ANCIENT LANDSCAPES
THEIR NATURE AND SIGNIFICANCE FOR THE QUESTION OF INHERITANCE

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INTRODUCTION

It is still widely believed that much of the world's scenery is youthful. Thornbury's (1954, p 26) asertion that little of the world's scenery is older than Tertiary and that most of it is no older than Pleistocene dies hard. Yet there is ample evidence, long recognised, that very ancient forms and surfaces (here the term "surface" is used in the sense of a planation surface, surface d'aplanissement or Einebnungsfläche) are an integral part of the contemporary landscape, and that such features are not restricted to the low latitude regions, though they are well preserved there. Many of them were formed in environments very different from that in which they now occur and are thus inherited. Paleosurfaces of many age ranges have been recognised. They can conveniently be considered as of three types - exhumed, epigene and etch.

EXHUMED LAND SURFACES

These are forms and surfaces that have been buried and then re-exposed. They range in age from Archaean to Pleistocene. For example, part of a late Archaean inselberg landscape is locally exhumed where the headwaters of the Yule River extend into the Chichester Range of the northern Pilbara in the north of Western Australia. Some of the ancient landforms can also be observed in unconformity. Proterozoic landscapes, some in the form of plains, others involving inselberg landscapes, have been re-exposed in many parts of Arctic Canada and Greenland (Cowie, 1961; Ambrose, 1964) and in northwestern Scotland (e.g. Williams, 1969) where old inselbergs and pediments are both exposed and preserved in unconformity. Glaciated pavements of various Pre-cambrian ages, once buried and now exhumed, have been reported from several of the world's cratons (see e.g. Harland, 1964; Perry and Roberts, 1968) and, of course, remnants of Late Palaeozoic glaciated pavements and related features of exhumed character are well known from various parts of Gondwanaland (see e.g. Crowell and Frakes, 1971). Watts (1903) long ago described fragments of a Triassic desert landscape from Charnwood in the English Midlands, and barchans of similar age are preserved beneath basalt flows in the Parana Basin of South America (Almeida, 1952).

Exhumed surfaces and assemblages of essentially Late Jurassic (or earliest Cretaceous) age are widely preserved. Such features are present, for example, at the margins of the Australian Craton - in northwest Queensland (the same surface has been traced into the western slopes and even into the higher areas of the Eastern

Uplands in north Queensland): the Tindal area of the northern N.T.; the Darwin area; the northern Flinders Ranges, South Australia; the northern Pilbara and Geraldton region of the central west coast of Western Australia (Twidale, 1956, 1984; Woodard, 1955; Twidale, 1981a; Jack, 1915; Wopfner, 1964; Playford et al, 1970). Exhumed and partially exhumed inselberg landscapes of this age can be seen east of Port Hedland in the north of Western Australia. Passarge (1895) argued that the Inselberglandschaft of Rovuma type is exhumed and of early Mesozoic age. Similarly, the famous inselberg landscapes of East Africa may in part be exhumed from beneath a Cretaceous cover (Willis, 1936). Various exhumed minor granite forms of Cretacious age have been described from southern Sweden (e.g. Lidmar-Bergström and Rapp, 1978; Magnusson and Lidmar-Bergström, 1983). Exhumed inselberg landscapes or slightly younger age (pre Eocene) occur in northern Nigeria where bornhardts and nubbins have been exposed as the Benue Sandstone has been stripped away (Falconer, 1911).

Inselberg landscapes of pre Piocene age are in process of re-exposure in the Murray Gorge in South Australia and pre (?late) Pleistocene inselbergs, including a suite of minor forms that are also being exhumed, from beneath Pleistocene dune calcerenite in northwestern Eyre Peninsula (Jack, 1912; Twidale and Bourne, 1976; Twidale and Campbell, 1984)

Clearly such exhumed features are especially significant in shield areas. The most important are related to major periods of world-wide marine transgressions of which the late Jurassic and early Cretaceous is a notable and geomorphologically significant example. The nature of the surfaces is frequently difficult to ascertain, for only rarely is there a saprolithic or sedimentary veneer preserved at the unconformity (but see Barbier, 1967). Most likely there has been marine trimming whatever the nature of earlier development. In places, the unconformity appears to be remarkable smooth, but elsewhere, as in the southern suburbs of Darwin, it is undulating. On the other hand, the preservation of such exhumed surfaces presents few difficulties, for they have been protected by the younger cover that has been eroded or is in process of erosion. Some exhumed features clearly evolved in environments different from those in which they now occur. This is most apparent in the case of those exhumed glacial forms now located in tropical or subtropical regions, but the observation applies equally where, for instance, marine features are exposed in continental areas.

EPIGENE PALAEOFORMS

These are surfaces that have apparently been exposed since their formation; they have not been buried, but survive despite their considerable antiquity. One of the oldest, if not the oldest, dated palaeosurfaces is preserved in the Gulfs region of South Australia. A laterite-capped high plain or plateau occurs on Fleurieu Peninsula, the Mount Lofty Ranges, the Lincoln Uplands (southern Eyre Peninsula), and on Kangaroo Island. On Fleurieu Peninsula and the Mount Lofty Ranges the lateritic high plain is defined by faults. Marine sequences of Eocene-Miocene age occupy fault angle depressionsl marginal to the uplands, suggesting that the laterite and the surface on which it developed predates the Cainozoic. And lateritic fragments are reported from the basal Tertiary sequences (Campana, 1958; Glaessner and Wade, 1958).

On Kangaroo Island the laterite is developed on Precambrian, Cambrian and Permian strata. To the west of Kingscote the laterite was truncated and a basalt extruded onto the plain cut in mottled and pallid zone materials and standing lower than the main lateritised high plain. The basalt has been radiometrically dated as of Middle Jurassic age. Thus the laterite and the surface on which it developed postdates the Permian but predates the Middle Jurassic: other stratigraphic evidence suggests a Triassic age (Daily, Twidale and Milnes, 1974). Near Penneshaw a similar basalt rests on ferruginous zone laterite (Tilley, 1921; Daily, et al, 1979). The lateritised land surface has not been preserved by burial. Not only is there no evidence for such an event, but the sandy A-horizon is widely preserved and the mineralogy, granulometric characteristics and textures are consistent with its being a pedogenic feature; there is no possibility of introduction or transport. The lateritic and bauxitic high plains of the Darling Ranges, in the southwest of western Australia are, on the stratigraphic evidence and according to Fairbridge and Finkl (1978), of Cretaceous and Eocene age. Laterite-cappecd land surfaces of Jurassic age are reported from West Africa (Beaudet, 1978) and southern India (Demangeot, 1978).

The ancient surfaces described from the Drakensburg of southern Africa are of Mesozoic age, for they stand well above lateritised plains (African Surface) that are of early-middle Tertiary age (King, 1962; but see also de Swardt and Bennet, 1974).

Another ancient landscape is preserved in the southern Flinders Ranges of South Australia. The Flinders Ranges is a fold mountain belt of Appalachian type. An exhumed late Jurassic surface is preserved in the northern part of the upland, and remnants of a high plain interpreted as of similar age, but possibly graded to the Jurassic or Early Cretaceous shoreline, dominate parts of the central Flinders and are also recognised in the southern regions. Following recession of the Cretaceous sea, streams again dissected the folded sedimentary sequences and the present ridge and valley topography, determined by the pattern of the Palaeozoic folds, was formed. That pattern had evolved by the Eocene (Twidale, 1966, 1981a), for Cainozoic sediments laid down in a lake that during the Eocene extended over the northern Willochra Basin (an intermontane basin eroded in a faulted anticline) tongue up valleys eroded between the quartzitic ridges, showing that the framework of the present relief was already in existence during the Eocene; it has changed very little since. And extrapolating, there is no evidence to suggest that the pattern of ridge and valley developed throughout the Ranges is not of similar antiquity.

In the arid interior of western Australia the major drainage features now represented by strings of salinas date from the late Cretaceous and early Tertiary (Van de Graaf et al, 1977). In the southeast, for instance, the rivers drained to the Eocene shoreline at what is now the margin of th Eucla Basin (Nullarbor Plain).

Less dramatic (only because they are younger) but more extensive land surfaces preserved by ferruginous or siliceous duricrusts occur in many parts of the world. In Australia such lateritised and silcreted land surfaces, of essentially early-middle Tertiary age, occupy very large areas of the north and centre of the continent (see Twidale, 1983). Early Tertiary drainage channels preserved by silcrete deposits persist in the north of South Australia (Barnes and Pitt, 1976). The Ooldea and Barton ranges, at the northeastern margin of the Nullarbor Plain-Eucla Basin region are coastal foredunes of probabvly Miocene age developed in relation to a marine embayment and preserved by virtue of a calcrete capping (M. Bembow, pers. comm.).

(Many other ancient land surfaces have been recognised and dated, as, for example, in the Cleve Hills, Gwaler Ranges, and Arcoona Plateau in South Australia (see e.g. Twidale, Shepherd and Thomson, 1970; Twidale, Bourne and Smith, 1976; Twidale and Campbell, 1985a) and the MacDonnell and other fold ranges of central Australia (e.g. Twidale, 1980). Some granite inselbergs are thought to be of considerable antiquity from correlations between their stepped morphology and dated duricrusted remnants (Twidale and Bourne, 1975a; Twidale, 1982a, b, c). The basic forms of Ayers Rock and the Olgas are demonstrably of at least Eocene age (Twidale and Harris, 1977; Twidale, 1978a; Twidale and Bourne, 1978). But in these and other instances very little in the way of saprolith remains and it is almost certain that the forms are of etch character - see below).

These very old epigene forms present obvious problems, for their survival is difficult to explain (Twidale, 1976a). Positive feedback effects, protection in interior situations, compression of bedrock and unequal erosion all ease, but do not entirely resolve, the difficulty. Nevertheless, as ancient landforms exist, they must be possible.

Long survival has several results. Where escarpments, whether of structural or erosional origin, are bing worn back only slowly, as in aridity or late in the dissection of plateaux (see e.g. Twidale, 1978b), scarp foot weathering causes a characteristic suite of minor forms to develop in the piedmont zone. On massive rocks flared slopes, platforms and enclosed linear or annular depressions are formed (see e.g. Clayton, 1976; Twodale, 1962. 1982a). In sedimentary environments scarp foot valleys, false cuestas and inverted channels develop. Gully gravure (Bryan, 1940; Twidale and Campbell, 1985b) and silcrete development take place, the latter a sure sign of slow landscape change (Hutton et al, 1972). More importantly, such scarp foot weathering and erosion ensure that scarps tend to a maximum steepness commensurate with stability (Twidale, 1960, 1967; Twidale and Milnes, 1983). On a regional scale long-continued deep and intense weathering mainly through the agency of water, though with significant contributions from microbial organisms (see Loughnan, 1969; Trudinger and Swaine, 1979), allows the saprolith to become thoroughly leached. It is no accident that the soils of ancient Australia and other old tropical landscapes are notoriously low in such solubles and phosphorus and various trace elements, and that they are readily eroded. The saprolith frequently becomes differentiated, and though most weathering can be regarded as geomorphologically negative or destructive, long-continued weathering allows the concentration of definite zones of horizons of minerals that, on desiccation, become remarkable tough. Such positive or constructional weathering effects are often overlooked , but they loom large in any consideration of the tropical lands. Geomorphologically such duricrusts not only form caprocks and so give rise to plateaux and in some areas lead to regional inversion, but they also form morphostratigraphic markers (see Twidale, 1981b, 1983). Another important geomorphological effect of deep, intense and long-continued weathering is the formation of a pronounced weathering front (Mabbutt, 1961a), an abrupt transition from friable weathered material to intrinsically fresh bedrock,. This is the basis of an assemblage of forms, etch forms, that are increasingly recognised as of prime significance in the modern landscape.

ETCH SUBCUTANEOUS AND INTRACUTANEOUS FORMS

An etch surface or form is one that was initiated as part of a weathering front and has then been exposed through the stripping of the saprolith. Such features range in scale from boulders and minor forms like basins and Rillen to plains of regional extent. Their morphology reflects the exploitation of every structural nuance by weathering agents, and expecially by moisture attack. The stripping of the saprolith, on the other hand, may be achieved by a variety of agencies - fluvial, glacial, marine.

The term "etch" originates with Wayland and Willis, but the essence of the idea was published much earlier. Thus, Hassenfratz (1791) and Logan (1849, 1851) recognised that minor granite forms had their origin in the subsurface at the weathering front (though they did not use the term). And Jutson (1914, see Brock and Twidale, 1984) was clearly aware that the New Plateau of the southwest of western Australia was an exposed weathering front, and that it is due to the erosional stripping of the lateritic saprolith that underlies the Old Plateau.

Though widely used (and etymologically apposite, for to etch is to engrave by means of a corrosive fluid), it is not certain that the term "etch" coined by Wayland (1934) and Willis (1936) is the most appropriate for describing the realities of nature. The saprolith is, in many areas, not a simple feature. In particular, resistant or potentially resistant horizons develop within the saprolith and are later exposed as surfaces or forms. For this reason alone it may be preferable to use Zwittkolvits'

(1966) evocative term "subcutaneous" for features that have evolved at the base of the saprolith (the true weathering front) and apply the term "intracutaneous" to those that are initiated within the saprolith. Thus, strictly speaking, many laterite-capped plateaux are etch or intracutaneous forms, for the A-horizon has most commonly been stripped to expose the ferrugin ous zone on which the land surface has stabilised. Intracutaneous forms originating deep in a lateritic saprolith occur in the Daly Basin, N.T. where the Bradbury Surface is coincident with the exposed ferruginous zone, but the Maranboy Surface, for instance, reflects the exposure of a silicified horizon within the profile (Wright 1963). But whaever terminology is used, the essence of etch/subcutaneous and intracutaneous forms is that they result from a structural contrast resulting from the weathering of the country rock: the saprolith is in whole or in part markedly less resistant than the fresh country rock.

Büdel (1957, 1977, 1982) has described etch surfaces from several parts of the world. Jutson's interpretation of the nature and relationship of the New and Old plateaux of Western Australia has been corroborated by later workers (Mabbutt, 1961b; Finkl and Churchward, 1973). The summit surface of the Mount Lofty Ranges is of similar type (Twidale and Bourne, 1975b; Twidale, 1976b), and various etch surfaces occur in the Mid North of South Australia (Alley, 1973). The prominent Hamersley Plateau is of etch type, though the surface is, in fact, morphologically so complex that it is best referred to as a Landscape (Twidale, Horwitz and Campbell, 1985). Pockets of pisolitic iron remain on the surface, but most of the weathered ironstone has been eroded. Some of the iron was re-precipitated in valley floor deposits (the Robe River Pisolite) that are of Eocene age. Thus, the earlier Hamersley Landscape is in one sense a Mesozoic feature: that is when the deep weathering occurred. The erosion of the saprolith, however, occurred in the early Tertiary. Etch forms have two ages: an age related to the period of deep preparatory weathering, when the weathering front was formed, and an age relating to the period of exposure, when the saprolith was stripped away to expose the front.

Several interpretations have been offered in explanation of granitic inselbergs of which the bornhardt is the basic form, and several have local applications, but most bornhardts are structural landforms that owe their resistance to weathering and erosion to the massive character of the compartments on which they are developed (Twidale, 1982 a and c). They originated in the subsurface as structurally determined projections of the weathering front (Falconer, 1911; Linton, 1955). It is no accident that the classical <u>Inselberglandschaften</u> are found in the interiors of the old supercontinents, where the rate of landscape change was slow, and there was ample time for deep differential subsurface weathering - first of the two stages involved in inselberg development. The inselbergs have been exposed by various agencies, including ocean waves and glaciers, though in this regard most are fluvial.

As might be expected in view of the origin of the host masses, many minor forms characteristic of granite outcrops are demonstrably initiated at the weathering front (Twidale, 1982; Boyé and Fritsch, 1973; Twidale and Bourne, 1975c, 1976).

Towerkarst may be of similar character. Certainly, minor features associated with limestone towers are suggestive of subsurface initiation and of the phased or episodic exposure of the major forms (see e.g. Sweeting, 1950; Lehmann, 1954; Jennings, 1976; Wilford and Wall, 1965; see also Twidale and Bourne, 1975a; Twidale, 1982a, b, and c).

Several features that are otherwise difficult of explanation may be of etch character. Thus, the Carnatic is an extraordinarily wide coastal plain in southeastern India. According to Cushing (1913) it averages some 60 Km width and is clearly of marine origin in an immediate sense, with spits and bars and what are construed as marine caves and stacks preserved near the inland margin (Cushing was not unduly influenced by the fact that the Ghats rise from the plain, and that the word "ghat" means water-steps - landing stairs from the body of water: there is apparently real evidence of the marine origin of the Carnatic). Yet the plain is altogether too wide to be due wholly and simply to marine planation. Very wide (up to 200 m from cliff base to outer edge) platforms in granite on northwestern Eyre Peninsula have been explained as etch forms, with the old saprolith stripped by wave action (Twidale, Bourne and Twidale, 1977). Could the Carnatic be of similar type, with marine agencies responsible for the erosion of a saprolith (under conditions of relative gradual rise of sealevel) and the retouching of the surface? Similarly, is the Labrador Plateau basically and etch surface due to the bulldozing (Boyé, 1950) of the preglacial saprolith by the Pleistocene ice sheets?

DISCUSSION

Ancient land surfaces are an integral part of the modern scenery. From an economic point of view they imply leached soils or, in the case of etch surfaces, only thin soils, with all that such conditions imply for agriculture, soil erosion, and so on; and also the possibility of mineral concentrations. They pose problems for all the conventional models of landscape evolution (Twidale, 1976). The fact of inheritance also poses the question as to which morphogenetic system should be applied when explanations of landscapes are sought. Ancient surfaces and forms are especially well developed and preserved in the shield lands, but they are not restricted to them, for palaeoforms are well represented in orogenic and platform area. Etch forms and surfaces are best developed in the protected interiors of continents or of former supercontinents. That regional drainage patterns may be inherited from such old planate surfaces is an importance consideration in the search for minerals (including water). Such palaeoforms frequently introduce an alien or exotic element to the landscape, for they developed in conditions different from those in which they are now found. Inherited glacier features are an obvious example (though caution is necessary in interpretation in some instances (see e.g. Daily, Gostin and Nelson, 1973; and Agassiz, (1865) and Romanes (1912). Torrid climatic conditions diminated the later Phanerozoic and many of the forms and surfaces reflect weathering and erosion under such warm humid conditions. Ayers Rock and the Olgas, for example, had their origins in the warm humid conditions of the Eocene, though they now stand in the desert plains of central Australia. Silcrete and laterite are also torrid forms, though silcrete especially is preserved in aridity (HUtton, et al, 1978; Wopfner, 1978).

Etch planation introduces another aspect to the question of inheritance, however. An etch, or subcutaneous, surface or form is an exposed weathering front, developed in the subsurface as a result of moisture (and biotic) attack. It develops regardless of the climate at the surface: the saprolith varies in thickness and character according to climate, but the nature of the front, it is suggested, basically reflects structure, and the effects of moisture and biotic action. It is largely independent of surface precipitation and temperature. Inselbergs, boulders, and minor basins, Rillen, etc. (see e.g. Boyė and Fritsch, 1973; Twidale and Bourne, 1975) are developed at the weathering front in a range of climatic conditions. The form of the front is retained regardness of the nature of the exposing agency. It is suggested that etch developments impose a significant commonality or azonality on the landscape. Together with structural control (which is in any case a prominent factor in subsurface weathering) it imposes a significant uniformity on landscapes, major elements of which persist from Tertiary and even earlier times, despite the effects of the ephemeral late Cainozoic glaciations.

Many landforms have their origins not at the land surface but at the weathering front. This is as true of gross morphology as of detailed sculpture. Not only hills and plains, but basins, gutters, elegant flares and linear depressions are initiated there. Alveolar weathering, which is of particular interest to students of Mars (Garvin, et al, 1981), also appears to be associated with iron concentrations at the weathering front.

The processes active at the weathering front are crucial to our understanding of the shape of much of the earth's surface. And whatever their precise character, water and microbial activities are prominent factors all over the world, so that the nature of the exposed fronts is similar over wide areas. This commonality adds another dimension to the question of inheritance.

Overall, then, the surface of the continents needs be viewed not as a simple feature comprehensible in terms of present or recent climatic conditions but rather as a mosaic comprising segments of different ages and origins, some of them of considerable antiquity. The events of the late Cainozoic loom large in our thinking, but the conditions then prevailing were ephemeral. Certainly lowerings of sealevel caused dissection and allowed dessiccation and hardening of some weathering horizons to produce duracrusts (though this would have occurred anyway though for different reasons). Otherwise landscapes were modified rather than drastically altered. The basics of much contemporary scenery date from earlier times and conditions.

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