THE MICROGEOMORPHOLOGY OF GRANITE HILLS IN NORTHEASTERN RHODESIA

by
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ABSTRACT

Three granite bornhardts within an 80 km radius of Salisbury have been studied in detail. The weathered surface features on these hills, particularly the development of gnammas, have been measured and compared. Particular attention is paid to the drainage channels or gullies which have been eroded into the upper slopes of the bornhardts. Geomorphic analysis of a specific small, perched drainage basin is applied as for that of a normal-scale landscape eroded into granite.

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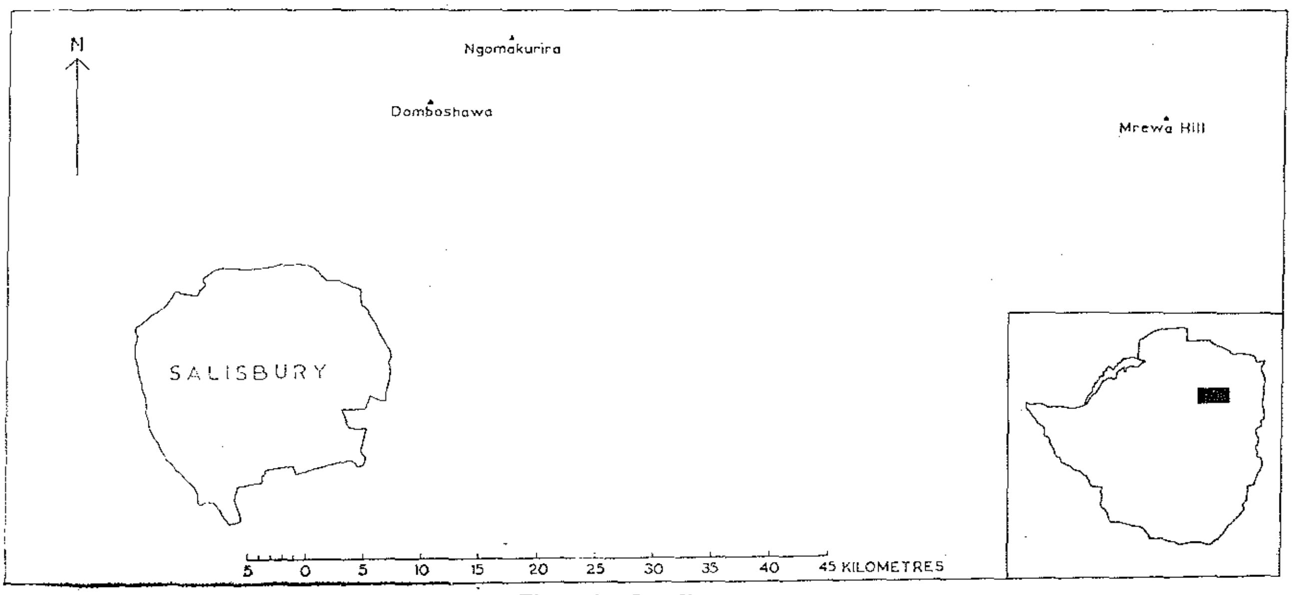

Figure 1. Locality map.

I. INTRODUCTION

Numerous granite hills in Rhodesia, especially in Mashonaland, have been studied and particular attention has been paid to three typical exfoliated bornhardts *viz* Domboshawa, Ngomakurira and a rather insignificant, nameless hill 5 km due north of Mrewa village. This last will henceforth be referred to as "Mrewa Hill" (Figure 1).

Domboshawa is a typical whale-backed, roughly symmetrical mass some 120 m high which rises on the southern margin of the Chinamora batholith, approximately 32 km due north of Salisbury. Several much smaller jointed "castle koppies" and small exfoliated domes are associated with Domboshawa and form a discontinuous surround to the main mass.

Ngomakurira is situated some 13 km north of Domboshawa, towards the centre of the Chinamora batholith. It rises approximately 270 m and has a more irregular shape than Domboshawa, being very much steeper on the southern flanks than the northern.

"Mrewa Hill," unnamed on all topographic maps of the area, rises only 70 m over an area similar to that occupied by Domboshawa. Its overall gradients are therefore significantly less than those displayed by both Domboshawa and Ngomakurira.

All the bare rock surfaces of bornhardts throughout South and Central Africa are liberally covered by a variety of lichen growths. Particular genera noticeably occupy specific localities on the rock surfaces. Clearly the microgeomorphology governs the biological environment, which in turn governs the distribution of the lichen types. For example, certain genera (e.g. *Heppia*) grow only along water channels whereas others (e.g. *Dermatiscum* and *Caloplaca*) are limited to the small watersheds and slightly drier micro-climates (Scott, 1967).

II. JOINTS AND INTRUSIONS

A common feature of the exfoliated granite domes is the abundance of joints which must necessarily be of secondary origin. Many of them have been subsequently sealed by quartz or pegmatitic material and appear as veins ranging from 2 mm to 50 cm in width. The trends of these joints and veins are always fairly straight and they normally extend for several metres before dying out. Frequently a number of roughly parallel joints occur within a very small area.

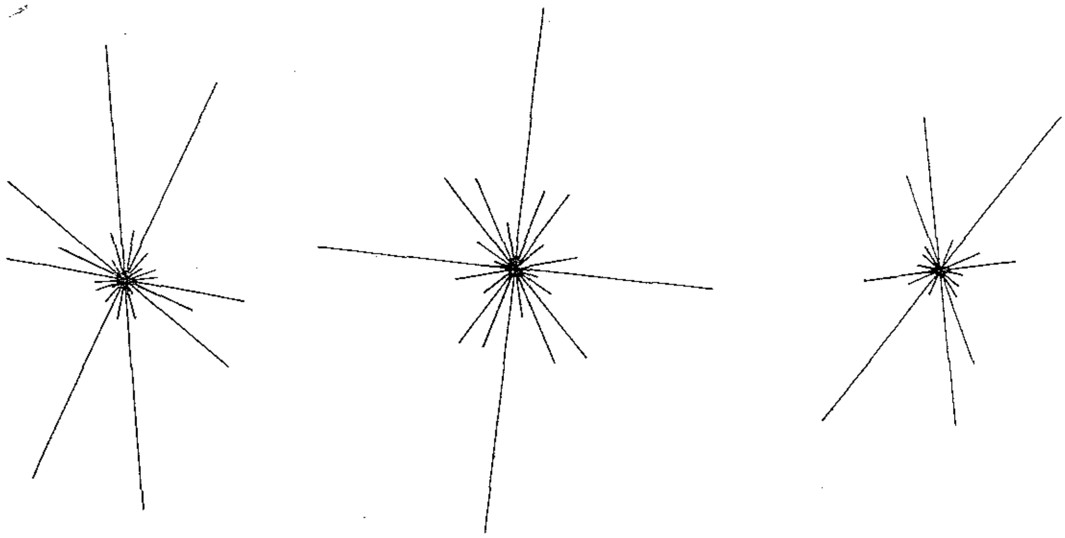

Figure 2. Roses showing the dominant joint directions on *a*. Domboshawa *b*. Ngomakurira *c*. Mrewa Hill.

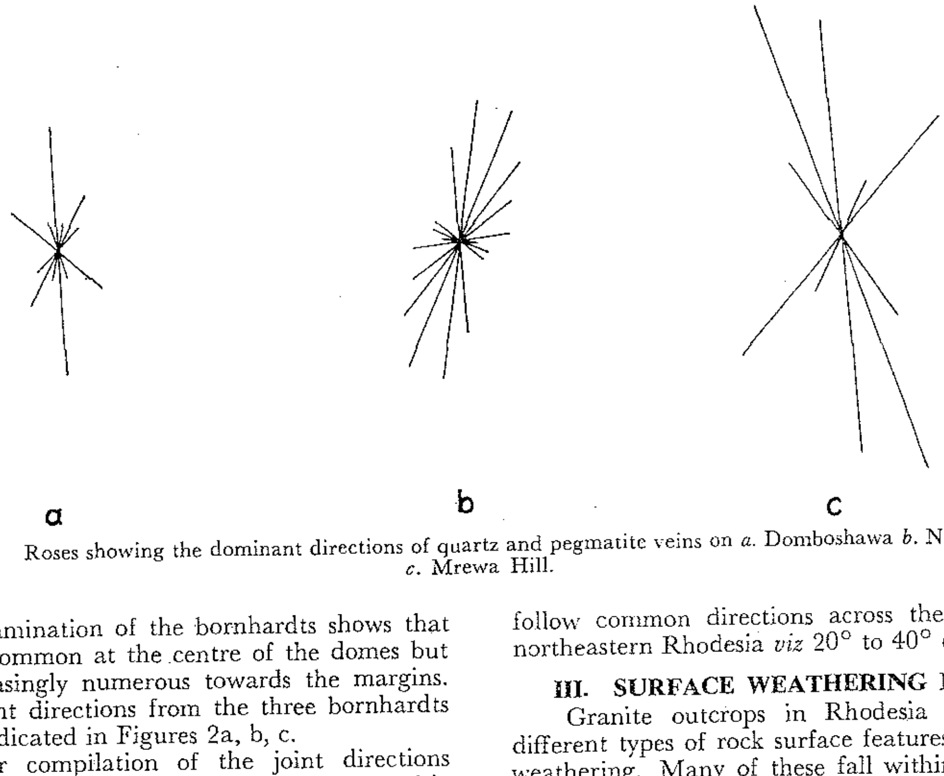

Figure 3. Roses showing the dominant directions of quartz and pegmatite veins on *a*. Domboshawa *b*. Ngomakurira *c*. Mrewa Hill.

Close examination of the bornhardts shows that joints are uncommon at the centre of the domes but become increasingly numerous towards the margins. Dominant joint directions from the three bornhardts studied are indicated in Figures 2a, b, c.

A similar compilation of the joint directions which have been filled by quartz or pegmatitic material (Figures 3a, b, c) clearly shows a close comparison between the quartz vein directions on Domboshawa and Ngomakurira, no doubt due to their geographical proximity and correlation with the Chinamora batholith. On both bornhardts joint planes within the range 60° to 165° have virtually no infilling whereas the sector 345° to 60° includes almost all the quartz and pegmatite veins. A small population clustered around 100° to 130°, particularly prominent on Ngomakurira, is of very minor importance.

Mrewa Hill, beyond the Chinamora batholith has similar, although not identical, dominant joint directions. The principal directions are 30° to 40° and 150° to 180°, with a minor cluster occurring at approximately 65°. Quartz veins are virtually limited to the first two directions. From these figures, jointing with subsequent quartz or pegmatite infilling seems to follow common directions across the bornhardts of northeastern Rhodesia *viz* 20° to 40° east of north.

III. SURFACE WEATHERING FEATURES

Granite outcrops in Rhodesia display several different types of rock surface features resulting from weathering. Many of these fall within the definition of gnammas (Twidale and Corbin, 1963), which are "small holes of varying shape, diameter and depth, found on hard granite outcrops and in the decomposed granite of the talus". Working in South Australia, Twidale has distinguished several different types of gnamma, the pit, pan, armchair and canoe varieties which depend on their cross-sectional shape and proportions for definition.

Flowing water has eroded numerous steep-sided gullies down the flanks of the granite bornhardts. These gullies or drainage channels are separated by an equal number of divides, usually between 1 m and 45 m wide. Shallow depressions (gnammas of pan type) are frequently scattered across these "micro-divides", thereby adding to the overall drainage. Although the gnammas are frequently of roughly circular or oval outline many, particularly on Ngomakurira, have complicated convolute outlines indicating

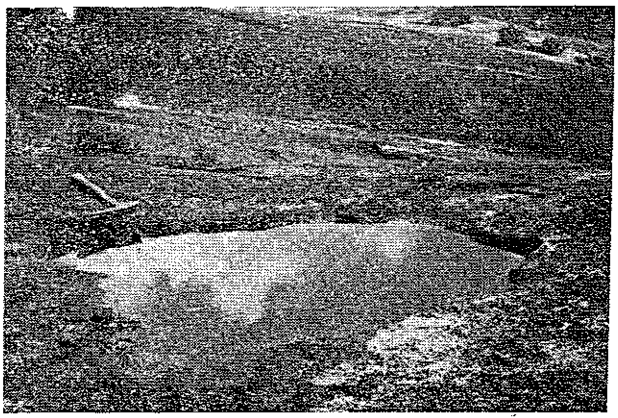

Plate I
A typical pan gnamma after recent rainfall.

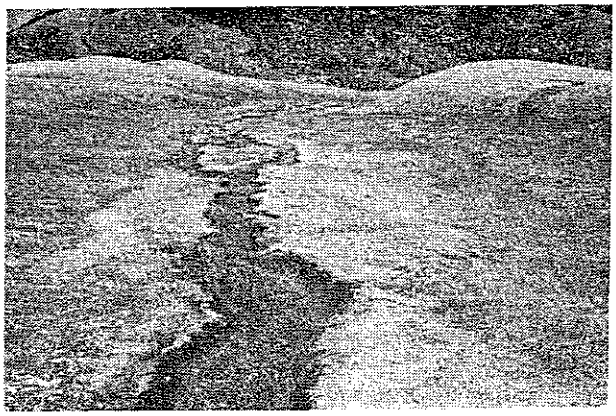

Plate II
A typical example of an incised channel with raised levée-like rim, crossing a micro-pediment.

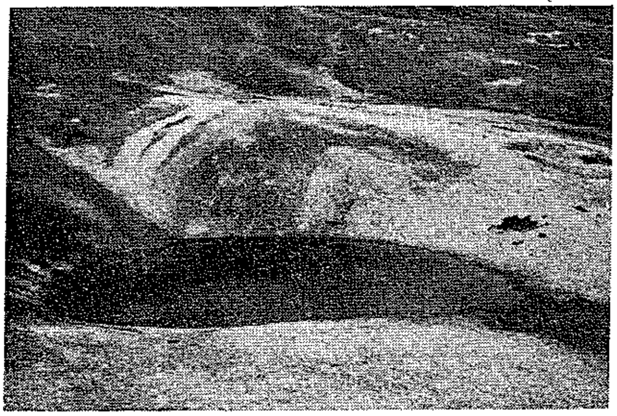

Plate III
The pit gnamma on Mrewa Hill containing water.

Plate IV
"Mud-crack" granite blocks.

Plate V
Two drainage channels; the one to the left following the position of a joint whereas the right-hand one is purely erosional.

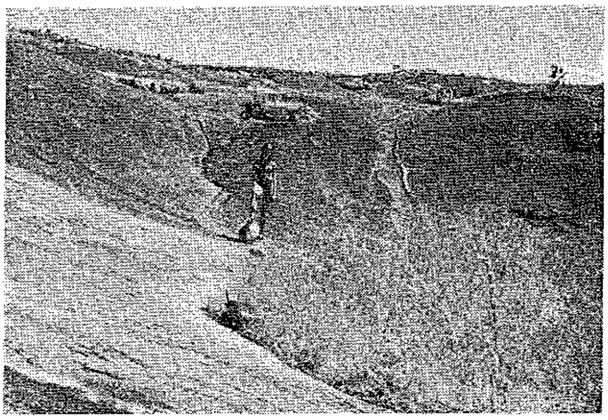

Plate VI
Small shallow basins containing soil and vegetation on Mrewa Hill.

that several separate gnammas have enlarged and finally coalesced. The depth of the flat-floored pan gnammas is between 2,5 and 10 cm, a depth of 7,5 cm being the most common. Lateral dimensions vary from less than 30 cm to more than one metre, with a mean of 30-40 cm (Plate I).

A frequent and curious accessory to the pan gnammas is the occurrence of discontinuous raised rims around their perimeters. These rims generally stand about 2,5 cm above their surroundings, and are therefore from 5 to 12 cm above the floor of the gnamma. Many of the water channels in the micro-valleys also display such rims parallel and adjacent to the water courses. In cross-section these have the surface appearance of levees (Plate II). In both instances, however, the rims are composed of solid granite and thin section examination reveals no difference between the rock composing the rims and that of the floors and surrounds. The reason for, and sequence of development of, the rims around the pan gnammas and alongside the water channels is a problem as yet unsolved, although Scott (1967) has suggested that they could be due to the protective effect of certain types of lichen which grow on the rock surface adjacent to water courses. By this means the rock surface in between the water courses would have been lowered by erosion, while the lichen-protected strips maintained their original height. Twidale (1964) recorded similar suggestions.

It is also possible that during flood conditions soluble silica is deposited on these rims in such a way as to harden and protect the underlying granite, without being visible even in thin section.

Clearly the pan gnammas themselves develop from the effect of rain water collecting in any hollow on the surface. This water accentuates chemical weathering upon the rock floor and sides, causing the hollow to enlarge. As a self-perpetuating process the gnammas thus developed continually expand, with neighbours coalescing as the intervening divides are reduced and removed.

Another type of gnamma described by Twidale and Corbin (1963) is the pit form, an excellent example of which occurs on Mrewa Hill. Such depressions are very much deeper than the pan-types, usually circular or near-circular in outline, and have smooth, evenly-graded slopes. Pit gnammas are far less common in Rhodesia than pan gnammas, only this one example having been recorded from the three hills studied. It is situated on the southeastern face of Mrewa Hill, approximately half-way up the slope and in the centre of a drainage basin. Practically circular in shape, it measures 3 m in diameter and is approximately 40 cm deep at the centre. The sides are smooth and slope evenly and regularly to the central deepest point (Plate III).

Occasionally, jointed blocks produce a curious concave appearance on the horizontal surfaces. Several such blocks are invariably grouped together and give the appearance of a patch of dried-out mud (Plate IV), hence the term "mud-crack" granite which has been applied to this weathering feature. Normally each block in these outcrops is up to 1 m across, with the edges raised at least 2,5 cm above the central depression. Thin section analysis shows no difference at all between the samples taken from the central depressed portion and those taken from the raised edge. It seems that the process of development is similar to that postulated for the pan gnammas, i.e. weathering accelerated at, and adjacent to, an initial depression where rain water collects. The variation in present appearance is due to original differences in the situation, the pan gnammas occurring on the high, central, relatively unjointed portion of the bornhardts, while the "mud-crack" granite is limited to the lower, jointed flanks, with each single joint block developing one depression weathered like a soup-plate.

Certain granite faces in near-vertical positions, facing in a variety of directions, have developed a series of regular hollows in roughly regular rectangular lay-out. Each hollow averages 2,5 cm in depth and 7 to 10 cm across. An entire face, perhaps five metres square, is frequently pockmarked by numbers of these hollows, while neighbouring similar faces remain smooth. Thus the development of these *pseudo-tafoni* must be the result of exudation granulation taking place upon surfaces of particular petrological characteristics. Thin sections show no distinction between the granites of adjacent, but differing, weathered surfaces. Honeycomb weathering, with pits not more than 1,25 cm in diameter and less in depth which clearly show the original positions of less resistant minerals, possibly quartz, which have been etched out, occurs occasionally on unjointed granite surfaces. Honeycomb-weathered surfaces are more common on Domboshawa than on the other two bornhardts.

IV. DRAINAGE CHANNELS

One of the most striking features of many granite bornhardts is the occurrence of marked drainage channels, eroded smoothly into the solid rock, coursing down the higher slopes. They are clearly water-worn and frequently diminish in depth and disappear on the lower slopes which, because of the position of the planes of exfoliation, steepen to sometimes near-vertical gradients. Thus, typically, water-flow is mainly within channels on the upper slopes and by sheet-flow on the steeper lower slopes. Observations on numerous bornhardts in Rhodesia indicate that upper slope channel development is particularly marked on the southward-facing slopes. This does not, however, have a clear meteorological explanation since neither maximum rainfall nor insolation strike from the south. Possibly they represent "fossil meteorological" conditions, derived during the Pleistocene pluvials. It is also possible that the more prolonged shade and reduced evaporation on the southward-facing slopes has permitted increased chemical attack, and hence greater erosion.

These drainage channels provide excellent examples of microtopography and, as such, reflect degrees of development normally referred to as stages of youth, maturity and old age. As a general guide, it seems that youthful microtopography is more likely to occur on bornhardts whose geographical position is close to the margin of the early-Tertiary and higher "African" erosion cycle, e.g. Domboshawa. Mrewa Hill, some 80 km from that margin, forms an intrinsic part of the late-Tertiary and lower "Post-African" erosion cycle and therefore, has microtopography of typically more mature development.

An analysis of slopes developed across the drainage channels looks very similar to that developed across normal macro-scale topography. The gradients across a micro-valley of crest, scarp, talus slope and pediment are matched very closely across the two environments, although the deposits which characterise macro-talus slopes and pediments are not present on the granite microtopography.

Sharply defined channels frequently bisect the micro-pediments, these having their floors incised by as much as 8 cm below their adjoining rocky micro-pediments. These channels of evidently later date, vary from a few centimetres to one metre or more in width, thereby occupying 10-30 per cent of the width of the micro-pediment. In some places where the micro-pediment is three metres or more across the water course splits into two or more distributaries, with "islands" of the earlier micro-pediment rising between the channels (Plate II). The banks of the channels are sharply cut in the rock and frequently rise to 2,5 cm above the level of the micro-pediment, thereby giving the appearance of a levee. These edges, composed of solid granite, have no genetic affinity to true levees and, as discussed under Surface Weathering Features, their origin is problematical.

A few drainage channels clearly originated along joint lines, which thereby decide the position of the water course. The vast majority of channels, however, follow no visible weakness in the rock and are governed entirely by hydraulic factors. Both types are clearly shown in Plate V.

In places a micro-valley widens suddenly to more than 10 m in width and encompasses a broad shallow basin which has accumulated weathered debris from the higher slopes, thereby allowing tufty grasses, aloes and sometimes even small trees to grow (Plate VI). These sponges are invariably fed by numerous tributaries from the surrounding ridges as well as by the main channel, and they absorb and store considerable quantities of water.

There is evidence of numerous minor stream captures on the micro-watersheds, particularly where adjacent pan gnammas draining into different channels have expanded and coalesced. Many more minor captures should occur in the near future.

Applying Strahler's system of stream orders to the principal micro-channels on Domboshawa and Ngomakurira, at least fourth order and frequently fifth order channels are found. Mrewa Hill, which shows greater areas of sheet flow and less gullying, has main channels dominantly of third order and a few of fourth order. The steepest gradients are invariably located in the streams of second order which are principally those descending the micro-divides. The gradients of the higher order streams are very variable and, although they steepen markedly at their lowest points where they merge into sheet wash (see above), their average gradients are considerably and consistently lower than those of the much shorter second-order streamlets.

Because all rainfall on the present bare rock surfaces must become run-off the constant of channel maintenance (C) on these granite bornhardts should be exceptionally low. By definition (Morisawa, 1968) the constant of channel maintenance represents "the area in square feet necessary to develop and maintain one foot of drainage channel". This is therefore the reciprocal of drainage density (Dd), which is the total length of stream channel per unit area. Stream frequency (Fs) is the number of channels per unit area, which clearly rises in sympathy with increase in run-off over soakage. Other extraneous factors can also affect the stream frequency, thus Fs values can be compared only between drainage basins of similar size.

Drainage densities measured from topographic maps over several areas of granite bornhardt terrain in the Mrewa district average 1,66, whereas the small perched drainage basins on Domboshawa (measured by means of a "Trumeter") gave an average value of 0,0882. This remarkably low figure is probably due to the relatively wide drainage channels of third and fourth orders when compared with width/length ratios of normal macro-scale streams. Storms, accompanied by heavy rainfall, occur several times per year in this region. At such times the author has observed considerable quantites of water flow with considerable turbulence, and hence erosive power, in sheets as much as five centimetres deep in third order micro-valleys; even deeper flows occur along the valleys of highest orders. Rarely do these same storms cause the nearby macro-streams to reach their bankfull stages. The drainage density figures therefore indicate that, although the proportions of the landscapes on macro- and micro-scales look similar, they are, in reality, very different. The constant of channel maintenance (C) on the micro-drainage basins on Domboshawa must similarly be abnormally high (11,34). Average stream frequency (Fs) for the same basins is 0,019.

The streams of different order within the head region of a perched drainage basin on Domboshawa yield the following bifurcation ratios (Rb):

Order	*Number of streams*	*Bifurcation ratio* (Rb)
1	28	3,5
2	8	4
3	2	2
4	1	

Milton (1966) is sceptical of the geomorphic value of bifurcation ratios and considers them to be solely the result of random statistical methods. Indeed, the above figures are not markedly different from figures obtained for very different drainage basins elsewhere (Leopold, Wolman and Miller, 1964).

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