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GRANITIC BORNHARDTS AND ASSOCIATED LANDFORM FEATURES IN ZIMBABWE

by

J R WHITLOW

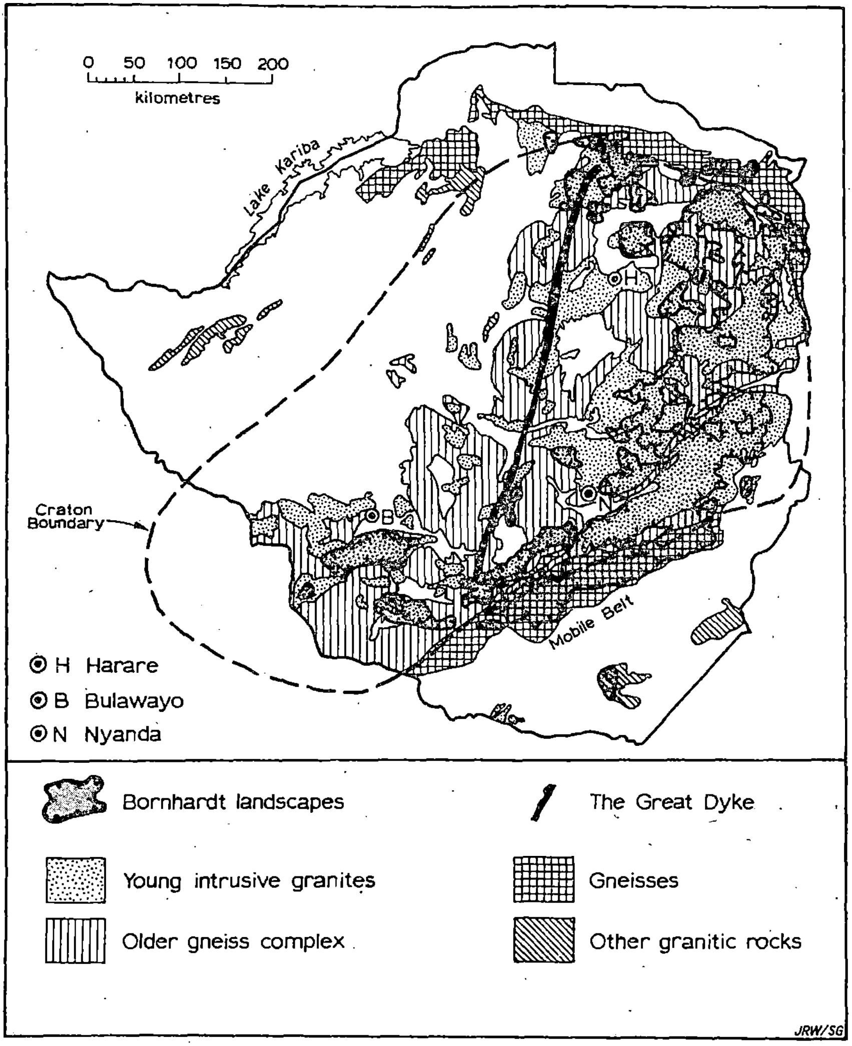
INTRODUCTION

Steep-sided convex domes or bornhardts are characteristic of about one third of the granitic landscapes in central and eastern Zimbabwe. These features are associated with batholith intrusions which make up a large portion of a massive and ancient craton that extends some 600 kilometres in a north-east to south-west direction across the country (see Figure 1). The bornhardt terrain forms a distinctive although discontinuous arc on the southern margin of this craton and the adjacent mobile belts of gneissic rocks. Morphologically, the granitic domes vary from completely stripped through to debris-covered hills, and from almost perfectly symmetrical 'whaleback' residuals through to irregular, sugar-loaf features.

The origin of these bornhardts in terms of a scarp retreat and pedimentation sequence has been disputed recently insofar as this hypothesis fails to account satisfactorily for the distribution and varied morphology of the granitic domes in this country (Whitlow, 1982). An alternative mode of development involving subsurface weathering and differential stripping of the regolith would appear to have greater validity, at least from an evaluation of the present evidence. Certainly the exhumation hypothesis seems to have more universal applicability providing an explanation of the characteristics of bornhardts at a variety of scales from the macro through to the micro level (Twidale, 1980). In this respect the extensive areas of bornhardt terrain in Zimbabwe present excellent opportunites for geomorphological research and teaching at different levels.

However, it is important not to adopt an approach which is too simplistic leading to erroneous reasoning on the reconstruction of the origins of rock dome features. Therefore, this paper is presented as an initial guide to the study of bornhardts in this country. The objectives are as follows:-

Figure 1: DISTRIBUTION OF BORNHARDT LANDSCAPES IN RELATION TO GRANITIC ROCK TYPES IN ZIMBABWE



1 to provide a general framework for the examination of granitic domes in Zimbabwe;

2 to describe the distribution of bornhardt terrain with reference to the main types of granitic rocks;

3 to discuss the significance of form-process relationships with reference to selected landform features on domes;

4 to elaborate upon the implications of rock outcrops for land utilization.

FRAMEWORK FOR STUDY

When examining any geomorphological feature it is important to be aware of the significance of scale. This determines to a large extent the relative importance of different denudational processes and variations in rock structure and lithology. Also the dimensions of features under investigation affect the methods used in field and laboratory observations. A provisional outline of factors applicable to granitic rocks in Zimbabwe is indicated in Table 1 where four orders of features are envisaged ranging from the archaean craton covering thousands of square kilometres through to micro-scale features such as surface pitting measurable on a scale of a few square millimetres.

Geological studies (e.g. Phaup, 1973; Wilson, 1979) on the origins and exposure of the ancient craton in Zimbabwe have revealed a complex history dating back some 3500 million years. Processes involved in the development of the craton within the earth's crust have included several phases of 'granitization', folding and metamorphosis of basement schists and periodic vulcanism. Crustal stresses during the cooling and alteration of magmatic material have resulted in widespread deformation and fracturing (Stowe, 1980), although after the formation of the Great Dyke complex about 2600 million years ago it seems that apart from vertical movement the craton has been more or less stable (Phaup, 1973). With respect to the nature and occurrence of bornhardts, this complex and long history of the craton has two important implications.

Firstly, the rocks have formed from magmas of varying composition and encompassed different crustal materials at the time of emplacement; therefore one might expect contrasts within and between batholiths. For example, it has been argued that the Chinamora batholith to the north of Harare was "originally a mantled gneiss dome mainly composed of tonalite which was modified subsequently by the addition of potassium to form granodiorite and in turn to form a granite core". (Viewing and Harrison, 1973, p 419). Such variations

TABLE 1

Scales of Geomorphological Features

Order	Unit	Areal extent (kms^2) and Time Scale (yrs)	Significant Environmental Factors
I	Craton*	10^5 kms^2 and over 10^8 yrs	Geomorphological - crustal deformation and fracturing followed by denudation cycles in response to uplift and tilting; Climatic - humid and arid phases varying in intensity and duration.
II	Batholith complexes e.g. Chinamora Batholith	10^2 to 10^4 kms^2 and over 10^6 yrs	Geomorphological - variations in jointing patterns and regional fractures influence weathering penetration and stream alignments; degree of exposure of domes depends on differential incision of main river systems; Climatic - as above, resulting in changes in the balance of weathering erosional and depositional processes.
III	Bornhardts e.g. Domboshawa	10^{-1} to 10 kms^2 and 10^4 to 10^6 yrs	Geomorphological - frequency, disposition and openess of joints, combined with local variations in composition, determine the forms of domes; Climatic - mesoclimatic conditions of importance, influencing the nature and duration of denudational processes partly through effects on plant cover.
IV	Minor landforms e.g. valley-rill systems, rock pavements, surface pitting	under 10^{-2} kms^2 and under 10 yrs (?)	Geomorphological - efficacy of sub-aerial processes influenced by local variations in structure and lithology; Climatic - seasonal and diurnal variations in microclimate and hydrological conditions, determined in part by plant cover, affect the balance and intensity of processes.

(* Note - referred to in the geological literature as the 'Rhodesian Archaean Craton') in mineralogical composition undoubtedly have influenced the subsequent development of dome features. Secondly, apart from the rectangular and curvilinear jointing systems which developed during crystallization of the granitic rocks, the effects of crustal stresses have resulted in regional fractures cutting across certain batholiths e.g. Chinamora. These lines of weakness have been exploited by weathering and incision of the major river systems, and have had a profound influence upon the exhumation of dome features (Whitlow, 1982). Although geomorphological research is unlikely to be involved directly with aspects of the genesis of the craton itself, it must be concerned with the findings of geologists and geophysicists. These have a definite bearing upon explaining the variations in morphology of granitic domes and reconstruction of their modes of development (e.g. Brook, 1978).

The time scale in Table 1 refers to the period of persistence of the features in the landscape. Whilst the granitic rocks are Pre-Cambrian in age, the land surfaces upon which bornhardts are currently exposed date back only to the late Tertiary 20 to 25 million years ago (Lister, 1979). In certain areas it is possible that exposure may have been fairly recent, notably in the head-water regions of river systems cutting into the plateau surfaces of the central watershed. Two aspects of time scales of significance in the development of Zimbabwean bornhardts need elaboration. Firstly, over what period have denud-ational processes been active? Rates of physico-chemical breakdown of granitic rocks in Zimbabwe have been estimated to be in the order of 3 to 6 millimetres per 1000 years (Owens, 1974). Assuming a constant rate of weathering over say 25 million years, this would result in alteration of rocks to depths of 75 to 150 metres. Strong jointing and foliation would facilitate greater depths of weathering penetration. Given that the mean relief of domes in Zimbabwe is in the order of 300 metres (Whitlow, 1982) and that there is the additional possibility of pre-weathering of the African erosion surface during the Tertiary period, there is some support for the exhumation hypothesis since there has been sufficient time for deep weathering and erosional stripping.

Secondly, it has been demonstrated that monolithic domes may persist through two or more erosional cycles resulting in gradual accentuation of their relief (Thomas, 1974). Two major phases of erosional stripping have resulted in exposure of many of the domes in Zimbabwe, over a period of several million years, during which climatic conditions are known to have changed considerably (Bond, 1968). These are the Post-African and Pliocene erosion cycles (Lister, 1979). Any investigation of this lengthy period of geomorphological history necessarily must be concerned with the question of environmental changes and their influence on geomorphological processes.

A question mark has been placed against the time of persistence of minor landforms in Table 1. Although certain features are apparently 'ephemeral' in character (at least on geological time scales), others may either be subject to reinforcement mechanisms thereby extending their persistence or be 'fossil relics' of past environments. Further comment on this is made at a later stage when discussing minor landforms.

DISTRIBUTION OF BORNHARDT TERRAIN

The bornhardt terrain in Zimbabwe is located mainly on the southern and eastern flanks of the ancient craton body forming a broad arc varying from 90 to 130 kilometres in width (Figure 1). It is apparent that there is a close spatial association between the incidence of domes and certain granitic rocks, especially the young intrusive granites and the gneisses in the mobile belts on the south-eastern margin of the craton. This association was noted first by Macgregor (1934) and appears to be related in part to the sheet-like structures of the batholith intrusions, as well as their mineralogical composition. It now seems that there is a causal link between granitic rocks which are rich in potash feldspars and the incidence and size of bornhardts (Brook, 1978). To what extent this is a function of the lithology of the rocks per se or simply an indirect reflection of a given mode of emplacement is not yet established.

The varying proportions of bornhardt terrain according to the main granitic rocks differentiated on the 1:1 million geological map of Zimbabwe (Stagman, 1978) are shown in Table 2. A broad classification of the granitic rocks is indicated in the footnote to this table.

The most commonly occurring rocks are tonalites and adamellites, the distinction between these being the greater abundance of potash feldspars in the latter, over 35 percent of feldspars are of the potash variety in the adamellites compared with under 15 percent in the tonalites (Stidolph and Stocklmayer, 1976). The prevalence of domes on the adamellites can be appreciated from the data given in Table 2. Whereas the massive, potash-rich younger granites constitute less than half of the area of the granitic rocks, nearly 70 percent of the bornhardt terrain occurs on them. In contrast, the tonalites generally give rise to flat or gently undulating landscapes, particularly on the older gneiss complex. These rocks tend to be more finely jointed than

TABLE 2

Granitic rocks and terrain types in Zimbabwe

Main rock type*	Bornhardt terrain+	Gently sloping terrain*	Proportion of granitic rocks
Young intrusive granites	69,8%	30,4%	45,9%
Older gneiss complex	19,2%	60,0%	35,9%
Gneisses	10,2%	5,2%	14,1%
Other granitic rocks	0,8%	4,4%	4,1%
	100,0%	100,0%	100,0%

+ 30% of granitic rocks; * 26% of granitic rocks

Young intrusive granites	-	mainly adamellites with some tonalites
Older gneiss complex	-	mainly tonalites
Gneisses	-	foliated rocks of varying composition
Other granitic rocks	-	include granophyre and syenite

the adamellites and this influences the pattern and penetration of weathering; in turn this affects development (or lack) of domes.

Macgregor (1951) used the term 'gregarious batholiths' to describe the pattern of ovoidal granitic masses within the main craton. These batholiths are separated by greenstone belts or metamorphosed rocks in many areas and typically form discrete 'islands'. The contrasts between the batholith intrusions and adjacent rocks are most marked when, as in the case of the Chinamora batholith, there are well-defined contact zones between the granites and the greenstone series. These lithological boundaries are easily identifiable in the landscape since rivers tend to follow the contacts and the rock domes rise abruptly along the margins of the batholiths. It should be noted, however, that not all the younger granite intrusions give rise to bornhardts. An example of this is the Somabula batholith where a radial drainage pattern occurs on a broad convex surface of low relief. In such instances it is possible that a situation on the main watershed may have prevented complete exhumation of dome forms. Also the granitic body located in the central part of the craton is probably under a high degree of compressive stress, reducing the frequency of open joints which can be exploited by weathering.

The patterns of jointing and regional fractures have clearly had a major effect on the distribution, orientations and relief of dome features within individual batholiths. For example, the domes in the Matopo batholith south of Bulawayo (see Figure 1) occur in well-defined ridges trending in a north-west to south-east direction. Although monolithic hills do occur, the granites are strongly foliated and many of the ridges are strewn with blocky debris. The ridges are generally in the order of 100 to 150 metres above the valley floors, but the larger domes may rise to well over 300 metres above the surrounding areas. In contrast, within the Chinamora batholith to the north of Harare (see Figure 1) the dome features exhibit three main trends. Within the central part of the intrusion they are aligned in a north-west to south-east direction; along the margins of the batholith they follow the trend of the contact zone; and in the eastern part of the intrusion, where the terrain is more open in character, there is an irregular pattern related to contorted jointing in the rocks. Residual regolith and boulders occur on the summits of some of the domes, but most domes are characterised by steep, bare rock slopes. The domes vary in their relief from 100 to 350 metres above the surrounding areas. The smaller domes less than 50 metres in height, invariably, are still blanketed with weathered material.

These examples suggest that the exhumation hypothesis offers a more logical explanation of the origins of domes insofar as it accounts for the differential subsurface and surface denudation of rocks in terms of the jointing patterns at various scales. The patterns of jointing within granitic rocks are important in these processes. They can be "likened to a rectangular lattice, varying in texture both spatially and in depth, so that larger joint blocks may occur, not only in different locations, but also at different depths below the landsurface of the time" (Thomas, 1965, p 66). Such jointing patterns are discernible on small scale aerial photography. There is a need for systematic mapping and analysis of such patterns in relation to differences in dome morphology in Zimbabwe.

MINOR LANDFORMS ON GRANITIC DOMES

The efficacy of sub-aerial processes that currently influence features on domes are dependent upon variations in micro-jointing, foliation and mineralogy of the bedrock. The influence of these on surface forms is obvious but there are two issues that need to be considered when attempting to account for the relationships between surface forms and processes. Firstly, there is a high degree of interdependence between the occurrence of water, the nature and density of plant cover, and variations in microclimatic conditions on domes. Hence the geomorphological processes of a bared summit are somewhat different from those of a sheltered hollow. In the latter, regolith material accumulates from inwash and in situ weathering, enabling the development of a herbaceous and woody vegetation cover. Weathering activity is greater, therefore, in the hollows than on the crests of stripped bornhardts. This is due, primarily, to differences in moisture supply and retention. Under dry conditions granites are extremely resistant to denudation, whereas when there is abundant water the rocks decompose fairly readily (Twidale, 1976); Plate 1 demonstrates this point. Secondly, there is the problem that the processes initiating a given landform feature are not necessarily the same as those currently operating upon it. This applies especially to features such as flared slopes and micro-valley systems that seem to have originated under a mantle of regolith material rather than as sub-aerial forms (Twidale and Bourne, 1975a). Examination of the current process-form relationships of these features is of limited value if the objective of study is to reveal the development sequence of the landforms. Indeed, where one is dealing with relatively homogeneous bedrock on a single dome, it is apparent that the prevailing geomorphological conditions often do not account satisfactorily for the initiation of certain features.

Plate 1

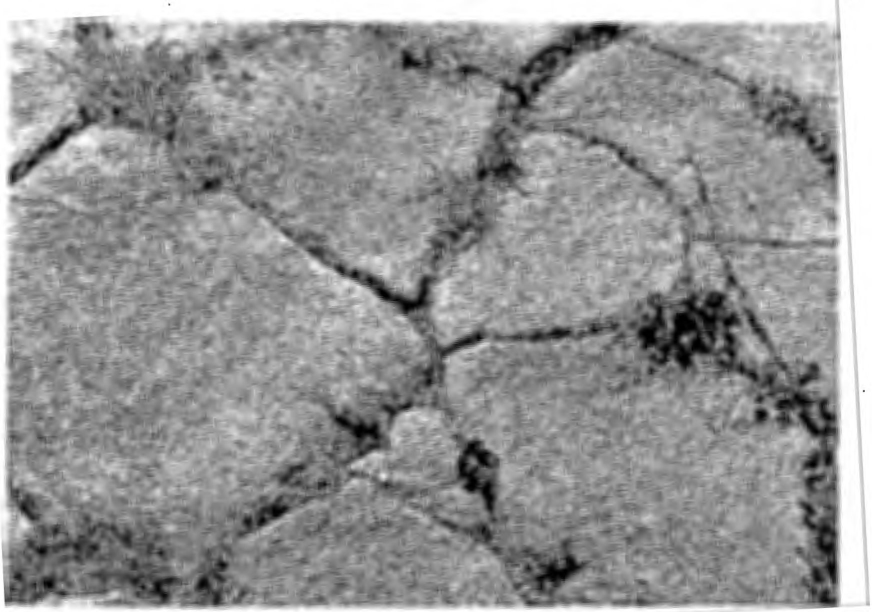


Plate 2

To demonstrate the form-process relationships of minor landforms on bornhardts, seven different types of feature are described below including surface pitting, rock pavements, weathering pans, tafoni, flared slopes, hollows and valley-rill systems (see Figures 2 A to G).

a) Surface pitting; this is caused by the "preferential weathering of feldspar and mica, leaving quartz in relief" (Twidale and Bourne, 1976), the texture of the pitting being dependent upon the relative sizes of crystals in the granite. It has been argued that pitting originates under a regolith cover adjacent to domes and, once exposed, does not survive for more than a few millenia (Twidale and Bourne, 1976). Evidence in Zimbabwe, in particular on Domboshawa, would seem to support the notion of a subsurface origin. In addition there is a further possibility, especially on the steeper convex flanks of domes, that the activity of crustose lichens should also be considered. Pitted surfaces, in the absence of flaking which only occurs on strongly foliated granites, are extremely durable and would act as a protective veneer on domes thereby assisting in their preservation.

Weathering cavities, sometimes referred to as honeycomb weathering, are also found on domes, especially on the vertical faces of residual boulders in sheltered situations. The irregular sizes and distribution of these shallow depressions on rock surfaces suggest that they are not unrelated to the growth and decay of foliose lichens. Once a hollow is initiated, it may be subjected to greater physico-chemical activity by virtue of retaining more moisture. However, in the absence of any systematic study of these features, such a hypothesis can only be tentative; certainly other factors such as degree of exposure, inclination of the surface and homogeneity of the bedrock would influence whether cavities develop or not. Once formed, such hollows may also persist for a long period of time in the absence of active exfoliation, the latter process being somewhat slower on exposed boulders than those embedded in regolith (Twidale, 1976).

b) Rock pavements; rectangular slabs of granite with upturned rims and hollow centres can form extensive pavements on gently sloping 'platforms' on domes (Plate 2). The alignment of the slabs often follows that of local joints which may, in some instances, be marked by quartz or pegmatite veins. They seem to originate under a shallow covering of regolith material (under 20 centimetres or so) on sites which receive

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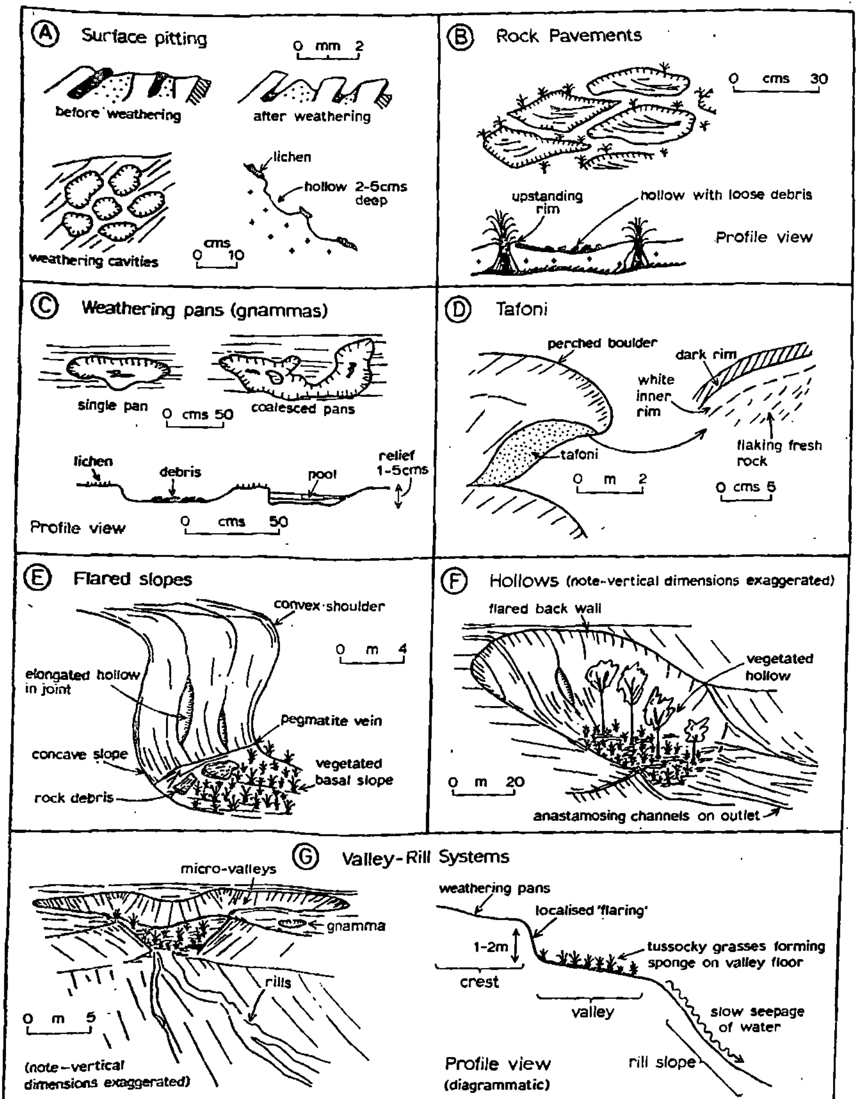
Figure 2: Some Geomorphological Features on Rock Domes

(Note – scales are approximate)



runoff from the upper parts of a dome resulting in more active and prolonged weathering. Pavements are poorly developed or absent on massive outcrops tending to occur only where there are extensive sheets in the order of 5 to 10 centimetres in thickness. The initial fragmentation of the large sheets into slabs may simply be a function of the release of compressive stresses within the bedrock (see Twidale, 1976). In well foliated granites, this would tend to produce rectangular blocks following the alignment of the main joints. This break-up would be assisted by weathering processes, especially on gentler slopes where more moisture was retained within the shallow regolith overlying the granite sheets. The origin of the raised rims is more problematic. One hypothesis is that they could represent areas of localised concentration of quartz and, as a result, are more resistant to weathering. Such concentration of silica rich material along micro-joints would occur in the final stages of magma cooling and may also account for the patterns of fragmentation of the granite slabs.

The rock pavements, once exposed, are subject to sub-aerial processes. On steeper slopes mechanical disintegration may occur resulting in the formation of debris-strewn surfaces. Where there are gently sloping platforms, the rock pavements tend to remain intact much longer, but their persistence is probably in the order of thousands rather than millions of years. For example, pavements on Domboshawa are breaking up as the covering of regolith is removed by the effects of cattle trampling.

c) Weathering pans; shallow depressions or gnammas (Twidale, 1976) are common features on the gently sloping summits of many bornhardts. In exceptional circumstances, especially where hollows receive additional runoff from adjacent slopes, they may be up to two or three metres in diameter and over a metre in depth. More commonly, weathering pans occur as roughly circular features which may have discontinuous, raised rims around their margins (Lister, 1973). Where frequent overflow occurs between adjacent hollows, the intervening bedrock is gradually worn down until the depressions coalesce.

The key factor in the vertical and lateral enlargement of gnammas is the period of contact between the retained water and the bedrock surface.

The longer the contact, the more active the alteration of the bedrock. Once a hollow is initiated the process tends to be reinforcing since water would remain for a longer period on the floors as opposed to the margins of the depressions. In some situations, colonisation by herbaceous plants might assist in the deepening of the hollows. An hypothesis has been suggested that gnammas may be initiated by subsurface weathering as well as sub-aerial processes (Twidale and Bourne, 1975a). However, a simple sub-aerial origin would appear to be more realistic for the smaller and shallower hollows (Lister, 1973).

Hollows are sometimes used for the grinding of grains in some parts of the communal lands, a fact which undoubtedly contributes to their enlargement!

A peculiar feature of weathering pans on domes like Domboshawa is the presence of discontinuous raised rims, about 2 to 3 centimetres in height and of similar width, around their margins. 'Outliers' within the pans (see Figure 2 C) are often characterised by raised margins as well. The origin of these rims, which also occur adjacent to runnels draining micro-valleys (Plate 3) off the summits of domes (Figure 2 G), is not understood fully. Lithological differences have been discounted by Lister (1973) on the basis of thin section examination, but field evidence suggests that a veneer of redeposited silica and slightly larger crystal sizes may be responsible for the relatively greater resistance of the rims. It has been suggested that the rims might be due to the protective effect of lichens (see Lister, 1973). However, the general absence of such plant cover (with some isolated exceptions) on raised rims today is difficult to reconcile with such a hypothesis.

The longevity of a gnamma depends upon whether the rate of deepening exceeds the rate of development of an outflow. For example, on Domboshawa the growth of pans has been terminated in many instances by gradual lowering of the margins on the downslope sides of depressions. Other hollows, where several runnels converge on lower slopes, are often full of water and are still being enlarged.

) <u>Tafoni</u>; these are 'hemispheric' caverns that typically occur on the undersides of perched boulders or exfoliation slabs. In the former case the 'negative exfoliation' (see Figure 2 D) is a result of the release of internal stresses within the rock giving rise to concave

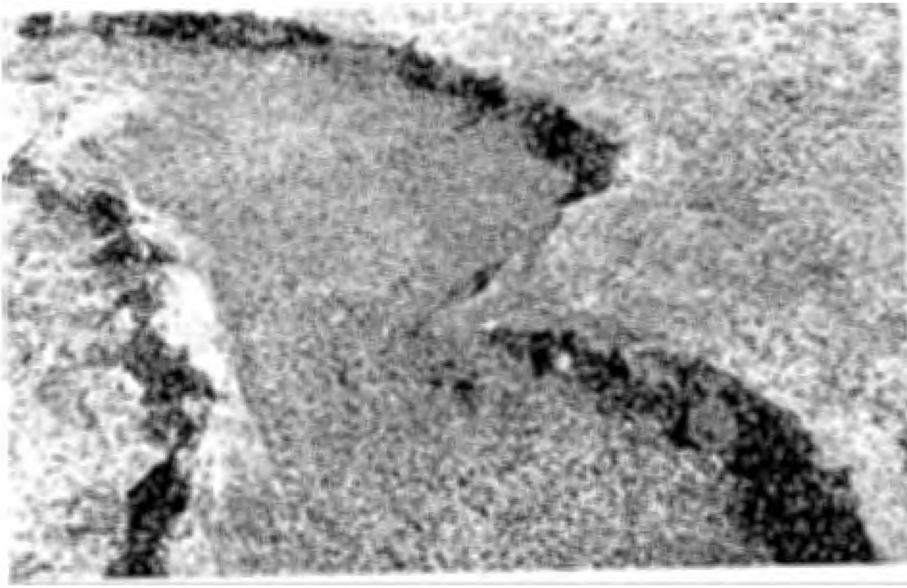


Plate 3

Plate 4

fractures (Ollier, 1978). Vertical clefts and lens in residual boulders are also attributed to such mechanisms. Relatively little is known about the occurrence of tafoni in this country, but limited field observations confirm the statements of Martini (1978). The detachment of particles from the inner walls of hollows is mainly through scaling and flaking rather than granular disintegration; consequently, the inner surfaces generally comprise fresh rock and are devoid of lichen growth e.g. as at Epworth Mission, Harare. The different micro-climates under rock overhangs affect the nature of weathering processes, partly through the effect on lichen growth. Where there is water seepage under exfoliation slabs and a dense vegetation cover surrounding the overhang, greater contrasts in micro-climate might be expected. Here active tafoni are found. In exposed situations e.g. residual boulders on a dome, limited micro-climate contrasts seem to inhibit further weathering; thus the tafoni become 'fossilised'.

Twidale and Bourne (1975a) have presented evidence to suggest that tafoni are initiated as subsurface phenomena. Given that tafoni may be observed on boulders on the upper parts of domes and in such situations they appear to be quiescent, it is possible that they could be an indication of the gradual exhumation of domes. That is, they might represent the levels of former land surfaces. Nevertheless, a simple sub-aerial origin can be invoked in many situations. In this respect a feature which occurs on many tafoni observed by the author deserves comment. Invariably the margins of tafoni are characterised by an outer black band and an inner 'ashen' one. This appears to be related to precipitation of salts in the latter, but to date no satisfactory explanation has been forthcoming.

) <u>Flared slopes</u>; these are near vertical convex-concave slope features which occur locally on domes. For example, on Domboshawa flared slopes occur along cliff lines half way up the dome and in association with large hollows. Twidale (1976) explains the origins of flared slopes in terms of two phases. Firstly, there is a period of subsurface weathering as a result of the concentration of runoff around the basal slopes of a residual dome. Secondly, there is a phase of removal of the weathered material around the residual resulting in exposure of the 'weathering front' as a flared slope. Thus, the convex shoulder of a flared slope (Figure 2 E) is interpreted as marking the level of a former land surface. Other features associated with flares are indicated in Figure 2 E. Pegmatite veins, for example, sometimes occur at the bases of flared slopes and may be indicative of zones of weakness in the bedrock that were exploited during the phase of subsurface weathering.

The stepped form of domes such as Domboshawa, (Plate 4) combined with the presence of flared slopes and other features indicative of earlier phases of subsurface weathering, provides support for the hypothesis of episodic exposure of bornhardts as expounded by Twidale and Bourne (1975b). More detailed observations, perhaps involving morphological mapping of individual domes, would be necessary to evaluate this hypothesis more fully.

f) Hollows; hemispherical hollows up to 30 metres across and 5 metres in depth are sometimes encountered on the flanks of domes. As in the case of flared slopes, these seem to originate as subsurface features which, once initiated, tend to become more pronounced in time. One can envisage localised concentrations of runoff around residual domes which might result in the development of shallow subsurface hollows; continued weathering and gradual exposure would eventually result in the hollows becoming more pronounced. Excavations in such hollows have revealed accumulations of regolith in excess of one metre depth near the back walls, becoming shallower towards the outer margins. Dense thickets of evergreen trees and bracken are common in these hollows, the organic litter assisting in the build up of the soil and promoting the retention of moisture.

The hydrological behaviour of these features is interesting since they act as sponges, retaining a great deal of moisture derived from runoff and slowly releasing the water into outlet channels. After the cessation of the rains, the flow in these channels may be maintained for several weeks from the reservoir in the hollow. Even after the outlet channels dry up there would still be sufficient moisture in the deeper parts of the hollows to maintain the vegetation and promote chemical weathering of the bedrock. The periodic 'flushing' of the regolith may, in fact, be necessary to enable continued breakdown of rock minerals otherwise saturated solutions in contact with the crystals would reduce the rate of weathering.

Clearly larger scale features like hollows and flared slopes are likely to persist much longer than features like gnammas or surface pitting. However, whereas flared slopes may in effect be fossilised upon exposure, it is obvious that the processes of deepening and widening of hollows are still active. What would be of interest is to investigate the spatial occurrence of these features on domes to establish whether they occupy particular 'levels' related to episodic exposure as described by Twidale and Bourne (1975b).

g) Valley-rill systems; these features occur on many bornhardts and, like the previous two landforms, may have been initiated under regolith covering when the domes were yet to be exposed. The valleys are generally in the order of 1 to 2 metres in depth and up to 10 metres wide. Unlike 'normal' fluvial systems they often divide and coalesce as one moves from the crests towards the flanks of domes. Their long profiles or 'thalwegs' may exhibit rapid falls of up to 12 metres in places and these possibly correspond to periods of relative stability, with concentration of weathering around channel outlets onto the adjacent pediment slopes, followed by erosional stripping (Twidale and Bourne, 1975a). Lister (1973) has argued that these 'micro-valleys' are water-worn, being attributed to the erosive effects of excessive and turbulent flows during intensive tropical storms. There is certainly evidence of smooth water-worn rock surfaces on granitic domes, but the actual wearing down of the surface is due primarily to corrasion by particles in suspension rather than the water itself. With some exceptions, sources of abrasive material are lacking on the summits of domes and there is little evidence of down-wearing in the manner indicated by Lister (1973), albeit the valleys do expedite efficient removal of water from these sites. Given this situation and the fact that the valleys exhibit morphologies which are more readily accounted for by gradual adjustments to bedrock irregularities under a regolith covering, it would seem that the alternative hypothesis of subsurface initiation and exhumation should be examined more closely.

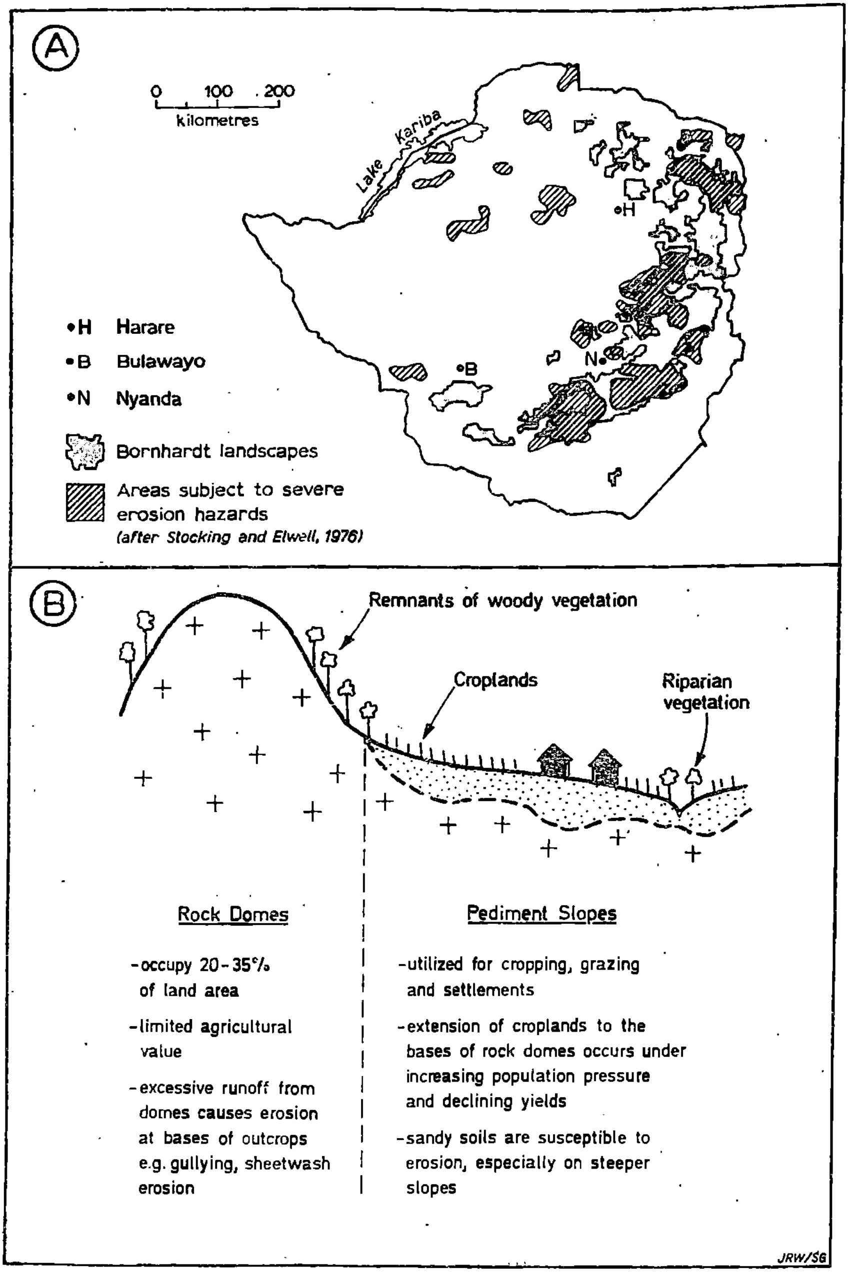
The valleys on the crests of domes generally drain into gutters or rills on the flanks of the outcrops. These channels are more likely to be the result of fluvial action, being somewhat shallower and narrower than their headwater sources. The reasons for this are relatively simple. The valleys on the dome crests sometimes support dense mats of vegetation on pockets of regolith which in places can exceed 20 centimetres in depth. This material absorbs a great deal of moisture during rainstorms and, after the cessation of precipitation, gradually releases water to the rills. Unlike the rainwater, this contains organic acids and consequently the effect of the drainage waters involves, not only prolonged wetting of the rock, but also greater chemical alteration. The poor development or absence of rills on slopes where crest valleys are devoid of vegetation tends to support this hypothesis. Human disturbance of vegetation in recent years can give rise to situations where well-defined rills occur, but which are no longer supplied with moisture as outlined above. In these cases, rills might be regarded as dormant like the tafoni mentioned earlier.

ROCK OUTCROPS AND LAND UTILIZATION

The occurrence of massive rock outcrops acts as a major constraint upon human activities in certain parts of Zimbabwe, especially the communal farming areas. Nearly two thirds of the bornhardt terrain is located in communal lands notably in the marginal agricultural areas to the south and south-east of Nyanda. The major problems in these areas include the following factors. Firstly, the steep slopes and shallow pockets of acid, granular soils of the rock domes precluding their use for farming although they may provide a source of firewood and limited grazing for livestock. Secondly, the domes may occupy between 20 to 35 percent of the land area (rising to over 50 percent in some regions) reducing the amount of land available for cropping. Thirdly, the steep bare slopes of the bornhardts promote rapid rates of surface runoff which, potentially, can cause excessive sheetwash and gully erosion on the adjacent sediment slopes. Here it is important to note that there is a spatial association between areas of severe erosion hazards (Figure 3A), incidence of rock domes and the occurrence of high population densities which results in extreme pressures upon the land (Stocking and Elwell, 1973). The implications of this are summarised in Figure 3B. The results of this situation are displayed well in the Mtoko region where widespread gully erosion has taken place despite the construction of contour banks. Problems are most acute around cattle dips where there is regular use of tracks converging on these sites from the surrounding hillsides (Stocking, 1972).

The occurrence of rock domes may be regarded as an 'anti-resource' in many areas but spectacular scenery of bornhardt terrain forms a major attraction in national parks such as the Matopos and Mushandike. Here, the diversity of habitats affords a wide range of opportunities for a variety of animal, bird

Figure 3: RELATIONSHIP BETWEEN BORNHARDTS AND EROSION



and plant species. These contrast strongly with the devastated conditions within the communal lands noted earlier. There are certainly opportunities for comparative studies between such areas.

CONCLUSION

Granitic bornhardts and their associated minor landform features offer a great deal of scope for geographical studies in Zimbabwe. The objectives of this paper were firstly, to provide a framework within which such studies could be placed; and secondly, to indicate the types of question that need to be considered with respect to the examination of process-form relationships. Whilst it is essential that studies of granitic landforms be carried out in the field, the utility of aerial photographs and topographic maps should not be neglected. Moreover, the implications of granitic domes for land utilization can also be explored, providing a useful link between the physical and human components of the landscape.

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