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ASPECTS OF THE DISTRIBUTION AND DISINTEGRATION OF SILICEOUS DURICRUSTS IN ARID AUSTRALIA[1]

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ABSTRACT

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Topographic, chronologic and climatic implications of siliceous duricrusts that are widely developed and preserved in inland arid Australia are discussed. Plateaux capped by siliceous duricrusts are characteristic, but are probably manifestations of large-scale relief inversion. Such duricrusts have been widely used as morphostratigraphic markers, and despite many possible difficulties, these interpretations may well be valid; but caution and consideration of the local evidence are necessary. The climatic context of silcrete both from the viewpoint of its formation and its degradation is uncertain. It may be that the various solutional features developed on these siliceous materials offer evidence on this point complementary to that derived from stratigraphic studies.

INTRODUCTION

Observations of siliceous duricrusts were recorded during the early exploration of the arid interior of Australia, where they form caprocks of many of the mesas that are typical of these regions. Thus in July 1840, E. J EYRE, pressing north into the inland, reached the southwestern part of the Lake Eyre basin, just north of the Flinders Ranges (Fig. 1) whence he reported a region characterised by 'many very singular looking table-topped elevations from 50 to 300 feet in height and with steep precipitous sides which were red, with the ironstone above and white, with a substance like chalk, below.' (EYRE, 1845, pp. 85-96). In 1845, CHARLES STURT was exploring far to the east and northeast of EYRE's tracks and, on January 16 of that year, approached ranges that he described as of 'singular appearance': 'The geological formation of these hills was perfectly new, for they were now composed almost exclusively of indurated or compact quartz. The hills themselves no longer presented the character of the ranges, properly so called, but were a group of flat-topped hills. . .' (STURT, 1849, p. 239). Despite EYRE's reference to 'ironstone' and a chalk-like material, what he had seen was a siliceous caprock with iron-stained surfaces and an underlying weathered profile composed of bleached kaolinitic material. The feature that STURT described (Fig. 2) was a group of mesas capped by the siliceous duricrust that is widely preserved in South Australia and southwest Queensland (Fig. 3).

The observations of these early explorers marked the beginning of a long period of geological, geomorphological and pedological concern with siliceous duricrusts in Australia. This interest has manifested itself in the writings of workers from JUTSON (1914), JACK (1915) and WOOLNOUGH (1927), to those of WHITEHOUSE (1940), WILLIAMSON (1957), STEPHENS (1961, 1964, 1971) and the various authors who contributed to a volume specifically concerned with Australian silcretes (LANGFORD-SMITH, 1978).

Originally coined by LAMPLUGH (1902; see also 1907), the term 'silcrete' has been applied in Australia to sediments, soils or saprolitic material indurated by secondary silica and, most commonly, with distinctive porphyroclastic texture. Other features of the classical silcrete are a conchoidal fracture, a vitreous sheen, and a range of colours including grey, red, yellow to yellow-brown, and white. However, there is in fact a considerable variety of silica-cemented regolithic materials occurring in association with such silcretes (MILNES & TWIDALE, 1983). They are developed in similar topographic situations and occur contiguously on the same landsurfaces.

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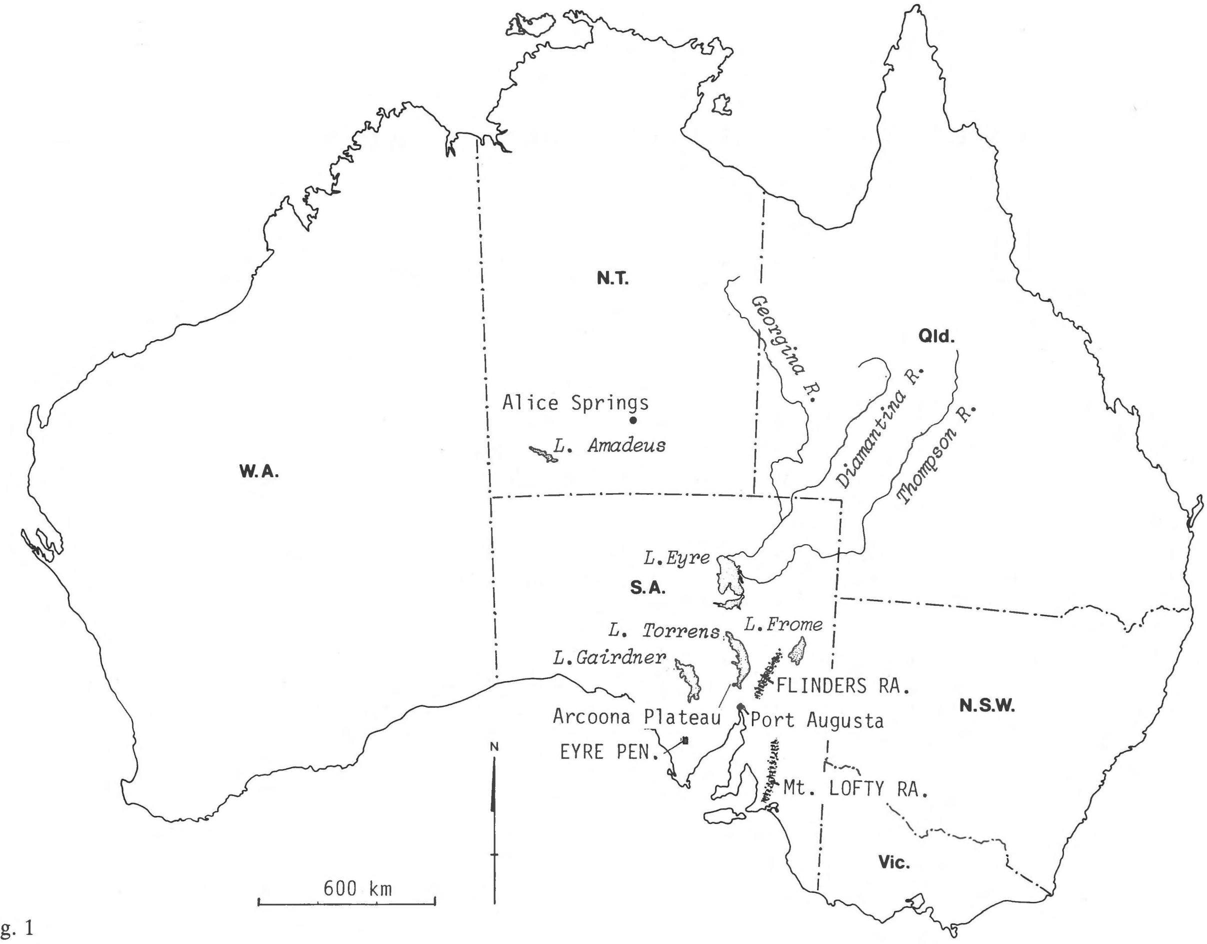

Fig. 1
Location map.

Though different in morphological and textural detail, such silica-indurated materials appear to be genetically related. Variously, or together, they comprise the siliceous duricrust of arid inland Australia.

This paper is concerned with the nature of the siliceous duricrusts in Central Australia, and with their disintegration. The duricrusts are generally conceded to be relic features, but consideration of their formation and degradation has important implications with regard to the tectonic, climatic and geomorphic events of the Cenozoic, and particularly the later Cenozoic. Here, data is drawn mainly from two areas: the southern Arcoona Plateau and Tent Hill region near Port Augusta, composed essentially of flat-lying Proterozoic quartzites, siltstones and shales that have been dissected to give a typical plateau and pedimented plain country; and the Emily and Todd plains and contiguous pediments of the MacDonnell and Ooraminna ranges located east and south-east of Alice Springs and developed in folded Proterozoic and Early Palaeozoic rocks.

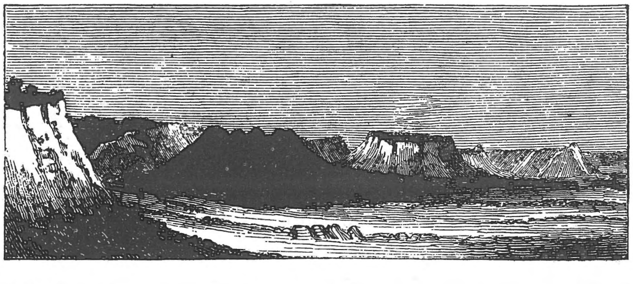

Fig. 2
Silcrete-capped mesas sketched by Sturt in northeastern South Australia in 1845. (From cut in STURT, 1849).

TOPOGRAPHIC SIGNIFICANCE OF SILICEOUS DURICRUSTS

Details of the nature and speculations concerning the origin of siliceous duricrusts in Cenozoic landscapes of arid Australia are given elsewhere (MILNES & TWIDALE, 1983). By their very nature, these materials are resistant to both physical and chemical degradation, particularly in the arid conditions that obtain in Central Australia at the present time. For this reason, siliceous duricrusts form caprocks. Where they remain essentially flat-lying, as is most frequently the case, the duricrusts give rise to plateau, mesa and butte forms (Fig.

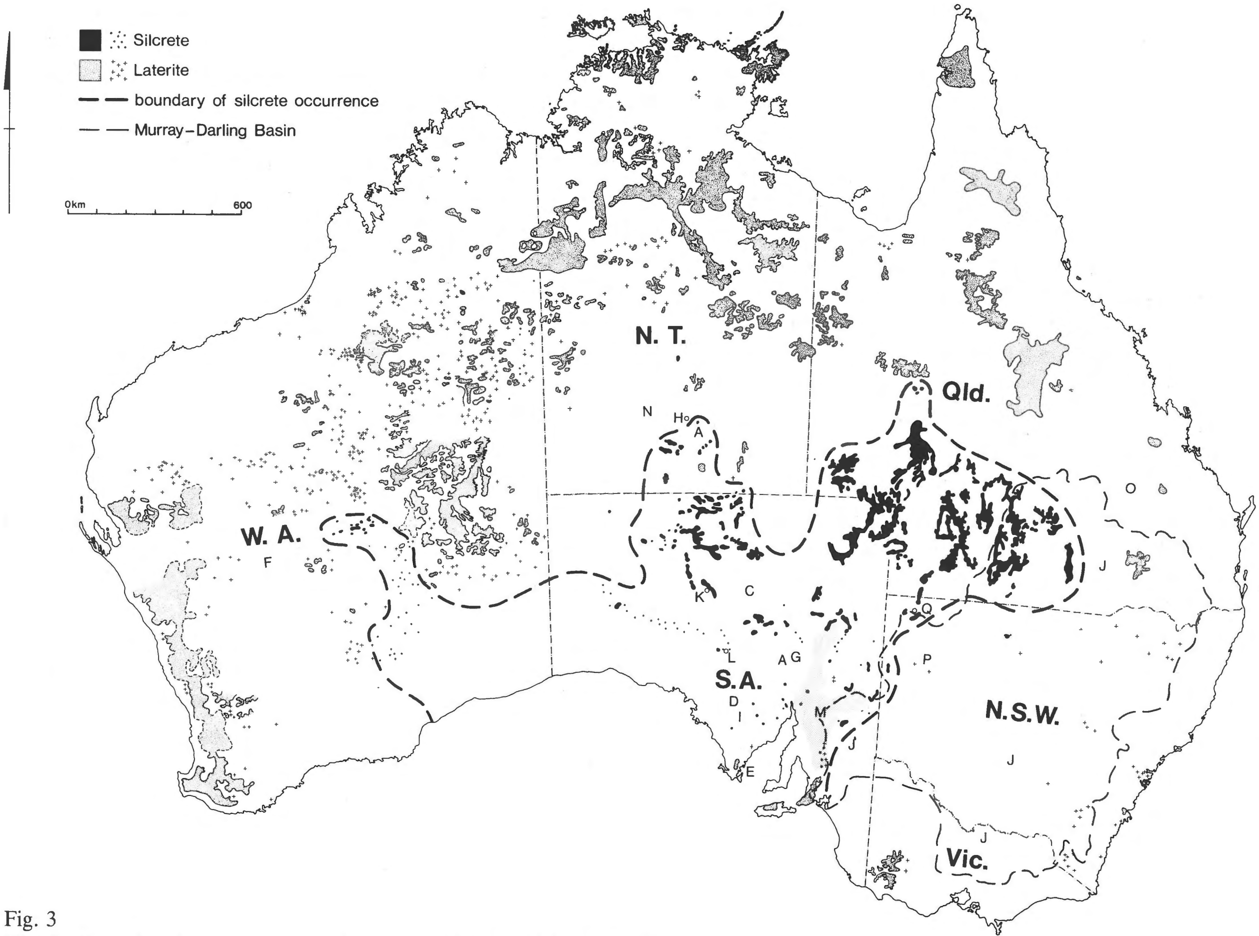

Fig. 3
Distribution of major occurrences of silcrete and 'laterite' in Australia.

4). On the other hand, in southwestern Queensland (WOPFNER, 1960; SPRIGG, 1963; SENIOR & MABBUTT, 1979) and in the northeastern piedmont of the Flinders Ranges (WOPFNER, 1960; CALLEN, 1983), the silcrete is folded or warped and gives rise to cuestas and other ridge forms, depending on its dip.

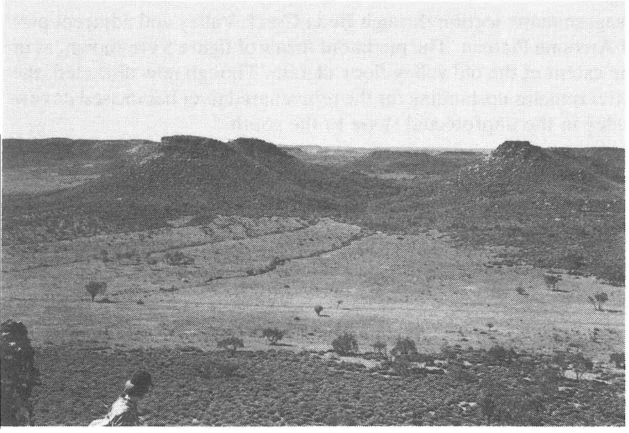

Fig. 4
Typical mesas with caprocks of silicified Miocene limestones along northern margins of Ooraminna Ranges, N.T.

Cuesta forms are also developed in present and former piedmont zones (TWIDALE ET AL., 1970; TWIDALE & MILNES, 1983) where silcrete acts as a protective capping to old footslopes, now dissected and typically preserved as flatirons separated from the present escarpment by incised depressions or by scarp foot valleys (Fig. 5). In such piedmont developments, the silcrete is rich in titania (as anatase) and in some

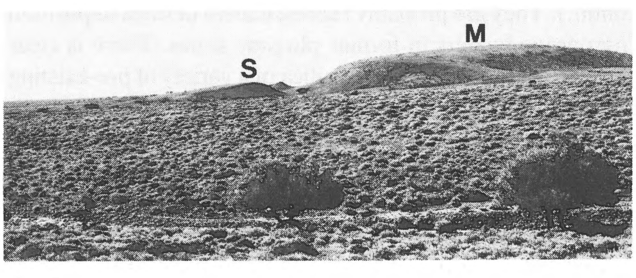

Fig. 5
Mesa (M) of Precambrian quartzite underlain by shale, southern Arcoona Plateau, S.A. The upper surface is of probable Cretaceous age. In the piedmont zone (left), a scarp foot valley has been eroded in weathered shale of the former footslope, isolating silcrete-capped cuesta forms (S) from the backing escarpment.

samples attains a concentration sufficient for it to constitute the cement (HUTTON ET AL., 1972; HUTTON ET AL., 1978; MILNES & HUTTON, 1974; MILNES & TWIDALE, 1983). Though the amount of titania varies, it is consistently concentrated in the piedmont. At Beda, in the southern Arcoona Plateau, for example, it comprises up to 27% of some samples, in contrast with 2-3% in silcretes preserved a few score metres downslope.

In addition to their direct and obvious, though important, effect on landscape development, siliceous duricrusts have also been used as morphostratigraphic markers by reference to which landscapes and landforms have been dated. Such applications are based on the assumption that silcretes were formed at or near ancient landsurfaces, and that in a given region silcretes of different ages developed sufficiently distinctive characteristics to permit their separate identification (e.g. WOPFNER & TWIDALE, 1967). CALLEN (1983), however, has suggested that these inferences may not everywhere hold true, and should be treated with caution. Notwithstanding such cautionary notes, and although there are, understandably, local and regional variations in the age range of siliceous (and other) duricrusts (e.g. LEITH, 1925; FAIRBRIDGE & FINKL, 1978), their use as time markers appears to be generally consistent with the range of chronological evidence (e.g. TWIDALE ET AL., 1976). But each occurrence should be evaluated on its merits and in light of the local evidence.

JUTSON (1914) and JACK (1915) both realised that silcrete was a relic feature and suggested that it formed on a surface or surfaces of low relief. This point was elaborated by WOOLNOUGH (1927) who specifically associated duricrusting with a cycle of peneplanation which he thought had reduced much of Australia to a surface of low relief by the Middle Tertiary. For the most part, this conclusion seems to hold, though SENIOR & SENIOR (1972) and SENIOR & MABBUTT (1979) argue that some silcretes may not be related to former landsurfaces, but may rather have developed through induration of materials at depth below the landsurface by silica deposited from mobile groundwaters. In support of this interpretation, thin layers of silica-indurated sands have been encountered during the drilling of Cenozoic sediments and underlying weathered Precambrian bedrock on Eyre Peninsula (M. J. WRIGHT, pers. comm.). They are probably representative of silica deposition from groundwaters in former phreatic zones. There is clear evidence of the induration by silica of a variety of pre-existing materials, and MABBUTT (1980) and CALLEN (1983) have both pointed to the importance of geohydrological factors (including the permeability of the host material) in controlling the nature of the silcrete formed, with particular regard to the structural state of the silica cement.

AMBROSE & FLINT (1981) were able to reconstruct ancient sedimentary environments in northern South Australia where they described silicified arenites forming the shoreline ridges of a regressive Miocene lake, as well as contiguous silicified fluvial conglomerates and lacustrine carbonate sediments. Other work (TWIDALE ET AL., 1970; HUTTON ET AL., 1972; HUTTON ET AL., 1978; TWIDALE & MILNES, 1983; MILNES & TWIDALE, 1983) has concentrated on studies in Cenozoic piedmont and lake environments, though other topographic settings have not been ignored. Thus, elongate duricrusted plateaux form the divides or watersheds between river valleys. The duricrust is composed of silicified sediments (including conglomerates and gravels) of fluvial origin, and the present divides thus appear to represent former valley floors (cf. BEAUDET, 1978).

By way of local exemplification, silicified fluvial sediments in the Beda Valley are well preserved though they are dissected. The contemporary drainage (Beda Creek) flows north of the duricrusted zone and is incised in the unprotected Precambrian shale of the lower pediment surface (Fig. 6). In the Lake Eyre basin, on the other hand, silcrete-capped plateaux form the divides between such major rivers as the Diamantina, Thompson, and Georgina. The exposures of duricrust are so widely preserved that it is tempting to link them in the mind's eye and to suggest that they are remnants of a once contiguous surface of low relief. But the silicified duricrusts are of alluvial origin, and again, entire divides have been eroded. As a result of recurrent tectonism, streams were rejuvenated during the later Tertiary, but instead of the then main streams cutting into the silicified valley floor sediments and maintaining their pre-eminence, competitors active on the former divides were able to incise more rapidly and became the dominant elements of the centripetal drainage system focussed on Lake Eyre. The old watersheds were eroded to become the present valleys, leaving the ancient valley floors as the present silcrete-capped plateaux: relief inversion on a grand scale (Fig. 7).

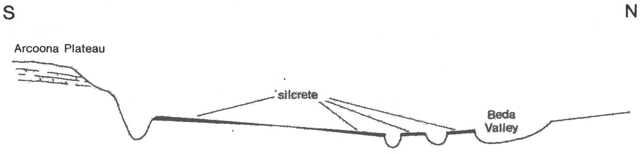

Fig. 6
Diagrammatic section through Beda Creek Valley and adjacent part of Arcoona Plateau. The piedmont forms of figure 5 are shown, as in the extent of the old valley-floor silcrete. Though now dissected, the latter remains upstanding for the rejuvenated river has incised its new valley in the unprotected slope to the south.

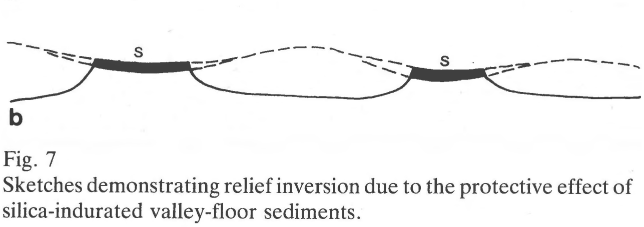

Fig. 7
Sketches demonstrating relief inversion due to the protective effect of silica-indurated valley-floor sediments.

Relief inversion, albeit in a rather different context, is also evidenced in the northern Ooraminna Ranges. There, the many mesas are capped by Miocene sediments of both lacustrine and probable fluvial origin (MADIGAN, 1932; LLOYD, 1968; MCMICHAEL, 1968; WELLS ET AL., 1970), which overlie folded Palaeozoic rocks that are commonly weathered and bleached. The caprock sediments include fossiliferous limestones that are irregularly impregnated and replaced by silica, as well as silica-indurated quartzose siltstones and sandstones. It is clear that the sediments relate to a higher Miocene base level of erosion in the region, and that the remnants that are preserved in part by virtue of induration by silica were in fact the depressions of earlier times.

On the northern side of the Emily and Todd plains, there are many mesas capped by a variety of silicified clastic sediments and possible soils (MILNES & TWIDALE, 1983; Fig. 8). Most of the mesas are detached from the backing Precambrian or Early Palaeozoic bedrock escarpments, but in a few instances there is physical continuity such that the original piedmont angle is still preserved (Fig. 9). In general terms, these mesas stand at about the same altitude as their counterparts in the northern Ooraminna Ranges, indicating a Miocene plain of very low relief and very low gradient. There are, however, variations in height of the duricrusted remnants preserved in the MacDonnell piedmont (Fig. 10) that appear the be related to the topography of the ancient valley-side alluvial or colluvial deposits. Because of their protective cappings, relics of the piedmont appear to have been preserved at various levels despite the probably continuous degradation of the scarp foot zones. On the other hand, differential collapse of the caprock of some mesas has occurred due to undermining by means of erosion or subsurface flushing of materials from the underlying weathered sediments (TWIDALE & MILNES, 1983), and may be responsible for local height variations.

CLIMATIC CHANGES

Various interpretations have been placed on scattered and not necessarily relevant evidence concerning climatic change.

Based on an overview of the distribution of tropical larger foraminifera in Cenozoic marine basins surrounding Australia, MCGOWRAN (1979a) deduced a broad climatic history for the continent consistent with published oxygen isotope studies from Deep-Sea Drilling Program cores. He suggested a major decline in temperatures from the Early to Middle Eocene, in agreement with data from palynological studies of non-marine sedimentary sequences (KEMP, 1977, 1978). The Oligocene was regarded as generally cool, with increases in temperature at the Oligocene-Miocene boundary and in the Early Miocene. A reversal in temperature was evident near the boundary between the Early and Middle Miocene, but after increases in temperature in the Middle Miocene, temperatures generally declined towards those of the present day.

On the basis of studies in the Lake Frome basin (CALLEN & TEDFORD, 1976; CALLEN, 1977), Miocene environments were deduced to have been 'warm temperate to sub tropical . . . with savannah landscape, and gallery forests around the large permanent streams and lakes.' In the Pliocene and Early

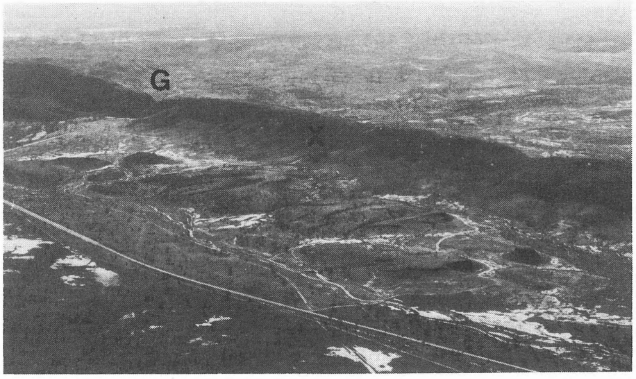

Fig. 8
Ancient dissected piedmont of the southern margin of the MacDonnell Ranges, N.T., east of Emily Gap (G). Note the several mesas each capped by silcrete and detached from the backing scarp. One mesa (X), however remains in essential continuity with the escarpment.

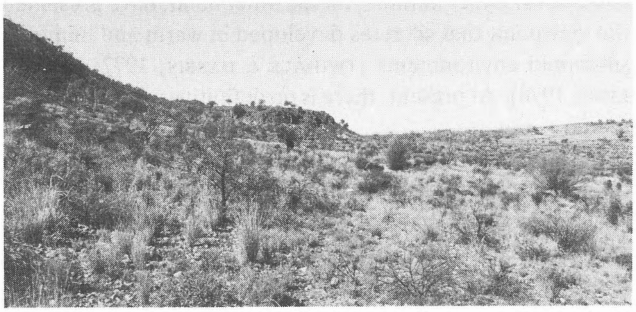

Fig. 9
Small mesa designated X in figure 8 in continuity with backing escarpment.

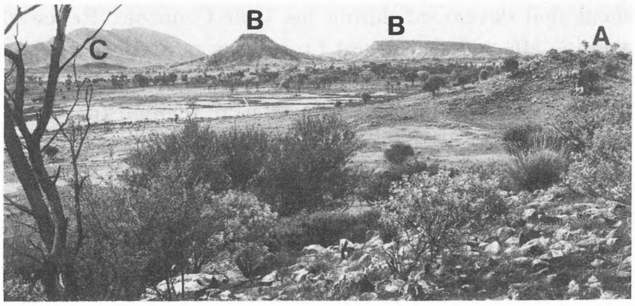

Fig. 10
Silcrete-capped residuals occur at different topographic levels in the southern piedmont of the MacDonnell Ranges, west of Undoolya Gap. Note, for instance, the contrasted altitudes of the residuals marked A, B and C.

Pleistocene, lakes and swamps disappeared due to a combination of tectonism and climatic change, and the drainage approached its present configuration. The climates were apparently subtropical with phases of seasonal aridity. Subsequently, conditions moderated towards warm semi-arid and eventually Mediterranean climates in the Middle Pleistocene.

MCGOWRAN (1979a, 1979b) speculated about the origin of continental duricrusts in relation to his climatic variations, suggesting that silcretes formed during times of cool, arid conditions, and 'laterites' during warm, humid climates. However, as CALLEN (1983) has pointed out, there are considerable difficulties in establishing such a relationship because of the uncertainty about the ages or age ranges of the various duricrusts, and because of the evidence pointing to their long and complex (polyphase) development. Furthermore, if the present provides any sort of yardstick, the 'climates' of ocean basins are determined in part by factors that do not apply in the continents. The climate of Australia is determined in large measure by its latitude and compact area; ocean currents have only a minor influence.

Though CALLEN (1983) has pointed to a correlation between some silcretes and major climatic cooling events, he argues in favour of silcrete formation during times of varying climatic extremes, particularly fluctuations from arid to high rainfall conditions. Other authors, on the other hand, have presented the viewpoint that silcretes developed in warm and humid to subhumid environments (TWIDALE & HARRIS, 1977; see also KEMP, 1978). At present, there is no definitive evidence on this matter.

In terms of landscape development, the temperature decline recorded in the Middle Miocene had dramatic consequences on landscape development, particularly in the interior of the continent. The onset of phases of aridity allowed the development of fields of dunes and other desert forms, and also caused derangement of the hitherto well-coordinated drainage systems. Instead of through-flowing rivers, there developed a host of interior basins, many of them centred on contemporary major salinas such as lakes Eyre, Torrens, Frome and Amadeus. This tendency was reinforced by a period of widespread and pronounced tectonic adjustment that developed during the later Cenozoic. Renewed faulting affected the Mount Lofty Ranges (CAMPANA, 1958; STEEL, 1962; TWIDALE & BOURNE, 1975; DAILY ET AL., 1976), and the northern Flinders Ranges were uplifted (CALLEN & TEDFORD, 1976). Perhaps more importantly but less dramatically, widespread regional warping added to the dismemberment of the earlier Cenozoic drainage systems and depositional environments. As a consequence of the lowering of various local base-levels, there was widespread exposure of recent sediments and the initiation of relief inversion through stream incision. Disintegration of the caprocks was achieved by a combination of physical collapse and chemical dissolution.

DISINTEGRATION OF SILICEOUS DURICRUSTS

Physical disintegration

Such is the toughness of silcrete, arising form its degree of induration and predominantly siliceous composition, and its low reactivity with most meteoric and groundwaters, that it acts as a stable landscape element. Siliceous duricrust surfaces have persisted in the landscape of Central Australia for many scores of millions of years. Indeed, and as has been suggested earlier, many of the present positive relief features associated with siliceous duricrusts originated as topographic lows, and are evidence of large-scale relief inversion.

Siliceous caprocks are being reduced, but only at a very slow rate. This reduction takes the form of marginal attack, rather than lowering of the duricrust surface, other than stripping of a thin soil cover. The headwaters of incising streams have in many places cut into the slopes below the caprock, thereby undermining the latter. Tension cracks develop a few metres back from the edge of the bluff (Fig. 11), and the mass of silcrete tilts outwards and eventually collapses (Fig. 12) as the underlying support is removed by stream erosion (TWIDALE & MILNES, 1983). Even then, as STURT astutely appreciated, the duricrust, though fragmented, remains resistant and forms the principal component of the stony plains (gibber, reg, serir, hamada, desert armour) that bear his name in Central Australia.

In some places, the caprock has experienced differential collapse, possibly as a result of evacuation, by solution or by flushing, of the underlying weathered bedrock. Thus at several sites in the southern piedmont of the MacDonnell Ranges, the central areas of some low mesas have subsided leaving a rim of siliceous caprock intact on three sides (Fig. 13).

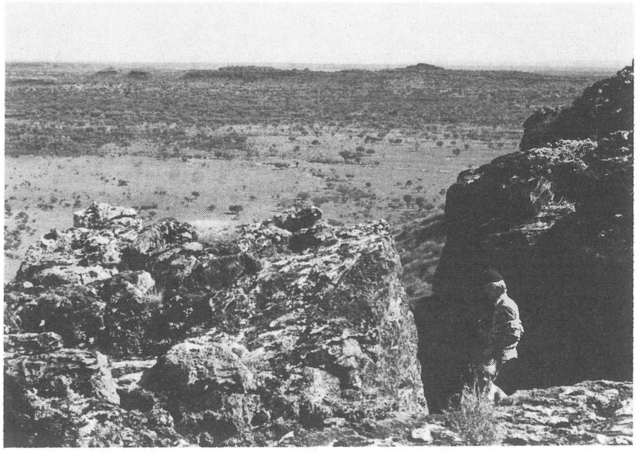

Fig. 11
This block of massive silicified limestone forms the caprock of a mesa in the northern Ooraminna Ranges, N.T., and is exposed in the bluff of the faceted slope. It has been undermined by streams cutting into the debris slope below, so that tension cracks have formed and the block has tilted outwards (down left).

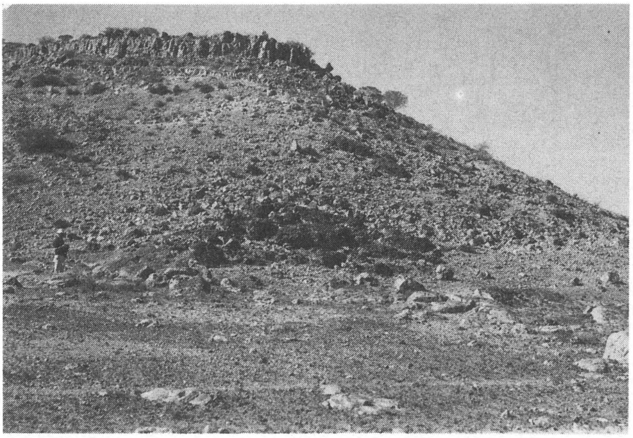

Fig. 12
Collapsed mass of silcrete from caprock of mesa. Note also columnar disintegration of silcrete caprock. Southern margin of MacDonnell Ranges.

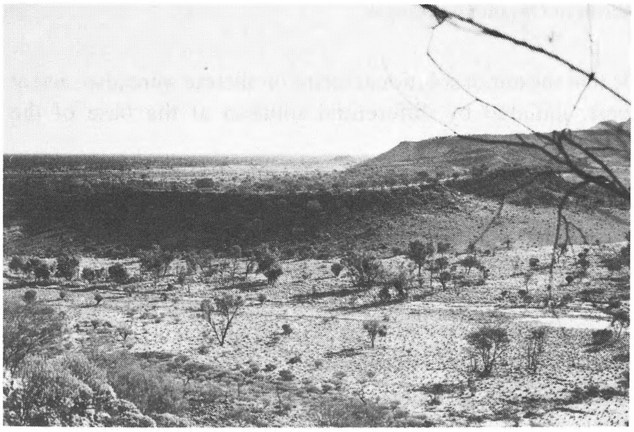

Fig. 13
Low silcrete-capped mesa in the MacDonnell piedmont west of Undoolya Gap showing shallow basin form, possibly due to preferential dissolution of the underlying sands.

Usually, it is only near the margins of the plateaux that the caprock is well exposed. Within a few metres back from the edge of the escarpment, the caprock is covered by a veneer of soil or regolith which appears to thicken slightly towards the centre of the residual, even though the surface is sensibly flat. Whereas the exposed silcrete tends to be dry, that underlying the regolithic veneer which retains moisture may be subject to chemical weathering. Yet is the marginal areas of the plateaux that display a suite of minor forms strongly suggestive of solution.

Dissolution

Apart from fabrics and structures inherited from original regolith materials, there are many macroscopic features inherent in silcretes in Australia and elsewhere that bear on the fundamental constructional processes involved in silcrete formation. Such features include intraformational nodules or pseudopebbles (FRANKEL, 1952; WILLIAMSON, 1957), columnar structures (see e.g. WOPFNER, 1978; THIRY, 1978; MILNES & TWIDALE, 1983); flow-like structures on surfaces (see e.g. AMBROSE & FLINT, 1981), structures resembling Liesegang rings, and open vermicular cavities and tubes (MILNES & TWIDALE, 1983): their origins are difficult to interpret. Another suite of forms developed on silcretes in the piedmont zones of the MacDonnell and Ooraminna ranges is however the result of dissolution processes. So pronounced and clear are these features that they are more reminiscent of limestone than of any other rock exposures.

The suite of forms includes rock basins, grikes, *Rille* or *Karren* - fluting and grooves – 'fingerprint' patterns, and large vertical pipes (Figs 14a-e). Such features are widely and well developed on limestone (e.g. JENNINGS, 1971; SWEETING, 1974) but have also been reported from sandstone (e.g. KLAER, 1957; WHITE ET AL., 1966; ZAWIDZKI ET AL., 1976; TWIDALE, 1980) and granite outcrops (e.g. TWIDALE, 1982). It is increasingly recognised that these forms may be initiated and largely developed beneath the soil cover or at the weathering front. They are subcutaneous in the marvellously evocative expression of ZWITTKOVITS (1966), and this interpretation may hold for some at least of the forms developed in silcrete. It has been argued that the duricrust-capped residuals are reduced in area largely as a result of the steepening of bounding scarps and undermining and collapse of the capping. As this scarp retreat takes place, the regolithic veneer is eroded, partly by being washed over the edge of the escarpment, and partly by being washed into tension cracks and into such solutional features as vertical pipes. As the scarps are worn back, so is the area of regolith reduced, and the bare duricrust surface exposed. The weathering front at the base of the regolith may well be irregular at both medium and microscales. Certainly this is true of weathering fronts developed on limestone, granite and sandstones. And it may

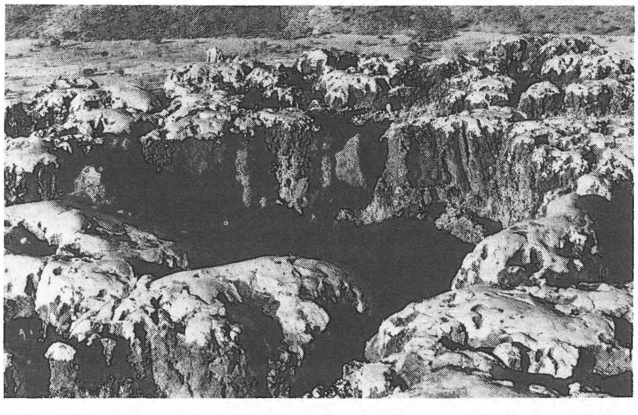

Fig. 14a
Solution depression, some 4 m diameter and 1 m deep, developed in silicified duricrust on upper surface of mesa in northern Ooraminna Ranges. Note also the fretted character of the entire surface, the rounded bosses, the small vertical pipes.

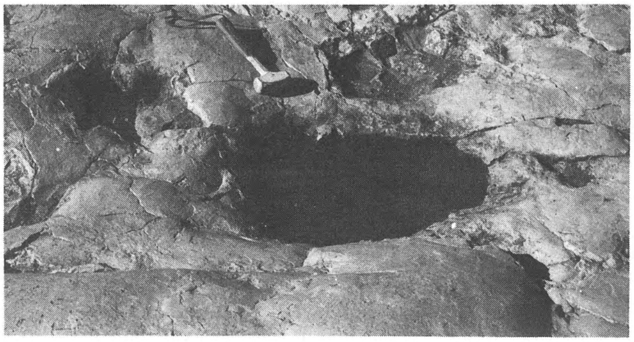

Fig. 14b
Small, shallow solution pan (filled with water) in siliceous duricrust, southern piedmont of MacDonnell Ranges.

Fig. 14c
Prominent grikes separating rounded bosses of siliceous duricrust, southern MacDonnell piedmont.

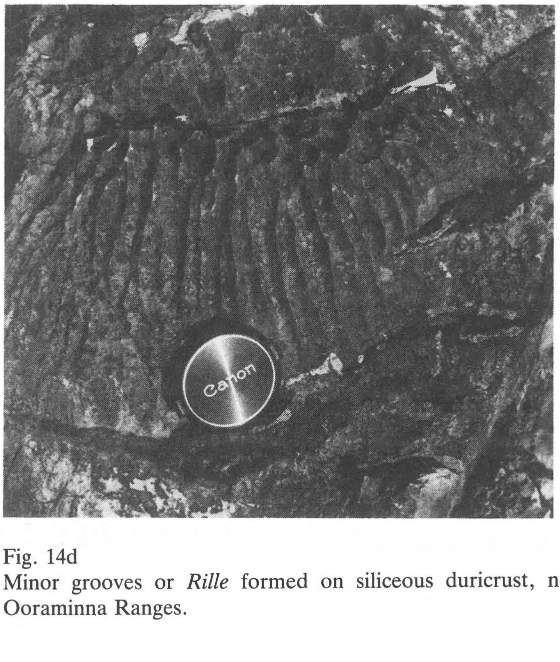

Fig. 14d
Minor grooves or *Rille* formed on siliceous duricrust, northern Ooraminna Ranges.

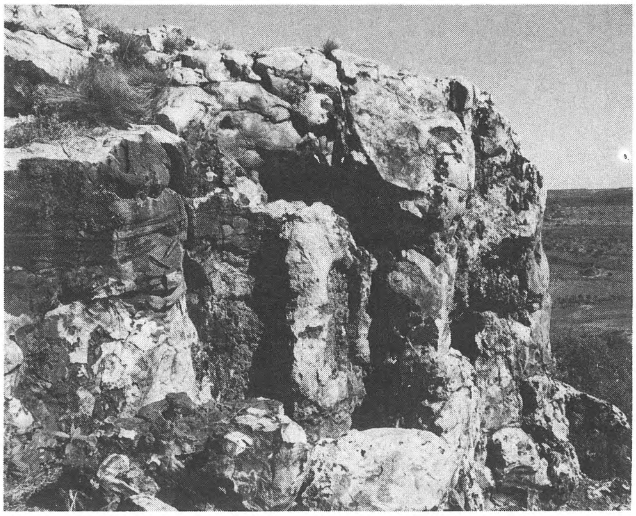

Fig. 14e
Prominent vertical pipes exposed in bluff of siliceous duricrust, northern Ooraminna Ranges.

be that the minor solutional forms on silcrete were also, and at least, initiated by differential solution at the base of the regolith.

There are nevertheless considerable difficulties in explaining the karstic features developed on silcretes. It might be argued that the rock has been degraded by dissolution of the diagenetic silica cement, thus releasing the framework quartz grains for removal by one of a variety of local sedimentary processes including rainwash, saltation, or downslope creep. The projection of quartz grains apparently freed from encompassing secondary silica, into the hollows of basins, pipes, and other structures tends to support this suggestion. But whether the process occurred at the surface or beneath a soil cover is not known. In order to dissolve the interstitial silica in either situation, it would be necessary to maintain low concentrations of dissolved silica in the local environment. This could be achieved through an influx of moisture through rainfall or uptake of soluble silica by plants (WILDING ET AL., 1977). If the karstic structures are of Pleistocene or Holocene age, then the erratic rainfall characteristic of the arid climates of these times would have ensured their formation over a comparatively long time and in a discontinuous fashion.

On the other hand, warm humid climatic phases of the later Tertiary may have produced rainfall and vegetation that facilitated the formation of the various karst forms in a short time at a relatively constant rate, as has been proposed for the structures developed on quartzite in the Roraima and Sarisarinama plateaux of Venezuela (POUYLLOU & SEURIN, 1983). Alternative hypotheses involving highly alkaline or highly acid moisture conditions to facilitate dissolution of the silica cement in siliceous duricrusts in Central Australia are difficult to substantiate, at least with reference to contemporary environments. Nevertheless, silcrete exposed near the shore of Lake Torrens (the surface of which is covered primarily with gypseous sediments but containing some halite) displays shallow rock basins or hemispherical weathering pits. On the Brachina pediment in the western piedmont of the Flinders Ranges, there is a cover of quartzite and limestone cobbles and boulders that each carries a film of carbonate. The limestone clasts are only fretted to a minor degree, but the quartzites display miniature flared slopes and platforms, and some cobbles are planed off flush with the soil surface (TWIDALE, 1979). Similar minor sculptures have been observed on cobbles of dacite and rhyolite lodged in the surficial halite-rich sediment of Lake Gairdner.

Alkaline groundwaters thus could have attacked the siliceous caprocks and produced the basins and flutings. The vertical pipes appear to have originated in similar fashion, and in fact be comparable to the *orges géologiques puits naturels*, or swallow holes of the chalk of the Paris Basin, and also observed in the English Chalk country. Whether long or short, of large diameter or only 2-3 cm across, the pipes invariably display a halo of alteration (Fig. 15) due to selective dissolution of the interstitial silica cement and subsequent partial infilling by later silicca phases, iron oxide and clay. Nevertheless, it is also possible that they relate to primary features of the siliceous duricrust rather than wholly to later dissolution processes.

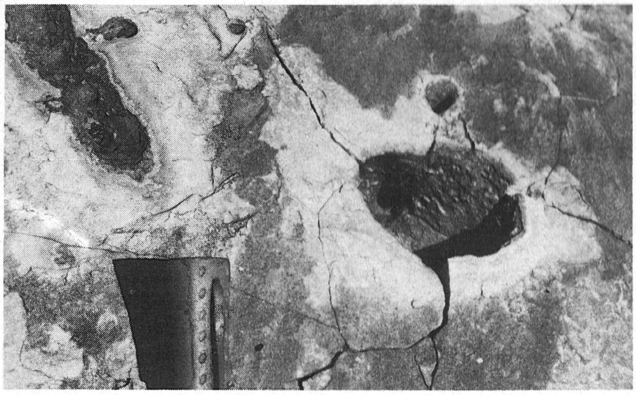

Fig. 15
Pipes in siliceous duricrust seen in longitudinal and cross section, but in each case with an alteration halo, due in part to dissolution and replacement of interstitial diagnetic silica. Western Ooraminna Ranges.

CONCLUSIONS

Siliceous duricrusts that formed in various topographic situations in the Cenozoic landscapes of Central Australia have persisted to become dominant landform elements. They are being reduced in area very slowly, and mainly by indirect physical attack. But in some environments, and probably beneath a soil or regolithic veneer, the duricrusts have reacted with meteoric waters or soil waters to produce a suite of karst features. Investigations are continuing, and these studies will hopefully clarify the formation and degradation of siliceous duricrusts in terms of the tectonic and climatic chronologies of the regions in which they occur.

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