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The Various origins of minor granite Landforms

Distintos orígenes para las formas graníticas menores

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The many minor forms developed on granitic terrains, on bornhardts and other residual hills, on boulders, on sheet structures and on platforms, vary in origin. Different modes of initiation and subsequent development are discussed and it is concluded that several forms typical of granite are convergent.

Key words: minor granite landforms, granite geomorphology.

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INTRODUCTION

Various minor, but well known, landforms are commonly developed in granitic rocks, on bornhardts and other residual hills, and on boulders, sheet structures and platforms. The field evidence demonstrates beyond doubt that their origins differ, and that representatives of the same form have evolved in different ways. Here different modes of intitiation and of subsequent development are discussed. Early workers such as WILHELMY (1958) interpreted granite forms in terms of climate, but others (e.g. TWIDALE 1982, 1993) have classified minor granite forms partly according to their location on slopes, partly according to origin, and particularly whether they are interpreted as primarily due to weathering or whether they are tectonic (see also VIDAL ROMANI 1989). Here, this generic classification is largely maintained; we are concerned first, with those forms for which weathering processes are largely responsible and second, with those in the evolution of which structural factors (sensu *lato*) play a significant role. Further subdivisions are based on whether the forms originated covered by regolith, half covered or uncovered, in the case of the weathering features, and according to whether crustal processes have been passive or active in the case of the structural forms (Table 1).

WEATHERING FORMS

Interaction between bedrock and the atmosphere and hydrosphere, and especially meteoric and ground waters, leads to alteration of the rock and the formation of a regolith. The thickness of the regolith is a function of the relative rates of weathering and erosion, and it varies between nothing and a few hundreds of metres. Where a regolith is preserved, the base of the regolith, the junction between regolith and bedrock, is called the weathering front (MABBUTT 1961). As a result partly of exploitation of structural weaknesses of various types and at various scales, and partly as a result of moisture concentration, the weathering front is irregular. Major irregularities lead to bornhardt massifs, inselbergs and plains, minor variations to several well known landforms (Fig. 1).

Pitting

Differential weathering at the crystal scale leads to feldspars and micas being altered to clays, leaving the quartz upstanding and giving a rough or pitted surface (Pl. 1; TWIDALE and BOURNE 1976a). In many areas, such surfaces can be exposed by scraping away the regolithic veneer, for example during the construction of local water conservation schemes, or even by lifting a rock slab, for moisture is conserved in such sheltered sites. Here, pitting is prominent only on recently exposed surfaces, suggesting that flaking and other processes quickly cause its elimination after exposure.

On the other hand, similar pitted surfaces are known from exposed sites, where weathering is especially intense or effective. For instance, on the eastern flank of Ucontitchie Hill such pitting can be seen in the floors of gutters *(Rillen)* draining from patches of regolith that are well vegetated and where, in consequence, the seepages are high in humic acids. Also, pitting is widely developed in granitic rocks on the coast at Pulau Ubin, in the Johore Strait, northern

TABLE I. A generic classification of minor granite landforms. Those forms in italics are probably convergent.

WEATHERING FORMS

Initiation at the weathering front	Subsequent development
Pitting	Rapid destruction
Flakes and spalls	Destruction
Rock basins	Diversification
Gutters and grooves	Enlargement
Polygonal cracks	Destruction
Flared slopes	
Scarpfoot depressions	Enlargement/destruction
Deep indents	*Tafoni*
Caves	
Clefts	Enlargement
Pseudobedding	
Blocks	Displaced blocks
Boulders	Split boulders
Kluftkarren/veins	
Forms due to partial exposure	
Rock levées	
Rock doughnuts	
Fonts	
Pedestal rocks	
Plinths	
Epigene initiation	
Rock basins	Diversification
Gutters and grooves	Enlargement
Tafoni	Destruction
Flakes and spalls	Destruction
Blocks	
Boulders	
Constructional forms	
Speleothems	
Boxwork pattern of ridges	
STRUCTURAL FORMS (SENSU LATO)	
Structural forms (sensu stricto)	
Crystal strain	
Clefts	
Gravitational pressure	
Basins	Diversification
Inverted hollows	*Tafoni*
Fracture and/or intrusive vein	
Clefts	
Walls	
Tectonic forms	
Strain and rupture	
A-tents	
Blisters	
Triangular wedges	
Orthogonal cracks	
Kluftkarren	

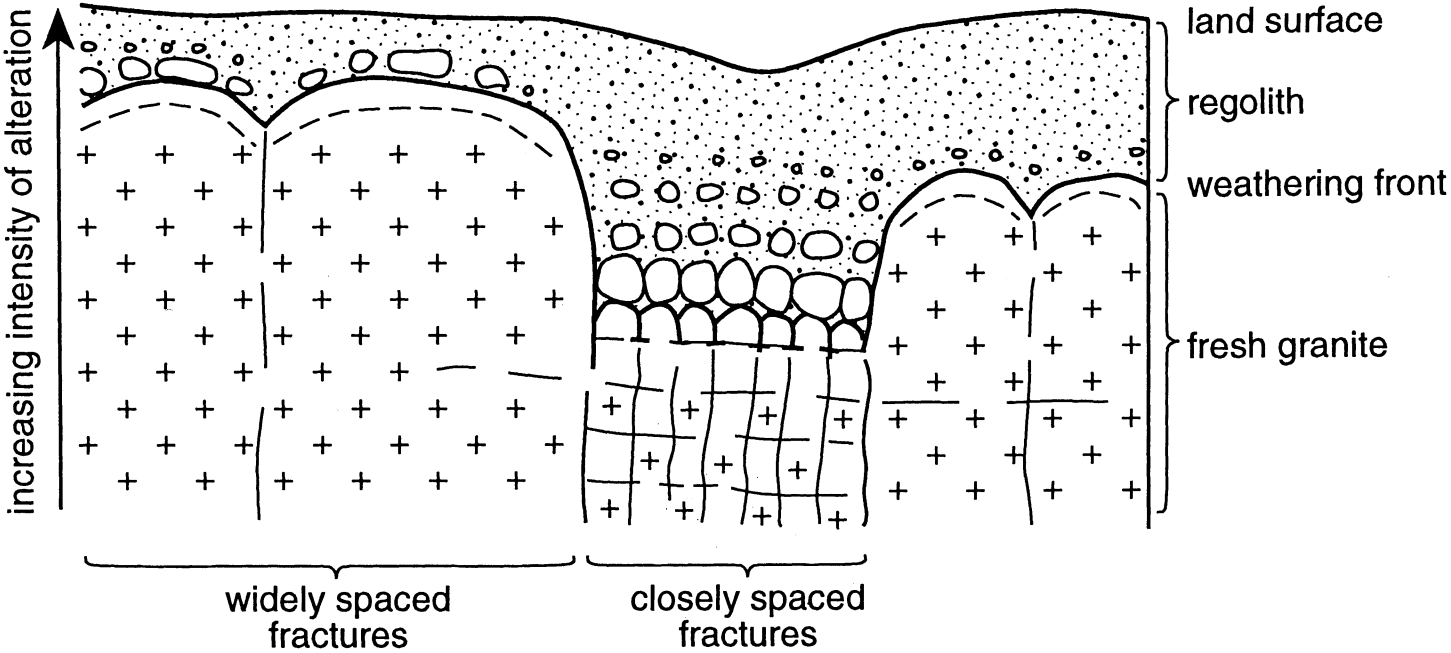


Fig. 1. Schematic diagram of fracture-controlled subsurface weathering (After Twidale1982a).

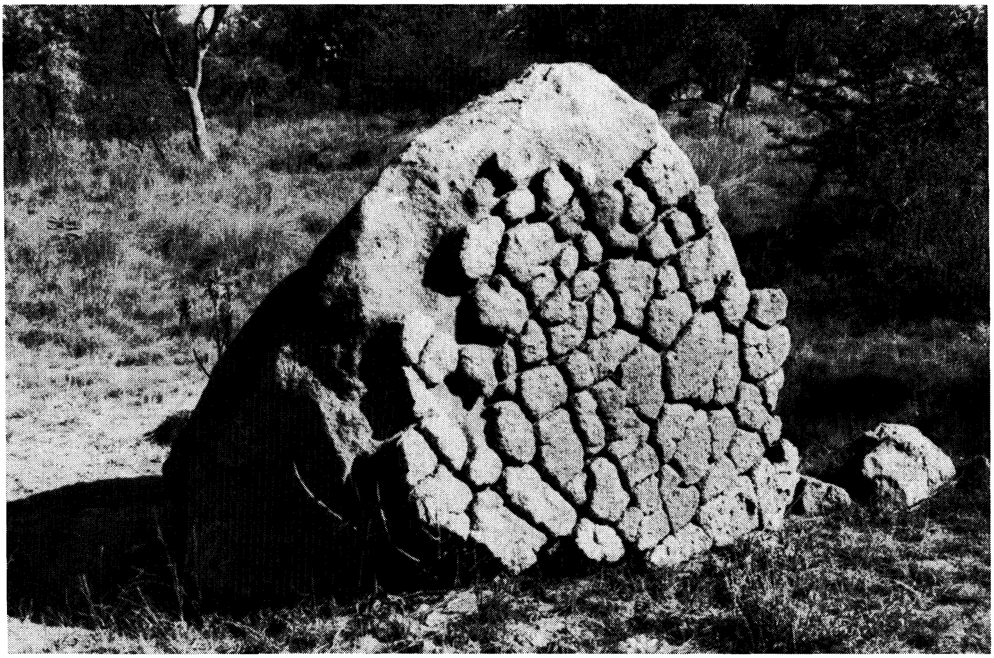
Pl. 1. Pitting on the floor of this gutter, Ucontitchie Hill, Eyre Peninsula, South Australia, may be due to the coating of dried algal slime.

Singapore; here it may be that the combination of high temperatures, and alkaline waters (sea spray) together promote rapid differential weathering on exposed surfaces.

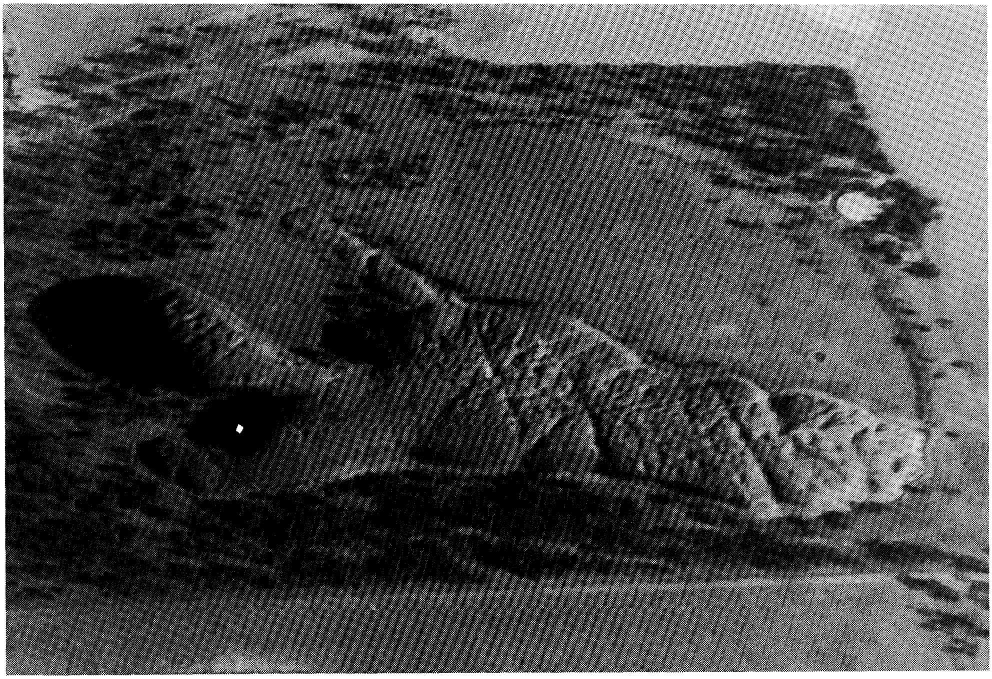
Flakes and spalls

Many exposed granite surfaces are covered, indeed essentially consist of, a skin, usually multilayered, of thin laminae, flakes or scales. Some, perhaps most, may be epigene in origin (insolation? hydration and hydrolysis?), though such features certainly develop at the weathering front, either around corestones (the surfaces of which can be regarded as discrete parts of the front) or at the base of the regolith (TWIDALE 1993).

Pl. 2. Corestones surrounded by layers of flakes or spalls, Snowy Mountains, New South Wales.



Pl. 3. Polygonal cracks on boulder, near Neue Smitsdorp, northern Transvaal.



Pl. 4. Oblique aerial view of Pildappa Hill, Eyre Peninsula, South Australia, showing the development of rock basins along fractures and particularly at fracture intersections.

Flakes are millimetres thick. Thicker laminae, greater than 1 cm thick, are referred to as spall plates. On the margins of corestones, books or stacks several flakes thick are commonplace (Pl. 2). They also occur on exposed surfaces, for example in the mamillated ceilings of tafoni. Both flakes and spall plates are associated with bush fires and other sources of ephemeral but intense heat.

Polygonal cracks

Polygonal cracking affects spall plates on boulders and platforms and may be due to a surficial compressional stress caused by the accumulation of silica, iron oxides and manganese oxides either on exposed surfaces or at the weathering front (Pl. 3; TWIDALE 1982). The cracks may be developed on as many as three successive spall plates at any one site. Such patterns of cracks have been observed on corestones (in the Snowy Mountains of New South Wales) and on the recently exposed slopes and platform on the flanks of bornhardts (e.g. at Dombashawa).

Rock basins

As is attested by the number of local names given to the forms, rock basins are perhaps the best known of all minor granite forms. One on Dartmoor, southwestern England, was noted more than 800 years ago (WORTH 1953). That some are initiated at the weathering front is demonstrated by the presence of shallow saucer-shaped depressions on newly or recently exposed platforms, as for example on several of the Kwaterski Rocks, north of Minnipa, on Eyre Peninsula, South Australia (TWIDALE & BOURNE 1975). Rock basins commonly form along fractures (giving bathtub-shaped basins) and at fracture intersections (Pl. 4), and again have been noted on newly exposed domes, as at Ebaka, Cameroun (BOYÉ & FRITSCH 1973). On the other hand, basins are also formed on exposed surfaces. For instance, a basin formed on the crest of a menhir at St Uzek, in Brittany, must have developed after exposure when the crest was placed in a roughly horizontal position about 5000 years ago (LAGEAT et al. 1994). Similarly, basins have formed on recently deglaciated surfaces, as for instance in northern Portugal and southern Galicia (VIDAL ROMANI 1989). After exposure, basins of etch origin evidently develop varied morphologies according to bedrock structure, slope, and depth of erosion: hemispherical pits on homogeneous rock on flattish slopes, pans in laminated rock on flattish slopes, armchair-shaped hollows on steeper slopes, and cyclindrical hollows where deep weathering and later erosion have extended any of the three aforementioned types through the base of a sheeting slab and into a sheet fracture, allowing throughflow and abrasion (Fig. 2; TWIDALE & CORBIN 1963; TWIDALE & BOURNE 1978).

Gutters and grooves

Similarly, some gutters and grooves (horizontal *Rillen* and vertical flutings - Pl. 5 - respectively) are manifestly initiated at the weathering front, for, like basins, they are exposed on recently cleared bedrock surfaces, as for example at Dumonte Rock, near Wudinna, Eyre Peninsula (TWIDALE & BOURNE 1975), and at the Cassia City of Rocks in Idaho. Just as the saucer-shaped precursors of basins are shallow, so the gutters on newly exposed surfaces are shallow and

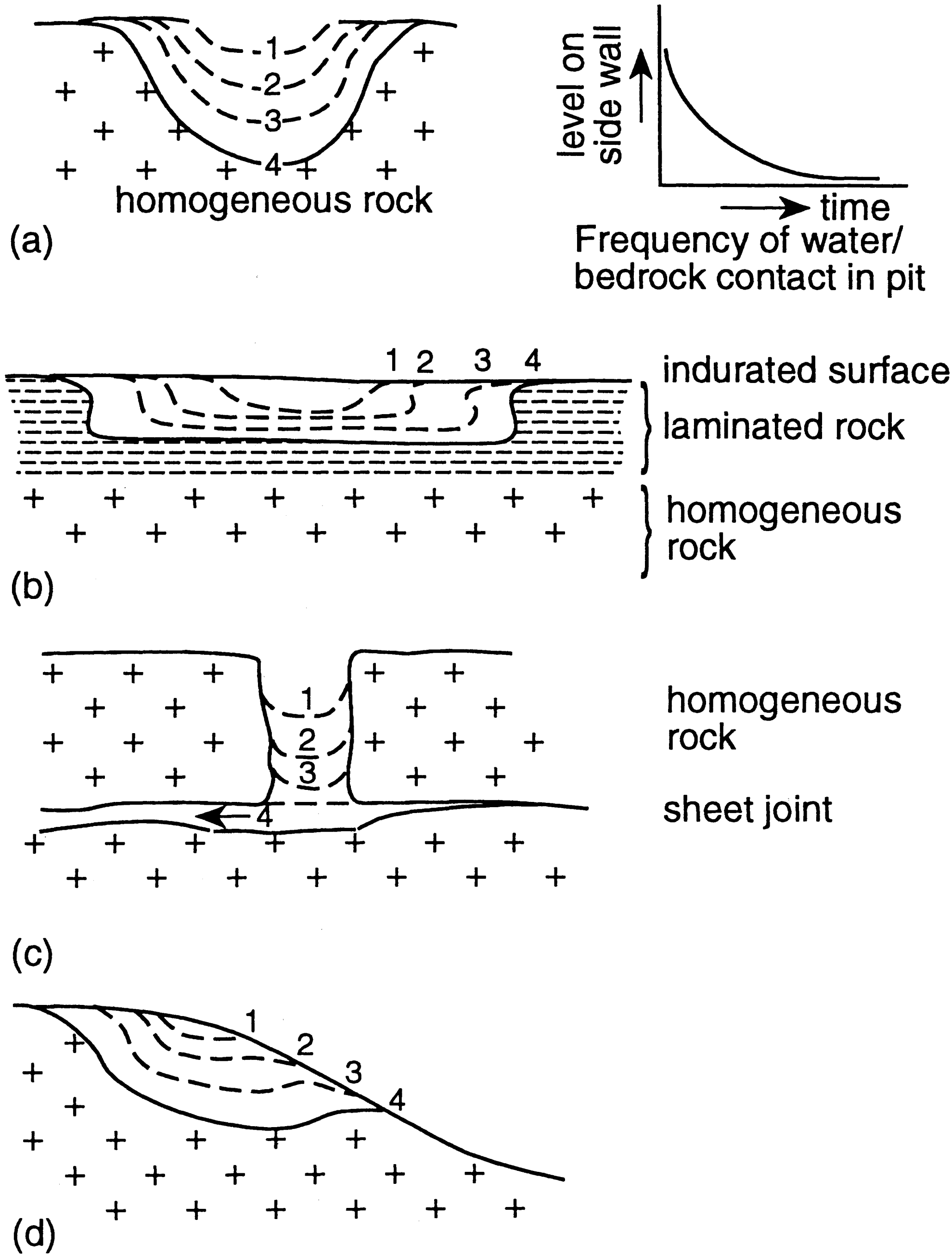


Fig. 2. Differentiation of rock basins after exposure: (a) Pit, (b) Pan, (c) Cylindrical basin, (d) Armchair-shaped basin (After Twidale 1982a).

narrow. Epigene gutters can be traced into the subsurface along the weathering front where in many cases they become shallower and wider, presumably as flow filtering between soil particles becomes diffuse. This is why, on many boulders and blocks, flutings that are strongly developed on upper slopes fade at lower levels. Elsewhere, however, as at Dumonte Rock, gutters converge along the weathering front before fading at a depth of some 2 m below the natural ground surface.

Equally, however, and spectacularly, at the menhir of St Uzek, grooves have formed on the flanks of the erected slab (Lageat et al. 1994) and again gutters are found on freshly deglaciated surfaces (Vidal Romani 1989), proving that some gutters and grooves have formed subaerially.

After exposure, rudimentary gutters are deepened by running water. Abrasion is evidenced by the development of potholes. In some cases the gutters have become flask-shaped in cross section as a result of the undercutting of side walls by streams. Some gutters have exploited and follow fractures (*Kluftkarren* - see below) but that slope is the prime determinant of the path followed by streams, and hence gutters, is demonstrated by the many places where the gutters leave fractures to follow the steepest local slope. Some grooves become inverted downslope and merge into ribs, as on the southern side of Yarwondutta Rock. In an immediate sense this is apparently due to the protection afforded by a thin veneer of desiccated algal slime, but why the present channel floors are not similarly protected has not yet been explained.

Flared slopes and scarp-foot depressions

That flared slopes are a special form of weathering front developed in the piedmont zone of hills and boulders is demonstrated at a number of sites in South Australia, and also in southern France, California and Idaho, where excavations have exposed incipient flares beneath the regolith *in situ* (TWIDALE 1962). On large residuals a basal concavity up to 12 m high and in some instances overhanging, develops as a result of moisture attack on massive rocks. The concavity is due to the relative drying at and near the surface, whilst at depth moisture, and hence

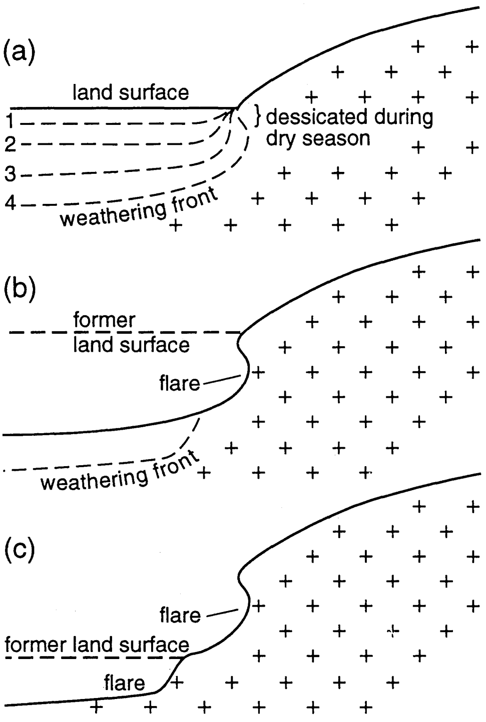
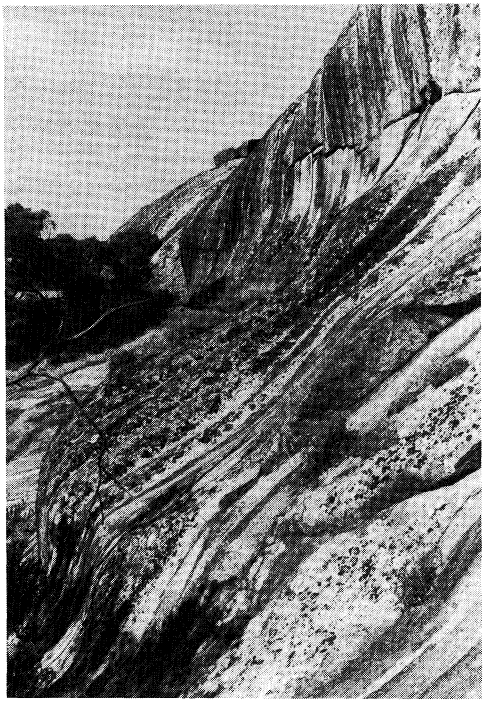


Fig. 3. Stages in the development of flared and overhanging slopes by scarpfoot weathering and subsequent differential erosion: (a) subsurface infiltration of moisture in the scarpfoot area and lowering of the weathering front; (b) lowering of base level and stripping of weathered debris resulting in exposure of the weathering front as a flared slope; (c) repetition of process and development of double flare (After TWIDALE 1976).

Pl. 5. Grooves on the side of a large boulder near Tampin, west Malaysia.



Pl. 6. Multiple flares on the eastern side of Ucontitchie Hill, Eyre Peninsula, South Australia.

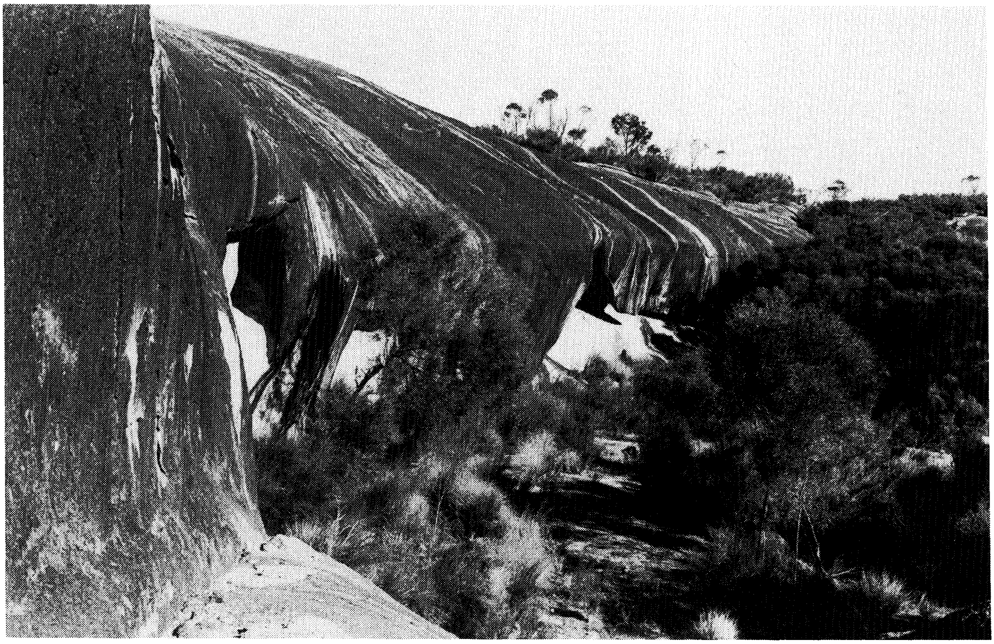
weathering, persists. Lowering of the plain surface results in exposure of the flares (Fig. 3). Multiple flares (Pl. 6) are explained by repetitions of subsurface weathering and lowering of the plain. Flared slopes are also well represented on boulders.

The flared slopes formed around the base of residual hills extend laterally into platforms, but at several sites a shallow enclosed depression, known variously as a scarp-foot depression, *dépression annulaire* and *Bergfussniederung* (see CLAYTON 1956), intervenes between hill slope and platform. Varying in width between a few metres and several hundreds of metres (DUMANOWSKI 1960; MABBUTT 1967), such depressions presumably reflect the more rapid weathering of the bedrock at the base of the slope, where water is more plentiful than elsewhere, though in places weaker bedrock has also been exploited (DUMANOWSKI 1960). Basal fretting is due to the same mechanism and can be regarded as an imperfect kind of flared slope.

Tafoni and alveoles

At Kokerbin Hill, Western Australia, flared slopes merge laterally with deep caverns (Pl. 7), leading to the suggestion that tafoni, like flared slopes, are initiated at the weathering front, presumably as a result of especially intense subsurface moisture attack. But no tafone has yet been uncovered at the weathering front and the question of their subsurface initiation remains open. At other sites, similar deep, if mostly minor, indentations are associated with basal fretting. Alveolar or honeycomb weathering (MUSTOE 1982), and also miniature hollows, which are more widely distributed and lack the clearly defined septal separation of alveolar weathering, may be related to tafoni development. Either or both may coalesce to form a hollow, which develops into a tafone. Alveolar weathering is typical of fracture planes and the weathering front and represents an early stage of weathering. Miniature hollows may form on exposed surfaces but little is known of their origin.

Tafoni undoubtedly evolve at the base of boulders and sheet structures, beginning with inverted saucers (see below) and enlarging upward into the rock mass as a result of salt crystallisation; hence the occurrence of tafoni in arid and semiarid lands, in cold arid Antarctica and also in some coastal areas. The preservation of the outer visor is an integral part of tafone



Pl. 7. At Kokerbin Hill, southwest Western Australia, flared slopes merge laterally with tafoni developed at the base of a sheet.

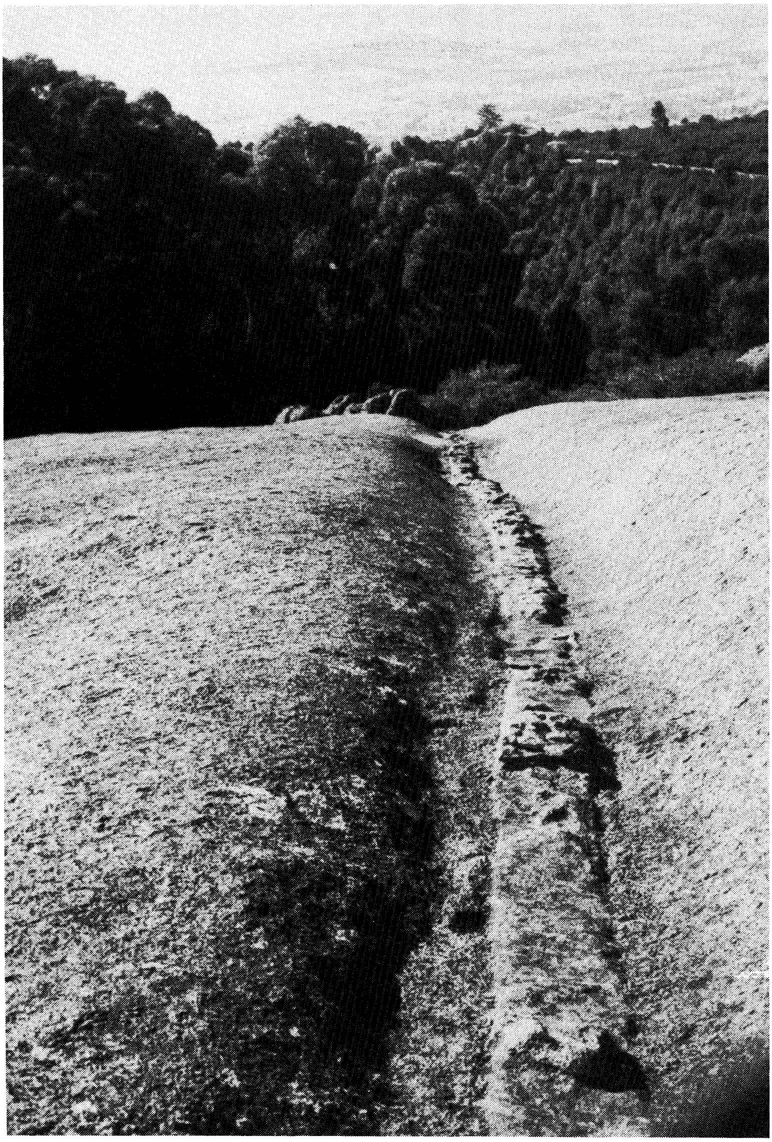
development and the slight but important concentrations of iron oxide (and silica?) may be due to epigene agencies (lichens, mosses, capillary concentration) but may equally be relic features associated with the weathering front, where iron concentrations are commonly 2-3 times that in the fresh rock. What is certain is that tafoni are inevitably self-destructive, for their very growth helps destroy the host mass in which they are located.

Caves

At a few sites weathering along sheet fractures has proceeded to such an extent that the resulting openings are sufficiently large to be called caves (e.g. KASTNING 1976). Other caves follow orthogonal joint systems, resulting from the evacuation of grus from between corestones, and the latter remaining piled to form the walls and roof of the cave system (e.g. OLLIER 1965; FINLAYSON 1981). Yet others form by the flushing of meteoric waters at the base of the regolith (e.g. SHANNON 1975), and others are due to the preferential weathering and erosion of veins intrusive into the granite (e.g. WOJCIK 1961).

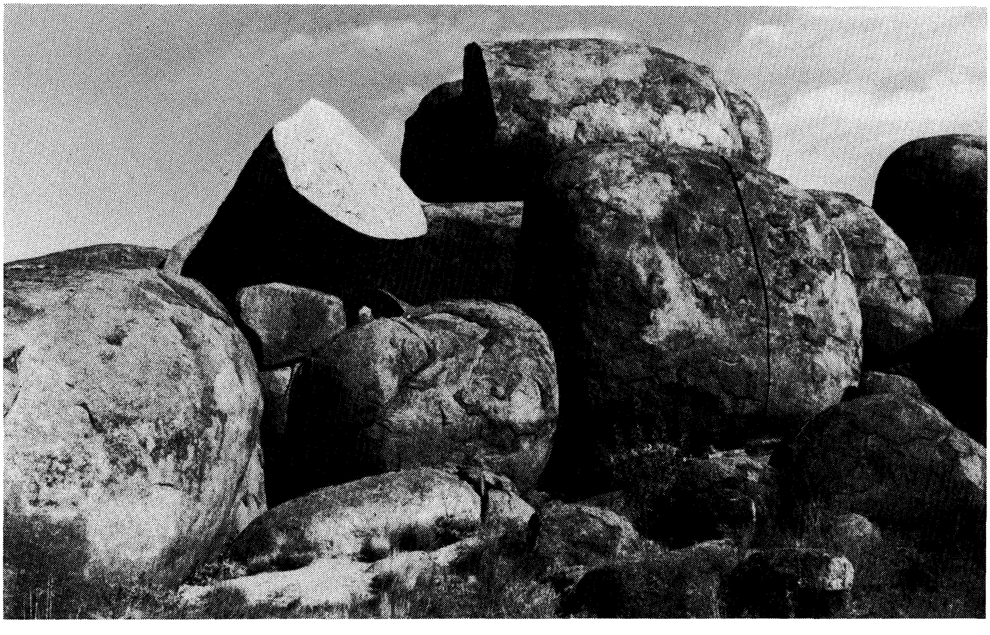
Clefts

Exploitation of vertical fractures leads to clefts or slots (*Klüftkarren* - TWIDALE 1982). Where intruded by veins the latter may remain upstanding as a wall, or be preferentially weathered and eroded to form a broad cleft, depending on the relative



Pl. 8. This aplite vein on Paarlberg, near Cape Town, South Africa, is less resistant than the main mass of granite, but more resistant than the immediately adjacent granite.

Pl. 9. A quartz vein and corestones revealed beneath the surface in a road cutting, near Pine Creek, Northern Territory.



Pl. 10. Split rocks, Devils Marbles, Northern Territory. The large boulder at right is divided by a secondary fracture.

resistance of the vein and the country rock. In places partings are more deeply eroded than the intrusion which is in turn less resistant than the host rock (Pl. 8): all is relative. Such exploitation of fractures and veins can, of course, take place either at the weathering front or after exposure, and the same is true of vein complexes that form *nerviaciones* (VIDAL ROMANI 1989) resulting from the exploitation of zones of fractures, some depressed, some raised, depending on the relative resistance of the material injected into the fractures during deformation. But that some, certainly, are etch forms is suggested by the flared sidewalls of some clefts, as at Yarwondutta Rock.

Pseudobedding

In some parts of the world, the near surface granite is subdivided into thin slabs and attenuated lenses by fractures that run parallel or subparallel to the surface. Commonly known as pseudobedding, it has been attributed to shearing of the rock and preferential alteration along the foliation planes (VIDAL ROMANI 1989). On the other hand, its occurrence in cold climates suggests it may be due to frost action.

Boulders and related forms

Where steeply inclined fractures or foliation are closely spaced, penitent rocks (*Büssersteine*, monkstones, tombstones - see Ackermann 1962) are formed, and where orthogonal systems are developed, preferential weathering along fractures leads to essentially spheroidal corestones set in a matrix of grus (Pl. 9; TWIDALE 1982). When exposed, the corestones become boulders. But blocks and boulders are also formed by the disintegration of sheet structures. Though some takes place in the subsurface, e.g. in a quarry at the foot of Paarlberg, Cape Town, South Africa, some clearly develops after exposure, for the blocks are in *situ* and are angular and not rounded or otherwise modified, as for instance on the slopes of Enchanted Rock, central Texas. After exposure, tafoni development and other weathering processes may cause the elimination of the block or boulder.

Displaced blocks and split rocks

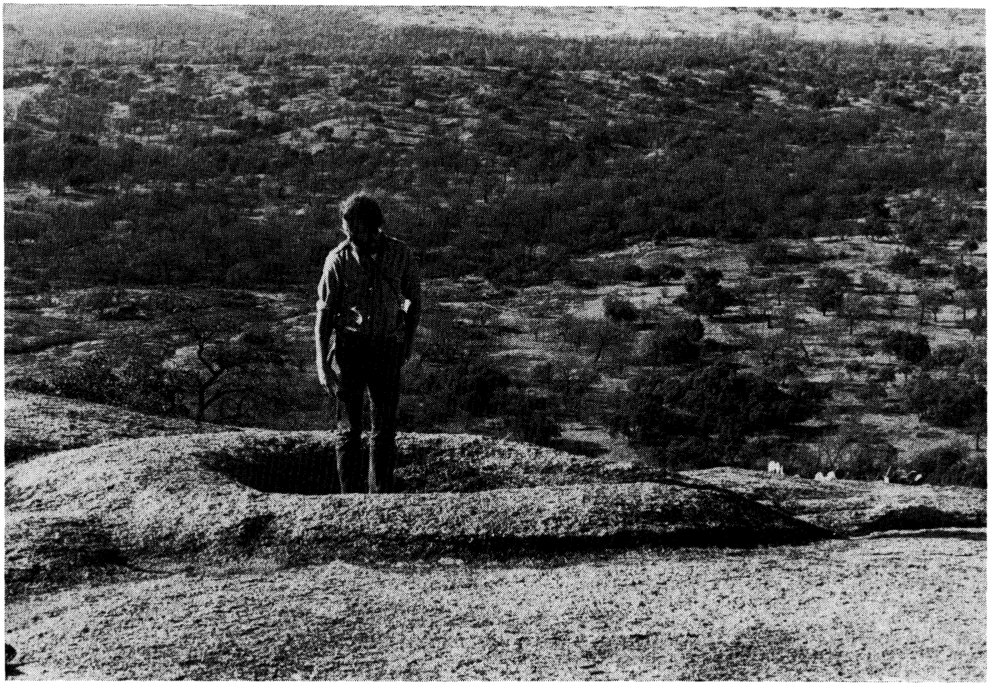
The rounded or subrounded mass of a boulder rests on the base on only a small part of the whole surface. This means that considerable parts are unsupported and the block or boulder maintains its integrity only because of cohesion endowed by the crystallinity of the rock. Where such rounded blocks and boulders include secondary partings, gravity causes unsupported sections to fall apart, in displaced blocks or split rocks (Pl. 10), depending on whether the two parts remain in *situ* or whether they tumble downslope. Shaking due to earth tremors may well assist this process (TWIDALE et al. 1991). Such seismic events certainly cause angular slabs already detached to slide downslope, leaving a corridor between.

FORMS DUE TO PARTIAL EXPOSURE

Rock levées

Some minor forms are best explained in terms of the partial exposure of the bedrock surface. Rock levées are rims bordering shallow channels or gutters scored in bedrock. They are well developed on the slopes of Domboshawa, a granitic bornhardt

Pl. 11. Rock levées on Dombashawa, a granite dome in Zimbabwe. Note the flattish pitted floor of the valley.



Pl. 12. Rock doughnut on Enchanted Rock, a granite bornhardt in the Llano of central Texas.

near Harare in central Zimbabwe. It has been suggested that a coating of opaline silica accounts for their being upstanding (WHITLOW & SHAKESBY 1989) though it is not clear whether such a coating is absent from adjacent surfaces. Protection by organisms has been suggested by others. Rock levées can also be explained by the contrasted behaviour of wet and dry granite (BARTON 1916; TWIDALE 1988). The gutters with levées occur on the upper slopes of the bornhardt. The flattish valley floors are rough (pitted) and there is a distinct break in surface texture at the base of the valley side slopes, suggesting that the earlier regolith was thin. Imagine the following sequence of events. Run off was concentrated into streams which eroded through the regolith and into the fresh granite beneath, thus creating a linear zone of exposed granite. The streams were intermittent and in the dry season the bedrock channel became dry. Moisture in the adjacent regolith drained to the channel, so that little weathering took place there. But weathering continued longer beneath most of the regolithic cover so that, in time, the weathering front was lowered more rapidly, leaving the bedrock surface adjacent to the channel upstanding. Hence, when the regolith was stripped rims or levées were left bordering the channel (Fig. 4; Pl. 11).

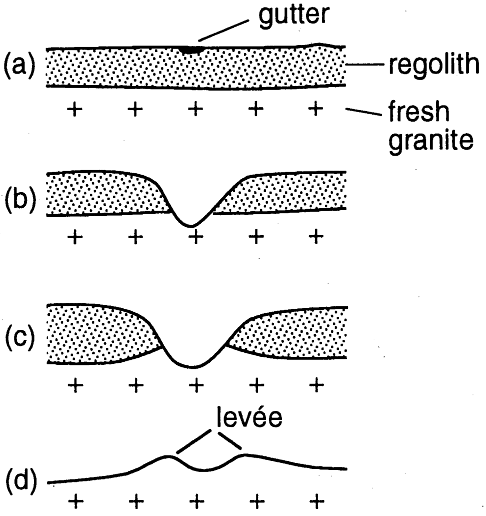


Fig. 4. Rock levée on Dombashawa, a granite bornhardt near Harare, Zimbabwe. Suggested explanation of its development in dry zones near the gutter or bedrock channel, exposed as a raised area after the regolith is stripped (After Twidale 1993).

Rock doughnuts

Rock doughnuts are annular rims encircling basins. They occur on Eyre Peninsula and Zimbabwe, but the largest examples occur in the Yilgarn of Western Australia (Paynes Find) and on Enchanted Rock, central Texas (Pl. 12). BLANK (1951a) and TWIDALE & BOURNE (1977) have offered explanations, but all are unsatisfactory. Doughnuts are best regarded as circular levées, due to the same contrast between dry and wet sites (TWIDALE 1993). Support for this interpretation comes from a single doughnut located on a platform only recently exposed by the stripping of a thin regolith in the complex of platforms known as Kwaterski Rocks, north of Minnipa, Eyre Peninsula. Fonts, which are small towers or cones each with a basin in the crest, may be doughnuts around which there has been long continued or intense weathering at the base of the regolith; but this remains conjecture.

Pedestal rocks

Pedestal rocks consist of a relatively wide cap or table supported by a narrow stem or

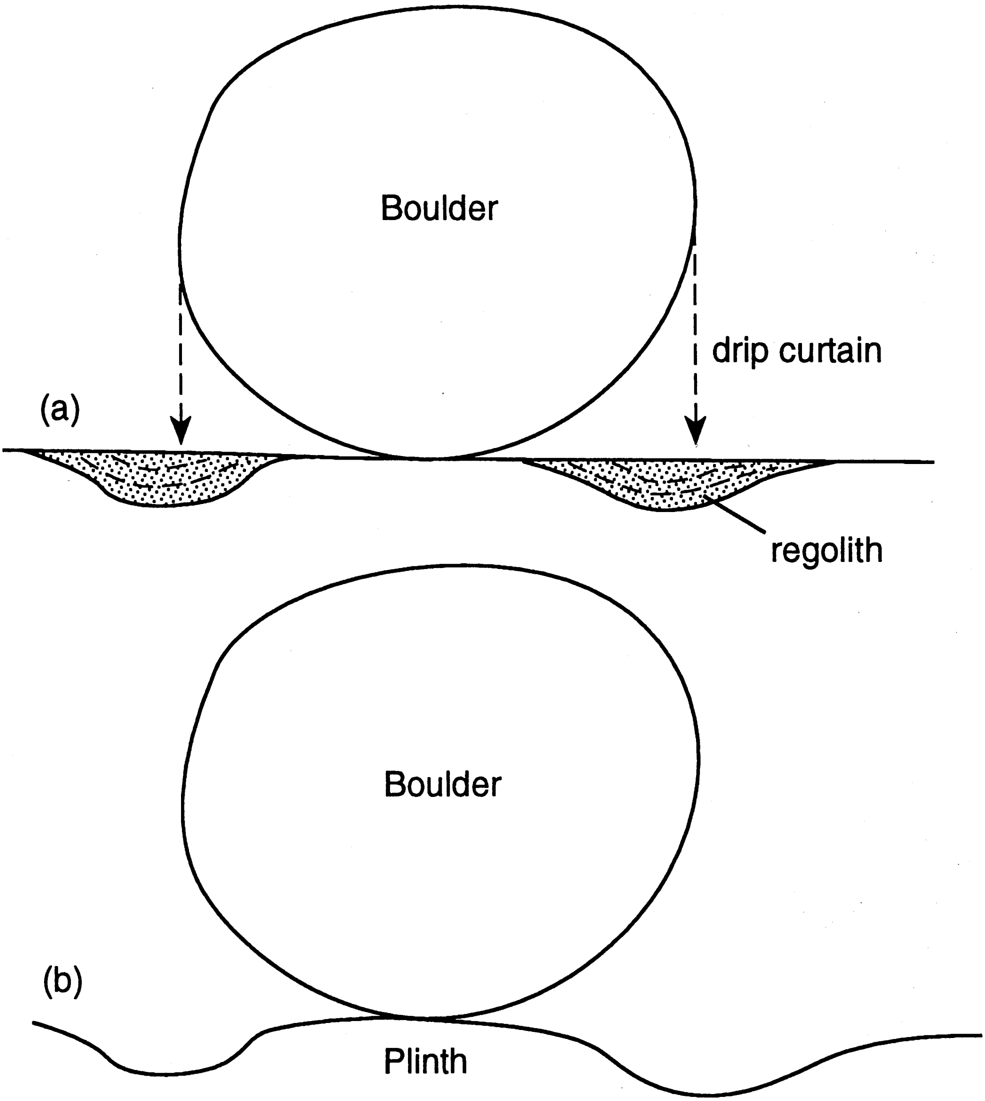


Fig. 5. Water dripping from the boulder causes weathering of the platform around the margin, but below the boulder remains dry (After Twidale 1982a).

shaft. Though in some lithological settings the cap may be developed in a more massive rock, this is scarcely ever a factor in granitic terrains. Here pedestal rocks are best explained in terms of contrasted wet and dry sites. The basic cause of the forms is the contrast between the comparatively dry, and hence stable, exposed and near-surface part of the cap and the continued contact of its subsurface extension with moisture contained in the soil and regolith. Moisture-related weathering such as hydration, hydrolysis and solution, plus the disintegration (slaking) consequent on fluctuations of the water table, have caused the formation of a relatively narrow shaft or stem (TWIDALE & CAMPBELL 1992).

Plinths

Plinths are low tabular forms standing a few centimetres higher than the adjacent surface. They commonly carry a block or boulder, for the latter act as a protective umbrella, shielding the underlying bedrock against rainfall. Thus the sheltered zone remains relatively dry, while the surface all around, whether bare rock or regolith, is moistened. Bare rock is weathered and eroded more rapidly where it is moistened, and a moist soil or regolith causes more rapid alteration at the weathering front, in both cases leaving the plinth upstanding (Pl. 13).

At Tolmer Rocks, South Australia, water dripping on to the platform from a protective boulder has caused the development of a series of shallow pools, the pattern of which reflects the plan shape of the boulder (TWIDALE & BOURNE 1976b; TWIDALE et al. 1983). The coalescence of these pools has formed a shallow moat which diverts runoff from the platform away from the boulder. Hence weathering proceeds less rapidly and a plinth or higher area results (Fig. 5).

CONSTRUCTIONAL FORMS

Speleothems

Depositional and constructional forms are rare in the granite context, though the products of granite weathering form important components of sediments. Silica is released by the weathering of quartz and of feldspar, mica and any other silicates in granite. It has, in places, been reprecipitated along fractures which are consequently sealed, and after weathering of the surrounding rock, forms a boxwork pattern of miniature ridges (Pl. 14). In some areas it is reprecipitated from water seepages in fracture clefts as small (up to 5mm high) speleothems, most commonly in the form of flowstone or as digital stalagmites, but with stalactites represented in places (e.g. CALDCLEUGH 1829; VIDAL ROMANI 1983). The stems of the digital forms are composed of opal-A but each has a tip of gypsum.

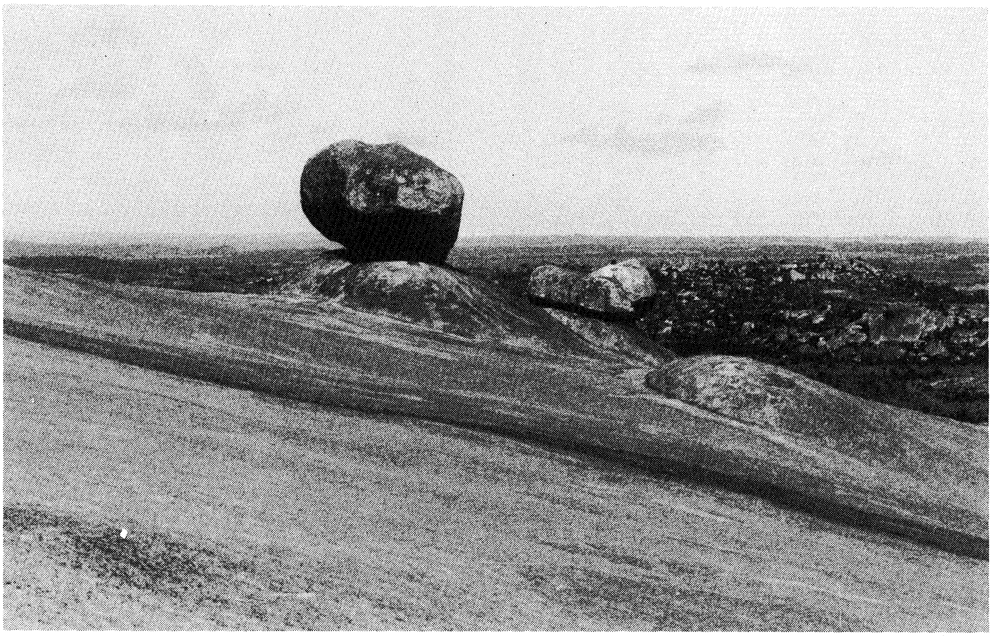
STRUCTURAL FORMS (sens*u lato*)

Tectonic forms, such as fault scarps, are due wholly and solely to processes active in the Earth's crust, whereas structural forms (*sensu stricto*) are due to the exploitation by external agencies of weaknesses in the crust. Some minor granite forms classed as structural have been referred to already: clefts and walls related to fractures and veins, basins and gutters located along fractures and at fracture intersections, and so on. Some forms develop where structural weaknesses cannot be seen in the field, but a zone of deformation is implied.

Structural forms (se*nsu stricto*)

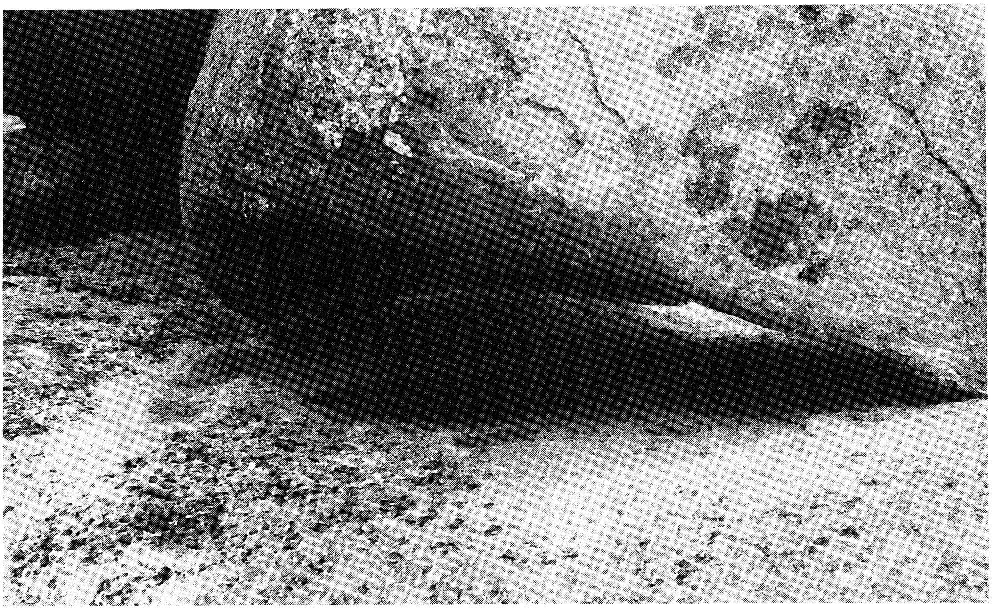
Crystal strain

It has long been known that crystals in strain, being in disequilibrium, are more susceptible to weathering than ones that are not strained (e.g. RUSSELL 1935) and some minor granite forms can be attributed to such exploitation. In many places it can be observed that *Kluftkarren* are developed along fractures but that the fractures are not

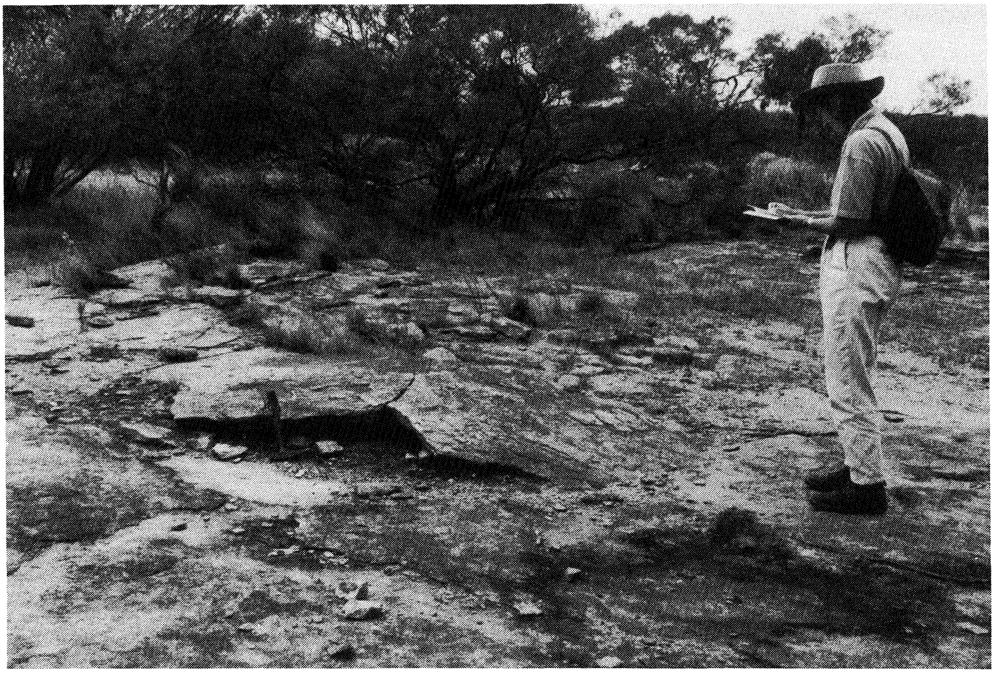


Pl. 13. Plinth capped by a boulder on Dombashawa, Zimbabwe.

Pl. 14. Boxwork pattern of ridges formed by reprecipitation of weathered material along fractures in granite, near Port Hedland, Western Australia.



Pl. 15. Inverted hollow and basin beneath a boulder, Mt Hall, Eyre Peninsula, South Australia.



Pl. 16. A-tent on a platform at The Granites, north of Mt Magnet, Western Australia.

apparently present along the entire length of the landform. Moreover, at some sites *Kluftkarren* are paralleled by clefts in which no fractures are discernible; presumably the stresses responsible for strain and rupture in the former affected adjacent zones but were insufficient to cause rupture there. Also, though the outlines of some rock basins are clearly determined by local textures and structures, such as foliation and fractures, others developed in homogeneous rock nevertheless display slightly angular plan forms consistent with the local fracture pattern, again suggesting that strain may be involved (TWIDALE & CORBIN 1963).

Gravitational pressure forms

VIDAL ROMANI (e.g. 1989, 1990) has suggested that gravitational loading of one block or boulder on another granite mass or on another block is enough to cause crystal strain at the point(s) of contact and to induce preferential weathering resulting in saucer-shaped depressions or basins on the lower surfaces and inverted hollows on the upper (Fig. 6). Eventually these hollows become rock basins and tafoni respectively (Pl. 15).

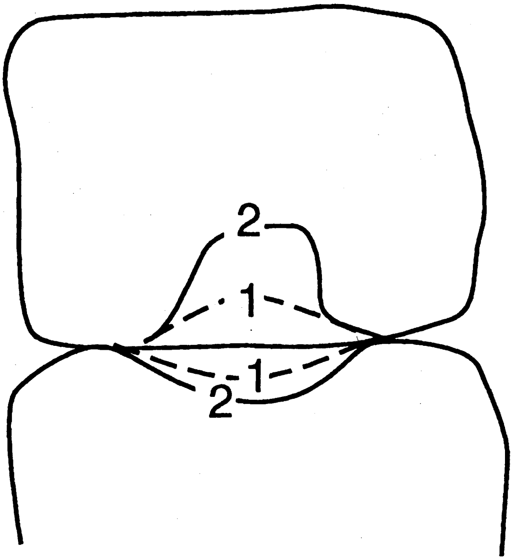


Fig. 6. Evolution of tafone and rock basin due to concentration of gravitational load (After VIDAL ROMANI 1989).

Tectonic forms

A-tents

Tectonic processes are responsible for a small but notable suite of landforms in granite. A-tents or pop-ups cannot in reason be attributed either to insolation or to erosional offloading. They involve a permanent expansion, are consistently oriented in a given area and, in some instances, have been induced by detonation of explosives. They are best explained as associated with the release of compressive stress, in natural conditions probably in response to earth tremors (Pl. 16; TWIDALE & SVED 1978). Blisters are arched but unfractured surficial slabs (BLANK 1951b). They could be due to weathering but, as they invove a small expansion, may be incomplete or incipient A-tents.

Triangular wedges

Triangular wedges are found at the exposed outer edges of sheet fractures. Some are *in situ*, but others have apparently been displaced laterally. They may be due to gravitational loading and consequent rupture of exposed and unbuttressed edges of slabs. But they have also suffered distortion for some do not fit into the hollows they vacated. They are everywhere associated with sheeting planes. If the latter were laterally compressed, their radii of curvature would change. Differential movement and friction might cause the outer edges to be squeezed off in triangular wedges (Fig. 7; Pl. 17). Triangular wedges explicable in these terms are found in the crests of domical structures, for example at Mariz Quarry, near Guitiriz, northwestern Galicia. Some are due to overthrusting; others could be construed as due to tension in antiformal crests but the fractures are not typical of tensional strain; the wedges are most reasonably interpreted as due to compression (VIDAL ROMANI et al. 1994).

Orthogonal cracks

At first sight, some patterns of cracks seem comparable to polygonal cracking, but they are orthogonal rather than pentagonal or hexagonal and give rise to chocolate blocks or tablets (Pl. 18). They occur on plane faces in association with slickensides and recrystallization and hence on planes of dislocation. They commonly occur on several parallel planes at the same site. The orthogonal cracks are interpreted as due to shearing stress on surfaces that touch during dislocation. Orthogonal cracking is also developed on the extended crests of domical structures, for instance at Mariz Quarry in Galicia (VIDAL ROMANI 1989).

CONCLUSION

Anyone familiar with granite outcrops will acknowledge that many curves, flakes, cracks and hollows occur which do not fall into the categories considered above. There are several minor granite forms which await analysis. Nevertheless those discussed here account for most of the features seen in the field. Minor granite forms originate in a variety of ways, for, though many are due to weathering, some are initiated at the weathering front, others on exposed surfaces; some evolve in response to structural weaknesses, others on intrinsically homogeneous surfaces; some develop and diversify after exposure, others are destroyed; some are structural, others tectonic. In addition, it is clear that several well known minor granite forms are convergent, for they originate at different sites and evolve in different ways.

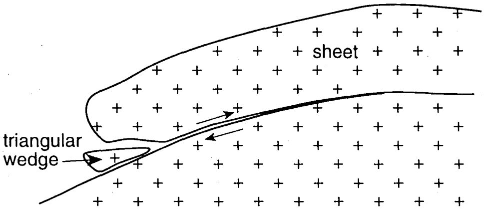
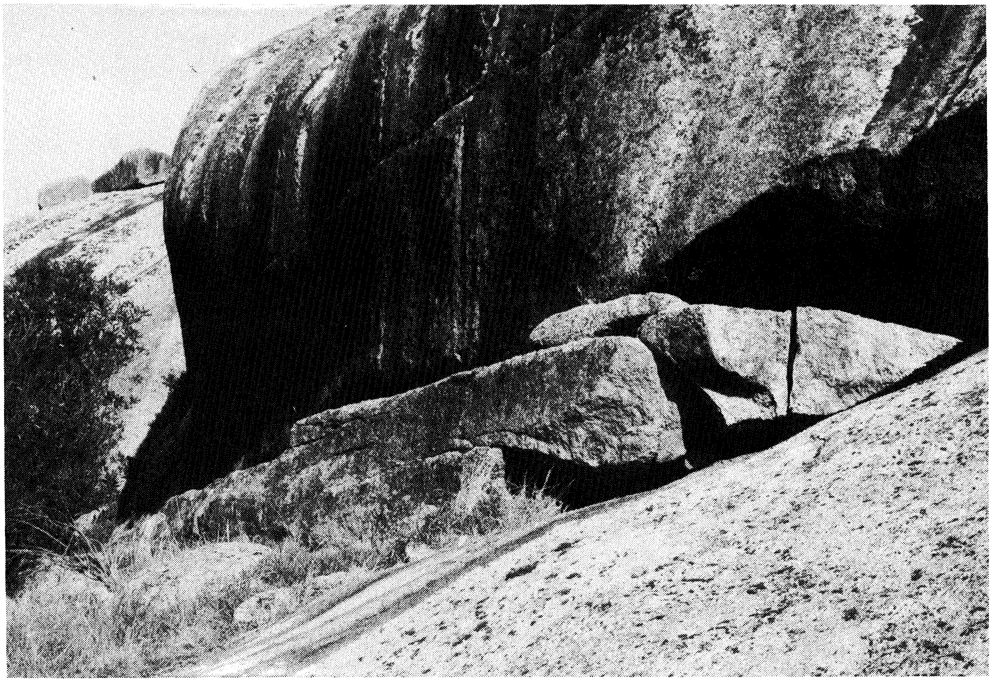
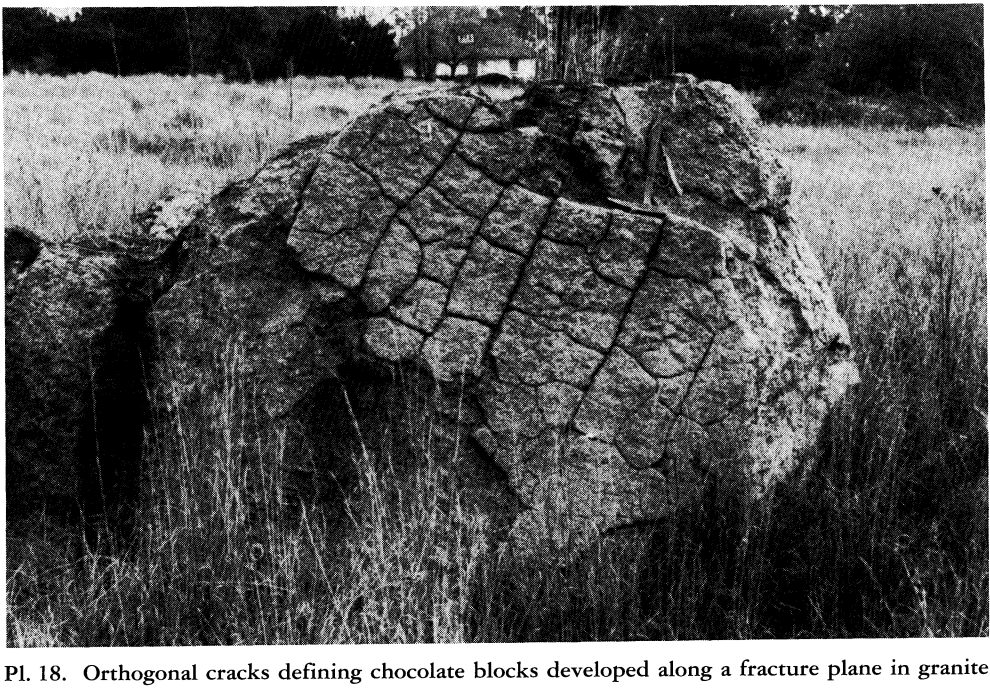


Fig. 7. Formation of triangular wedge by differential movement along a sheet fracture.



Pl. 17. Displaced triangular wedge on the eastern flank of Ucontitchie Hill, Eyre Peninsula, South Australia.



Pl. 18. Orthogonal cracks defining chocolate blocks developed along a fracture plane in granite, Buccleugh, near Johannesburg, South Africa.

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