LANDFORMS

GRANITE LANDFORMS OF THE WHEATBELT - A BRIEF REVIEW

C.R.Twidale and J.A.Bourne

GRANITIC rocks underlie all of the continent and crop out over about 15% of the land areas. Exposures typically give rise to plains interrupted by isolated hills or inselbergs ('island mounts'). Many of these hills are domical – they look like half-oranges set down on their cut surfaces - and are, increasingly, known as bornhardts after the German explorer of central Africa, Wilhelm Bornhardt, who in 1900 published a wonderful account of such forms in what is now Tanzania.

Tafoni or alcove formed inside a boulder on Kokerbin Hill.

Bornhardts are developed in massive rocks, typically granite (but also volcanics, sandstone conglomerate and limestone), with few open fractures. Their plan form is determined by steeply-dipping fractures, which also find expression in the orientation and shape of various minor forms A few outcrops have produced tall angular towers and blades of rock, as around Mt Manypeaks, east of Albany. The convex-upward profiles of bornhardts is associated with arcuate sheet fractures, which delineate massive slabs of rock and which, though widely attributed to offloading are basically due to crustal compression. Bornhardts occur in many climatic environments and many topographic settings but all are found in multicyclic landscapes in which there is evidence of more than one period of planation in the form of an overall stepped morphology.

A characteristic suite of minor landforms is developed on granite outcrops. It includes basins or gnammas, gutters and grooves; tafoni or alcoves and alveoles or small hollows, pitting or rough surfaces, polygonal cracking, flared slopes, A-tents or pop-ups (U.S.), triangular wedges of rock, and slipped slabs.

These various forms, major and minor, are of three types. Some originated below the land surface at the base of the soil or regolithic cover and subsequenty were exposed and modified: they are *etch* forms. Some have been shaped by processes active on exposed rock surfaces and are of *epigene* or subaerial origin. Others are due to earth movements and are *tectonic*.

Etch forms

('etch' - to eat away by chemical action).

Water, and especially soil or shallow groundwater charged with chemicals and biota, reacts with rock-forming minerals. Granite consists of interlocking crystals of quartz, feldspar and mica. Thus, granite is of low porosity and permeability, i.e. water does not easily pass through the body of the rock. On the other hand, granite is typically well-jointed, with orthogonal systems (three sets of joints disposed at right angles to one another) and arcuate sheet fractures delineating thick slabs of rock, well represented. If open, such fractures allow water penetration and are avenues of weathering. Feldspar and mica are altered (or weathered) to clays, and even quartz is eventually taken into solution. Where open fractures are numerous or where weathering has been active for a long time, the granite is transformed into a weathered mantle or regolith consisting of clay and quartz fragments or simply clay. The base of the regolith, the junction between regolith and fresh rock is frequently abrupt and is known as the weathering front.

Shallow groundwaters exploit weaknesses in the country rock. Fractures, for example, or rocks that are vulnerable because of their composition (e.g. an abundance of mica) are more rapidly weathered than massive compartments lacking mica. Thus the weathering front is frequently topographically differentiated both in gross and in detail. Nevertheless, long periods of weathering of well-jointed granite have in many places produced weathering fronts that are essentially planate,

LANDFORMS

interrupted only by isolated protuberances based in massive or resistant rock.

Thus, where for whatever reason the regolith has been eroded, the weathering front is exposed as a plain with isolated hills. The latter tend to be steep-sided because water percolating through the regolith flows down the slope of the projecting mass and it and so weathering are concentrated at the base. The inselberg landscapes so typical of the Wheatbelt and other parts of Western Australia have formed in this way. The plains are mainly soil covered, but rock platforms, some of them quite extensive, are common. That bornhardts originate beneath the soil cover is demonstrated by their exposure in artificial excavations and in valley-side slopes and by various other lines of evidence and argument.

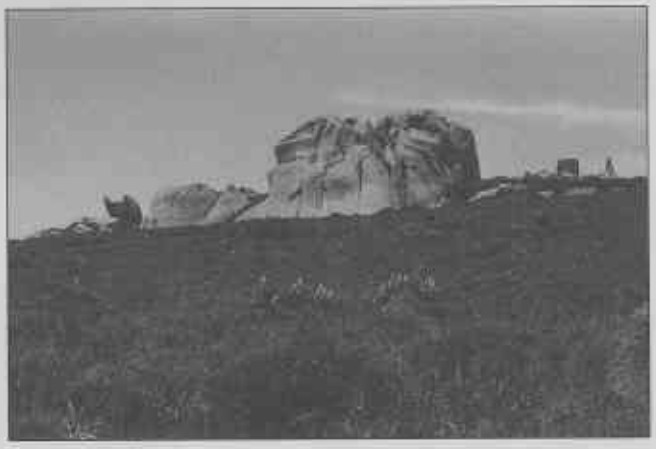
Subsurface weathering of the outer shells of bornhardts has produced block- and boulder-strewn nubbins or knolls (U.S.). They are common in the tropical north. Pronounced weathering of the margins of domes just beneath the surface has resulted in small steep-sided castellated hills or koppies (the 'tors' of Britain and other parts of Europe). They are rare in Australia but Castle Rock, near Mt Manypeaks, is a fine example and there are others in the Brookton area.

Such etch forms are also referred to as two-stage features for they have developed in two stages and have two ages: a period of subsurface weathering followed by exposure.

Many minor forms associated with inselbergs were also initiated at the weathering front. Steeply dipping fractures are exploited to form clefts or slots (U.S.), many of them with flared sidewalls due to intense subsurface weathering in the at the base of the slope. Sills or veins of relatively weak rock, such as pegmatite or coarse granite, are preferentially weathered, giving rise to shallow linear depressions and intervening linear ribs. Such differential weathering occurs at a variety of scales. Boulders are the result of the rounding of blocks derived from the break down of sheeting slabs (because corners and edges of blocks are more rapidly weathered than are plane faces). Pitting is due to the differential weathering of mica and feldspar leaving quartz and large feldspars in microrelief. Rock basins or gnammas are initiated by weathering of pods of feldspar or of fractures, and gutters by runoff along the weathering front.

Whether the hollows or alcoves known as tafoni (Italian, aperture or window; and alveoles are etch forms is debatable. At some sites (Kokerbin Hill, Uluru) tafoni are developed alongside flared slopes known to be of subsurface derivation. At The Humps, near Hyden, there is compelling evidence that basal tafoni undermining boulders were initiated below soil level. On the other hand, no tafoni have been exposed in excavations and the enlargement of the hollows, due to salt crystallisation, demonstrably occurs after exposure because at many sites flakes of rock can be seen in the ceilings and on the floors of the hollows.

Part of Kokerbin Hill, a typical Wheatbelt bornhardt with a wide range of minor landforms developed. Note the flared slopes and alcoves at the base of the slope.



Castle Rock a caste koppie with flared sidewalls located in the Mt Manypeaks district east of Albany. Note the angular remnant on the skyline and near it an ensate or blade-like form.

Tafoni at the base of Kokerbin Hill alongside flared slopes.

Epigene forms

Most granite forms were initiated at the weathering front but the exploitation of fractures to form clefts continues after exposure, and the saucer-shaped

continued on page 12

continued from page 11

LANDFORMS

depressions formed at the weathering front evolve into pits, pans or armchair-shaped hollows according to rock structure and slope. But patches of soil (especially if vegetated) retain moisture and seepage from such hollows supports black algal veneers that apparently protect the rock surface and in places have converted the floors of gutters into slightly raised ribs. Similarly, water drains into gnammas but the surrounding rock surface, especially if soil-covered, retains moisture so that weathering is faster there than around the basins. Hence the annular rims or rock doughnuts found at some sites.

Tectonic forms

Earthquakes affect all parts of the crust though some areas are more unstable than others. Brittle rocks like granite crack under pressure so that fault scarps, fissures and rock bursts are quite common. Of particular interest are the A-tents or pop-ups that develop during tremors and which are well represented on massive granite outcrops. Wedges that are triangular in cross-section also are formed by compressive stress, squeezed vertically adjacent to steeply-dipping fractures on platforms and gentle hillslopes. Larger wedges have been pushed out along sheet fractures on steep rock faces. Broken slabs have been shaken and have slipped downslope.

Forever or Everlasting hills

Perhaps the most astonishing feature of the Wheatbelt inselbergs is their apparent age. The rocks in which they are shaped are very old, varying between 2.3–3 billion years according to locality. Many of the inselbergs were shaped beneath the soil cover during the Cretaceous period about 70-130 million years ago and later exposed. The crests of a few, however, like The Humps, Boyagin Rock, Jilakin and Pingaring hills were evidently already hills during the Cretaceous for they stood above the plains that carried an ironstone (lateritic) soil at that time. They have withstood the elements for at least 70 million years, and in some instances longer. They are truly what Penny Hussey has called the Forever Hills. They are the 'everlasting hills' of Genesis (49: 26).

A-tent or pop-up on King Rocks.

Slipped slabs on King Rocks.

Further reading

Twidale C.R. 1982. Granite Landforms. Elsevier, Amsterdam.

Twidale C.R. and Bourne J.A. 1998 Origin and age of bornhardts, southwest Western Australia. Australian Journal of Earth Sciences 45, 903-914.

Twidale C.R. and Bourne J.A.2001. Field Guide to Hyden Rock. Including Wave Rock. Wave Rock Development Company.

Prof Rowl Twidale and Dr Jenny Bourne can be contacted at: School of Earth and Environmental Sciences, University of Adelaide, Adelaide SA 5005
E-mail:
rowl.twidale@adelaide.edu.au