression for the older and maximal of his two 'periglacial' episodes, on the basis of modern lapse rates and a hypothetical modern snowline. Although this may well represent a conservative estimate, the assumptions made are disturbing.

Sparrow (1967a) and Harper (1969) are duly cautious about dating these various phenomena, many of which may be older than the late Pleistocene. In Lesotho, Ellenberger (1960) linked an old generation of landslides to a pre-Acheulian river terrace via alluvial fans, while his nivational niches and firn moraines (?) are tied in with a complex valley alluvium with an Acheulian industry (see also Visser & van Riet Lowe 1955). Other slope screes, of

Fig. 1. Southern Africa. Areas above 2000 m shaded.

younger age, are linked via footslope colluvia with the late Pleistocene 'Older Fill' of the lower valleys (see Visser & van Riet Lowe 1955; Butzer 1971a; also Butzer & al. 1973).

Pleistocene 'periglacial' features in Rhodesia?

G. Harper (1969), working there at the suggestion of and under the guidance of the glacial geologist R. F. Flint, has claimed the existence of 'periglacial' phenomena in the Rhodesian high country, with the possibility of two phases of Pleistocene cold climate, implying a 9 °C drop in mean annual temperature and a 12° latitudinal shift of temperature zones. The materials cited come from (a) the Inyanga Highlands, at 17°40′–18°20′ S latitudes and with summit elevations of 2200–2600 m, and (b) the Chimanimani Mountains, 18°30′–20° S and with crests of 2200–2400 m.

The 'evidence' from these highlands of eastern Rhodesia consists of (1) 'frost-wedged', massive igneous rocks and quartzites (above 2250–2400 m), (2) 'inactive scree surfaces' (above 1680 m), and (3) valley-floor colluvia. Such undifferentiated screes and colluvia can be dismissed as undiagnostic, while the argument that deep rock-jointing must be a result of frost-wedging (instead of chemical deep-weathering and mechanical dilation as a result of pressure unloading) can only be considered as unusual. Equally surprising is the attribution of dome-shaped granitic outcrops in a tropical region to frost-weathering.

Until and unless better descriptions and stronger supporting arguments are presented, these inferences for Rhodesia should best be ignored. We also decline to comment on the novel interpretation of tropical stone lines and self-mulching gilgai soils recently offered by Voss (1970) for the Angola uplands (10° S) at 1700–1800 m.

Pleistocene 'periglacial' features in the Transvaal?

A claim for 'periglacial' phenomena on the Transvaal High Veld has been made by Linton (1969) on the basis of two isolated examples:

(1) 15 km south of Pretoria (25° 55′ S), on a convex slope of Precambrian dolomite, steepening to a maximum of 10°. A 1m thick veneer of 'geliflual' material of small stones (partly derived from older fluvial gravels) in a brown earthy matrix with grit and 'frost' chips, including some fragmented in place, thickens downhill into concentrated 'stone stripes' or 'actual gelifluxion tongues ending in lobate stone ramparts' (Linton 1969:85). The present writer has worked intensively on similar bedrock and elevations, 50 km further west, studying non-functional slope deposits in relation to the australopithecine cave breccias of the Sterkfontein valley (Butzer 1971c; Butzer & C. K. Brain, in preparation). Several generations of slope deposits occur there, some relatively fine-grained, others highly detrital, in part with highly irregular disconformities. These, and the allied cave fills, are typical sheet-wash, creep, and occasional mudflow deposits (moderately-sorted silt loams), collectively best called 'colluvial', although the possible co-agency of some frost weathering is possible. Any lobate forms in the Sterkfontein valley are simply a result of subsequent dissection. Other horizontal arrangements shown by Linton (1969, Pls. 6–8) suggest complications on a micro-karstic surface reflecting either on large-scale gryke-and-clint features or on the litho-structural effects of chert lines or quartz veins following the complex fracture-patterns of the area.

(2) Northern slopes of Magaliesburg (25° 40′ S), at 1200 m, on a slope of deeply-weathered Precambrian quartzite, steepening from 7 to 15°. Linton (1969) elaborately describes a massive deposit of 'tumultuous' blocks, exhibiting an inversion of the weathering profile through redistribution by 'gelifluxion'. Inverted weathering profiles are not uncommon in footslope sectors of the High Veld wherever colluvial agencies are or have been prominent. The blocks suggest mudflow transport, and such blocks pointing nose-downvalley can be seen in small fossil valleys, filled with silt loams, in the Lower Vaal Basin.

In sum, we feel that these claims by Linton (1969) for bonafide 'periglacial' features in the High Veld cannot be accepted. In the same context it is probably relevant that despite ongoing research by several geomorphologists in Southwest Africa at similar latitudes and higher elevations, no claims of 'periglacial' phenomena have yet been forthcoming. This all does not, however, preclude accelerated frost-weathering in the interior of South Africa during the Pleistocene cold phases. In fact, the Gaap Escarpment of the northern Cape (at 1100 m elevation) records at least 3 generations of mechanically-fractured footslope breccias, consisting of very crude, angular dolomite debris. These are best attributed to frost weathering, and the last period of such modelling can interestingly be dated shortly before a tufa with a C^{14} date of 26,130 $\pm$ 620 B. P. (SI–1301; Butzer 1973b).

Pleistocene cold-climate phenomena in the Cape Ranges

The writer has made extensive observations in the Cape Folded Ranges, the Karroo, and along the southern and southwestern coastal regions during the course of intensive field work at various points between Saldanha Bay and Algoa Bay. The following generalizations can be offered.

(1) The semidesert Karroo is a typical arid-zone landscape with extensive pediment plains, mantled by late Pleistocene to Holocene alluvial spreads, and residual or structural mountain ranges that generally give little indication of past or present 'periglacial' conditions. Talus and screes are poorly developed. Two mountain groups, however, deserve closer study for possible nivation niches, oversteepened slopes, and blockfields. These are the Sneeuberg (2469 m, at 31° 15′ S) above about 2100 m, and the Nuweveldberge (1887 m, at 31° 40′ S) above about 1700 m.

(2) The semi-arid valleys between the Cape Ranges commonly show well-developed, coarse fanglomerates and cones ranging from the footslope zone to floodplain margins, where such crude detritus may rest on finer fills. However, there are no comparable developments of mountain-side talus or scree slopes except, as already noted, in the Stormberge of the northeastern Cape. Typical arid zone features prevail until the key coastal range is reached and here, as in the case of the Langeberge or Outeniquas, there is a sharp transition between humid and arid land-forms. Linton (1969) cites the great stranded blocks of the Gydo Pass (1100 m, 33° 14′ S), near Ceres, as examples of blocks rafted downslope in a 'geliflual' sludge. However, planar gliding of blocks on 35–45° slopes has so far never been considered typical of 'periglacial' processes, particularly when no trace of that sludge remains today.

An interesting late Quaternary sedimentary profile was sampled by H. J. Deacon and R. G. Klein in Kangkara Cave, in quartzitic bedrock with northerly exposure and 450 m elevation, 39 km northwest of Plettenberg Bay. The sediments have been studied by the writer and begin with non-calcareous Middle Stone Age deposits, abnormally rich in coarse sands and with characteristic, mechanically weathered *éboulis*. The Later Stone Age sequence follows a period of decalcification and is calcareous, beginning with relatively coarse sands and crude angular debris, then becoming significantly finer grained and almost lacking in spalls. Radiocarbon dates are pending to fix the implied intervals of late Pleistocene frost weathering.

(3) The coastal platforms and slopes of the Cape Ranges show well-developed talus, alluvial cones and fans, as well as scree slopes (south of latitude 33° 20′). We have studied numerous examples of these in detail. All are fossil and dissected, and several generations can be recognized on the basis of multiple terracing or differential weathering. The oldest of these are crude, angular, quartzite rubbles intercalated with a beach complex at +98 —120 m, forming part of the early (?) Pleistocene Formosa Formation (Butzer & Helgren 1972). The rubble was probably detached by frost-shattering, but bedding is strictly fluvial or of beach type.

The oldest cones and fans preserved in the coasted sector today interfinger with mid-Pleistocene eolianites and are attributed to intensified denudation at a time of drier and more seasonal climate (Butzer & Helgren 1972). Other ancient screes of variable rounding interfinger with interglacial terraces in the coastal valleys — alluvia invariably coarser than modern floodplain deposits and suggestive of a less complete vegetative mat (Butzer & Helgren 1972). The two youngest generations of widespread screes mantle the flanks of the coastal platforms and in some areas their gradients (5–35° or more) project to below modern sea-level. They consist of angular rock rubble, crudely stratified in matrices without lenticular sorting. The younger generation has a humified, grayish to brownish, loamy matrix, whereas the older consists of reddish-yellow clays with rock in an advanced state of decomposition. Both generations find pedogenetic equivalents among the talus or alluvial cones of the coastal ranges (Butzer & Helgren 1972), and the younger is of late Pleistocene age.

The present writer attributes the origins of much or most of the scree and talus of the coastal sector to frost-weathering. However, soil-frost phenomena are not invoked for their transport and bedding, and these are typical slope deposits transported by sheetwash, creep, and other gravitational movements, with or without accessory frost-generated motions. Fully comparable deposits have been studied by the writer at high elevations in the Balearic Islands (Butzer 1964a), at intermediate elevations in Catalonia (Butzer 1964b), and at low elevations in northwestern and northern Spain (Butzer 1967, and in preparation). We attribute such deposits to ruptures of slope equilibrium and intensified denudation, in relation to an opened, incomplete vegetation mat and marked rainfall periodicity and/or intensity (Butzer 1971b: 306 ff.). We simply cannot accept identical deposits, such as those described by Linton (1969) from 450 m elevation near Grahamstown, in the low mountains east of Stellenbosch, or along the shores of the Cape Peninsula, as 'geliflual aprons'. In fact we did not find a single example of *grèzes litées* or other geliflual sorting or contortions in the thick, well-exposed mantles of slope deposits found at angles of 5° to greater than 60° around the Cape Peninsula. Linton (1969, with discussion) explicitly interprets the Cape coast materials with reference to British 'periglacial' screes or 'head', and infers a 'similarity of climatic conditions at the time of deposition' (Linton 1969:88). However, the British 'head' was partly associated with ice wedges and permafrost and Linton (1969:87) does use the term cryoturbation in one instance. We not only concur with Verhoef (1971) that no convincing evidence of permafrost has yet been discovered in southern Africa, but reject outright Linton's overall interpretation of cryonival and geliflual activity in the Cape Province.

The screes of the coastal regions do reflect on some intensity of frost-weathering. This by itself is characteristic of the world's subtropics and middle latitudes, and has yet to be equated with a 'periglacial' regime. Nonetheless, the evidence for frost-weathering, including a carefully analyzed and interpreted sequence of frost-shattered *éboulis* in a coastal cave at Robberg (Butzer 1973a), is quite remarkable. Of twelve climatic stations along the southeastern Cape coast, mean minimum temperatures of the coldest month range from −1.4 to +5.3 °C, and only three have ever experienced sub-freezing conditions, the coldest being −2.8 °C in the 67 year record of a station in 241 m elevation (see Climate of South Africa, 1, 1954). Furthermore, mean soil temperature at −30 cm at one station at 519 m elevation is +10.6° C for the coldest month. Consequently we believe that a 10 °C lowering of winter temperatures would be necessary to produce effective frost-weathering along this sector of the Cape Coast for the type of cryoclastic debris found both in certain slope breccias and in the lower beds of the Robberg cave, which all date primarily from the Lower Würm Pleniglacial, prior to 30,000 B. P. (Butzer 1973a). Similar deductions can probably be made with regard to the early Pleistocene land rubble of the Formosa Formation, and for early Middle Stone Age *éboulis* that follow high shorelines both in the Die Kelders and Klasies River Mouth caves of the southwestern and southern Cape coasts (Butzer, in preparation).

Summary and conclusions

The re-evaluation of 'periglacial' phenomena in southern Africa suggests that work has been of variable quality, that concepts have sometimes been vague or even erroneous, and that too much interpretation has been based on high latitude preconceptions.

Bonafide 'periglacial' forms and deposits of late Pleistocene age are present in the Drakensberg and adjacent parts of the northeastern Cape Province. The lower limits of these features appear to lie between 1500 and 1800 m elevation across the latitudinal belt 28° 30′–31° 20′ S in the eastern Cape Province and Natal, and at 2600 m or so in Lesotho, while considerable nivation of some antiquity is in evidence at higher elevations.

Alleged 'periglacial' phenomena in Rhodesia, the Transvaal, and in the Cape Folded Ranges and coastal sectors are not 'periglacial'. However, there is evidence of significant late Pleistocene (and earlier) cryoclastic – but neither cryonival nor gelifluaI – activity at about sea level, along parts of the Cape Coast that now experience next to no frost. A minimum winter temperature depression of 10 °C is deduced for these features. In accord with the palynological evidence (Coetzee 1967) there is no reason to question the existence of colder Pleistocene climates in southern Africa. The only problem is that of imprecise geomorphological observation and reasoning.

Acknowledgements. – The field and laboratory work represented in this paper was made possible by grants from the Wenner-Gren Foundation (No. 2344), the National Science Foundation (No. GS–3013), and the Anthropology Department of the University of Chicago. Repeated, stimulating discussions on the topic were enjoyed with E. M. van Zinderen Bakker (Bloemfontein). Stefan Hastenrath (Wisconsin) provided valuable comments on an interim draft of the manuscript.

REFERENCES

Alexander, J. 1962: Phénomènes périglaciaires dans le Basutoland et le Drakensberg du Natal. *Biuletyn Peryglacjalny 11*, 11–13. Łódż.

Butzer, K. W. 1964a: Pleistocene cold-climate phenomena of the island of Mallorca. *Zeit. Geomorph. 9*, 7–31. Berlin.

Butzer, K. W. 1964b: Pleistocene geomorphology and stratigraphy of the Costa Brava region, Catalonia. *Abhandl. Akad. Wiss. Liter., Math-Naturw. Kl., 1*, 1–51. Mainz.

Butzer, K. W. 1967: Geomorphology and stratigraphy of the Paleolithic site of Budiño. *Eiszeitalter und Gegenw. 18*, 82–103. Öhringen.

Butzer, K. W. 1971a: Fine alluvial fills in the Orange and Vaal Basins of South Africa. *Proc. Assoc. Amer. Geog. 3*, 41–48. Washington.

Butzer, K. W. 1971c: ***Environment and Archeology: an Ecological Approach to Prehistory.*** 705 pp. Aldine-Atherton, Chicago, and Methuen, London.

Butzer, K. W. 1973a: Geology of Nelson Bay Cave, Robberg, South Africa. *South Afr. Arch. Bull. 28*, in press. Cape Town.

Butzer, K. W. 1973b: The Taung australopithecine revisited: Stratigraphic and paleoclimatic revisions for the Gaap Escarpment. *Amer. Anthropol. 75*, in press. Washington.

Butzer, K. W. & Helgren, D. M. 1972: Late Cenozoic evolution of the Cape Coast between Knysna and Cape St. Francis, South Africa. *Quaternary Research 2*, 143–169. New York.

Butzer, K. W., Helgren, D. M., Fock, C. J. & Stuckenrath, R. 1973: Alluvial terraces of the Lower Vaal Basin, South Africa. *Jour. Geol. 81*, in press. Chicago.

Climate of South Africa 1: Climate statistics. Pretoria, South African Weather Bureau. 159 pp. 1954.

Ellenberger, P. 1960: Le Quaternaire au Basutoland. *Bull. Soc. Préhistorique Française* 57, 439–475. Paris.

Embleton, C. & King, C. A. M. 1968: *Glacial and Periglacial Geomorphology.* 608 pp. E. Arnold, London.

Harper, G. 1969: Periglacial evidence in southern Africa during the Pleistocene epoch. *Palaeoecology of Africa 4*, 71–101. Cape Town.

Hastenrath, S. 1960: Klimatische Voraussetzungen und grossräumige Verteilung der Froststrukturböden. *Zeit. Geomorph. 4*, 69–73. Berlin.

Hastenrath, S. & Wilkinson, J. 1972: A contribution to the periglacial morphology of Lesotho, Southern Africa. *Biuletyn Periglacjalny 22*, in press. Łódż.

Linton, D. L. 1969: Evidences of Pleistocene cryonival phenomena in South Africa. *Palaeoecology of Africa 5*, 71–89. Cape Town.

Sparrow, G. W. A. 1964: Pleistocene periglacial landforms in the southern hemisphere. *South Afr. Jour. Sci. 60*, 143–147. Johannesburg.

Sparrow, G. W. A. 1967a: Pleistocene periglacial topography in South Africa. *Jour. Glaciology 6*, 551–59.
Sparrow, G. W. A. 1967b: South African cirques and arêtes. *Jour. Geography*, 9–11. London.
Sparrow, G. W. A. 1971: Some Pleistocene studies in southern Africa. *Tydskrif vir Aardrykskunde 3*, 809–814. Stellenbosch.
Tricart, J. & Cailleux, A. 1967: *Traité de Géomorphologie.* T.II: *Le modèle des régions périglaciaires.* SEDES, Paris, 512 pp.
Troll, C. 1944: Strukturböden, Solifluktion und Frostklimate der Erde. *Geol. Rundschau 34*, 545–694. Berlin.
Verhoef, P. 1971: Periglasiale bodemstrukture. *Tydskrif vir Aardrykskunde 3*, 801–808. Stellenbosch.
Visser, D. J. L. & van Riet Lowe, C. 1955: The geology and archaeology of the Little Caledon River Valley. *Geological Survey Memoir 47.* 64 pp. Pretoria.
Voss, F. 1970: Kaltzeitliche Ablagerungen im Hochland von Angola. *Eiszeitalter und Gegenw. 21*, 145–160. Öhringen.
van Zinderen Bakker, E. M. 1965: Über Moorvegetation und den Aufbau der Moore in Süd-und Ostafrika. *Botan. Jahrbuch 84,* 215-231. Göttingen.