A study of the post-Permian quartzites of south-eastern New South Wales

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A STUDY OF THE POST-PERMIAN QUARTZITES OF SOUTH-EASTERN NEW SOUTH WALES.

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Department of Geology
1978.
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<td>Pocket at rear.</td>
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SUMMARY

Silcretes are indurated, silicified quartz-rich rocks. In an attempt to understand the genesis of such rocks, twenty two deposits of post-Permian quartzites were chosen for investigation from the widespread occurrences of this rock type in the Tallong, Bungonia, Windellama, Nerriga, Lake Conjola and Cooma regions in south-eastern New South Wales. Petrographic and field examination has shown that the quartzites are equivalent to the silcretes of South Africa and inland Australia and the name silcrete is used to avoid confusion with the metamorphic rock term. The silcrete deposits studied occur over a wide range of elevations and are associated with weathered rocks which overlie parent rocks of various types and ages. Petrographic examination has shown that iron minerals have etched allogenic quartz and that chalcedony is not an essential mineral. Each region studied has a characteristic pattern of occurrence of the iron, titanium and aluminium oxides. It is considered that the silcretes formed under climatic conditions and favourable environments which existed at or near the time basalts were extruded in the region. Some poorly silicified silcretes represent siliceous laterites from which iron oxide or carbonate has been leached. Field and chemical evidence shows that silcretes have formed in the sub-surface as part of soil profiles and have passed through a viscous liquid phase during formation.
1. INTRODUCTION

The siliceous rock common at the surface in arid regions of inland Australia is known as "silcrete". Deposits of this material are widespread in southeastern New South Wales, and have been mined as "silica" or "quartzite" since 1919.

Twenty-two post-Permian quartzite (silcrete) deposits were chosen for study in the belief that they fairly represented the more numerous occurrences of this material in the Tallong, Bungonia, Windellama, Nerriga and Milton regions of New South Wales. A small, isolated deposit at Rock Flat, 13km south of Cooma was also investigated. These regions and localities are shown in Fig. 1.

The localities chosen range from 34°43' to 36°21' latitude south and from 149°20' to 150°22' longitude east. Distance from the coastline varies from occurrences at the sea-edge (at Bendalong) to 85km inland. The altitudes of the deposits range from sea level to 893m above sea level.

The silcrete occurrences studied lie within the broad structural provinces of the Sydney Basin and Lachlan Geosyncline south of the Capertee Geanticline and Hill End Trough. The Tallong, Bendalong and Pattimore Lagoon deposits lie towards and on the southern and southwestern margin of the Sydney Basin. The superficial deposits of these three regions overlie sub-horizontal Permian sediments, and are, in general, associated with Tertiary basalts (Sutherland et al., 1973).

The Bungonia, Windellama and Nerriga deposits lie just beyond the southern and southwestern extremities of the Sydney Basin. The superficial deposits of these regions overlie steeply-dipping Ordovician sediments or quartz porphyrite of the Marulan Batholith (Osborne & Lovering, 1953).

The Rock Flat deposit also overlies vertically dipping Ordovician rocks of the Central and Southern Fold Belt.

The Tallong, Bungonia, Windellama and Nerriga deposits occur on the elevated plateau country north and west of the deeply entrenched Shoalhaven river.

The Bendalong and Pattimore Lagoon deposits occur less than 30m above sea level and some occur below water level. Some deposits occupy the flanks of low east-west ridges and headlands.
FIGURE 1. Showing locations of the silcrete deposits studied. Detail within the insets for Tallong, Bungonia, Windellama & Conjola is shown in figures 2, 3, 4, 5 respectively.
The individual silcrete seams are invariably associated with other superficial deposits: clays, laterites, sands. The silcrete association unconformably or disconformably overlies a variety of rock types. These associations and relationships are summarised as follows:

TABLE 1

<table>
<thead>
<tr>
<th>SILCRETE DEPOSIT NAME</th>
<th>OTHER ASSOCIATED ROCK TYPES (sequence detailed in relevant section)</th>
<th>UNDERLYING COUNTRY ROCK</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Tallong Region</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1.1 Caoura Road</td>
<td>Tertiary olivine basalt.</td>
<td>The Berry Formation (Permian)</td>
</tr>
<tr>
<td></td>
<td>Loose, micaceous grey silt.</td>
<td>a grey, micaceous argillite. (sub-horizontal)</td>
</tr>
<tr>
<td></td>
<td>Sand, white clay.</td>
<td></td>
</tr>
<tr>
<td>2.1.2 Caoura Homestead</td>
<td>As for Caoura Road.</td>
<td>The Nowra Sandstone (Permian), a fine to medium-grained quartz sandstone (sub-horizontal)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1.3 Badgery Lookdown</td>
<td>Soil with basalt fragments, medium grained sand</td>
<td>As for Caoura Homestead.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2 Bungonia Region</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2.1 Old Feltham</td>
<td>White kaolinite clay rich sand. Recent poorly sorted alluvium.</td>
<td>A quartz porphyrite of the Marulan Batholith (Devonian)</td>
</tr>
<tr>
<td>2.2.2 Jerrara Creek</td>
<td>Sand, pebbly sand, grey clay-rich sand, poorly sorted river gravel, very fine-grained loose white quartz silt, silicified iron-stained pebble conglomerate.</td>
<td>As above.</td>
</tr>
<tr>
<td>2.2.3 Stockyard</td>
<td>Unconsolidated pebbly sand, sandy clay, poorly sorted pebble gravel, clayey sand.</td>
<td>As above.</td>
</tr>
<tr>
<td>2.2.4 Morris</td>
<td>Unconsolidated pebbly sand, coarse gravel and possibly other rock types not exposed.</td>
<td>Steeply-dipping metaquartzite (Palaeozoic).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3 Windellama Region</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3.1 Croker</td>
<td>Unconsolidated pebbly sand, white kaolinite clay, grey clayey sand.</td>
<td>Steeply-dipping metaquartzite and phyllite (Palaeozoic)</td>
</tr>
<tr>
<td>2.3.2 McGaw</td>
<td>Unconsolidated sand and possibly other rock types not exposed.</td>
<td>Steeply-dipping metasediments (Palaeozoic)</td>
</tr>
<tr>
<td>NAME</td>
<td>OTHER ASSOCIATED ROCK TYPES</td>
<td>UNDERLYING COUNTRY ROCK (and attitude)</td>
</tr>
<tr>
<td>-----------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td><strong>2.4 Nerriga Region</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4.1 Oallen</td>
<td>Sand and possibly other rock types not exposed.</td>
<td>Steeply-dipping metasediments (Palaeozoic)</td>
</tr>
<tr>
<td><strong>2.5 Lake Conjola Region</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5.1 Bendalong</td>
<td>Pale sandy clay, pale clayey sand.</td>
<td>Sub-horizontal, Snapper Point Formation (Lower Permian, Artinskian), a medium-grained sandstone (Gostin &amp; Herbert, 1973).</td>
</tr>
<tr>
<td>ML 26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5.2 ML 17</td>
<td>White sand, white to grey kaolinite clay.</td>
<td>As for ML 26</td>
</tr>
<tr>
<td>2.5.3 ML 30, ML 7</td>
<td>Grey kaolinite clay, laterite and weathered basalt fragments</td>
<td>Not known but probably as for ML 26</td>
</tr>
<tr>
<td>2.5.4 ML 18, ML 36</td>
<td>Lateritic remnants of weathered Tertiary, Buff white sandy clay and possibly other rock types not exposed</td>
<td>Not known but probably as for ML 26</td>
</tr>
<tr>
<td>2.5.5 ML 16, ML 19, ML 31</td>
<td>Sand, semi-silicified very angular sand, grey, stiff kaolinite clay, laterite, weathered basalt fragments.</td>
<td>Probably as for ML 12</td>
</tr>
<tr>
<td>2.5.6 ML 15, ML 14, ML 21</td>
<td>Sand, white kaolinite clay grey, red, mottled kaolinite clay. Laterite</td>
<td>Not known but probably as for ML 12</td>
</tr>
<tr>
<td>2.5.7 ML 12, ML 35</td>
<td>Laterite, weathered Tertiary basalt fragments, mottled red and grey kaolinite clay, grey clay, grey clayey sand, poorly sorted river gravel.</td>
<td>Sub-horizontal, fine-grained micaceous siltstone with Ulladulla mudstone (Permian)</td>
</tr>
<tr>
<td>2.5.8 ML 53, ML 20</td>
<td>Laterite, weathered Tertiary basalt fragments, mottled red and grey kaolinite clay, grey clay, grey sand.</td>
<td>As for ML 12, ML 35.</td>
</tr>
<tr>
<td>2.5.9 Beach</td>
<td>Grey sandy clay, Laterite, recent beach sand.</td>
<td>Not exposed</td>
</tr>
<tr>
<td>2.5.10 Headland</td>
<td>Grey clay, grey sand</td>
<td>Tertiary basalt.</td>
</tr>
<tr>
<td>2.5.11 Pattimore Lagoon</td>
<td>Grey clay, grey sand, Tertiary basalt.</td>
<td>Not exposed</td>
</tr>
<tr>
<td><strong>2.6. Cooma Region</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.1. Rock Flat</td>
<td>Residual deposit, no other associated rock types remain</td>
<td>Steeply-dipping Palaeozoic metaquartzite &amp; quartz rich metasediments.</td>
</tr>
</tbody>
</table>
The siliceous material which is the subject of this study has been known by various names in the subject area since its reported occurrence on the South Coast about 1915 (Harper, 1918). In the refractory silica mining industry the material was known only as "silica" up to 1961. Australian geologists have also used the terms "grey billy" (David, 1950), "quartzite" (Craft, 1931), "billy", "flint", "siliceous duricrust" (Browne, 1972) and as late as 1962, the term "silica" was used in a brief description of the occurrence and origin of the deposits in the Milton district of New South Wales (Kennedy, 1962). Although the term "silcrete" has been used overseas for the same material, its use in Australia has not been observed prior to 1957. Recent authors have used the word "silcrete" although in Mining Legislation in New South Wales, "silcrete" is not recognised as a mineral. "Quartzite" is used to refer to both Palaeozoic metaquartzite and "silcrete-like" materials mined for use in the refractory, steel, road metal and other industries. Browne (1972) preferred to restrict the term "silcrete" to the inland indurated siliceous rock and used "grey billy" to describe sub-basaltic indurated siliceous material.

Lamplugh (1902) first suggests the term "silcrete" and later applies it in his description of the geology of the Zambezi Basin (Lamplugh, 1907). In both publications, the word "silcrete" is defined concurrently with and as being analogous to "calcrete" and "ferricrete". Exon et al., (1970) state that, "it is clear that Lamplugh intended silcrete as a very general term for any material indurated by silicification, without regard for size or shape of the constituent particles or for the presence or absence of associated weathering profiles". Grant & Aitchison (1970) have defined silcrete in terms of its genesis rather than in terms of properties.

The definition of "quartzite" in the "Dictionary of Geological Terms" (American Geological Institute, 1962) includes both "metamorphic" and "silicified" materials as two separate, alternative meanings.

"Quartzite" implies "metamorphism" in current usage and this extension to include silicified materials can only create confusion when it contributes nothing and a satisfactory term exists. Frankel and Kent, in 1937 used "surface quartzite" in their title as it had been formerly known. (Lamplugh, 1907 refers to this in the works of Livingstone, 1857), but stated their preference for "silcrete" as originally defined.
Although "silcrete" is considered the most satisfactory of the terms available for the silicified rocks of this study, several of the rocks described are barely "indurated", but have been included.

The term "silcrete" is retained because both "silicification" and "induration" has occurred and because of the petrographic likeness to highly indurated silcretes.

The following terms which are used in the descriptions are defined:
A "deposit" is an economic or potentially economic concentration of silcrete which may or may not be continuous but sufficiently isolated such that no arbitrary dividing line is required between it and surrounding deposits.

A "seam" is a tabular, more-or-less laterally continuous body of silcrete. Seams may be virtually unbroken for more than 100m yet are commonly as thin as 5cm. Seams may extend beyond deposits, and may be continuous between adjoining deposits. Seams may split, lens out, coalesce, intertongue. Where there are coherent multiple seams, these are numbered from lower to upper. "Reef quartz" is translucent, white quartz. This commonly occurs as veins in Palaeozoic rocks.

"Chalcedony" is fibrous, or stellate, fine-grained silica, observed in thin-section. Williamson, (1957) restricted chalcedony to silica having demonstrable fibres.

The "matrix" in silcrete is the finer-grained cementing material between quartz grains. Frankel & Kent (1937) refer to the quartz clasts as "allogenic" material. In thin-section, "clasts" are commonly poorly sorted subangular to acicular quartz grains. The "matrix" is fine grained intersutured, interlobed, commonly equigranular quartz.

The "cockade" structure, common on the upper surface of the Bendalong silcretes is noted by Kennedy (1962) as "Cockade textures of precipitation of silica are present at the contact zone indicating the method of mobilisation and conversion of the clay to silica by a hydrothermal effect of the basalt, possibly a gaseous fluxing from the highly volatile lava". Kennedy does not describe the "cockade texture", but the surface looks similar to the surface of cream, or sauce which has thickened during stirring (Figs 35,43). The structures are rather reminiscent of load clasts, yet commonly have a relief of less than 1cm.
Smale (1973) describes a "terrazzo" texture as "...a framework of angular to subrounded quartz grains, some showing effects of solution, set in a matrix of amorphous, cherty or opaline silica containing abundant leucoxene:. A similar texture is described as "floating" texture, in contrast to the "grain-supported" texture of sandstone (Watts, 1976). This texture is commonly visible in silcrete thin-sections and also macroscopically in some coarse-grained silcretes, notably at the Morris, Stockyard and Croker deposits.
The field relationships of the silcretes listed in table 1 are described as individual deposits under regional sub-headings in Appendix 2. The individual deposits studied are as follows:

2.1 Tallong Region. Locality map: Fig. 2.
   2.1.1 The Caoura Road Deposit
   2.1.2 The Caoura Homestead Deposit
   2.1.3 The Badgery Lookdown Deposit

2.2 Bungonia Region. Locality map: Fig. 3.
   2.2.1 The Old Feltham Deposit
   2.2.2 The Jerrara Creek Deposit
   2.2.3 The Stockyard Deposit
   2.2.4 The Morris Deposit

2.3 Windellama Region. Locality map: Fig. 4.
   2.3.1 The Croker Deposit
   2.3.2 The McGaw Deposit

2.4 Nerriga Region
   2.4.1 The Oallen Deposit (location: Fig. 1).

2.5 Lake Conjola Region. Locality map: Fig. 5.
   2.5.1 The Bendalong: ML 26 Deposit
   2.5.2 The Bendalong: ML 17 Deposit
   2.5.3 The Bendalong: ML 7, 30 Deposit
   2.5.4 The Bendalong: ML 18, 36 Deposit
   2.5.5 The Bendalong: ML 16, 19, 31 Deposit
   2.5.6 The Bendalong: ML 14, 15, 21 Deposits
   2.5.7 The Bendalong: ML 12 Deposit
   2.5.8 The Bendalong: ML 20, 53 Deposit
   2.5.9 The Bendalong: BeachDeposit
   2.5.10 The Bendalong: Headland Deposit
   2.5.11 The Pattimore Lagoon Deposits: PML3 & ML11

2.6 Cooma Region.
   2.6.1 The Rock Flat Deposit (location: Fig. 1).
BUNGONIA SILCRETE DEPOSITS
LOCALITY MAP

LEGEND

- Silcrete deposit herein described
- Other silcrete deposits
- Water course
- Roadway
- Irrigation station

FIGURE 3
FIGURE 4.
2.2 Summary & Discussion of Field Occurrences:

Silcretes in the areas studied occur over a range of elevations from sea level to 920m above sea level. In general, the elevations range from the highest in the west to the lowest in the east.

It has been suggested (Frankel & Kent, 1937) that silcretes could have been accumulations of sand and colloidal silica which was precipitated by seawater. The apparent ripple marks and shrinkage cracks observed in the upper surface of the silcrete seams at the Bendalong Beach Deposit and at the Tallong Caoura Road and Tallong Badgery lockdown deposits may suggest that this has occurred. Krauskopf (1967) notes that "...where hot springs associated with volcanic activity supply water to the sea, silica may become so concentrated that direct precipitation of silica gel is possible" and also that"...the shrinkage cracks, the common banded appearance..., the intricate crumpling often observed in bedded cherts all suggest gel behaviour". The Tallong silcrete deposits occur at above 500m above sea level. It is not suggested that the Tallong deposits have ever been at sea level so although these and the Beach deposit silcretes may have contained colloidal silica in their formation, they formed above sea level. Some undermining unconsolidated sediments by seawater and resultant slumping of the overlying silcrete slabs has caused the submarine occurrences at Bendalong. It is considered that the present-day elevation is a function of isostatic and eustatic changes rather than an original relationship to sea level.

The behaviour of colloidal silica is further discussed in section 4. Within the subject area, the majority of silcrete deposits occur on the tops and flanks of ridges. The larger deposits observed commonly occur at the heads of re-entrant erosional features. The Tallong deposits flank an elongate east-west plateau between the Shoalhaven River Valley and Tallowa Creek. Each of the outcrops of silcrete dip towards the long axis of the residual basalt which fills the "Caoura Valley" described by Craft (1931), (Fig. 6.)

It is considered that these silcretes formed on each side of the basalt filled "Caoura Valley" and that they represent quartz-rich zones in the Tertiary sediments that accumulated in a "chain-of-ponds". Taylor & Smith (1975) consider that the basalts associated with the silcretes they studied provide "a confined aquifer within the sand deposit and a favourable environment for SiO₂ deposition."
TALLONG SILCRETE DEPOSITS
SHOWING SILCRETE OUTCROPS AND THEIR AREAL RELATIONSHIP TO RESIDUAL BASALT OUTCROP.

Scale 1: 63,360

Basalt.
- Silcrete deposit not included in this study.

FIGURE 6.
For the Tallong silcretes at least, this is probably also true. The specific physico-chemical environment necessary for this is further discussed in Section 4.

At Bendalong, on several mining leases, silcrete boulders and cobbles are enclosed in impervious clay. This represents a sand accumulation between basalt flows. Perhaps some unconsolidated sand was removed by erosion between basalt phases. The enclosing basalts are weathered to clay. In many occurrences, isolated cobbles are joined by a thin layer of fine, white clay-poor sand. In this area particularly, silcrete appears to have accumulated in depressions in the palaeo-land surface. Hiern (1965) describes the accumulation of opal in small depressions in bedding and fault planes at Coober Pedy. He attributes these occurrences to (a) metasomatic replacement of other material with silica (and notes that opalised shells are a clear example of this), (b) a silica rich solution became trapped and became opalised.

In the Bendalong area, the seams are horizontal or inclined at up to 5 degrees and appear to have formed in sands and conglomerates.

Smale (1973) notes that the silcretes in South Australia are extensive. He does not quantify this but notes that the thickness is generally 0.5 to 1.5m. In discussing the physiography of the Daly River Basin, Northern Territory, Wright (1963) describes extensive areas of "silicified rock" within the Bradshaw pallid zone. The description of "silicified rock" indicates that it is silcrete and although he does not specify how extensive the silcrete is, his maps and sections indicate that it could occur over regions up to 30km long. Maps of escarpment features in the Officer Basin described by Wopfner (1967) indicate that silcrete occurs as mesa caps of up to 800m in diameter.

Langford-Smith & Dury (1965) note the area of occurrence of a silcrete sheet in north-western New South Wales and the adjacent areas of Queensland as "40,000 square miles" (100,000 km$^2$).

Chugg (1956) describes silcrete deposits at Allandale near Codnadatta in which he calculates reserves of refractory grade silcrete from an occurrence 467m wide by 548m long with a thickness of 91cm to more than 1.82m but notes that the deposit is far more extensive than this.
It is sometimes difficult to define continuity in silcrete deposits.

Lamplugh (1907) in describing the silcretes of the Zambezi Basin, South Africa, notes that silcrete commonly occurs as "loose blocks strewn over the flats" with thicknesses of over 3m thick. He notes that it occurs between sands and basalt but does not occur as a continuous layer. The silcrete in the Zambezi Basin is associated with the Kalahari Sands and although the sands are shown on the map over linear distances of greater than 80km he does not attempt to quantify the extent of the silcretes. At Tallowa Creek, silcrete occurs discontinuously along approximately 11km of the creek bank. At Bendalong, it occurs discontinuously along the flanks of a ridge (Fig. 7) for at least 3.5km. The occurrence at the Bungonia Jerrara Creek is continuous for over 1km. Grant and Aitchison (1970) note the variable and discontinuous nature of silcrete and on a map depicting principal silcrete and ferricrete occurrences in Australia they show silcrete areas of over 500km in diameter. They point out that a considerable proportion of silcrete occurs as a peripheral cap-rock and dissected edges of an old land surface which is now undergoing erosion. This cap rock may be 2 to 15m thick and occurs in areas of considerable extent and also as isolated residual mesas. At least part of the original silcrete at Tallong and Bendalong has been removed by erosion and certainly the attitudes of large silcrete blocks in both areas have been altered by erosion (notably the Beach, Headland, ML14 and Tallong Caoura Road deposits). Although host sediments may have been more continuous than present-day silcrete deposits, much of the discontinuity of the silcretes described is original and related to degree of silicification by allogenic solutions.

Raggatt (1938) discussing silcrete in the Hunter River Valley notes that it forms a prominent 1.6km terrace edge near the Muswellbrook-Denman Road. He suggests that the existing silcrete blocks are remnants of a continuous seam which has been broken up in situ. He argues that the silcrete is syngenetic because all similar deposits occur as terraces at about the same level and no other rock type boulders are associated. Further, the boulders do not have the appearance of "tumbled debris". It is noted however that at Reedy Springs, South Australia, Wopfner et al., (1974) show a "pre and post-folding silcrete" as steeply dipping and horizontal respectively.
Taylor and Smith (1975) describe a sequence of silcretes in Tertiary fluvial deposits below and between basalt flows. In one location there are several basalt flows and several silcrete seams each above a gravel or sand deposit. In the Bungonia Jerrara Creek, Stockyard and Old Feltham deposits there are also multiple seams but these are not associated with basalt. Although they could perhaps have been overlain by a basalt, now eroded, the interseam rocks are sands and clays.

At the Pattimore Lagoon deposits the multiple seams are separated by sands and clays and only the upper seam is overlain by basalt. At the Headland deposit multiple seams are separated by sands and clays and overlain by sands. The sequence overlies basalt.

In the Zambezi Basin, Lamplugh (1907) describes silcrete along the eastern margin of the Marramba River on a plateau overlying a decomposed basalt and is brecciated with "rounded lumps of chalcedonic quartzite enclosed in a gritty, siliceous matrix...." Wopfner (1964) describing a silcrete in the Granite Downs area of South Australia notes an"...intensely fractured and fragmented, partially silicified and ironstained zone" up to 5m thick below a columnar silcrete. The fragments are of silicified and kaolinitic parent rock and the silicification increases upwards. In cross sections of the Eyre Formation of the Oodnadatta region, Wopfner et al., (1974) show a brecciated zone of the silcrete profile beneath columnar silcrete.

It has apparently been assumed that the widespread occurrence of a "brecciated" or "fragmented" zone underlying the more compact silcrete (Lamplugh, 1907; Wopfner, 1964; Wopfner et al., 1974) indicates an upward migration of silica. This phenomenon is ascribed to "pressure solution" by Lerbekmo & Platt (1962.)

The brecciated or fragmented zones are apparently typical of the inland South Australian silcretes but were not observed in the deposits studied. The columnar silcrete noted above and also by Frankel and Kent (1937) was not observed except for small "columns" at the Bendalong Beach and Headland deposits.

Hallsworth and Costin (1953) describe a silicified bauxite laterite profile from near Tingha, New South Wales. The profile appears to be very similar to that described for the Bendalong ML12 deposit.
LAKE CONJOLA: BENDALONG
SILCRETE OUTCROP

FIGURE 7.

autical deposit
HEADLAND DEPOSIT

Silcrete outcrop.
The upper surfaces of some silcretes have distinctive markings or structures such as the "cockade texture", common in Bendalong silcretes, "ripples" at Tallong and Bendalong and the "cross structures" at the Beach deposit. Within a multiple seam sequence, only the upper appears to display these markings. The "cockade texture" is observed only on sub-basaltic silcretes or silcretes which may have been overlain by basalt. The "cockade" markings and flattened, elongate voids described (Figs 43,47) and other surface features (Figs 2, 58) indicate pressure from an incumbent mass causing de-watering and compaction. This implies that the seams were in a viscous state when overlain by either a considerable thickness of sediment or a viscous, mobile basalt flow. Not all the upper surface features can be ascribed to basalt lava flow. Watts (1976) describes concentric rings observed on silcrete near Tibooburra, New South Wales. He considers that these are the result of shrinkage. The relief of the upper surface features described in appendix 2.5.9 suggest a more positive agency than atmospheric drying. The structures appear too irregular to be the moulds of basalt shrinkage pattern. These unusual structures occur in the littoral zone and may have been enlarged by weathering. They could be the weathered remains of a radiating root system or they may in fact be the bases of shot holes drilled from above at a time when some mining of the Beach Deposit was carried out. Stevens (1971) suggests that such features could be "extrusion" structures due to uneven loading by overlying sediment.

Jointing is irregular in both highly indurated and more friable silcrete. The jointing is due to fractures of the inhomogeneous silcrete as a result of flexure. The movement of the silcrete is due to uneven compaction of underlying residual clays and sediments by overburden and expansion and contraction of clays in wet and dry conditions.

Some irregular apparent "incipient jointing" and evidence of discrete blocks of viscous silcrete having been pushed together with resultant fusion of touching surfaces is evident in several deposits. Examples are described (Rock sample Nos. 29, 33, 45) and illustrated (Figs 45,58). The deposits from which these samples were taken are all associated with basalts (Bendalong Headland Deposit, Pattimore Lagoon Deposit, Bendalong ML17 Deposit).
Sedimentary structures are evident in most silcretes but are commonly external only. The silcretes occur as part of a sedimentary sequence, e.g., as conformable lenses among horizontal beds of clay and sand at Pattimore Lagoon deposit. Bedded pebbles commonly occur at tops of silcrete seams, e.g., at the Caoura Homestead deposit at Tallong. Bedding is present in sands overlying silcretes (Fig. 54) and is evident externally but absent internally at the Woolshed deposit at Tallong (1.5km east of the Caoura Road deposit) and at the Beach deposit at Bendalong. It is clear that silicification, perhaps preceded by iron induration may have removed any bedding traces. Similarly, some cobbles and pebbles in the Bendalong ML17 silcrete have been partially destroyed by silicification. This is further discussed below.

Retallack (1976) describes fossil roots in Triassic palaeosols in the Narrabeen Group sediments where, as in modern soils, the root's interior is decomposed and infilled with sediment. The occurrence of sub-vertical root fossils in some silcrete deposits (e.g. Bungonia Stockyard deposit, Bendalong ML53 deposit) indicates that these silcretes were part of a soil horizon. The persistence of these fossils (Fig.38) when internal sedimentary structures have been destroyed indicates that the plants came after sedimentary structures were disorganised and when the silcrete was in a viscous state. The occurrence of rounded metamorphic rock pebbles and silicified derived Permian fossils (Figs 20, 29) indicates a high-energy environment late in the sedimentary history of the silcretes. Langford-Smith & Dury (1965) argued that the silcretes of north-western New South Wales were formed on the surface.

The soils associated with the silcretes appears to be primarily related to overlying lithologies, climate and land-use rather than to the existence or influence of the silcrete.

Certainly the soils and vegetation associated with silcretes in the study area bear little resemblance to the vegetation depicted above silcretes in the inland regions of Australia (Wright, 1963).
Vegetation appears to be related more to soils, climate and land-use than to the presence of silcretes. The vegetation associated with the silcrete deposits near Bendalong varies from stunted ti-tree, casuarina and banksia on the sands at the Headland deposit to a bloodwood-messmate association in both weathered basalt and sands over most of the mining leases and to a white gum stand on similar soils further west.
3. CHEMICAL ANALYSES

3.1 Introduction:

Many partial analyses of silcretes have been carried out during prospecting and quarry production projects.

Analyses of silicon dioxide, manganese dioxide and phosphorous pentoxide have rarely been made. It is assumed, on the basis of rare analyses, that percentages of the latter two oxides are low or negligible, and that the balance is silicon dioxide.

In general, the most likely deleterious contaminants for commercial silica refractory production are: total iron oxide, aluminium oxide and titanium dioxide. Hence, in many sampling projects, only analyses of these three oxides is carried out. It is clear from other analyses that the variation in these three oxides is greater than for the other oxides.
### 3.2 Analyses

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3.3 Discussion:

The iron content of silcretes in the regions described is more variable at Tallong and Bendalong than at the other regions (Fig. 8). These two regions are also those in which the silcretes are sub-basaltic. The mode for all analyses of total iron is 0.17%, which is much lower than the total iron for average igneous rock (6.88%), average shale (6.47%), and average sandstone (1.37%) (Mason, 1966).

The mode for alumina content in the regions noted (Fig. 9) is higher at Bungonia, Windellama and Bendalong, than at Tallong and Nerriga. For all analyses the mode is 0.29%, also lower than the average igneous rock (15.34%), average shale (15.40%), and average sandstone (4.77%).

The titania content of silcretes in the regions described (Fig. 10) is most variable in the Bungonia region where a secondary mode is evident. For all analyses, the mode is 0.49% which is below the average igneous rock (1.05%), average shale (0.65%) but above the average sandstone (0.25%).
FIGURE 8.
FIGURE 9.
FIGURE 10.
Chemical Relationship between Silcretes and Overlying Clays.

The clay sequence overlying the silcrete at ML 12 is typically as follows:

(Profile at eastern end of ML 12)

Red-brown topsoil (about 20cm)
Uniformly coloured and textured red clay (about 70cm)
Grey and red clay, (mottled) plastic with rare fragments of fine angular quartz (about 1m)

Indurated zone - Indurated irregular ferruginous material, at top this is mixed with grey clay, below it forms a more or less continuous layer (about 90cm)

Mottled zone - grey clay with ferruginous fragment up to 10cm. Vertical iron staining is common (90cm to 1.2m). The iron staining is variable laterally and vertically.

Silcrete - commonly there is 5 to 10cm of fine, angular, loose sand at the top of the silcrete in the eastern part of ML 12 (thickness see below).

The silcrete and overlying 60cm of clay was sampled to determine if there was a chemical relationship between the two. The exercise was limited by the variability of the clay due to the ferruginous zones in it. A thin channel representing 2 to 3cm² was cut vertically above the silcrete sample site for 60cm in each case. In some samples this channel intersected one or more of the dark, very ferruginous zones (much the same as the ferruginous zones in the clay above the silcrete seam in ML 20, ML 53 (Fig.41).

Where this occurred, the percentage of iron oxide was so great as to mask changes in other oxides, especially silica.

The six silcrete samples were taken 15m apart along an east west line. These were chipped evenly from the vertical face at the close of quarrying activity in ML 12.
For the following analyses all samples were oven dried for 12 hours before analysis. Proportions are expressed as percentages.

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1 to 6 silcrete channel samples; west to east, thickness as shown.
7 to 12 clay channel samples; west to east;
7 above 1, 8 above 2 etc., each 60cm.

Analyses - Research Laboratory, Newbold General Refractories Limited.
Collected by J.H. Callender.
RELATIONSHIP BETWEEN SILCRETE AND OVERLYING CLAY

LEGEND

CLAY

SILCRETE

PERCENTAGE (DRIED BASIS)

SAMPLE NUMBERS

FIGURE 11.
RELATIONSHIP BETWEEN SILCRETE AND OVERLYING CLAY

LEGEND

CLAY
SILCRETE

CLAY ANALYSES (percentages - dried basis)

SILCRETE ANALYSES (percentages - dried basis)

ANALYSES

Sample numbers.
FIGURE 12
The results of Table 3 are expressed graphically in Figs. 11, 12. The vast disparity between percentages of individual oxides in silcrete and those of the clay rules out most possible comparisons between oxides, or even thickness or ignition losses. When these are all plotted on the same arithmetic ordinate scale, the high silica content of the silcrete obscures all other relationships. This perhaps illustrates a similarity between the relative abundance of titanium oxide (presumably as anatase or leucoxene) and carbonaceous matter (assuming that the ignition loss represents carbon content) in the clay.

A more tenuous relationship between ignition loss, titania and alumina in the clay may be suggested by the curves in Fig. 11. An inverse relationship between iron oxide and silica plus alumina might also be suggested, but any relationship at all between the silcrete and overlying clay is not evident from these curves.

Fig. 12, where scales are variable, indicates an apparent similarity in the relative abundance of titanium oxide in silcrete and overlying clay. There may also be a relationship in the relative abundance of clay silica and silcrete alumina.

The possible significance of these results is discussed below in relation to chemical data over a broader area.
3.4 Physico-chemical Considerations:

In considering the physico-chemical environment in which a silcrete may have formed, it is necessary to consider the properties and forms of silica minerals and other minerals which are commonly associated in silcretes.

Silica occurs in nature as quartz, chalcedony, tridymite, cristobalite, opal and rare glasses and high pressure forms (Mason, 1966). Chalcedony is a quartz with a fibrous habit. Tridymite and cristobalite are forms which are stable at temperatures over 867°C. Quartz, tridymite and cristobalite are silica polymorphs. Much of the quartz in the silcretes described is thought to be allogenic and to have crystallised in a sediment from silicic acid solution. Solubility of silica becomes significant in considering a source, transport and precipitation of silica. Siever (1962) reports on experimental determination of solubility of amorphous silica (produced from a gel or from synthetic opal).

At 25°C the solubility of the amorphous silica ranges from 120 to 148 parts per million (p.p.m.) in distilled water. At 25°C quartz is insoluble. At elevated temperatures solubility of amorphous silica rose to 430 p.p.m. at 95°C and crushed quartz crystal reached a solubility of 100 p.p.m. at 125°C. Siever (1962) assumes that pressure remains near to atmospheric in the formation of cherts and this assumption is also made here.

The effect of pH on solubility is shown in Fig. 13 (Loughnan, 1969). For natural environments (Mason, 1966) pH ranges from 4 to 9. Water logged soils may have pH values of about 4, but rain water, river water and oceanic water is neutral or slightly alkaline. In Fig. 13 it can be seen that in natural environments, alumina is insoluble (except in extreme acid conditions such as water-logged soils), TiO₂ and Fe₂O₃ are insoluble but Fe(OH)₂ and CaCO₃ are soluble. Siderite (Krauskopf, 1967) is also soluble.

The effect of other ions (CaCO₃, Fe(OH)₃, and clays) on solubility of silica (Krauskopf, 1959) is negligible but Al₂O₃ can reduce the solubility of silica significantly. He notes that this implies that the alumina ion may react slowly with silicic acid to form clay minerals. Hallsworth and Costin (1953) assume that this does occur in the formation of laterite profiles.
The relationship between Eh (oxidation potential) and pH is described by Garrels and Christ (1965). The behaviour of iron with changing Eh, pH conditions is illustrated in Fig.14, showing stability fields of common iron minerals. This clearly shows that siderite is soluble in acid conditions. Krauskopf (1967) notes that hematite may form from siderite in response to a change in Eh or pH.

If silica solutions are transported any distance, a normal temperature would be assumed, but supersaturated silica solutions or colloidal suspensions may remain stable under these conditions. If silcrete is formed below the surface in the manner described by Mountain (1952) or Hallsworth and Costin (1953), this would also be at normal temperature and close to atmospheric pressure.

Siever (1962) mentions the effect of "pressure solution" in compaction of sandstones where pore water may become saturated in silica solution. He also notes that silica is released in solution in the transformation of montmorillonite to kaolinite, and that lowering of pH will displace the montmorillonite to kaolinite reaction toward the production of kaolinite plus silica.

Lerbekmo & Platt (1962) describes stylolites in sandstones which were formed by the "pressure solution" phenomena. Stylolites were not observed in the silcretes studies but most other internal sedimentary structures had been destroyed. Lerbekmo & Platt (1962) note that solution of silica is promoted by the presence of carbon and iron compounds and show that extensive solution can occur. Heald (1955) notes that stylolites formation can be generated by tectonic stresses under near-surface conditions.

"Abrasion solution" is also mentioned as a source of silica in solution. Experimentally (Siever, 1962) supersaturated solutions of 300 p.p.m. of dissolved silica were obtained by tumbling quartz in water.

Siliceous fossil diatoms or sponge spicules were not detected in the silcretes studied, nor are they mentioned by most authors quoted. Plant fossils and charcoal fragments do occur in the silcretes described. Wright (1963) reports the occurrence of radiolaria and sponge spicules in "porcellanites" (which appear to be silcretes) Siever (1962) notes that if interstitial waters are undersaturated in silica, they will dissolve siliceous organisms in their passage upward due to compaction pressure.
Solubility in relation to pH for some components released by chemical weathering.

FIGURE 13.
Garrels & Christ (1965) suggest that, in the presence of amorphous silica and silica solution, iron silicate will form in preference to magnetite. The field shown for magnetite (Fig. 14) is alkaline and reducing and corresponds to organic-rich, saline waters.

Suitable conditions could exist in some zones of internal drainage, but the petrographic observations (section 4) show that conditions corresponding to the siderite field (Fig. 14) are more likely.

The accumulation of silica solutions in a zone of internal drainage is favoured by Stevens (1971) as a mechanism of origin of silcrete. In view of present-day topography and the occurrence of silcrete in Central Australia, this seems likely. This closed environment concept is also favoured by Taylor & Smith (1975) and the writer. In such a closed system, a mechanism is sought to separate various minerals, as they cannot be removed. One of the common silcrete associates, calcrete is described in South Africa by Smale (1973) where he notes evidence of replacement of quartz by CaCO$_3$ in thin-section. Both Smale (1973) and Taylor & Smith (1975) mention the implication that the occurrence of length-slow chalcedony has for the former association of evaporites.

Loughnan & Bayliss (1961) note that in the formation of bauxites at Weipa, soluble iron migrates upward from a reducing zone to an oxidising zone where stabilisation occurs. The iron content is highest at the zone of fluctuating water table.

The origin of silcretes as proposed by Hallsworth & Costin (1953) depends on the above physico-chemical parameters. In describing the origin of several laterite profiles, Hallsworth & Costin note that the silcrete is a final and unessential part of the profile. The characteristic pattern in the profiles is:

An accumulation of iron and aluminium oxides and hydroxides as laterite. An underlying mottled zone, with downward decreasing ferric iron content. An underlying pallid zone, rich in kaolin, commonly with quartz and part of which may be silicified. Underlying decomposed rock.
Eh–pH diagram showing stability fields of common iron minerals. Total activity of dissolved carbonate, 1 M of dissolved sulphur, $10^{-6}$ M. Solid field boundaries on left side of diagram are for total dissolved iron $= 10^{-6}$ M, dashed lines for $10^{-4}$ M.

After Garrels and Christ (1965). Page 224
Hallsworth & Costin contend that the pallid zone is formed in the low pH, low Eh (reducing) zone where iron is ionized and carried upward by capilarity and alumina may precipitate as kaolinite or as aluminium hydroxide. Under acid conditions the formation of montmorillonitic clays is not considered likely. In the pallid zone, silica dissolved in situ forms kaolinite with the alumina. If there is excess silica, this can be precipitated or laterally transported. Variations to this profile may be caused by changes in base level and water table.

In discussion below (sections 4&5) petrographic and field observations are used to show that the above hypothesis is a possible mechanism for the mode of origin of some silcretes.
4. ROCK DESCRIPTIONS

4.1 Introduction:

The classification of quartz clasts after Folk (1968) is used in thin-section descriptions. Here a genetic classification (modified after Krynine in Folk, 1968) is used to categorise quartz clasts according to grain morphology, inclusions and optical characteristics. The classes are: common (plutonic), volcanic, vein, recrystallised metamorphic, schistose metamorphic and stretched metamorphic.

The terms quartz, chalcedony and opal are used in the same sense as Williamson (1957) has except that a lower size range of "ca. 10 microns across" is not implied for quartz. Chalcedony is to have "demonstrable fibers". Opal is to be isotropic and with negative relief. In describing silcrete from Bombala, Williamson noted that "clouds of minute dark grains appeared in the finer-textured portions of the rock, and at least some of these were rutile". Frankel & Kent (1937) found that the darker material in "colloform structures" was leucoxene and "ferric hydroxide". Hutton et al. (1972) describe silcretes of the Beda Valley (South Australia) where some "massive" silcrete had a matrix which was "light coloured and generally littered with fine inclusions". A titania-rich "skin" silcrete was also described where the matrix is "brownish aphanitic" anatase.

In the thin-sections described here, the matrix is commonly of fine-grained quartz or chalcedony containing many finer-grained microlites. Some of these microlites are quartz, coated with iron, aluminium or titanium oxides and hydroxides. Some are colourless, anhedral, isotropic with high relief. These are considered to be opal. These microlites are further discussed in the summary which follows the sample descriptions.

The matrix in most of the silcretes examined is made up of interlocking quartz. The matrix material is called "cryptocrystalline silica" by some authors (e.g. Williamson, 1957) but was found in the samples described to have a uniaxial positive interference figure and other optical features of quartz.

Many silcrete thin-sections examined have a "floating" texture (Watts, 1976) in which the quartz clasts are not touching each other but are separated by the finer-grained quartz matrix. Although this term implies that the quartz is less dense than the matrix, it is preferred to "terrazzo" (Smailes, 1973) as the former is more descriptive.

Seven of the silcretes described were collected by Mr. K.R. Steggles and are numbered 1/66, 13/66 etc. Other samples collected by J.H. Callender, except where acknowledged.
4.2 Discussion of Rock Descriptions:
The petrographic characters of the thin-sections studied is summarised in Table 4. Certain rock properties are predominant in certain regions, for example, chalcedony is only observed in abundance in the Tallong region; euhedral quartz is observed in the Bungonia region; quartz overgrowths are observed in the Tallong region. Many properties do not appear to be restricted to any areas. Notably embayment in quartz clasts, similarly the presence of opaque minerals is general. Although these properties appear to be ubiquitous, the quartz clast embayments, discussed in section 2.2, could be original features of the quartz clasts, prior to formation of silcrete. Heavy minerals are present in many sediments and their presence in silcrete is not unique.

Generalisations which can be made about bulk characteristics are:
Tallong and Lake Conjola region silcretes are more indurated than those from other regions considered. The silcretes in these regions are associated with basalts. The exceptions are the Headland and Pattimore Lagoon deposits where considerable volumes of friable material is present. The silcrete in both of these deposits occurs as multiple seams. Much of the silcrete at the Windellama Croker deposit is coarse grained and intensely indurated but the silcretes of the Bungonia and Nerriga regions are less indurated and do not exhibit a sub-vitreous lustre. Phases of the Stockyard deposit and Morris deposit are exceptions and do contain intensely indurated silcrete with vitreous lustre.

Wopfner (1964) describes silcrete as consisting of medium to fine grained quartz grains in a dense micro-crystalline siliceous matrix. The fragmented, or brecciated zone described above (section 2.7) consists of angular rock fragments with an average size of 2 to 7 cm derived by physical disintegration of the underlying parent rock, kaolinitic, partly siliceous and generally coated with a ferruginous material. Hallsworth & Costin (1954) describe silcrete as silicified material analogous to "grey billy" and of pure quartz. Browne (1972) describes "grey billy" as fine grained and compact with a glassy lustre to coarse grained and saccharoidal. Also noted were other types with fine "glassy" quartz grains and "rock chips" in an "irresolvable or felsitic matrix" with a porcelainous appearance and conchoidal fracture, which appears to be very similar to the "porcellanite" described by Wright (1963). Lamplugh (1907) describes the rock as a "hard sandstone or quartzite" with a
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### TABLE 4. (cont.)

**SUMMARY OF THIN-SECTION OBSERVATIONS**

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<th>Thin section Number</th>
<th>Friable</th>
<th>Porous</th>
<th>Bimodal Grain-size distribution</th>
<th>Euhedral Quartz</th>
<th>Embayed Quartz overgrowth</th>
<th>Colloform swirls</th>
<th>Anhedral cusp</th>
<th>Metamorphic rock fragments</th>
<th>Opaque minerals associated with basalt</th>
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chalcedonic cement and has abundant "irregular cavities", giving the surface an extremely irregular surface. This appears to be similar to the "pumice-like" silcrete at Windellama (fig. 44). Frankel & Kent (1937) describe silcrete as lacking bedding and having fine-grained, angular to sub-angular quartz grains held in a siliceous matrix. Finer and coarser types are noted as well as some containing older silcrete fragments. All have a conchoidal fracture and elongate voids similar to those described in the Bendalong ML53 deposit. Frankel & Kent (1937) describe the thin-section properties of silcretes from several regions, typically these contain rounded to angular quartz grains in a chalcedonic matrix. The quartz grainsize is from 0.01 to 0.5mm and a small percentage are embayed. Accessory zircons, rutile and "iron ore" are noted with cubes of limonite and colloform "whorls".

Smale (1973) has described five distinct silcrete types in Australia and South Africa: terrazzo, conglomeratic, Albertinia, opaline, quartzitic. The "terrazzo" type consists of a framework of angular to sub-rounded quartz grains in an amorphous chert or opaline matrix containing abundant leucoxene. He notes that the leucoxene is present in colloform structures. The conglomeratic type is of brecciated "terrazzo" type in a silcrete matrix. The Albertinia type is of common opal or chalcedony, either massive or porous, quartz detritus being rare. In the quartzitic type, cementation is solely by secondary quartz overgrowths in the original quartz grains. The Albertinia and quartzitic types were not observed in the subject area, although the quartzitic type is similar to that described by Wright (1963) and the Albertinia type could be similar to his "porcellanite". Although conglomeratic silcretes occur in the subject area, these contain rounded clasts of older quartzites or older silcretes (appendix 2.1.2., 2.5.2.).

Smale's "terrazzo" type has a texture similar to that referred to as a "floating texture" by Watts (1977). Some indurated silcretes (e.g. sample 53.1 from Bendalong ML53) are composed of an even grading of angular to rounded quartz grains from less than 0.01mm to 3mm, i.e., from fine silt size to pebble size. Such an even grading provides an indurated, dense rock with the minimum of silicification. Many silcretes are made up of bimodally distributed quartz grains with 1 to 2mm clasts set in a fine-grained matrix of fine or very fine silt size. Here there appears to have been considerable silicification required, especially in silcretes where the quartz clasts are relatively sparse in the matrix. Textures such as these are reminiscent of an igneous porphyritic texture.
This is described as "floating texture" by Watts (1977) in contrast to the normal grain-supported texture of normal sandstones. Of the silcretes examined there were no internal sedimentary structures or evidence of sedimentation so that clearly the silicification did not occur while the host was in a liquid state. This need not imply that silicification did not occur in a viscous state. Hutton et al., (1972) consider that there are at least two forms of silcrete, one produced by extensive leaching of the rock to the stage where even quartz is attacked, and the other by accumulation of "silicon" from an external source. The first type contains a high content of weathering-resistant minerals while in the formation of the second these were diluted and is found in the lower part of the landscape. The first type is referred to as the "skin" type and is composed of very angular quartz grains in a predominantly anatase-rich matrix. The other type has subrounded grains of quartz in a chalcedonic matrix with fine angular quartz. Types such as these were not observed in the subject area. Wright (1963) describes two distinct types of "silicified rock", porcellanite and quartzite which appear to be very similar and identical to Smale's (1973) Albertinia and quartzitic types. The porcellanite is a pale, fine-grained rock with a conchoidal fracture, mainly of fine (silt size) secondary massive quartz, with up to 20% of quartz, felspar clasts and sponge spicules. This type has chalcedony rimmed cavities. The quartzite consists of detrital quartz with quartz overgrowths which weld the grains together.

Exon et al., (1970) do not describe the silcretes in the Michell-Roma region but note its similarity to that of Southwest Queensland described by Senior et al., (1968) as "predominantly pale grey, extremely indurated, highly siliceous rock with numerous angular quartz clasts distributed in an amorphous or cryptocrystalline matrix. Considerable variation exists in the ratio of quartz clasts to siliceous matrix, and in the size of the quartz fragments".

This description could be used as a definition of silcrete and adequately describes most silcretes described in the study area. Taylor & Smith (1975) give a description of silcrete in the Dalgety area of New South Wales which indicates that these silcretes are similar to the Tallong silcretes (appendix 2.1) and contain quartz and quartzite fragments cemented by quartz overgrowths, micro-quartz and chalcedony. Although neither alunite (Wopfner, 1964) nor jarosite (Taylor & Smith, 1975) were observed.
Taylor and Smith show that the jarosite crystallises early in the post depositional history of the silcretes. Alunite commonly occurs in the kaolinite associated with silcretes in Northern South Australia (Wopfner, 1964). Taylor & Smith imply that alunite was an early post depositional crystallisation product.

The occurrence of glauconite (thin sections 7A, 11B, 20/66, 38, 50), although rare, is so widespread that the origin noted by Kerr (1959), (weathering of detrital biotite) is preferred to that of Folk (1968). Folk states that the present of glauconite is considered very diagnostic of marine beds.

The high silica content of silcretes has been reported as unusual (Brown, 1925). The silica content of silcretes studied by Taylor & Smith (1975) is similar to many localities of Hawkesbury Sandstone studied by Standard (1964). Standard noted several localities where near 100% quartz was present. The silica content of silcretes is therefore not exceptional.

Many authors have reported the presence of chalcedony in silcretes. Taylor & Smith (1975) and Siever (1973) note that this is typically length-slow normal to void margins and that this indicated the former presence of evaporites. Chalcedony was observed in abundance in only one deposit studied (appendix 2.1.3) and was of typically length-fast fibres although centres of vein-fillings were length-slow. Waterhouse & Browne (1929) also reported that chalcedony from this deposit was length-fast. Presence of evaporites is in accordance with mode of genesis postulated by Stephens (1971) and is also related to palaeoclimatic considerations discussed below.

Colloform structures were observed in many silcretes (Fig. 86). These were similar to the "colloform whorls" described by Frankel & Kent (1937). The dark mineral present in these structures is diagnosed as anatase (Hutton et al., 1972).

The embayed quartz present in silcrete from the Morris deposit could have been transported detrital quartz grains from the local quartz porphyrite. Osborne & Lovering (1953) describe similarly embayed quartz grains in the porphyrite. Any embayed quartz need not have been etched in situ. The anatase present in embayments may be the end product of weathered pyroxenes (Fieldes & Swindale, 1954) present in quartz embayments in the porphyrite. It is considered that the schards or elongate angular quartz fragments which are near embayed or etched quartz clasts are fracture fragments separated by the pressure of
quartz crystal growth (fine-grained matrix) from a partly fluid (possibly colloidal) mass. The pale brown "shadow" or "cusp" on the lower (often concave) surface of rounded or subrounded quartz grains (Fig. 80) is composed of fine microlites of an isotropic, anhedral, high-relief, colourless mineral. In concentrated aggregates the microlites become opaque (Fig. 84) and with crossed polars become brown. The microlites do not occur as isolated entities and at the edges of thin sections, quartz fragments can be seen in the fine traces. It is considered that the microlites are probably of opal and are coated with oxides of iron, aluminium and titanium as these are the most common elements present after silicon. Williamson (1957) notes "clouds of minute dark grains" tended to concentrate against detrital quartz grains and in "corrosion pits" on their surface. Williamson found that at least some of the dark minerals were rutile. It is concluded that the mechanism proposed by Callender (1977) has occurred at the Morris deposit. Etching and solution of quartz clasts in situ did in fact occur and that the ferruginous material was replaced by silica-rich solution which crystallised as the fine-grained quartz matrix now present. Standard (1964) has shown that siderite can replace quartz and clay and that siderite is the most common type of reduced iron in fresh water sediments.

As noted above, Garrels & Christ (1965) suggest that under reducing, silica-rich, saline conditions, an iron silicate could form. The mineral chamosite occurs in marine and fresh water environments (Kerr, 1959), but was not observed in the silcretes studied. Suitably saline, reducing, soluble silica-rich environments could perhaps exist in zones of internal drainage but siderite is considered more likely as it is stable in less extreme Eh, pH conditions than are required for iron silicates.

Whether the iron was displaced upward or downward depends on the direction from which the silica-rich solution or colloidal suspension came. Siderite is soluble in near neutral pH conditions and may precipitate as hematite with an increase in Eh such as might occur if dissolved siderite moved upward from a reducing zone. Since laterites commonly overlie silcretes in the areas studied it is assumed that the iron-rich solutions did move upward and were displaced by a silica-rich solution. This upward movement can only have been produced by de-watering pressure of overlying sediment weight. The cusps on the lower sides of the quartz clasts at the Morris deposit may have been formed by late-stage etching by residual siderite trapped under the quartz. If the above sequence of events did take place then the source of the silica would have to be
below the silcrete. Weathered older rock occurs below all silcretes examined (e.g. Bendalong M153, Bungonia, Old Feltham deposit).

This mechanism is in conflict with the conclusions of Watts (1974) and Callender (1977) who argue that downward movement of siliceous solutions occurred. Callender, however, assumed that residual quartz clasts created "shadow zones" where iron-rich material remains. This could only occur if movement was rapid, and analogous to shadow zones created by obstacles in wind-blown sand. Watts (1974) conclusions are reached from field evidence which may be valid for the inland silcrete areas he studied.
5. PHYSIOGRAPHY, CLIMATE AND AGE OF SILCRETES.

Hallsworth & Costin (1954) tie the origin of silcretes to that of laterites. They consider that silcretes are an unessential component of some laterite profiles and argue that neither peneplain topography nor tropical climate is necessary for the formation of these profiles. They contend that topographic relief is necessary for the accumulation of more iron and aluminium oxides than could be derived from weathering of rocks in situ.

It is assumed, from the argument outlined above, that deep weathering of older rocks may be related to the formation of silcretes in at least some of the areas studied. Some topographic relief would appear to be necessary for subsurface to be effective in removing soluble products of the breakdown of primary minerals thus promoting further chemical dissolution. Loughnan (1969) regards "rolling to gently sloping uplands where surface runoff is not excessive and subsurface drainage unimpended" as the ideal topography for chemical weathering. For the formation of silcretes by the mechanism described below (appendix 4.3) i.e., those of the Bungonia, Morris, Stockyard, Tallong and Bendalong deposits a restriction on surface runoff is necessary although it is not intended to imply that lateral translocation of solutions did not occur. Ideally, a zone of internal drainage is necessary to accumulate the weight of unconsolidated sediment necessary to create the de-watering pressure necessary. Callender (1977) considers that a fluid basalt flow can provide the necessary incumbent load but although this could be so for some occurrences, it is a special case. The basalt flows probably interfered with surface drainage, creating zones of internal drainage, especially at Tallong and Bendalong. It is, therefore, assumed that the basalt age is similar to that of the silcrete hence an age range of 26 to 30 m.y. (Wellman & McDougall, 1974) can be assigned.

This also places the silcrete formation late within the range proposed by Wellman & McDougall for major east coast uplift (mid-Cretaceous to late Oligocene) hence it is probable that the study area was well above sea level at 30 m.y. ago. It is not intended to imply that all the silcretes were formed in the one phase. Silcrete conglomerates show that at least two phases of formation occurred. A subsurface mode of origin, similar to that proposed by Hallsworth & Costin (1954) appears to provide the sufficient variation in Eh, pH zones so that separation of accumulated weathering products is possible. Elevation is then a necessary condition for the removal of evaporites and calcretes which are still associated with the silcretes of inland Australia.
Watkins (1967) argues that different climatic conditions are required for laterite and silcrete formation and that the suitable climatic zones in Queensland have moved toward the coastline since Pleistocene times. He notes that the critical condition is the arid-humid climate boundary which is controlled by precipitation and temperature. The boundary between arid and humid climates is defined as the line where mean annual runoff is equivalent to a runoff depth of 5cm per year.

Silcrete forming conditions are ideally arid, and laterite forming conditions are ideal close to the arid-humid climate boundary. An arid climate (as defined) can have an annual rainfall as high as 150cm if annual temperatures are as high as 27°. Under these conditions the water table remains below the ground surface and consequently linear stream channels are not commonly formed and sheet erosion occurs. It is difficult to postulate palaeoclimatic conditions in the subject area, for if Watkins' hypothesis holds for south-eastern New South Wales, the effects of one climatic type will be confused with the other as the climatic boundary has moved east. Watkins does not consider the effects of runoff from one climatic regime might have in flowing through another.

As internal sedimentary structures are commonly destroyed in the silcrete forming process described above, it is difficult to recognise fluvial sedimentary features in some silcretes. The outcrop pattern of most silcretes studied is fluvial (or chain-of-ponds described in appendix 2.7) although fluvial type sedimentation is not observed.
6. **CONCLUSIONS**

A summary of the original contributions made by this study:

1. Petrographic study of the silcretes has shown that iron minerals have etched allogenic quartz clasts.

2. A mechanism for the formation of some silcretes is proposed which is consistent with the known physico-chemical behaviour of the associated minerals.

3. Detailed subsurface examination of the structure of several silcrete occurrences have been carried out.

4. Petrographic study of many silcrete deposits has shown that chalcedony is not necessarily an essential mineral.

5. Petrographic study of many silcrete deposits has shown that the secondary silicification necessary to create an intensely indurated rock varies according to the degree of sorting of the allogenic quartz clasts.

6. Evaluation of chemical analyses from the silcretes studied has shown that each region has a characteristic pattern of occurrence of the common oxides which is compared with other sedimentary rocks.

7. Petrographic and field studies have shown that the silcretes of the study area are similar to some of those of the interior regions of Australia and of South Africa.

8. Silcretes formed in the regions described in favourable environments which existed only at or near the time the basalts were extruded.

9. It is not considered that significant silcrete formation is occurring in the subject area. In fact, at Bungonia, it is suggested that desilicification of silcrete is occurring as finer grained interstitial quartz and chalcedony are more soluble than larger clasts. Lack of a basalt or clay aquiclude is allowing this desilicification to take place.

10. All silcrete outcrops observed were accompanied by loose, surficial sediments and many were interbedded with these. A mechanism proposing a causal relationship between deep weathering and silcrete formation is proposed.
11. The existence of an extreme "floating" texture in some silcretes indicates that the removal of all original interstitial detrital matter and much of the detrital quartz clasts and subsequent replacement by secondary quartz.

12. Silcrete breccia, metasediment conglomerates in silcretes and silcrete conglomerates are described in the subject area.

13. Intimate association of silica-pure silcretes and basalts are described. Basalts would more readily impregnate sediments less silica pure, and hence less refractory and resistant to attack by slags and alkali-rich solutions.

14. Field evidence is used to show that the silcretes described formed as part of soil profiles.

15. Some poorly silicified silcretes represent intermediate stages between iron oxide or carbonate-rich siliceous rocks from which the iron mineral has been leached.
7. ACKNOWLEDGEMENTS

The support of my colleagues at Newbold General Refractories Limited, the encouragement and guidance of Professor A.C. Cook and Associate Professor E.R. Phillips of Wollongong University is gratefully acknowledged.
8. REFERENCES


1.0 PHOTOGRAPHS
Fig. 15. Tallong: Caoura Road Deposit: Dust covered upper surface showing "cockade structures". Scale: lens cap diameter 5cm.

Fig. 16. Tallong: Caoura Road Deposit: "Ripples", site of sample 83 under pen. Second slumped slab. Pen is 13cm long, points to north.
Fig. 17. Tallong: Caoura Road Deposit:— showing fine charcoal, variation in texture, lines of concentration of anatase. Scale: coin diameter 17mm.

Fig. 18. Tallong: Caoura Homestead Deposit:— view north showing a small quarry face from which approx. 50 cu.m of silcrete has been removed. Scale: 50cm rule can be seen leaning against the face.
Fig. 19. Tallong: Caoura Homestead Deposit:— small wood fossil fragment, typical of this deposit. Scale in millimetres.

Fig. 20. Tallong: Caoura Homestead Deposit:— showing the abundance of palaeozoic meta-quartzite clasts in the upper surface of the western silcrete outcrop. Scale: Hammer shaft width 2cm approx.
Fig. 21. Tallong: Lookdown Deposit:— Man made galleries cut in sandstone below the silcrete sheet. Scale: 50cm.

Fig. 22. Tallong: Badgery Lookdown Deposit:— On the western bank of the creek. Showing "ripples" in the upper surface of the silcrete seam. Scale: 50cm rule. (Looking north).
Fig. 23. Tallong: Badgery Lookdown Deposit:— View east under waterfall showing lower surface of silcrete. Scale: 50cm.

Fig. 24. Tallong: Badgery Lookdown Deposit:— Showing the lower surface of the silcrete. Scale not shown but brightly lit surface is about 80cm across.
Fig. 25. Bungonia: Old Feltham Deposit:- showing land west and south of deposit (at left). Looking toward 213 degrees from a point 100 metres east and 70 metres south of track. The gully is a minor, unnamed tributary of Jerrara Creek.
Fig. 26. Bungonia: Old Feltham Deposit:- prominent granodiorite outcrop west of deposit. White rule on outcrop length 50cm. The quarry is beyond the grassed area.

Fig. 27. Bungonia: Old Feltham Deposit:- showing contact between weathered granodiorite and poorly sorted sediment north-west of quarry. Scale: length of rule.
Fig. 28. Bungonia: Old Feltham Deposit:— showing grey "cores" of indurated silcrete enclosed in paler, more friable silcrete. Scale: 50cm rule.

Fig. 29. Bungonia: Old Feltham Deposit:— Derived Permian marine fossil from level of the top of seam 2. Approx. 13cm wide.
Fig. 30. Bungonia: Jerrara Creek Deposit:— View of upper seam at western end of outcrop. Platform Hill — southern section. Seam 3 just visible to right of base of 50cm scale.

Fig. 31. Bungonia: Jerrara Creek Deposit:— Indurated ferruginous gravels at top of sequence at western end of deposit. Scale: hammer head approx. 16cm across.
Fig. 32. Bungonia: Jerrara Creek Deposit:- Showing site of specimen No. 136 at base of 50cm rule (centre of face at left foreground). This is the equivalent of the lower seam in this region. The middle seam is poorly developed and upper seam not visible. Refer also figure 92.

Fig. 33. Bungonia: The Stockyard Deposit:- Seam 2 at south-east end of worked face. Location of sample 52. Note: 50cm scale. Boulders in upper right of face are of indurated silcrete. Remainder is of more friable silcrete.
Fig. 34. Bungonia: Tho Stockyard Deposit:- View of workings from the south east. The large open area in centre is the exposed upper surface of seam 2. The working face is seen at the perimeter of this area, beyond which are tailing dumps and a small stockpile at right. Seam 3, with gravel and sandy overburden are in the left foreground. The "Old Feltham" workings can barely be seen just to right of the open area in the centre beyond the trees.
Fig. 35. Bungonia: The Stockyard Deposit:—The sandy lateral equivalent of seam 3 interbedded with a pebble conglomerate. Seam 3 here extends about 60 cm upward from the 30 cm mark on the white rule.

Fig. 36. Bungonia: The Stockyard Deposit:—Seam 2 outcrop on southwestern edge of deposit. Sample 55 from lower end of 50 cm scale.
Fig. 37. Bungonia: The Stockyard Deposit:— showing location of sample 54 on the western face. Note vertical and horizontal jointing. Scale: 50 cm rule.

Fig. 38. Bungonia: The Stockyard Deposit:— showing silicified plant root fossils present in seam 2. The fine graduations on the scale at right are millimetres. Thin section 87 made from main cylinder shown.
Fig. 39. Bungonia: The Stockyard Deposit:— showing outcrop at north-western part of the deposit. Note the "scribbly gum" and dearth of undergrowth. (50cm scale on tree far right).

Fig. 40. Bungonia: Morris Deposit:— showing eastern side of silcrete capped, timbered hill and cleared slopes.
Fig. 41. Bungonia: Morris Deposit:— Petrographic type of silcrete which is characteristic of this deposit, especially at the northern outcrops. This sample from the north-western outcrop. (See figure 12 for locations). The small graduations on the scale at left are millimetres.

Fig. 42. Bungonia: Morris Deposit:— Thin section No. M36/66, crossed polars, showing large embayed quartz clast in an even grained matrix. Note "shadow" of anatase adjacent to quartz clast.
Fig. 43. Windellama: Croker Deposit:- Irregular upper surface of indurated silcrete, planar upper surface of seam. Scale: 50 cm scale lying horizontally on darker grey silcrete.

Fig. 44. Windellama: Croker Deposit:- "Pumice-like" surface. Coarse, sandstone-like bulbous projections are common on upper surfaces of the dense silcrete. Scale: centimetre rule shown.
Fig. 45. Bendalong: ML 17 Deposit: Conglomeratic silcrete. The smaller graduations on the scale are millimetres.
Fig. 46. Bendalong: ML 30 Deposit:— Looking towards the west.
Showing the attitude, continuity, thickness and overburden of the
seam (September, 1966).
Fig. 47. Bendalong: ML 18 Deposit:— Ferricrete from south east end of deposit. Note metaquartzite clasts. Coin diameter 19mm.

Fig. 48. Bendalong: ML16, ML 19, ML 31 Deposit:— Laterite from costean at western end of deposit. Scale: diameter of coin is 22mm.
Fig. 49. Bendalong: ML 15 Deposit:— 9.12.72 "Cockade structures" on upper surface of seam after overburden removed. The lower end of the 50cm rule points towards north. The broken fragments were produced by quarrying activity.

Fig. 50. Bendalong: ML 14 Deposit:— chips of silcrete, possibly produced by disintegration of the thermally unstable silcrete by fire, in a poorly developed grey sandy soil. Scale is marked in centimetres.
Fig. 51. Bendalong: ML 12 Deposit:— Fenestellid fragment from drillhole cuttings. Depth 5m.
Fig. 52. Bendalong: ML 12 Deposit:- View to south, overlooking quarry as it was in 1968. ML 20, ML 53 lies beyond the trees. Scale: Steel bin is approximately 1m high and 2m wide.
Fig. 53. Bendalong: ML 20, 53 Deposit:— View towards the south-western extremity of the deposit showing the seam split. The lower member is 1m thick just left of the junction.

Fig. 54. Bendalong: ML 20, 53 Deposit:— Fine grained, bedded, poorly silicified sandstone at top of silcrete seam in northern part of deposit. Note "castellated" appearance of vertical jointing and slight iron staining. Typically dense, sub-vitreous silcrete of the top of the seam is shown. Scale: marked on notebook.
Fig. 55. Bendalong: M1 20, 53 Deposit:— High alumina grey clay with weathered basalt fragments and associated iron staining. This is overlying the seam at the northern end of the deposit. Scale: rule marked in centimetres.
Fig. 56. Bendalong: ML 20, 53 Deposit:— Mottled clay, brown subsoil and topsoil overlying seam at southern end of deposit.
Scale: Rule shown marked in centimetres.
Fig. 57. Bendalong: ML 20, 53 Deposit:— The "cockade structure" (Kennedy, 1962) on the upper surface of the seam, also showing the cream-brown veneer and sub-angular and sub-rounded quartz particles protruding through the veneer. The small graduations on the scale are millimetres.

Fig. 58. Bendalong: ML 20, 53 Deposit:— Less dense zone of friable silcrete associated with incipient jointing. This was observed near the top of the seam in the northern third of the deposit. The smaller graduations on the scale are millimetres.
Fig. 59. Bendalong: ML 20, 53 Deposit: - Bands of anatase rich silcrete in a vertical, recent fracture surface at the northern end of the deposit. Coin diameter 29mm. (Photograph A.C. Cook).

Fig. 60. Bendalong: ML 20, 53 Deposit: - Showing a section and face view of fissures or joint planes partly filled with secondary quartz crystals. Lens cap diameter is 5cm.
Fig. 61. Bendalong: ML20, 53 Deposit:— Lines of very fine elongate voids in indurated silcrete.

Fig. 62. Bendalong: ML 20, 53 Deposit:— Charcoal fragment 30cm from top of seam. Lens cap diameter 5cm.
Fig. 63. Bendalong: ML 20, 53 Deposit:— Softer, iron stained silcrete from southern part of deposit (ML20). Scale shown is marked in centimetres.

Fig. 64. Bendalong: ML 20, 53 Deposit:— Dense silcrete boulder with iron stained joint planes. Typical of the southern (ML20) part of the deposit. Scale shown is marked in centimetres.
Fig. 65. Bendalong: Beach Deposit:— showing a western extension of the deposit under kraznozemic soils. This outcrop was exposed during the construction of Erningold Drive.

Fig. 66. Bendalong: Beach Deposit:— Outcrop at base of small cliff face just north of crusher site. Here dense silcrete is overlain by friable silcrete with irregular ferruginous zones. This is overlain by dark ferricrete. Whiter parts at centre-right are recent splashes of portland cement. Scale marked in centimetres.
Fig. 67. Bendalong: Beach Deposit:— Irregular, columnar silcrete-ferricrete outcrop. Darker parts are ferruginous. Scale: lens cap diameter 5cm.

Fig. 68. Bendalong: Beach Deposit:— Major outcrop of the deposit, view to south, note level of seam at right. It is assumed that much of the remainder of the seam shown has been undermined. Note soil at rear. Scale: The nearest wooden post has a diameter of approx. 30cm.
Fig. 69. Bendalong: Beach Deposit:— Major outcrop of the deposit, view to the east, showing apparent bedding.

Fig. 70. Bendalong: Beach Deposit:— Dense dark grey silcrete with fine grained, well preserved "bedding" or "extrusion" structures. Scale: lens cap diameter 5cm.
Fig. 71. Bendalong: Beach Deposit:— Etched, columnar top of seam with linear structure in centre. In section this would possibly have a "castellated" appearance. Scale marked in centimetres.

Fig. 72. Bendalong: Beach Deposit:— Horizontal, water washed upper surface of seam at eastern end of deposit, showing linear structures. At the right hand end is a water filled "cross" structure. Scale: lens cap diameter 5cm.
Fig. 73. Bendalong: Headland Deposit:- Section A, showing pale, weathered basalt, yellow-green clay, grey clay. Scattered thin silcrete boulders occur just below the topsoil, overlying grey clay. Note darker basalt of the rock platform. Looking toward north-west. Scale: largest of the silcrete boulders at the base of the slope is about 1m in diameter.

Fig. 74. Bendalong: Headland Deposit:- Looking south-west from water's edge towards Sections E and D respectively. Large slabs of silcrete have fallen onto the basalt rock platform. Scale: the largest silcrete slabs are up to 1m thick.
Fig. 75. Bendalong: Headland Deposit:— Indurated ferruginous pebble bed, section C, just above seam 2. The "semi-castellated" top of seam 2 can be seen. Scale shown is 50cm long.

Fig. 76. Bendalong: Headland Deposit:— Indurated ferruginous pebbly sandstone, Sample No. 23 from Section D. Scale: The sample is 21cm long.
Fig. 77. Bendalong: Headland Deposit:— Nodular, slightly castellated silcrete. Section E. Scale: 50cm rule.

Fig. 78. Windellama: The McGaw Deposit:— Typical silcrete outcrop at north-western edge of deposit. Scale: 45 cm of white rule is visible.
Fig. 79. Tallong: The Badgery Lookdown Deposit:— Photomicrograph of stellate chalcedony. Sample No. 40/66 (crossed polars).

Fig. 80. Bungonia: The Morris Deposit:— Photomicrograph of abundant fine-grained quartz matrix with one quartz clast. The dark area in the embayment of the quartz clast is an accumulation of iron-stained opal microlites. Sample No. 36/66 (crossed polars).
Fig. 81. Bendalong: ML17 Deposit:— The upper half of the photomicrograph shows angular quartz clasts in a limonite-rich matrix. The lower half is an older, rounded silcrete pebble. The outer zone of the matrix in the silcrete pebble has been replaced by limonite. Note the angular quartz fragment in the centre of the field lies partly in the quartz matrix and partly in the limonite (crossed polars).

Fig. 82. Nerriga: The Oallen Deposit:— Photomicrograph of typical section of saccharoidal silcrete. Sample No. 60 (crossed polars)
Fig. 83. Tallong: The Badgery Lookdown Deposit:— Photomicrograph of transgressive, chalcedony-lined vein in silcrete. Sample No. 40/66 (crossed polars).

Fig. 84. Pattinore Lagoon: P:L3 Deposit:— Photomicrograph of typical "floating texture" of friable silcrete. Sample No. 34 (crossed polars).
Fig. 85. Windellama: The Croker Deposit:— Bipyramidal quartz in photomicrograph of Sample No. 1/66 (crossed polars).

Fig. 86. Bendalong: The Headland Deposit:— Photomicrograph of "colloform structures" of ironstained microlites. Sample No. 7A (plane polarised light).
2.0. LOCALITY DESCRIPTIONS

2.1.1 TALLONG : THE CAOURA ROAD DEPOSIT

Location and Physiographic Setting:

This deposit is located about 5 km south-east of Tallong village about 200 metres east of the Tallong-Caoura Road, at the head of a short, steep gully draining east into Tallowa Creek (Fig. 2). The deposit was noted by Craft (1931). Some exploratory drilling was carried out in 1964, and a trial quantity was quarried early in 1973. Further exploratory drilling was carried out in May 1973.

The deposit is at the eastern edge of a relatively flat grazing area. Silcrete is exposed in a small gully. East of the deposit the gully is much deeper, and both gully and hillside fall away steeply to the east.

Local Stratigraphy and Seam Structure:

The deposit overlies a dark grey finely micaceous siltstone, the Berry Formation (Permian). The upper part of the siltstone is weathered and coloured khaki, buff and orange. This is overlain by a transition from the mica-rich weathered siltstone to a fine siliceous silt. This silt is pale fawn to white and locally clayey. Where the silcrete seam occurs, it is underlain by either sand or a white clay. The pale siliceous silt appears to be a lateral extension of the silcrete. The silcrete is overlain by basalt. The basalt is in various stages of weathering, and occurs in boulders. The contact between the silcrete and basalt is sharply defined.

The silcrete occurs as a single seam, the upper surface of which forms a "spur" to the south-east (Fig. 83). Locally the upper surface is more irregular, but there is some evidence of erosion on part of the outcrop surface.

Jointing is irregular and no preferential direction was observed. Slumped blocks are irregular and not rectangular. Three prominent slumped blocks are 3 to 4m across.
Small Scale Structures:

The upper surface of this deposit has both "cockade" structures (Fig. 15) and other more impressed structures which may have been caused by uneven loading by overlying basalt or soft sediments (Fig. 16).

The "ripples" (Fig. 16) appear to be the result of small scale slumping of thixotropic sediment. Small fragments of charcoal and silicified fossil wood fragments have been observed (Fig. 17). No soft zones within the seam have been exposed.

Petrography:

The silcrete of this deposit is more indurated, compact and tenacious than most silcretes of other areas studied. Coloured zones occur at the top of the single seam. Red, black, brown and yellow colouration is abundant in outcrop in the creek bed although to the north the colour is predominantly pale grey.

Much of this silcrete, especially that which is more strongly coloured is highly indurated, fine-grained, compact, with a conchoidal fracture and vitreous to subvitreous lustre. Fine angular fragments of transparent quartz occur in a fine-grained matrix. Fragments of charcoal and plant fragments are common in parts of the seam. Some of the coloured parts of the seam have a chalky weathered surface of up to 6 mm thick.

Thin bands of very fine-grained silcrete were observed. Similar structures are common in indurated silcrete from other areas, (e.g. ML 53 at Bendalong). The silcrete at the top of a large slumped block in the creek bed (Sample No. 83) is made up of rounded to sub-angular white "reef" quartzite fragments up to 10 mm and angular transparent quartz fragments in a banded fine-grained matrix. This material is also deeply coloured red-brown.

Vegetation and soils:

The soil of the deposit is friable, open, chocolate coloured and immature. The parent material is the underlying alkali olivine basalt. This is grazing land where clearing and pasture improvement have taken place. The soil of the grassed slope north of the main outcrop is thinner, more siliceous and immature. This soil is grey-brown and does not contain basalt fragments. The parent material is underlying micaceous siltstone.
FIGURE 88.

The contours show the morphology of the upper surface of the silcrete seam.
CAOURA ROAD SILCRETE DEPOSIT

CROSS SECTIONS

LEGEND

\[ \begin{array}{c}
\text{basalt} \quad \text{silcrete} \quad \text{sand} \quad \text{older sediments}
\end{array} \]

HORIZONTAL SCALE 1:1200

FIGURE 89
2.1.2 TALLONG : THE CAOURA HOMESTEAD DEPOSIT

Location and Physiographic setting:

This deposit is about 500m north-west of "Caoura" homestead, and is at the northern edge of a basalt-capped ridge. The deposit is at the head of a gully which falls away sharply to join Tallowa Creek about 1.2km north (Fig. 2).

Stratigraphy and Structure:

The silcrete is underlain by a bed of loose, white, medium-grained sand about 20cm thick. This sand is underlain by sandstone (Permian) which outcrops prominently just north of the quarry face (Fig. 18). The silcrete is overlain by basalt and basalt-derived soil.

The deposit is made up of several outcrops of silcrete and two main sheets are linked stratigraphically by discontinuous thin sub-surface silcrete and white sand. The two sheets are on the eastern and western flank of a minor spur at the head of the gully (Fig. 90). Other minor outcrops and slumped blocks occur north of the main exposures.

Single seams only have been encountered. These are less than 1m thick and at the margins of outcrop and under weathered basalt thicknesses of between 5 and 15cm have been observed.

The upper surface of the eastern outcrop dips at approximately 10° to approximately 60° and the western outcrop 7° to 10° to 135°. The seam, where exposed is continuous with vertical jointing which is irregular and not prominent. Individual slumped blocks are 4 to 5m across. Areas of the western sheet are also 4 to 5m across.

This is similar to several Bendalong deposits in that induration has not occurred at the crest, is well developed either side and is linked lithologically across the ridge (Fig. 90).
Small Scale Structures:

The upper surface of the silcrete as exposed in the eastern outcrop (Fig.9Cl) is relatively planar, with slight undulations which are featureless except for fine cavities in the surface from which small plant fossil traces have probably been dissolved.

Wood fossil traces are common in the quarry face (Fig. 19).

The western outcrop upper surface has largely been spalled, presumably by fires or long exposure to frost and sunlight, so that the surface (Fig.20) is not in fact the original upper surface of the seam.

Petrography:

The silcrete of this deposit is typically pale, buff to grey, indurated and compact with fracture surfaces having a vitreous to subvitreous surface. The fracture surface is similar to that of the Oallen Deposit. The upper few centimetres of the silcrete in the western outcrop has abundant angular to subrounded metaquartzite clasts included (Fig. 20). Similar, smaller clasts were less abundant at the Caoura Road deposit. The quartzite clasts probably protruded above the surface of the silcrete but the upper part of this surface has been spalled by temperature changes. Chert and rounded quartzite pebbles and cobbles protrude from the upper surface of silcrete deposits at Windellama.

Soils and Vegetation:

The soils of the deposit are improved, immature basaltic soils rich in basalt rock fragments. Introduced grasses grow on this soil, the original scrub having been cleared.
2.1.3 TALLONG : BADGERY LOOKDOWN DEPOSIT

Location and Physiographic Setting:

The deposit is situated on a ridge which overlooks the Shoalhaven River and is known as Badgery's Lookdown. The lookout is 7km south of Tallong and is situated on the northern side of the easterly flowing Shoalhaven River. Most of the silcrete crops out on the western side of a small tributary which flows along the eastern side of the ridge. The outcrop can be traced along 300m of the tributary. At the northern end of the outcrop is a waterfall. Under the silcrete ledge at the waterfall are neat man made galleries which are reputed to have been constructed by convicts (Fig. 21).

The deposit has not been worked, and minor, thin, scattered outcrop occurs around the lookout itself, and on the road just west of the main outcrop.

Local Stratigraphy and Seam Structure:

Underlying the silcrete and associated sands is the fine-grained Nowra Sandstone (Permian). Directly overlying this is the silcrete seam which is up to 1.2m thick. There appears to be little vertical variation in the silcrete seam itself. Overlying the seam is weathered basalt and soil, similar to that at the Caoura Road Deposit.

The upper surface of the main outcrop dips slightly east and north. The easterly component could be due to slumping along the creek edge. The lower surface structure is well exposed at the waterfall and along the creek and is parallel to the upper surface.

The thickness of the seam varies from 30cm to 1.2m in the main outcrop, but is commonly around 15cm thick in the scattered scree of the lookout.

The main area of outcrop is continuous for up to 200m north-south. Jointing is irregular. Discontinuous zones extend over a greater area than the main outcrop and areas of broken silcrete indicate that the deposit was originally more extensive.

Only one seam was observed, in common with the nearby Caoura Road deposit.
Chemical Analysis:

The following are partial analyses of silcrete from the Badgery Lookdown deposit. Samples were oven dried at 110°C for 12 hours before being analysed.

<table>
<thead>
<tr>
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Totals: 2.73 0.86 3.48 1.81 0.98

1. White silcrete, west end of outcrop, high iron content.
2. Yellow-brown silcrete from western section (Sample No. 38/66).
3. Red silcrete from central area west of creek, high iron content.
4. Black silcrete from north central portion (Sample No. 40/66), high ignition loss.
5. Dark grey silcrete; north end of outcrop.

tr. : trace
L.O.I.: loss on ignition
Analyst: Newbold General Refractories Limited-Research Laboratory.
Coll.: K.R. Steggles.

Soils and Vegetation:

The same can be said for this deposit as for the Caoura Road and Caoura Homestead deposits.
Small Scale Structures:

The upper surface of the seam is well exposed between the creek and the road. Much of it has been thermally spalled but some small scale structures such as the "ripple marks" remain (Fig. 22). These are on the west bank of the creek about 150m south of the waterfall.

The lower surface of the silcrete is unusually well exposed under the waterfall (Figs 23, 24).

The lower surface is similar to that exposed during quarrying at Bendalong. Surface undulations are greater than those at the upper surface of the seam, and there are no indications of fluvial or other transporting processes.
Location and Physiographic Setting:

This deposit is located 8.8km south of Marulan and 3.6km off the Marulan - Bungonia road. The deposit was worked for silcrete from 1960 to 1965.

The silcrete occupies a knoll overlooking the junction of Stoney Creek and Jerrara Creek to the south and the Jerrara Creek gorge to the east. The land to the north and west of the deposit is undulating in comparison with the steep slopes to the south and east (Fig. 25).

Local Stratigraphy and Seam Structure:

A relatively fresh granodiorite surrounds and underlies the deposit. It crops out in the creek beds to the south and east, in the higher ground to the north and cleared ground to the west (Fig. 26).

In the floor of the gully to the west of the deposit is an unknown thickness of in situ weathered granodiorite, overlain by a semi-consolidated, disorganised pebbly mudstone, upstream parts of which lack silcrete fragments, but downstream of the quarry contain angular fragments of silcrete (Fig. 27).

The contact observed in the gully dips strongly west and slightly south. The gravelly sediment is probably of mixed age, and although the silcrete-bearing parts are probably contemporary, other parts are rich in clay containing weathered granodiorite fragments and charcoal, devoid of silcrete, and are probably older, possibly pre-silcrete.

To the east of the gully, the weathered granodiorite upper contact is at a higher level, and dips steeply to the east. This is overlain by a bedded, fine pebble conglomerate (similar to that found at higher levels of the Stockyard and Jerrara Creek deposits). A thin but variable thickness of sand overlies this and in turn is overlain by a variable thickness (locally up to 3m) of white clay. The clay lies beneath silcrete seam 1, of variable indurated and friable silcrete (Fig. 28 ). This seam contains indurated boulders of up to 1m in a total thickness of 1.3m. Above seam 1 is 2.5m of white, clean, friable sand, (containing rounded and etched clasts). The seam dips at about 4° to 5° and thickens to the south where a quarry face of up to 5m was worked. Seam 2 is similar to seam 1 when observed after quarrying activity has ceased. It is up to 2m in thickness, was made up of indurated boulders in friable silcrete and is more ironstained than the lower seam. The upper seam caps the hill, overlying variable, ironstained sand. The
upper seam was all but removed by quarrying when observed, maximum thickness reported (Olliver, 1968) was 60cm. It is likely that a greater thickness than this was worked before this.

The deposit is made up of three seams, each of which has been worked. The two lower seams are of up to 3m boulders of indurated grey silcrete enclosed by friable silcrete (Fig. 28). The upper seam is not reported to be more than 60cm (Olliver, 1968) and is commonly between 30 and 60cm. The full extent of seam 3 is not known, but occurs mostly as outcrop.

**Small Scale Structures:**

The so called "cockade" structures (Kennedy, 1962) although common in the South Coast deposits, have not been observed further inland. Similar structures (Fig.15) have been observed at Tallong but not at Bungonia. The apparent absence may be due to the predominantly soft upper surface of the silcrete, thermal damage to the upper surfaces, or that the structures do not occur in such deposits. This is further discussed in section 3.

A silicified "derived" fossil (Fig.29) of a Permian pecten-like pelecypod was found by Mr. M.V. Anderson at the base of a tree where it had been brought to the surface by root growth.

Although plant fossils have been found at the nearby Stockyard and Jerrara Creek Deposits, none has been recorded from this deposit.

**Petrography:**

Seam one is well exposed at the western side of the deposit. The indurated darker "cores" are of angular quartz grains set in a fine grained matrix (Sample No. 124). Aggregates of quartz do occur. The fracture surface is commonly subvitreous. The indurated silcrete is enclosed in more friable, but similarly textured silcrete. The bulk of this is white (Sample No. 126), but slightly ironstained parts (Sample No. 125) are common.

Seam 2 is not well exposed at present, and the quarry faces are perhaps atypical as parts of the quarry were abandoned when suitable silcrete became sparse or was not present. Silcrete from this seam is coarse, saccharoidal and has a coarse grained matrix.
The residual traces of seam 3 contains silcrete which has a semi-saccharoidal fracture surface, is pale but with a "terrazzo" texture although the matrix is coarse. This is typical of the seam and similar to seam 1 at the nearby Stockyard deposit. In thin-section, however, seam 3 silcrete resembles that of the second Stockyard seam. In a thin section (Sample No. 13/66) of seam 3 subangular quartz clasts are set in a finer-grained matrix. Small anatase-rich zones are associated with each of the coarse clasts, in part mantling them.

Chemical Analyses:

The following are partial analyses of silcrete from Bungonia - PML 65 deposit. Samples were oven dried at 110°C for 12 hours before analyses were carried out.

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1. Indurated silcrete, eastern end of seam 1.
2. Indurated silcrete, eastern end of seam 3.
3. As for 2.
4. Indurated silcrete, seam 1 (western quarry) (thin-section 13/66).
5. As for 4 (Fig.28).
6. Dark brown lumps selected from crushed sample.

L.O.I. : loss on ignition
tr. : trace
Analyst : Newbold General Refractories Limited Research Laboratory

Vegetation and soils:

No original vegetation now occupies the area of the deposit. The soil remains are similar to that of the Stockyard deposit and it can only be assumed that vegetative cover was also similar.
2.2.2 BUNGONIA : THE JERRARA CREEK DEPOSIT

Location and Physiographic Setting:
This deposit was worked from 1966 to 1969 and is situated on the northern bank of Jerrara Creek about 2km east of the Marulan-Bungonia road (Fig.3). It is one of four deposits within an area of 6km\(^2\). Each of these deposits occupies a greater area than deposits examined in other areas and this deposit is the largest of the four.

Silcrete occurs almost unbroken along the east-west ridge for over 2km. The ridge is at the centre of an area which is gently undulating, although within 2km to the east, Jerrara Creek becomes deeply entrenched and topographic relief much greater.

Local Stratigraphy and Seam Structure:
The Glenrock granodiorite (Osborne & Lovering, 1953) crops out in small areas at the eastern and western ends of the deposit. This is more prominent west of the deposit. The outcrop of the lower silcrete seam is 2m above the granodiorite. Between the granodiorite and lower seam is a bed of loose, sandy gravels, rich in subangular metamorphic rock fragments. Four to five metres of sand lie between the first and second seams. The second seam, commonly between 30cm and 1m thick is overlain by medium pebble conglomerates, which are variably indurated and of variable thickness, up to 2m but commonly 20 to 40cm. Overlying the second seam at the centre of the deposit (Fig.92) is a soft grey clay-rich sand. In this part of the deposit a third seam is interbedded with the soft clay-rich sand and occurs as a 15cm slightly indurated pale grey silcrete (Fig.92).

Above the sands are pebble beds associated with seam 3. These are ferruginous, indurated pebble beds up to 1m thick (Figs 31,91,92).

The silcrete of the deposit, which has been worked extensively, occurs in three seams.

The seams are approximately horizontal. The lower seam outcrop is limited and is probably not continuous. Like the lower seam at the Stockyard deposit it is less than 5cm thick and was not quarried. The second seam is more continuous than the other seams and in general more siliceous and more indurated. The second seam is of both indurated and friable silcrete, commonly as rounded, tabular hard parts within
BUNGONIA: JERRARA CREEK DEPOSIT

CENTRAL SPUR-TYPICAL SECTION

SOUTH

NORTH

SCALE: 1 METRE

FIGURE 92.
friable surrounds. The second seam is from 1 to 3m thick. Much of the second seam is friable, dull grey silcrete.

The third, or upper seam, is of variable thickness, extent and induration. It occurs up to 3m above the second seam.

The third seam is well developed on a small knob at the western end of the deposit (Figs 30, 91).

The upper seam becomes a clean sand band, interbedded with gravels and siliceous clays at the centre of the deposit but is more indurated in several places.

Where the silcrete occurs as rounded indurated blocks surrounded by softer, more friable material, the vertical jointing is irregular. Regular horizontal jointing is commonly 40 to 50cm apart. The silcrete is fine-grained, brittle, white, friable to indurated (especially at the western end of the deposit). This silcrete has close jointing, both vertical and horizontal, with a "castellated" appearance due to the close vertical jointing.

Jointing in the friable, clay-rich parts of the upper seam is obscure.

Plant root fossils have been collected by M.V. Anderson. These were not observed in situ by the writer, but are similar to plant root fossils from the Stockyard deposit.

Rounded Palaeozoic metzquartzite clasts up to 3cm have also been observed in silcrete won from this deposit.

**Petrography:**

The first (lower) seam is not well exposed so that outcrop may be atypical. The silcrete exposed is even grained, finely saccharoidal and silicified.

Seam 2 is of dull, fine grained, friable to indurated grey silcrete. This material has a "terrazzo" texture and encloses irregular, rounded "cores" of indurated silcrete with a dull to subvitreous lustre. The indurated parts are absent or poorly-developed in some parts of the seam.

The third seam is very similar to the second in that indurated silcrete "cores" are enclosed by friable material which is less indurated than silcrete but of a similar texture and composition.

The third seam is less continuous than the second, and becomes a thin (15cm) poorly-indurated bed. Much of the third seam, even where more than a metre thick, is of more friable silcrete. Dense, subvitreous silcrete has been won from the third seam. In thin-section anatase is commonly present as bands or concentrated areas.
Vegetation and Soils:

Scribbly gum (probably *Eucalyptus rossi*) dominates. Minor stringybark (*Eu. sp.*) with rare oaks (*Casuarina sp.*) and wattles (*Acacia sp.*) also occur on the poor soil which is mainly sand and gravel with fine ironstone dust and very little organic matter. The improved soils surrounding the ridge are also sandy, but support grasses.
2.2.3 BUNGONIA : THE STOCKYARD DEPOSIT

Location:

The deposit is situated in a minor knob on the southern side of the junction of Stoney and Jerrara Creeks (Fig. 3). Relatively gently undulating country lies to the south of the deposit. Steep slopes north, west, and east of the deposit fall to Jerrara Creek (Fig. 34).

The deposit has been worked intermittently since 1971.

Local Stratigraphy and Seam Structure:

This silcrete deposit and unconsolidated clays, sands and gravels overlies the Glenrock granodiorite. This cropped out approximately 10m below outcrops of poorly silicified sandstone. Although neither drilling nor quarrying has exposed a weathered zone, a variable thickness of in situ weathered granodiorite is considered likely because of the similarity of the sequence and proximity to that of The Old Feltham Deposit\(^1\). Although three apparent silcrete seams, as well as the poorly silicified sandstone were evident in the original outcrop, the upper seam 3 contains very little silcrete while seam 1 has not been encountered in drilling to date. Underlying seam 2 is a variable thickness of more than one metre of sand. Seam 2 has been quarried.

The absence of subsurface traces of the lowest silcrete seam need not necessarily imply that the outcrops were in fact slumped parts of the upper seams. The drilling has not been sufficiently extensive as to preclude the possibility of the existence of the lower seam and in the ML 31 (Bendalong) deposit, a lower seam is moderately indurated in outcrop and a loose sand underlying the main seam.

Petrographic differences in outcrop and the existence of three seams in nearby deposits lend weight to the possibility of a lower seam in the deposit.

Overlying seam 2 is a coarse, cross-bedded, ferruginous, poorly-sorted, indurated, sandstone-conglomerate. It is made up of rounded clasts of metaquartzite and quartz. Interbedded with this is the soft clay-rich, subsurface equivalent of the upper seam (Fig. 35).

The three seams are parallel and sub-horizontal. The middle seam dips at 2 to 3 degrees to the north. The lower seam is poorly exposed and to date little of its structure has been observed.

\(^1\) Approx. 1 km north of this deposit at the Old Feltham deposit, the granodiorite is overlain by a variable thickness of weathered granodiorite.
Seam 2 has been observed in natural outcrop and during quarrying. The substantial nature of this seam can be seen in original outcrop where it was more than 50cm thick (Fig. 36). The structure of seam 2 is better seen in the quarry where it is 1 to 1.5m thick (Fig. 33). The thickness of sand between seams 1 and 2 is probably up to 2m.

**Small Scale Structures and Fossils:**

The silcrete of this deposit is lacking in small scale structures such as "cockade texture", but does have a variation in jointing which is related to induration, i.e., less indurated silcrete has more frequent jointing (Fig. 32). Seam 2 is marked by more horizontal jointing than that commonly observed elsewhere and has fairly close vertical jointing (Fig. 37). This vertical jointing is not as close as it is in some seams which have been described as "castellated".

Fossil roots are present in seam 2 (Fig. 38) which are very similar to those from the Jerrara Creek, i.e., extensively silicified traces. Fossil roots present in the ferruginous, partly-consolidated gravels associated with seam 3 are far more friable and appear to be more recent. These retain more of the original structure (Fig. 39).

**Petrography:**

The southern 1000 m$^2$ (approx.) of seam 2 is of relatively friable silcrete. North of this, the silcrete is more indurated and subvitreous.

The coarser-grained silcrete from seam 1 is made up of transparent subangular to subrounded quartz clasts of 1 to 2 mm diameter, set in a finer grained but saccharoidal matrix. The colour is pale grey to pale buff. Finer-grained, more friable zones were also observed.

Fine and coarse-grained, indurated and friable silcretes are present. Silcrete with a fine, vitreous matrix and rare coarse clasts (similar to that of the Morris Deposit) is present at the north-western part of the deposit.

Extremely vitreous and brightly coloured types have not been observed. Some very fine grained types which have a conchoidal fracture, lack the vitreous or subvitreous lustre which is commonly characteristic of fine-grained silcrete (Sample No. 80).
Differences between the friable and indurated types are far less marked in thin-section examination. For example, although megascopically sample No. 50 appears to be even grained, microscopically it exhibits the "terrazzo" texture common to most silcrete in the deposit. The friable zones of the lower seam are more porous than indurated parts, yet both types lack anatase and clay and both are silicified. The friable zones of seam 2 are also more porous than indurated zones (but less porous than observed in the lower seam) and granular anatase is more abundant.

Vegetation and Soils:

Thin, poorly-developed soils occur between outcrops of silcrete, sandstone and granodiorite. The area in which the deposit is situated is timbered. Trees are generally poorly developed.

The dominant vegetation is a poor, grey barked "scribbly gum" (c.f. Eucalyptus rossii) which tended to develop a "mallee" habit in response to the poor soil. Rare stringy barks (Eucalyptus sp) and very rare (Casuarina sp) were the only trees observed (Fig. 39).

The area was devoid of undergrowth, except for "grasstrees" (Xanthorrhoea australis).
Location and Physiographic Setting:

This deposit is situated on a small hill on the northern side of Jerrara Creek, 800 m west of the Marulan-Bungonia Road (Figs 3, 40).

The broad shallow valley of Jerrara Creek lies at the southern foot of the silcrete-capped hill. The creek is mature, meandering and swampy in places, in contrast the far more youthful occurrence 4 km east.

The country to the south and east is undulating; that to the north and west is undulating to hilly. A smaller hill, just east of the deposit is of Palaeozoic metaquartzite and not capped by silcrete.

Local Stratigraphy and Seam Structure:

Steeply dipping metaquartzite outcrops strongly on a prominent small hill just east of the deposit and also on the slopes below the deposit. This is the lowest stratigraphic unit associated with the deposit. The bedrock is overlain by up to 12 m of gravels, rich in subangular metamorphic rock fragments. The sand and gravel is overlain by silcrete up to 1 m thick.

The silcrete seam itself is overlain by up to 5 m of metamorphic rock fragment gravels. The deposit is of a single seam which is planar and subhorizontal. A minor monoclinal structure on the western outcrop may be due to local slumping.

The thickness of the seam is commonly 20 to 30 cm and up to 1 m in outcrop. The southern part of the outcrop is of more friable silcrete, especially uphill from the south eastern edge of the outcrop where it is a poorly silicified sandstone. The northern flanks of the outcrop are of indurated silcrete with a vitreous lustre (Fig. 93).

The upper surface of the single seam observed dips radially away from the centre of the hill. If the silcrete is continuous under the hill, then up to 5 m of overburden gravels may overly the seam. The upper surface of the seam was thermally spalled, probably by bushfires and no original upper surface remains.
Petrography:

A range of petrographic types exist within the seam. Friable, slightly ironstained "sandstone" occurs at the south eastern part of the deposit. This material is very highly siliceous (Table 2) and has a "terrazzo" texture similar to the harder parts of the seam. The harder parts of the outcrop are commonly coarse grained. Rounded and angular quartz clasts occur in a finer matrix. Lustre of fracture surfaces is subvitreous and the silcrete is pale grey to white. At the northern end of the deposit the silcrete is commonly white, and clasts are sparse. Areas of up to 5cm in diameter which are devoid of clasts have been observed (Figs 41, 42).

In thin-section this "Morris" type silcrete has rare, large quartz clasts, often embayed or having cuspat e "shadows" of anatase in an unusually evenly fine-grained matrix (Fig. 42).
Chemical Analyses:

The following are analyses of silcrete from the Morris deposit. Samples were oven dried at 110°C for 12 hours before analysis. It is assumed that other oxides are negligible.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
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<th>4</th>
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<tbody>
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<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>MgO</td>
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<td>0.05</td>
<td>tr.</td>
<td>0.05</td>
<td>tr.</td>
</tr>
<tr>
<td>Na₂O</td>
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<td>0.03</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>K₂O</td>
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<td><strong>1.48</strong></td>
<td><strong>1.03</strong></td>
<td><strong>0.92</strong></td>
<td><strong>1.02</strong></td>
</tr>
</tbody>
</table>

1. Indurated silcrete, eastern outcrop
2. Soft sandstone, eastern outcrop
3. Indurated grey silcrete, southern side
4. Friable white sandstone, western side
5. Indurated white silcrete, western side (thin section No. 36/66).

tr. : trace
L.O.I. : Loss on ignition
Analyst : Newbold General Refractories Limited - Research Laboratory

Soils and Vegetation:

In common with most silcrete deposits in the Bungonia region, the soil overlying the deposit is very poorly developed. A sandy gravel, barely enriched by leaf litter supports a dense population of grey "scribbly gum", (C.f. Eu. rossi) with rare "stringybark" (Eu. sp).

2.3.1. WINDELLAMA: THE CROKER DEPOSIT

Location and Physiographic setting:
This deposit occupies two adjacent spurs immediately north of the Spa Road, 3.2 km east of the Bungonia - Nerriga Road. A small creek which parallels the road to the east flows north between the two spurs and joins Nerrimunga Creek (Fig. 4).

Local Stratigraphy and Seam Structure:
The deposit is situated in an area of folded Palaeozoic metasediments, commonly micaceous sandstones, phyllitic shales and metaquartzites. These crop out in the creek bed and in nearby road cuttings. Sands and kaolinitic clays overly the metasediments.

The silcrete overlies sand and clay. Indurated grey silcrete is in places overlain by more friable, paler silcrete which is itself overlain by gravel, rich in metamorphic rock fragments.

The Croker Deposit is made up of two seams at about the same level on either side of the creek, which dip slightly (1 to 2 degrees) towards each other.

The upper surface of the indurated silcrete is very irregular (Fig.43) and some slumping has occurred above the creek. The silcrete on the eastern part of the deposit occurs as a continuous seam. Although there are friable zones within the seam, indurated grey silcrete with subvitreous texture forms the bulk of the deposit. The western part has not been worked but is probably similar, although outcrop is not as extensive as the eastern position and thicknesses in outcrop are greater (up to 2.5m).

Jointing is irregular but commonly with a greater frequency than 3 m. In common with other deposits in the Bungonia and Windellama regions, the overburden is thin. Sand and gravel, up to 1m occur as overburden. The thickness of the worked seam is between 1 and 1.5m.

Smaller scale structures:
Parts of this deposit show considerable variety of surface textures, although fossils and cockade textures have not been observed. Irregular hard and soft zones are common but not abundant. Extremely irregular parts of the upper surface, the result of erosion of soft parts, have been observed. Finely crenulated, "pumice-like" surfaces are present, particularly in the south-western end of the eastern seam (Fig.44).
Petrography:

This deposit is characterised by abundant zones of indurated grey subvitreous silcrete, rich in coarse transparent subangular quartz clasts. Such texture is not unique but the abundance of this petrographic type is unusual.

In thin-section this type has subangular clasts which range from 0.1 to 4 mm. Clasts smaller than 0.1 mm are rare and in general the matrix is fine, less than 10 microns. There is commonly a break in grain size between matrix and clasts.

Other petrographic types occur, including some in which the matrix particles are up to 0.1 mm with very little cryptocrystalline matrix. Earthy fracture, dull grey, fine-grained silcrete is also present.

Rare, iron stained zones occur, particularly in association with coarser, sandy zones.
Chemical Analyses:

The following are partial analyses from the Croker deposit. The samples were oven dried at 110°C for 12 hours before analysis. Silica was not determined. It is assumed that other oxides are negligible.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
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<td>CaO</td>
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<td>tr.</td>
</tr>
<tr>
<td>MgO</td>
<td>0.10</td>
<td>0.10</td>
<td>0.15</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.01</td>
<td>0.02</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>L.O.I.</td>
<td>0.20</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
</tr>
</tbody>
</table>

Totals: 1.46 0.99 1.22 1.06 1.59

1. See thin-section description W1/66
2. Indurated, coarse grained, pale grey to white silcrete (field No. 55).
3. Indurated, fine grained, pale grey silcrete (field No. 56)
4. Indurated, fine grained, white silcrete (field No. 57)
5. Porous, buff coloured friable silcrete (sandstone) (field No. 61)

tr. : trace
L.O.I. : Loss on ignition
Analyst : Newbold General Refractories Limited - Research Laboratory

Vegetation and Soils:

Stunted, thin but dense scrub of "scribbly gum" and very little else, is supported by the poorly developed "soil" or sandy gravel. This is very similar to the vegetation of some Bungonia region deposits, further north.
2.3.2 WINDELLAMA : THE McGAW DEPOSIT

Location and Physiographic setting:

This deposit occupies the north-eastern rim of a flat-topped spur on the northern side of the Spa Road about 100m north of the residence "La Theta".

Occurrence:

The deposit overlies folded Palaeozoic metasediments and is associated with loose sands and some lateritic capping on the Palaeozoic rocks. The silcrete outcrop is most prominent at the north-western edge of the deposit (fig. 78).

Petrography:

Silcretes of this deposit are variably iron-stained and although indurated are not as difficult to shatter as the Croker Deposit silcrete. Conglomeratic silcretes are common, as are metamorphic rock fragments. Embayed quartz clasts are common.

Vegetation and Soils:

Stuned thin eucalypt scrub with a mallee habit has developed on the poorly developed sandy soils associated with the deposit. There is not the same abundance of coarse rounded pebbles overlying the silcrete as at the Croker deposit or some Bungonia deposits.
2.4.1 NERRIGA : THE OALLEN DEPOSIT

Location and Topography:

The deposit is located on the southern flank of a slight rise in a moderately undulating terrain. Silcrete crops out on the road and can be traced north.

Description:

The silcrete occurs on the surface and is underlain by white fine to medium-grained sand of unknown depth and considerable areal extent. The silcrete has not been drilled but loose boulders of 20 to 30 cm thick were common. The silcrete is saccharoidal and friable.
Location and Physiographic Setting:

The ML.26 deposit crops out on a relatively flat area about 200 m south of the major ridge and about 4 km west of the village of Bendalong. The outcrop, which is scattered, reaches the track known locally as the "Green Hills Road".

This deposit although known from about 1920, has not been worked. It occurs on a deserted timber track, and there is a slight drop in elevation at its south-eastern edge. About 40 m south west of the deposit is a non-perennial waterfall, over quartzose sandstone.

Local Stratigraphy and Seam Structure:

The single seam is underlain by clay-rich, unconsolidated sand, the base of which cannot be observed near the seam. Beyond the immediate vicinity of the silcrete itself are several outcrops fine to medium-grained sandstone, probably the Snapper Point Formation (Gostin and Herbert 1973).

The whole of the seam is exposed (Fig. 94) and is planar, horizontal and up to 30 cm thick.

Other Features:

The upper surface of the silcrete is featureless but this is probably because the original upper surface has been spalled by bushfires and removed. The "scree" (Fig. ) is made up of loose chips and fragments of silcrete, probably the spalled remains of a very thin (1 to 3 cm) part of the seam.

The outcrop lies on a timber track not far from a graded property access and fire trail on which are several loose particles of silcrete up to 50 kg which have been disturbed by road construction.

The silcrete, in hand specimen is similar to that of ML 12, ML 53, ML 31 areas, i.e., indurated, grey with a subvitreous lustre and conchoidal fracture. Only one chemical analysis has been carried out and in this respect appears similar to the above silcrete also, except that Calcium Oxide is higher than that commonly encountered.
BENDALONG SILCRETE ML 26 DEPOSIT.

LOCATION AND OUTCROP

Bendalong Road 280m

LEGEND

[Diagram showing outcrop and scree areas]

FIGURE 2 r.
Chemical Analyses:

The sample was oven-dried at 110°C for 12 hours before partial analysis. Silica was not determined. Other oxides are assumed to be negligible.

**TABLE 6.**

Indurated grey silcrete from centre of outcrop.

<table>
<thead>
<tr>
<th>Oxide</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TiO₂</td>
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</tr>
<tr>
<td>Al₂O₃</td>
<td>0.26</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.18</td>
</tr>
<tr>
<td>CaO</td>
<td>1.05</td>
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<tr>
<td>MgO</td>
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<tr>
<td>Na₂O</td>
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<tr>
<td>K₂O</td>
<td>0.05</td>
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<tr>
<td>L.O.I.</td>
<td>0.65</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>2.80</strong></td>
</tr>
</tbody>
</table>

Analyst: Newbold General Refractories Limited-Research Laboratory
(Sample collected by writer).

**Vegetation and Soils:**

The soil is sandy, rich in carbonaceous and plant matter. The vegetation is chiefly of stunted "snappy gum" (*c.f. E. haemastoma*), *Banksia cf. serrata*, *Callistemon cf linearis*.
Location and Topographic description:

The ML 17 Deposit is situated on the southern flank of the main east-west ridge between the Conjola Post Office site and Red Head. The deposit is 150m south of the Bendalong Road and about 250m south of the North Bendalong turnoff. The deposit itself forms a cap to a subsidiary ridge which extends little further south than the silcrete (Fig.95).

Local Stratigraphy and Seam Structure:

The single seam at ML 17 is underlain by sand and clay of undetermined thickness. The sub-silcrete stratigraphy is probably similar to that of other deposits nearby such as ML 16, ML 19, ML 31 described below.

The deposit in ML 17 is made up of separate outcrops of the single seam which may have been continuous at some time but which has been separated by erosion. It is a less coherent seam than some described in other nearby deposits and may have had large zones of poorly-silicified silcrete which have been eroded. The seam is in general thicker than others in the area, being from 1 to more than 2m thick over the whole area examined. A dip to the south east is apparent, about 4 degrees over the width of outcrop, but greater at the southern end of the deposit.

The silcrete in this deposit is generally more friable and higher in iron content than other nearby exposures. There are many soft zones and the incidence of vertical joints is far greater than at other deposits such as ML 20, ML 53 and ML 16, ML 19, ML 31, however, where the silcrete is more indurated, joint blocks 3 to 4m across are common.

Petrography:

There are three broad petrographic types in the deposit. These are, indurated, compact grey silcrete, conglomeratic silcrete, sandstone. The three types are intermixed. Yellow stained and red-brown stained friable and indurated silcrete is very common. The present day mobility of the iron staining is reported to be surprisingly high (K.R. Steggles, personal communication). Stained silcrete which was freshly broken by explosives became bleached within weeks. This mobility was noted in the thin-section cut from iron stained silcrete in ML 17 (thin-section No. 46). However, not all iron staining is mobile, blocks of silcrete which had been shattered by explosives in 1967 are still iron stained.
The indurated grey refractory silcrete is compact and massive, made up of fine, (commonly less than 1mm) quartz clasts in a finer matrix. The fracture is conchoidal. In general, this material lacks the density, compactness and tenacity of the ML 20, ML 53 and ML 12 silcretes. However, some highly indurated silcretes occur as well as some coarser varieties. Coarser material has been reported (Olliver, 1968) from the reclaimed northern part of the lease.

The conglomeratic silcrete is made up of rounded silcrete granules, pebbles and boulders from 1mm to 40cm. These are most commonly of indurated, tenacious silcrete cemented by both friable, ironstained, weakly silicified matrix and by more densely silicified grey matrix. Note that the ironstaining transgresses the boundary between 1st and 2nd generation silcrete.

The red and yellow ironstaining is partly mobile, as noted above.

The sandstone is a poorly sorted, red, brown and yellow stained, weakly silicified quartz rick rock which on casual examination could be confused with the local Permian sandstones. This rock is nevertheless similar to the more indurated silcretes in texture and silicification.

The conglomeratic silcrete is not concentrated in any particular part of the central region of the deposit, has no observed preferential occurrence on the top, middle or base of the seam and generally occupies volumes of from 0.1 to 1.0m³.

Other Features:

At the southern end of the deposit, close pattern vertical jointing, having secondary silicified deposits on the joint faces, has a "castellated" appearance.
Location and Topographic Description:
This deposit is the largest recorded in the district. It is situated at the western head of a minor re-entrant at a broad flat part of the main east-west topographic ridge, about 2.4km west of the village of Bendalong. The deposit occupies approximately 5 ha (Fig.46).

Local Stratigraphy and Seam Structure:
It is not known what underlies the sandy clays below the silcrete seam. Weathered basalt traces and a limited extent of reddish kraznozemic soil overlie the silcrete. The seam is generally continuous and is thickest under the greatest thickness of cover at the centre of ML 30. The thickest part of the seam coincides with a structural low, as it does in ML 53. The deposit is divided by a gully which extends to the coast and separates the deposits along the main ridge (e.g. ML 12) from the ridge on which the North Bendalong Road was constructed.

Petrography:
In general, the silcrete in this deposit is similar to that of the ML 12 deposit, further east (section 2.5.7).

Vegetation and Soils:
The predominant tree type in the vicinity of this deposit is Eucalyptus haemastoma (known locally as "snappy-gum"). In common with other deposits in the region the soil covering the deposit is basaltic in origin. The "snappy gum" is more typical of the country to the north and west of this deposit which is generally devoid of traces of weathered basalt and in which there are no silcrete occurrences known to the writer. South and East of ML 30, ML 7, the "snappy gum" occurs sparsely, and commonly only on ridges.
2.5.4 BENDALONG : THE ML 18 & ML 36 DEPOSIT

Location and Topographic Description:

The ML 18 deposit was worked during 1961 and 1962. The silcrete was depleted and the area has been backfilled and considerable regrowth of the scrub has occurred. No records of the silcrete type remain but the deposit was probably similar to the remaining silcrete in ML 36. Ferricrete (Fig.47) was associated with the silcrete at the southern end of the deposit.

The deposit of (approx.) 1.5 ha occupied a gentle slope on the southern flank of the major east west ridge. The deposit was approximately 2 km west of the village of Bendalong. The deposit may have been worked to the north and may have joined the ML 36 deposit on the northern side of the crest of the ridge. The road was re-routed prior to 1966, probably with a view to complete exploitation of that part of the deposit.

1. Mr. A.J. Brook, Quarry Manager, described the silcrete won from the deposit as being compact, indurated grey silcrete similar to that of ML 30 and ML 12 deposits.
Location and Physiography:

The deposit is located on the northern flank of an east-west ridge originating in higher country near the Conjoala Post Office site and which reaches the coast at Red Head, just east of Bendalong. The bulk of the deposit is on the northern flank of the ridge.

Stratigraphy:

Four auger holes were drilled in the vicinity of the deposit, in which a yellow, micaceous, siltstone was encountered. This was assumed to be weathered Permian sandstone as discussed in section 2.5.7.

Outcrop of Permian sediment was not observed near this deposit although Permian sandstone crops out abundantly in the region, especially to the west, nearer the Princes Highway, and to the north west.

In two adjacent auger holes a soft damp chocolate coloured clay with fine pale green and white angular fragments was encountered. This very local occurrence may be a buried soil profile or perhaps a soil horizon which was disturbed, transported and deposited on the eroded Permian surface.

Overlying the Permian sandstone is grey clay, commonly sandy but locally high in kaolinite content.

The clay has no obvious structures and was not observed in section, but as drill hole cuttings. Nevertheless the clay is assumed to be of sedimentary origin because of its high sand component and because in auger hole cuttings the grey sandy clay grades very gradually into the underlying micaceous siltstone. The silcrete seam overlies the grey clay. At the edge of the deposit a thin band of fine white silt is the lateral extension of the seam.

Overlying the silcrete is a stiff pale grey, high alumina clay, up to 2m thick. This grades into a mottled grey and red clay. The grey component is similar to the underlying grey clay and the red clay contains partially weathered basalt fragments, as dark iron-rich nodules are present in some of the red stained spots (Fig.48). Above the mottled grey and red zone is a more iron rich red-brown zone commonly containing dark hard nodules (thought to be fragments of a final weathering stage of basalt). Overlying this red zone is a brown-red soil, the lower part of which often contains lateritic nodules or dark fragments as described above. In the western part
BENDALONG - ML 16, 19, 31 DEPOSIT

GENERALISED STRUCTURE CONTOURS, UPPER SURFACE OF SILCRETE BODY

METERS A.S.L.

LEGEND

Data Control Point

SCALE

20 metres

FIGURE 96
of the deposit the dark fragments and "box-work" laterite blocks are more common (Fig. 48). The deposit is weakly connected, laterally to other deposits to the west, south and east (described below).

Seam Structure:

The altitude of upper surface of the silcrete body is greatest at the western edge of the deposit and falls away towards the centre of the ridge to the south, and largely follows the topographic fall of the northern flank of the ridge to the north and east (Fig. 96).

The silcrete body is discontinuous especially in the eastern extremity where it occurs as discrete, tabular but irregular blocks up to approximately 7 tonnes. These blocks have rounded ends and have a buff coloured, sandy coating and do not appear to be joint blocks which have drifted apart by gravitational means. Nevertheless they lie as discontinuous parts of the larger, tabular body, or seam. In the southern part of the seam, the silcrete becomes thinner and discontinuous. Drilling and costeaning in the area indicate a thickness of as little as 15cm and near a thin discontinuous outcrop on the southern flank of the ridge it occurs in the subsurface as rounded blebs up to 25cm thick. In the south eastern part although discontinuous the seam can be traced as thin residual zones (as outcrop and subcrop) to join with the ML 53 deposit.

In the subsurface, under the centre of the ridge, the deposit appears to grade laterally into an ironstone-laterite deposit which can also be traced from drilling results to ML 53.

On the outcrop towards ML 9 grey silcrete also grades laterally into an iron-laterite. In this same area costeaning exposed a discontinuous laterite in the subsurface (Fig. 48). The seam is irregularly jointed but appears as a continuous seam.

The vertical thickness of the seam varies from 15cm to 1.6m. This variation occurs within a short distance in certain parts of the deposit although for much of 1,000m² of the eastern part of the deposit it is uniformly around 30cm thick and from 2 to 7m below the surface.

A lower seam of less indurated siliceous material is present further north.
Petrography:

The silcrete of the main seam is of relatively uniform compact grey, indurated tenacious material with a subvitreous lustre on fracture surfaces.

The lower seam is more friable, moderately silicified, and ironstained in outcrop but grading laterally into a yellow sand below the main seam.

Vegetation and Soil:

A red, brown, friable kraznozemic soil supports a dense vegetation dominated by large "bloodwood" (*Eucalyptus gummifera*), trees with less common "turpentine" (*Syncarpia glomulifera*), "blackbutt" (*Eucalyptus pilularis*) and "stringybark" (*Eucalyptus cf. delegatensis*).
Location and Topographic Setting:

The ML 14, ML 15 and ML 21 silcrete deposits occur on the northern side of the gully which bifurcates the main ridge from the coast to ML 7. The track to North Bendalong village follows this northern limb of the ridge. The ML 15 deposit occurs on the crest of the ridge, the ML 14 and ML 21 deposits occur on two minor spurs on the southern side of the ridge. Subsurface lithological traces link the three deposits.

Distances from Bendalong and North Bendalong are:
ML 14 1.3 and 1.2 km; ML 15 2.4 and 1.6 km; ML 21 1.6km and 600m respectively.

These deposits have been known since 1919, and each have small quarrying pits which were probably dug before 1950. Topography and outcrop are shown on Figs 97 (ML14), 98 (ML15) and 99 (ML21).

Stratigraphy:

Less than 1 m below the surface on the ridge crest and on the flanks of the silcrete capped spurs is a yellow micaceous siltstone, probably the Ulladulla Mudstone (Gostin & Herbert, 1973).

Variable sand-rich and sand-poor clays overlie the siltstone beneath and surrounding the silcrete deposits. A white or pink clay, commonly with little sand, occurs west and south of the ML 15 silcrete deposit and is up to 3m thick. Drilling results show that this overlies the weathered siltstone. Other salmon pink, brown, grey-brown sands occur south of ML 15. Although grey and white low silica, refractory clays occur at about the stratigraphic level of the silcrete, there is no unambiguous evidence that any of these are products of weathering basalt. In many drill holes in the ML 15 area a thin layer of white, fine sand was encountered at the stratigraphic level of the silcrete. The silcrete occurs at the surface in much of the area of the three deposits.

Overlying the silcrete, where relevant is a red-brown subsoil, with or without ferricrete overlain by a grey poorly developed sandy soil. The ferricrete, commonly highly indurated, occurs abundantly as surface and subsurface encrustations, discrete pebbles and prominent blocky outcrops.
FIGURE 97. SHOWING TOPOGRAPHY & SILCRETE OUTCROP.
FIGURE 98, SHOWING TOPOGRAPHY & SILCRETE DEPOSIT
Structure:

The ML 15 deposit is linked by a thin subsurface silcrete seam to the ML 14 deposit. Discontinuous surface and subsurface traces link the northern end of the ML 14 deposit east to the northern end of the ML 21 deposit.

The three deposits are themselves discontinuous. The ML 15 deposit thins under cover to the north where it is replaced by a thin white sand layer overlain by indurated ironstone. Just north of the ridge crest there are small outcrops of ironstone and also small silcrete outcrops. The bulk of the ML 15 silcrete was visible on the surface with a dip of one degree towards the south-east.

The seam occurs under shallow overburden a few metres to the north west and was traced, by drilling south east to ML 14 at depths of up to 3m. The ML 14 deposit consists of four outcrops, two of which are linked by subsurface silcrete (Fig.99) and two which are not. The bulk of the deposit is in one large outcrop 9m below the level of the ML 15 outcrop. At 3m below the lowest part of the large outcrop is a smaller outcrop, which occurs part way down the steeper slope above the gully. From the structure (Fig.97) it can be seen that the seam may be traced continuously from 49m above sea level in ML 15 to 29m in ML 14.

Although the dip on the ML 15 outcrop is 1 degree and on ML 14 is 1.6 degrees, the dip overall is 1.6 degrees, all towards the south-east.

The ML 21 deposit is tenuously connected to the ML 14 and ML 15 deposits by discontinuous surface and subsurface silcrete. The ML 21 is on a minor spur which is more or less parallel to the ML 14 spur. The deposit is made up of scattered outcrop zones, some of which are connected by very shallow subsurface silcrete. The dip of the largest continuous outcrop is approximately 2 degrees towards the south east.

The ML15 seam is up to 1m thick, but less in most parts. The maximum thickness is at about the centre of the outcrop and thins to the northwest and south-east. In a prospecting area pegged between ML15 and ML14 a series of drill holes encountered silcrete which was probably a discontinuous seam. The thickness encountered was not necessarily representative of the actual seam. In a prospecting area drilled near ML31, similar drilling results were obtained but when costeamed, the deposit was merely a small number of 20 to 30cm cobbles linked by a 3 to 4cm bed of white fine sand. Subsurface thickness in the ML14 were less than the thickness of the silcrete in outcrop. In other areas previously worked further south it was found that the greatest thickness occurred in subsurface parts of deposits, although clearly the silcrete thickness is not proportional to the depth of overburden.
At the south eastern end of ML 14 was an outcrop of about 1,500 m². This was not connected to the main outcrop although there is a stratigraphic link.

Between the northern ends of ML 14 and ML 21 are scattered, thin outcrop and subcrop zones. Since the drilling in this area was concentrated around actual outcrop zones it cannot be stated with certainty that there is a stratigraphic link between ML 14 and ML 21.

The ML 21 silcrete is a largely surficial deposit and generally thin (from 10 to 20 cm) but reaches a thickness of 1m at the south-eastern edge, where the ground surface falls away rapidly.

No evidence to suggest the existence of more than one seam has been observed in the area of ML 14, ML 15, ML 21. In general, the jointing has been fairly sparse and vertical, with irregular distribution.

**Petrography:**

The ML 15 deposit contains a variety of petrographic types including a highly indurated blue-grey silcrete with conchoidal fracture. In general, the exposed silcrete is of this type. Beyond 30 cm below the surface, the seam is commonly more friable, sandy and iron stained. Towards the margins of the deposit, iron stained red or brown bands commonly occur in the indurated silcrete. This more compact rock is composed of abundant fine and rare coarse angular fragments of transparent to translucent white quartz in a matrix which is finer-grained and commonly pale grey. The fracture is subconchoidal to even, and the fracture surface is dull.

The more friable portions of the seam are of finer semi-silicified sand. The fracture is uneven and the fracture surface dull to earthy. Colour is off white, buff, to red-brown.

**Small Scale structures:**

The exposed parts of ML 15, exhibit no features other than the common spalling due to the effects of bushfires. Subsurface parts of the seam at the south eastern extremity of ML 15 have well defined "cockade structures" (Fig.49).

The upper 3 to 15 mm of the seam in ML 15 is commonly bleached.
Vegetation and soils:

As mentioned, the soils overlying the silcrete deposits are commonly grey, poorly developed sandy soils. These are mainly sand with a small proportion of carbon and humus (Fig. 50).

These soils appear to have been formed by removal of clay from the sandy clays (fawn or white), which overlie the Permian. At the crest of the major ridge are red-brown, clay and laterite-rich soils.

Dominant trees of this location are Eucalyptus gummifera (bloodwood) and Syncarpia glomulifera (turpentine) with less common E. pilularis (blackbutt), "stringybark" (cf. E. delegatensis) rae "snappy gum" (cf. E. haemastoma). The latter was observed in ML 15. Smaller trees and undergrowth are mostly Banksia serrata and Callistemon linearis.

It is interesting to note that the vegetation in the ML 53 area is virtually identical although the soils are different. However, the two areas have both well drained soils, clayey subsoils, and occupy southern flanks of ridges.

Bark of trees which are growing through the silcrete outcrop commonly covers the upper surface of the silcrete around the trunk where it meets the silcrete. In areas of thin subsurface silcrete, broken pieces of silcrete are commonly observed at the surface around the bases of larger trees.
2.5.7 BENDALONG : THE ML 12 DEPOSIT

Location and Physiographic Setting:

The deposit is located on the northern flank of a spur which occurs along a line between the Conjola Post Office site and the coast at Red Head, which is just east of Bendalong. The ridge decreases in altitude from west to east. The deposit lies on the northern flank of this ridge (Fig. 5).

The deposit is approximately 500m west of Bendalong village and extends approximately 200m west and approximately 150m in extent in a north-south direction. Aerial photographs (Dept. of Lands) taken before any quarrying commenced show a barely perceptible "ledging" effect which is outlined by small pits (1 to 2m wide) from which silcrete was won during the depression years. Such pits were recorded in 1967 as being in the south-eastern extremity of outcrop and in 1962 a line of prospecting pits, up to a metre in depth, was recorded along the south-western edge of the outcrop.

Stratigraphy:

A micaceous, quartzose, yellow, fine laminated siltstone was encountered in exploratory auger holes just east of ML 12. This is assumed to be a weathered Permian sediment as in the auger cuttings of one hole a fenestellid fragment was found (Fig. 51). Weathered, soft pebbles of red and yellow micaceous sediment were encountered in several of the 40 exploratory auger holes drilled in a 6 ha area east of ML 12. In more than four holes a much harder, quartzose sediment was encountered. This was considered to be silcrete by the drillers at the time (1969) but was most likely the quartzose sandstone (Snapper Point Formation) underlying the Ulladulla Mudstone (Gostin & Herbert, 1973).

Weathered Permian sediment was encountered in most exploratory drill holes except where silcrete was encountered, overlying the weathered Permian was a younger sand, gravel, clay or sandy clay. A poorly-sorted gravel was observed in the floor of the quarry at the north-eastern corner of ML 12. In certain of the auger holes pebbles of Permian sediment were observed in the younger stiff, pink clay.

The silcrete itself was similar to that encountered in ML 7, ML 30, ML 20 and ML 53 and is exposed at the surface or under poor, iron-rich subsoil and topsoil. Toward the east of the deposit the silcrete is overlain by up to 2m of stiff grey, high alumina clay, up to 2m of grey clay red stained with iron and containing red-black nodules of weathered

basalt. This is overlain by up to one metre of coarsely porous but indurated ironstone, which is open in texture and contains some grey clay within its pore spaces. Above the ironstone band (which is not continuous) is up to 1.2m clay, mostly red-brown, becoming darker and containing less grey towards the upper red soil horizon, commonly 1m thick. In the small area (approx. 1,000 - 1,500m²) where there are two seams, these are separated by stiff, grey, high alumina clay. The lower seam is less indurated, more friable than the upper. The upper seam is planar, thinning gradually to the east. The upper seam is of high quality, (i.e. indurated, brittle, high silica, low alumina, low iron) silcrete. The upper and lower 3 to 8 cm of the seam in this area is of well-sorted, loose fine sand.

Structure:
The deposit is, in general, a continuous, tabular body which dips at approximately 5 degrees to the north with a variable thickness of approximately 1m.

The northern and western margins of the silcrete are of discontinuous boulders. The deposit can be traced, by intermittent, thin surface and subsurface silcrete traces to the south, across the crest of the ridge to the ML 20, ML 53 deposit, and by similar but weaker traces to the west and the ML 16, ML 19, ML 31 deposit. The upper surface is roughly planar, in common with other occurrences in the region.

A localised lower seam development is present near the north-east corner of ML 12. At this point the upper and lower seams are approx. 30 to 40 cm thick, separated by a similar thickness of sand and clay.

The silcrete crops out along the northern, western and southern parts of the deposit. To the east the seam thins under greater overburden. Where the silcrete is thin, east of ML 12, it is continuous and of high quality. The thickest part of the deposit is at the centre (over 2m).

Although in most Bendalong deposits the upper surface of the silcrete is broadly planar or is warped gradually, the lower surface is more irregular, although still remaining very roughly parallel to the upper surface. In the area explored by auger drilling just east of ML 12, considerable variation in the altitude of the top of the underlying Permian sediment was observed although no relationship between this and the structure or thickness of the overlying silcrete was established.
2.5.8 BENDALONG : THE ML 20, 53 DEPOSIT

Location and Topography:

The deposit is located on the southern flank of an east-west spur (described in previous sections). The silcrete extends from about 500m west of the village to midway between ML 16, ML 19, ML 31 and ML 20, 53 (i.e. subsurface silcrete extends west of the area marked as ML 20, 53 in Fig. 5). ML 12 is 200m north of ML 53.

Local Stratigraphy and Seam Structure:

The Ulladulla Mudstone (Gostin & Herbert, 1973) was encountered in drill holes augered north, west and south of ML 53. This is the lowest stratigraphic unit cropping out in the area. It is believed to be Permian for the reasons outlined in Section 2.5.7. The weathered Ulladulla Mudstone is overlain by up to 5m of clayey sand with rare clean sand lenses, which is overlain by the lower silcrete seam. A seam split occurs in the south-west central part of the deposit (Fig. 53), (Figs 106, 107 at rear).

The lower seam is up to 3m thick in the central structural "trough" of the deposit. Where the split is present, the lower member is about 1m thick and the upper member up to 30cm. The two are separated by up to 50cm of dark grey, stiff clay.

For the most part this deposit consists of a single seam which dips south from the crest of the topographic ridge. The seam is more or less planar except for the prominent "trough" which runs north-south through the deposit (Fig. 100). The western extension of the seam is thin (less than 30cm) and discontinuous. The seam is thinner and more discontinuous towards ML 16, ML 19, ML 31.

It is thought that ML 16, 19, 31, ML 20, 53 and ML 12 are genetically related and are in fact, parts of the one deposit. Sparse, thin surface and subsurface silcrete occurs between the former two deposits. Links between ML 12 and ML 20, 53 are less clear but it is believed that the thin (15cm) white sand band which extends north of ML 53 to the iron rich silcrete at the crest of the ridge does in fact continue to join with the ML 12 silcrete.

The silcrete is partly overlain by up to 50cm of fine, poorly-silicified, bedded white sand (Fig. 54). For much of the seam this is absent or less than 1cm thick.
BENDALONG - ML 53, 20 DEPOSIT

GENERALISED STRUCTURE CONTOURS, UPPER SURFACE OF SILCRETE BODY

METERS A. S. L.

LEGEND

• Data Control Point

SCALE

20 metres

FIGURE 100.
Above the seam is a mottled zone of grey clay and weathered basalt fragments with iron staining (Fig. 55). At the northern end of the deposit mottled zone is overlain by an indurated iron rich layer, up to 1.5m thick. This is only present where the silcrete seam is more than 5 m below the surface. At the southern extremity of the deposit the clay is more uniformly mottled (Fig. 56). The mottled clay, or iron stone layer is overlain by a red to brown open subsoil and topsoil.

Small Scale Structures and Other Features:

The upper surface of the silcrete is in general planar with a relief of no more than 12cm per linear metre of surface. The upper surface of the northern part of the deposit was either covered by a thin (1 to 2mm) soft, white, fine-grained sand, an even thinner cream-brown veneer (Fig. 54) or the bedded sand described above. The "cockade texture" is commonly present on the upper surface of the silcrete (Fig. 57). These markings are not present over the whole of the seam, nor is there any suggestion that they previously had been.

Rare zones of friable, less dense silcrete are present in the northwestern part of the seam where the low silicification appears to be related to incipient jointing (Fig. 58).

The lower surface of the seam is far more irregular than the upper. The lower surface is featureless apart from undulating having an amplitude of 20 to 30 cm and a wavelength of 40 to 50cm (c.f. section 2.1.3).

Concentrations of anatase, marked by more vitreous lustre and yellow-buff colouration commonly occurs in a linear fashion (Fig. 59). These bands are planar rather than linear features and are commonly irregular in direction. They occur vertically as well as horizontally.

Fissures, commonly filled or partly filled with secondary quartz crystals (Fig. 60) occur rarely in the northern two-thirds of the deposit. Lines of very fine, elongate holes, commonly concentrated in zones (Fig. 61) also occur in the same region. Neither of the latter two features are abundant, but can generally be found without difficulty.

Charcoal fragments, common in the upper 15 to 20cm of the seam at the Caoura Road Deposit (Tallong) occur rarely in the ML 20, 53 deposit. The charcoal shown in Fig. 62 was 30cm from the upper surface of the seam.

Obvious plant fossils also occur. Those observed appear to be totally silicified, at the top of the seam. Their morphology and orientation suggests that they are plant roots which may have been silicified in situ.
Petrography:

The northern two-thirds of the deposit is of relatively uniform, indurated grey, brittle silcrete. This silcrete has a sub-vitreous lustre, conchoidal fracture and is translucent. Colour is commonly mid-grey but dark grey and rare zones of black silcrete also occur. The southern third of the deposit also contains indurated grey silcrete but also a considerable proportion of softer, iron-stained silcrete (Fig.63). Here, the highly indurated silcrete occurs as rounded boulders, separated by iron-stained zones (Fig.64).

In thin-section the silcrete from ML 53 is fine to medium-grained and notably of varying grain size from sub-microscopic to 2mm. This silcrete does not commonly exhibit the "terrazzo" texture common in many silcretes. There is however the abundance of angular quartz clasts and areas of very fine-grained interlobed quartz. Metaquartzite rock fragments are common but not abundant. The yellow-brown, fine-grained bands previously described are areas in which granular anatase is concentrated (Fig.59).

The silcrete from the southern third of the deposit (ML 20) is largely of the same appearance macroscopically and in thin section. However there are abundant zones in which the proportion of sand-sized clasts is greater, interlobed and intersutured clasts rare and with a matrix which is a mixture of finer grained quartz clasts, anatase, clay and carbon. This silcrete has a hand specimen appearance which is paler, dull and less indurated.

Soils and Vegetation:

The open, brown basalt-derived soils support a dense strand of "bloodwood" (E. gummifera) and including, less common "blackbutt" (E. pilularis), "stringybark" (E. c.f. delegatensis) with dense undergrowth of Banksia c.f. serrata, Callistemon spp. This assemblage is similar to that of ML 14, 15, 21 as noted above.
Location and Topographic Description:

The deposit is located at the very southern end of Wreck Bay where it crosses the beach at the foot of a small headland. A western extension of the seam is observed along Erningold Drive (Fig. 65). Some extension under weathered basalt may occur to the south and east.

Some quarrying may have taken place since 1919 but probably the greater part of the deposit remains. Some disturbance has occurred as a result of the construction and dismantling of a jetty, flying fox and crusher installation. Large underwater slabs are at times visible up to 100m from the shore.

Stratigraphy:

At times, a clay derived from weathered basalt is exposed just south of the outcrop. It is therefore assumed that the silcrete overlies basalt. The silcrete, where exposed in section is fairly uniform in texture, but just north of the old crusher site, indurated, grey, sub-vitreous silcrete is overlain by friable, dull, pale grey silcrete with irregular iron-stained zones. This is overlain by up to 15cm of dark ferricrete (Fig. 66).

At the western end of the major beach outcrop is an extensive zone of columnar silcrete - ferricrete (Fig. 67). Here the silcrete is above the ferricrete. Overlying the silcrete and ferricrete is a brown subsoil and a dark brown to black basalt-derived soil.

Structure:

The silcrete occurs as a single seam. It is assumed that the different levels of occurrence at the main outcrop are due to slumping caused by marine undermining (Fig. 68). The Erningold Drive outcrop (Fig. 65) is higher than the main outcrop, indicating a dip to the east. This is in accordance with the level of occurrence of the ML 12 deposit.

The seam thickness, excluding softer parts is up to 1m, commonly 60 to 70cm. Several mining leases were pegged east of this deposit; these expired more than 10 years ago.

Vegetative cover is heavy along the small cliff behind the beach, this obscures traces of a likely eastern extension of the Beach Deposit.
Small Scale Structures:

A great variety of small structures may be observed on the upper surface of the seam, although none observed to date are unique. "Bedding" (Figs 68, 69) is observed in one part of the seam. This is at the top of the seam. Similar structures are observed at the Badgery Lookdown Deposit (at base of seam) and also an unconsolidated sand forms similar structures at the top of the ML 53 Deposit.

Other structures include "cockade structures" (previously described), rather similar "nodular" structures (also common on joint faces e.g. ML 17), and variations of these and the following structures.

"Castellation" structures are best observed in vertical section and are common in some less indurated silcretes. An etched, columnar structure observed at low tide at the eastern end of the Beach Deposit is probably this "castellation" structure (Fig. 71).

Small-scale, vertical, shallow cracks have been observed in an area of no more than 5m² at the eastern end of the Beach Deposit (Fig. 72). These fine cracks are commonly parallel to joint fractures and more coarse "crosses". The crosses are shallow, (about 1cm deep), from 2 to 4cm wide and often red-stained.

Soils and Vegetation:

Soils are described above. Vegetation has been removed. Beach sand overlies the edges of the deposit except on the southern edge.

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1. e.g. ML 27, Headland area (Fig. 77).
BENDALONG SILCRETE HEADLAND DEPOSIT.

PLAN

WRECK BAY

SCALE - 1:4000

SOUTH PACIFIC OCEAN

basalt platform, approximate only angular silcrete blocks up to 1.5 metres - in ocean.

silcrete and pallid zone

cobble beach 10%
silcrete cave
70-80% silcrete boulders up to 2 metres on basalt pavement mine adit

 SECTION A

SECTION B

SECTION C

SECTION D

SECTION E

stainless steel plate.

post-silcrete bedding

beach.

thin discontinuous silcrete.

Red Head.

basalt cobbles and boulders sheltered lagoon.

FIGURE 101.
Location and Topographic Description:
This is the headland east of Bendalong known as "Red Head" (Fig. 10). The point is well elevated (about 20m a.s.l.) over most of its area, is flat-topped and bounded on the north and east by steep cliffs and rock platforms. On the southern side of the point there is a shallow "lagoon", bounded by the sea and a small beach (Fig. 10). At the southern end of the beach and lagoon is a smaller red-coloured knob capped with thin residual silcrete and red-brown basalt subsoil. To the south of this minor headland is a more extensive beach backed by a narrow dune systems.

Stratigraphy and Seam Structure:
This deposit is made up of more than one seam.

The lowest strata associated with the silcrete seams is a dark, medium-grained basalt 6 to 12m thick, the top 2 or 3m of which is paler and partially decomposed (Figs 73, 74). The partially weathered basalt passes upwards into a green yellow clay, above which is approximately 1m of grey, plastic clay, rarely red, with very rare 2 to 5mm rounded white quartz pebbles. The lowest seam, where developed, occurs above the grey plastic clay. Between the three silcrete seams are pale sands with variable clay content. A lenticular ferruginous sand and pebble bed (up to 20cm thick) was observed 15cm above seam 2 in sections C and D (Figs 102, 103). Between seams 2 and 3 there is an increase in grainsize mode downwards reaching a maximum just above seam 2.

Seam continuity is probably persistent for approximately 200m. Exposure is limited by slumping. At Section E only two seams can be observed (Fig. 104). Above seam 3 in sections C and D there is a grey, sandy, poorly-developed soil containing angular fragments of silcrete and fragments of ferricrete. The fragments commonly occur in thin 2 to 3cm bands. The bands were observed in similar, but darker, more organic and clay-rich soil at the southern end of the "lagoon" to the south. This soil type is very similar to that associated with the ML14 silcrete deposit, but lacking the abundance of silcrete chips at ML14. Above seam 3 at section E, 40cm of stiff grey clay occurred overlain by 1m of red-brown, weathered basalt.

At section B (Fig. 10) a horizontal drive has been constructed to exploit a 1m seam of blue and white high alumina clay which underlies seam 1. Above the three seams at section B is up to 3m of mottled brown clayey sand. Above the sequence in all sections is the grey, sandy soil...
described above. South of the measured sections, the single silcrete seam is underlain by basalt and clay (as described above) and overlain by a thin red-brown basaltic soil.

Approximately one third of the perimeter of the headland has a visible substantial silcrete outcrop. Further thin, single layer, silcrete continues to the north of the main outcrop and a thin silcrete capping occurs on the southern extremity of the headland. Locally, the seams appear to be horizontal but a slight dip of between 1 and 2 degrees to the east exists.

The deposit consists generally of three seams. The seams are not always visible due to slumping or vegetation. The seams do not appear to be well developed in certain localities. It is difficult to determine whether the seams are not continuous, or are so soft in certain areas as to be hidden or confused with the softer interseam sands.

Vertical jointing is present and commonly prominent. The jointing is in general vertical only and the system appears to be fairly orthogonal, north-south and east-west. Slumped blocks of from 30cm to 2m diameter are common (Fig.74).

It is possible that at Section D (Fig.103) there are four seams. Although slumping has occurred, the elevation of seam 1 is such that a lower seam, corresponding to seam 1 at section C exists.

Small Scale Structures:

The silcretes show few traces of bedding. Sample No. 7A, from the top of seam 3 (Section C) clearly shows very fine horizontal bands. These in thin-section are alternating anatase rich and poorly silicified "coarse matrix" bands. This is interpreted as a silicification function and not related to bedding. Similar banding in ML 53 for example is commonly vertical. The ferruginous fine pebble beds and associated non-ferruginous sands above seam 2 in sections C and D were prominently bedded.

The mineralogical and grainsize differences between the seams and their associated sediments above and below define the silcrete seams themselves as bedding structures, although unambiguous bedding structures have not been observed within the silcrete seams.

The absence of observed plant root fossils in the deposit is not taken to indicate their complete absence as these are found rarely but persistently in other deposits.
BENDALONG SILCRETE - HEADLAND DEPOSIT.

SECTION C.

grey sandy soil

sand friable ironstained contains organic
matter more friable and cleaner downwards

very poorly cohesive silcrete.
SEAM 3 also rich in ultra fine silica
quartz angular no visible clay

soft low clay white sand fairly fine

does not become coarser downwards rapidly

SEAM 2 very fine grained poorly

cemented silcrete
very little clay; rich in ultra
fine silica

stiff but plastic grey clay, some red
coloured horizontal bands.

1.4m SEAM 1 not well developed laterally

7.13m ironstained finely sandy clay
yellow green clay, some mottled grey red
zones. about 50cm exposed.

FIGURE 102.
FIGURE 103
BENDALONG SILCRETE-HEADLAND DEPOSIT

SECTION E.

1 metre

- soil
- red-brown weathered basalt
- stiff grey clay
- seam of silcrete
- "soft silcrete"
- typical slump movement.
- "soft silcrete" obscured by slumped soil
- "soft silcrete"
- silcrete seam
- clays etc
- obscured by dense vegetation
- top of weathered basalt
- basalt cliff face

FIGURE 104.
These silcrete seams commonly have a "nodular" structure and are castellated. This is most noticeable on the eastern-most parts of the seams e.g. section E (Figs 77,104).

The "nodules" are variable in size but are commonly 2 to 4cm in diameter. The nodules appear to be more resistant to weathering than the surrounding silcrete and are commonly rounded to sub-spherical, standing proud.

The "castellated" appearance is only moderately developed, and is associated with "nodular" silcrete, not to be confused with the conglomeratic silcrete e.g. ML17.

Petrography:

The headland silcretes are less indurated than most other deposits in the Bendalong area, but similar to that of the ML27 in the Pattimore's lagoon area, and to the western end of the Bungonia Jerrara Creek deposit. This cannot be attributed to the action of salt spray as the more exposed silcretes at the Beach deposit are dense and indurated being very similar to the silcretes in ML53 or 12.

The silcretes are composed of fine, colourless, angular quartz which is weakly bonded. The material is friable to touch, porous, but resistant to fracturing. The fracture surface is dull to uneven.

The following is a generalised description, points mentioned being common to all sections examined: The material is made up of angular to acicular particles of colourless quartz, rarely exceeding 1mm in diameter. Certain fields show a complete size gradation from one millimetre down to sub-microscopic but other sections show the "terrazzo" texture which is usually obvious in hand specimen examination. In all sections examined there was some embayment and evidence of merging of the quartz grain boundaries with the matrix.

Rare composite metaquartzite grains occur in common with thin-sections of silcrete from ML 53.

"Colloform" structures (Frankel and Kent, 1937) generally associated with anatase-rich bands are present in all sections, some more common than others.
Vegetation and Soils:

The soils observed on the headland are composed of medium-grained sand with allogenic pebbles, (notably angular silcrete fragments and rounded fragments of ferricrete and friable silcrete), contaminated with organic matter and variable clay. This poorly developed soil is from grey to chocolate-grey, depending on the clay and organic content. A red, partly developed subsoil occurs locally.

The vegetation is perhaps more relevant to the exposed location than the geology. The taller vegetation is mainly of *Banksia cf. Serrata* with rarer *Casuarina sp.* and rare *B. integrifolia*. The lower heath type vegetation of the steeper slopes is of smaller shrubs such as *Westringia rosmariniformis* and indigenous grasses.
2.5.11 THE PATTIMORE LAGOON AREA DEPOSITS

Location and Physiographic Setting:

The PML3 deposit remains are on a ridge which occurs along a bearing of approximately 120 degrees. The ridge, which is capped by sand, silcrete and basalt for about 2km at its eastern end is just south-west of Pattimore Lagoon.

The basalt capped silcrete outcrop remains as an artificial mesa overlooking the ocean and Pattimore Lagoon. The original area of outcrop is not known. The deposit was abandoned because of the decline in the perimeter length and thickness of relatively fresh basalt overburden. It now occupies about 750m$^2$ and is approximately 8 to 10m above the surrounding area. The ML 27 deposit is approximately 500m west of the PML3 deposit on the same ridge.

The deposit has been partly worked, although probably only about half or less has been won.

Stratigraphy and Seam Structure:

The PML3 deposit is made up of up to six seams which vary greatly both vertically and laterally, lensing on a large and small scale.

Strata lower than the lowest silcrete seam were not observed in the immediate vicinity of the PML3 deposit, due to large overburden and waste dumps but it is assumed that this deposit rests on a weathered top of the quartzose sandstones (Permian) which crop out prominently to the west.

The silcrete seams are interleaved with clayey sand beds and overlain by up to 2m of basalt (Fig. 105).

The same can be said of strata below the ML 27 seam as for PML 3. Overlying the silcrete is a white clayey sand up to 9m thick and overlain by a thin, poorly developed sandy soil.

All exposed parts of the PML3 deposit are lenticular, the number of seams varying laterally.

Vertical jointing is present, the periodicity, in common with softer silcrete deposits being high, generally less than 1m, commonly less than 30cm. A preferred direction was not observed. Horizontal jointing is not present.

The ML27 deposit is a single seam deposit. The seam is generally about 1m thick. There is a dip of about 10 degrees to the east. The upper surface is undulating with a relief of up to 30cm and periodicity of less than 1m.
PATTIMORE LAGOON SILCRETE DEPOSITS PML 3

TYPICAL SECTION - SHOWING SAMPLE POINTS.

1 metre

view to west

basalt

indurated siliceous-ferruginous vein 1-2 cm.

hard silcrete, horizontal banding

sand, and iron stone

silcrete coarse

sand, some silcrete, ie harder bands.

hard, dense but dull lustre, uneven fracture

sand, some poorly bonded silty silcrete

uneven hard-soft zone

2-2 ½ metre seam of hard silcrete with some soft bands

silcrete - sand

scree covered

hard silcrete

FIGURE 105.
The seam underlies up to 9m of white clayey sand and thin sandy soil. The seam is continuous but is strongly, vertically jointed. The preferred direction of the jointing is northeast-southwest and northwest-southeast and the joint sets are roughly orthogonal. Jointing parallel to the upper surface of the seam is also present.

Petrography:
The petrographic variation observed in the small PML3 deposit was considerable. Examples which are typical of silcretes from other deposits such as those at Bungonia and Windellama were observed. Indurated, compact grey silcrete, with conchoidal fracture occurs in intimate association with poorly bonded friable sandstones, not sufficiently indurated to be termed "silcretes". Fine-grained, compact, highly indurated silcrete made up of angular fragments of quartz in a fine-grained matrix was observed as well as both pale and grey strongly coloured specimens.

Some silcrete was well indurated nevertheless lacked conchoidal fracture and had a dull lustre (e.g. sample No. 38). Paler less indurated material occurred as seams and although it could be argued that these are not silcretes as defined, their field occurrence and thin section appearance was difficult to distinguish from that of the highly indurated varieties.

Softer clayey sands occurred between and graded into the seams.

The silcrete of the ML27 seam is petrographically consistent, very little vertical or lateral variation in colour and texture was observed. The material is made up of sparse, angular quartz fragments, of less than 1mm within a ground mass of finer quartz. The material has a dull lustre, is friable to touch, and lacks conchoidal fracture and translucency. Although the material lacks the tenacity of the subvitreous types, it is nevertheless indurated, and included as a silcrete. It has a fine grained "terrazzo" texture and is uniformly pale grey in colour.
Small Scale Structures:

PML3: The soft top and base of the major seam is a small scale structure in common with many other deposits, both inland and in the Bendalong area. The major seam also contains soft portions in common with inland deposits such as those at Bungonia and Windellama.

Castellations, such as those at the Headland deposit are absent. The castellations have been observed only in friable silcretes and associated sands in this locality, and only after having weathered for some time. This material in general lacks the short period vertical jointing common to silcretes in which "castellation" was observed.

The small scale structures observed in ML27 were few, the material was uniform, no soft top or base was observed, nor were there hard subvitreous "cores" as seem in some other deposits (e.g. The Old Feltham Deposit).

"Castellation" was observed, due apparently to the jointing frequency and outlined by 26 years weathering which has taken place. Although the upper surface was clean and clearly exposed, "cockade" structures were not observed.

Although these deposits were last worked prior to 1950, and were known as long ago as 1920, it is thought that the very thin soil is a natural feature and not a result of quarrying or timber activity. The trees above the quarry face have been periodically affected by bushfire and timber exploitation. They are chiefly "ironbark" (Eucalyptus sp.) and "stringy bark" (Eucalyptus, cf. delegatensis).
2.6.1. COOMA REGION: THE ROCK FLAT DEPOSIT

Location and Physiographic Setting:

This deposit is located along a prominent north-south ridge, on the eastern bank of Rock Flat Creek, just south of the Cooma-Nimmitabel road.

Occurrence:

The locality is described in detail by Browne (1972). The silcrete and associated sand overlies near-vertically dipping sandstones and a silica pure quartzite. Some silcrete is conglomeratic, with palaeozoic metasedimentary pebbles in a fine-grained slightly saccharoidal silcrete matrix. The deposit has been quarried for over forty years. At present the palaeozoic quartzite is exploited, not the silcrete.
3.0 ROCK DESCRIPTIONS

Rocks from which thin-sections were made are described in numerical order, followed by hand specimen descriptions of other rocks.

3.1 Thin-section descriptions page 102.

3.2 Other rock descriptions page 154.
Sample No: E.D.1  
Locality: Bendalong, the Beach Deposit.  
Sample site: Cutting in Erningold Drive (Fig.66).  
Hand specimen description:

Indurated, pale grey silcrete with an iron-stained plane through centre of sample.

Thin section description:

The rock is composed of poorly sorted quartz clasts ranging up to 1mm diameter. The clasts are mostly less than 0.5mm and most are about 0.1mm. The clasts are sub-angular to angular, rarely sub-rounded. The quartz is mainly plutonic but metamorphic quartz, composite clasts. Quartz with undulatory extinction, although not abundant, is more common than at Tallong. Lines of fine vacuoles and isolated larger vacuoles are common in quartz clasts. The grainsize distribution is such that in some fields a matrix is distinguished with difficulty. The matrix, where distinguished is of various sized interlocking quartz clasts. Some clasts have fine, fragile lobes extending into the matrix. These lobes are optically continuous with the clast. Where the matrix is anatase and carbon rich (perhaps also containing clay), it is in general finer grained than elsewhere in the section.

A prominent brown band up to 3mm thick traverses the otherwise colourless section. This band contains quartz clasts similar to the rest of the rock except that there are fewer fine quartz grains and the matrix is yellow to brown resinous or botryoidal material. This material is probably siderite or ironstained opal. The edges of the ironstained band are sharp, and appears to have not altered the adjoining silcrete except for fine branches and rare zones of impregnation by the ironstaining. Some fine, ironstained veins transgress quartz matrix and clasts. The most common accessory is zircon. Apart from the ironstained band, the remainder of the section is buff to colourless and porosity appears to be low. Anatase, occurring in places as "colloform swirls" is abundant, and unevenly distributed in diffuse zones.
Sample No: 1/66

Locality: Windellama, Croker Deposit
Location: From quarry
Hand specimen: not available.

Thin-Section Description:

This rock is made up of quartz clasts set in a fine-grained matrix of interlocking quartz. The clasts are evenly distributed with a wide range of grainsize from less than 0.1mm to 3mm. The clasts are subhedral, angular and rounded. Most are plutonic, with abundant fine vacuoles and fracturing. There are many volcanic quartz grains which are clear, commonly subhedral and deeply embayed. Metamorphic quartz fragments and undulose extinction is rare. The clast boundaries are mainly sharp, with rare secondary quartz overgrowths. The matrix is fine (less than 0.01mm) and obscured by aggregates of very fine-grained, colourless, high relief, isotropic microlites. These fine, angular microlites are irregularly distributed through the quartz, chalcedony and ?opal in the matrix. There is no iron-staining. Rare accessory zircon is present. The section is compact with no apparent porosity.
Sample No: 7A

Locality: Bendalong, the Headland Deposit.

Sample site: Section C seam 3.

Hand specimen description: This is a friable, pale grey to white silcrete. There are alternating clay and anatase rich zones.

Thin-section description:

This section is composed of angular quartz fragments ranging from submicroscopic up to 0.7mm. Most clasts are about 0.05 to 0.1mm. There are rare subrounded clasts. Quartz is mostly plutonic with some clasts which are composite, have undulatory extinction and probably metamorphic quartzite fragments. Rare silcrete composite grains are present. The grainsize distribution is random and poorly sorted. Grain boundaries are mainly sharp with common corroded or diffuse edges. Embayed clasts are rare. Rare thin secondary enlargement may be present.

The matrix appears to be of finer quartz clasts and is distinctly horizontally banded. The interlocking lobed quartz matrix observed in many other silcrete samples was not detected. The matrix is zoned and there are bands of turbid clay and anatase-rich matrix and clear zones. Much of the section is very porous and overall is a cream and buff in colour. The matrix is obscure, so that it is difficult to observe accessories although some fine, elongate zircon crystals are present and anatase in bands. "Colloform swirls" are throughout the section. Rare glauconite grains are present with small, anhedral opaque grains evenly distributed throughout the section.
Sample No. 7B

Locality:  Bendalong, the Headland deposit.

Sample site:  Section C.

Hand specimen description:  Pale grey, friable, silty and clayey sandstone with floating texture.

Thin-section description:

The section is composed of angular quartz clasts from less than 0.1mm to 0.5mm in a finer grained quartz and clay matrix. The section is porous, in randomly distributed zones. Clast grain boundaries are mostly sharp but some are diffuse and embayed quartz grains are common. The rock fabric is largely obscured by the matrix. Composite hornfelsic quartzite grains and clasts with undulatory extinction are present, but most quartz is plutonic. Some zones of the matrix are clearly visible and were mostly of finer quartz clasts although rare areas of interlocking lobed quartz are present. Rare accessory glauconite and zircon was observed with difficulty in transparent parts of the section. Diffuse opaque fragments were distributed throughout the section. This is carbon or carbonaceous clay.
Sample No. 11A

Locality: Bendalong, the Headland Deposit.

Sample site: Section C

Hand specimen description: Pale grey, nodular, friable silcrete which has a silty matrix and abundant clear quartz clasts, mainly of fine sand size but rarely up to 1 mm.

Thin-section description:

The section is composed of angular quartz clasts which range up to 1 mm in diameter. In parts of the section the larger clasts are set in a fine grained matrix but in other parts there is a gradation of grainsize from 0.5 mm to submicroscopic. Most quartz is plutonic quartz but metamorphic, composite quartz grains and grains with undulose extinction are present. The section is porous and zones of anatase-rich "colloform swirls" are present in about 6 pieces in the section. Rare pale green epidote and glauconite occur in the matrix. Rare zircon is present in the matrix and as an inclusion in quartz. One dark, olive green equant isotropic grain which occurs in the matrix resembles spinel, although this is rare as a detrital mineral. Fine fragments of clay and carbon are also present.
Sample No: 13/66

Locality: Bungonia, The Old Feltham Deposit

Hand specimen description: not available.

Thin section description:

This rock is made of quartz clasts set in a fine-grained matrix of interlocking quartz. The clasts are mostly evenly distributed with a range of grainsize from less than 0.1mm to 1mm. Most of the clasts are plutonic and angular to subrounded. Clasts contain lines of small (less than 0.01mm) bubbles and are almost all separated by the matrix. Clast boundaries are sharp, with some limited embayment. Composite clasts and undulose extinction are rare. Overgrowths of secondary quartz were observed. The matrix is fine to medium-grained (10 to 50 micron) interlocking quartz with irregularly distributed microlites which are most densely packed near large clasts. The section is non-porous and colourless in plane polarised light except for a grey to black colouration in the matrix. Rare accessory zircon and glaucophane are present with patches of opaque limonite.
Sample No: 11B

Locality: Bendalong, the Headland Deposit.

Sample site: Section B.

Hand specimen description: Friable, pale grey to white fine sandstone.

Thin-section description:

This rock is composed of angular quartz clasts which range from submicroscopic to 1 mm and are most commonly about 0.1 mm in diameter. A matrix of fine grained quartz and minor anatase is present throughout most of the section but there are many porous zones. Most grain boundaries are sharp but diffuse boundaries and embayed clasts are common.

Most quartz clasts are of plutonic quartz, containing fine vacuoles and lines of bubbles. Rare metamorphic composite quartzite fragments and quartz with undulose extinction are present.

The matrix contains fine quartz clasts, and rare chalcedony, and anatase with some fine clay rich zones. Common, small (25 micron) equigranular clasts of glauconite occur in the matrix as well as rare, elongate zircon subhedra. One euhedral rutile crystal was detected. Sparse, well distributed carbon is present.
Sample No: 19/66

Locality: Bungonia, The Jerrara Creek Deposit.

Location: Eastern end of Western Quarry

Hand specimen: Indurated, grey silcrete.

Thin-Section Description:

The specimen is made up of a wide range of quartz clasts grading from silt size to coarse sand. The quartz clasts are angular to subrounded and are less than 0.5mm to 1mm in diameter. The sand sized quartz clasts are mostly of plutonic quartz with common metamorphic (crystalloblastic and schistose) composite grains. Undulatory extinction is common in many grains. The larger clasts are randomly distributed throughout the rock. The clasts are poorly sorted and bedding or other sedimentary structures were not observed. The grain boundaries of the clasts were uneven and generally graded into the finer-grained matrix quartz, giving the appearance of having been partly dissolved by the matrix. Embayment of the clasts was common but deep embayments were rare. Rare, thin overgrowths were observed. The matrix was composed of fine (less than 0.01mm) to coarse quartz. The finer matrix was of equi-granular, interlocking quartz and the remainder was of fine, angular clasts which graded into coarser clasts. Ironstaining was present but rare. Very fine, interstitial vacuoles are spread throughout the section. These vacuoles darken the section where they are aggregated and impart a pale buff colour and translucency to the section. The vacuole aggregates also obscure the accessories which are more common than in the sections from the Morris Deposit. Accessories recognised were: brown limonite, fine acicular rutile and brown, granular anatase.
Sample No: 20/66

Locality: Bungonia, The Jerrara Creek Deposit.

Location: Eastern side of Western quarry

Hand specimen: Friable, white silcrete (Coll. K.R. Steggles)

Thin Section Description:

This rock contains angular to subrounded quartz clasts in a matrix of finer quartz clasts. The clasts, up to 2mm but most commonly from 0.1 to 0.2mm and grading into the matrix material, have a "floating" (Watts, 1976) texture. Most quartz grains have grain boundaries which appear to have been dissolved and grade into the matrix. The quartz clasts are most commonly of plutonic quartz with rare recrystallised metamorphic (composite) grains and rare grains having undulatory extinction. Rare thin overgrowths are present in parts of the section where the matrix is relatively transparent in plane polarised light. Embayed clasts are common but deeply embayed clasts are not present. The matrix is generally clouded by interstitial vacuoles and brown granular anatase, but is predominantly of silt-sized angular quartz fragments. "Colloform" structures (Frankel and Kent, 1937) are present in parts of the matrix. These contain abundant fine, brown anatase. The section appears to have a bimodal distribution of particles but this appearance is due to the effect of interstitial vacuoles in the finer-grained parts of the section. The size distribution in most of the section is evenly graded from 0.3mm to less than 10 microns. Accessories are obscured by the matrix. Green glauconite, brown limonite, rare aggregates of grey-brown clay and irregular opaque minerals are present.
Sample No: 34

Locality: The Pattimore Lagoon Deposit

Sample site: Cliff Section, PML3, (fig.105).

Hand specimen description: Pale buff to white indistinctly banded compact rock. The fracture is uneven and lustre dull.

Thin-section description:

The section is of sub-angular to very angular quartz clasts in a matrix of fine quartz grains and clay which is evenly but sparsely distributed. The quartz clasts range up to 1mm in diameter but most are from 0.1 to 0.3mm. Grain boundaries are mainly sharp, but embayment and diffuse grain boundaries are common. Rare metamorphic quartz occurs as hornfelsic composite grains. The grainsize distribution is uneven and variable. There are concentrations of fine and coarse grained zones which form the banding. The matrix is almost opaque under crossed polars due to fine voids, clay and anatase. It is difficult to detect accessories in the dark matrix but fine elongate subhedral zircon was observed.
Sample No: 36/66


Location: Western side of hill

Hand specimen description: Hard white silcrete.

Thin-Section Description:

This silcrete is composed of relatively few coarse clasts in an even-grained interlocking quartz matrix. The clasts are rounded and subrounded up to 2mm in diameter but commonly from 0.1mm to 1mm. The finer clasts tend to be more angular. Some clast grain boundaries are sharp but commonly, one side of a clast grades into the matrix. On one side of many clasts is an accumulation of fine interstitial vacuoles which are commonly opposite a concave side of a clast. One clast, with diffused boundaries is surrounded by an aggregate of fine interstitial vacuoles.

Some clasts are deeply embayed, the embayments containing aggregates of vacuoles. Rare clasts have corroded bipyramidal quartz outlines. Most clasts however have fine lines of vacuoles and appear to be "plutonic" quartz.

The matrix occupies at least 75% of the section and is commonly equigranular and of interlocking quartz grains about 0.01mm in diameter. Accessories are rarer than in most silcretes. Also present is high relief, colourless, length-slow zircon and irregular, fine grains of limonite.
Sample No: 38/66

Locality: Tallong, the Badgery Lookdown Deposit.

Sample site: Western side of creek.

Hand specimen: Unavailable. Red colour noted.

Thin-section description:

This silcrete is composed of sub-rounded to angular quartz clasts of from 0.1mm to 1.5mm diameter set in an ironstained matrix of finer grained interlocking quartz grains. Most clasts are between 0.2 to 0.4mm diameter. The clasts are of plutonic quartz, rarely metamorphic. Lines of fine vacuoles common, rare elongate vacuoles. Clasts are evenly distributed but poorly sorted. Grain boundaries are commonly sharp, some are diffuse. Little embayment of quartz clasts observed. Thin secondary overgrowths on quartz clasts are common. Composite clasts and metamorphic rock fragments are rare.

The matrix is sparse and obscured by iron staining. It is irregularly distributed throughout the rock and is composed of interlocking quartz grains, mainly about 20 microns in diameter.

The section is slightly porous. This is difficult to assess because of the obscured nature of the matrix. The section itself has a yellow-brown colour. Accessories were not visible in the dark, obscured matrix and fine grained parts of the section.
Sample No: 38

Locality: The Pattimore Lagoon Deposit.

Sample Site: Cliff section, PML3 (fig. 105).

Hand specimen description: Very fine grained dense, mid-grey silcrete with fine grained angular quartz fragments in a silty matrix. The rock tends toward a khaki siliceous siltstone where weathered. Where fresh it has a sub-conchoidal fracture but where weathered, the fracture is earthy.

Thin-section description:

This rock is of sub-angular to angular quartz clasts set in a matrix of finer quartz clasts and chalcedony. Clay is dispersed throughout the matrix and also partially obscures some larger quartz clasts. The grainsize ranges up to 1mm but the clasts are most commonly about 0.1mm. Most grain boundaries are sharp but diffused edges and embayed clasts are common. Composite, metaquartzite and silcrete grains are present.

Glaucanite, and one crystal of epidote and one of a blue to neutral, moderately birefringent mineral, possibly Lazulite was noted. Many accessory mineral grains could be obscured by the matrix.
Sample No:  40/66

Locality:  Tallong, the Badgery Lookdown deposit.

Location:  Not recorded.

Hand specimen:  Unavailable. Black colour noted.

Thin section description:

This rock is composed of sub-rounded to angular quartz clasts set in a finer grained matrix of chalcedony and quartz. Clast grain size ranges from 0.05mm to 3mm. Clasts are composed of plutonic quartz commonly with 10 to 20 micron vacuoles and with finer lines of bubbles. Metamorphic quartz, composite clasts and undulatory extinction occurs rarely. Clasts are poorly sorted and evenly distributed throughout the matrix. Grain boundaries are generally sharp, diffuse boundaries are not as common as in many other silcretes and embayment is rare. Secondary quartz overgrowths are common.

The matrix is predominantly of chalcedony of grainsize less than 50 microns, mostly less than 20 microns. Matrix material is evenly distributed throughout the rock. The porosity of this silcrete appears to be low. The section is almost totally colourless with irregular shreds of opaque black material evenly distributed throughout the rock but locally concentrated along clast boundaries. This material is black in reflected light, the fragments are mostly less than 100 microns. This material is probably graphite. Graphite is common in the Hawkesbury Sandstone (Standard, 1969). The Hawkesbury sandstone occurs within 7km of this site. Rare accessory zircon was observed.
Sample No:  40

Locality:  The Pattimore Lagoon Deposit.

Sample site:  Cliff section, PML3 (fig.105).

Hand specimen description:  Friable very pale grey, silty sandstone with coarse quartz clasts up to 3mm but mostly less than 0.5mm. It has an earthy fracture surface.

Thin section description:

This section is composed of sub-rounded to very angular quartz clasts up to 1mm in diameter. The model size is about 0.2mm. The larger clasts are enclosed in a matrix of finer clasts with some chalcedony. Grain boundaries are mostly sharp but diffuse and embayed grain margins are common. Rare metaquartzite rock fragments and metamorphic quartz grains are present. Silcrete clasts are also present.

The matrix is of two types; one half of the section is transparent in plane polarised light and the other contained pores, some clay is obscured. Rare, small accessory zircon subhedra are present but other accessories were not detected.
Sample No: 40A

Locality: The Pattimore Lagoon Deposit.

Sample Site: Cliff section, PML 3 (Fig. 105).

Hand specimen description: Mid grey, highly indurated silcrete with quartz clasts up to 1mm. The silcrete is dense and compact with pale, anatase-rich zones.

Thin section description:

This section is composed of sub-rounded to angular quartz clasts. The quartz clasts range in size from submicroscopic to over 3mm and the grainsize distribution is even. The range of grainsize is so great that secondary silicification is sparse. The clast grain boundaries are most commonly sharp but abundant diffused grain margins are intergrown with lobed, interlocking parts of the matrix. Many grains are embayed but rarely deeply embayed. Metamorphic quartzite rock fragments and composite silcrete fragments are present. Metamorphic quartz grains occur but most quartz is plutonic.

Clay is sparsely and irregularly dispersed throughout the section, especially at the upper, coarser end. Fine grained zircon and glauconite accessories are common as well as rare, fine rutile needles, epidote, tourmaline (schorlite) and one occurrence of rutile needles in a 0.1mm quartz clast.
Sample No: 41

Locality: The Pattimore Lagoon Deposits, MLll.

Sample site: Top of seam, about 6 metres east of western end of seam. Typical of whole seam.

Hand-specimen description:

This is a semi-friable, pale grey silcrete with an earthy fracture. It is composed of fine and rare coarse (up to 2mm) quartz clasts in a finer grey silty matrix. Few other features can be observed macroscopically, except that obscure banding may be observed on the thin section itself, even though this is not visible in the hand specimen.

This banding is very fine, slightly flocculent in places and parallel to the top of the seam (note sample 34, which is also reminiscent of the "flocculent masses" of Krauskopf, 1959).

Thin-section description:

The silcrete is composed of fine angular to acicular quartz clasts in a matrix of finer clasts (20 micron and less), the nature of which is obscured by fine, irregularly shaped pore spaces and brown colouration which is probably fine anatase. This brown colouration is unlike the red-brown iron staining observed in some silcretes, and is concentrated in the bands mentioned above.

Edges of fine acicular clasts are etched and although partly obscured do not appear to be diffused into the crystalline matrix as in more dense silcretes. In this section these edges appear to be minutely porous.

Rare high-relief zircon was the only accessory mineral observed.
Sample No: 42

Locality: Bendalong, ML20

Sample site: Quarry face, eastern part of lease, from top of face.

Hand specimen description: Partly dense, banded buff, pale to mid grey intensely indurated sub-vitreous silcrete and partly friable, clayey, ferruginous, white, yellow and red. In the indurated silcrete pale to mid grey, 5mm bands are parallel to top of seam.

Thin section description:

This section is composed of rounded to angular quartz clasts of grain size ranging from submicroscopic up to 1mm. The model size range is from 0.1 to 0.2mm and clasts rarely exceed 0.5mm. Most grain boundaries are sharp but these are commonly diffused parts of boundaries and some embayed margins. Silcrete rock fragments are common but some are difficult to distinguish from coarse parts of the matrix. The matrix is porous and iron stained in thin, sub-parallel veins.

The grainsize is so evenly distributed that in many zones of the section, secondary "matrix" is difficult to determine. Much of the matrix is of poorly sorted interlocking lobed quartz grains. Rare accessory glauconite and fine zircon crystals are present in the matrix and as inclusions in quartz clasts. Opaque minerals were not observed but some dense clay fragments were opaque. Iron stained zones appear on the edge of the section, the upper surface of the seam.
Sample No.: 44
Locality: Bendalong, ML53 Deposit.
Sample site: From quarry face.

Hand specimen description: Dense indurated, banded (dark to mid grey) even grained silcrete tending to be finely saccharoidal. The fracture surface displays fractured quartz clasts giving a glistening appearance like limestone. Some fine, buff coloured anatase rich zones.

Thin section description:
This silcrete is composed of sub-rounded to very angular quartz clasts in a finer grained quartz matrix. Most clasts are from 0.1 to 0.2mm in diameter but range up to 1mm. Angular silcrete rock fragments are common, with irregular and diffused boundaries. Most clasts have sharp, grain margins for most of their perimeter. Minor embayments of grain margins were present. The section is porous with round holes of up to 0.5mm distributed throughout the section.

Abundant fine carbon shreds are concentrated in elongate zones or bands. Rare accessory fine zircon grains are present.
Sample No:  46

Locality:  Bendalong, ML17.

Sample site:  Western face of abandoned quarry. Top of face in conglomeratic zone.

Hand specimen description:  Conglomeratic silcrete, made up of pale grey, rounded silcrete pebbles up to 20mm set in yellow and dark red ironstained matrix. Weathered zones lack ironstaining.

Thin section description:

This silcrete is made up of sections of rounded silcrete pebbles up to 20mm in diameter set in a partly iron stained matrix of silcrete. The silcrete is composed of rounded to very angular quartz clasts in a matrix of finer quartz clasts, interlocking quartz grains and chalcedony. Most quartz clasts are from 0.1 to 0.2mm in diameter but range up to 1mm. Most grain boundaries are sharp. Angular, composite metaquartzite and silcrete rock fragments are present. Embayed quartz clasts are rare.

The silcrete pebbles are porous, and the outer margins of some has been impregnated by ironstaining. Parts of the section are clay and anatase rich. Rare fine grained zircon accessories are present and opaque minerals absent. Slightly translucent haematite occurs in the section.
Sample No: 50

Locality: Bungonia, the Stockyard Deposit.

Sample site: Lower seam (seam 1)

Hand specimen description: Moderately indurated, compact to porous, partly friable and semi-saccharoidal silcrete with a silt sized matrix.

Thin section description:

This rock is composed of poorly sorted sub-rounded to angular quartz fragments from submicroscopic to 0.4mm in diameter. The section is extremely porous and much of the void area is interconnected. Porous zones are irregularly distributed in the section. Fine fragments of clay and carbon with grains of anatase are present.

Grain boundaries are commonly diffused, sutured and indistinct.

Angular silcrete rock fragments or zones of highly indurated silcrete are present in the section. Embayed quartz grains are common but not abundant.

Rare accessory fine zircon granules and glauconite are present.

Opaque irregular shreds of graphite occur throughout the section.
Sample No: 51

Locality: Bungonia, the Stockyard Deposit.

Sample site: Surface outcrop, seam 1.

Hand specimen description: Pale grey to buff, poorly sorted silcrete rich in coarse vitreous, fractured quartz clasts up to 3mm diameter in an even grained semi-saccharoidal matrix. This silcrete is dense and indurated.

Thin section description:

This rock is made up of rounded to sub-angular quartz clasts up to 2mm in a matrix of finer, interlocking quartz grains. The matrix is irregularly distributed and free from contaminants. The section is porous with up to 25% pore space area in zones but about 5% overall. Some large clasts (over 1mm) are of metamorphic quartz but most quartz is plutonic. Metamorphic rock fragments are common but not abundant.

Rare fine grained subhedral grains of zircon are present in the matrix.
Sample No. 53.

Locality: Bungonia Stockyard Deposit.

Sample site: Seam 2.

Hand specimen description: Moderately indurated, pale grey silcrete with sub-conchoidal fracture.

Thin-section description:
This section is composed of sub-rounded to acicular quartz clasts in a fine grained matrix. The quartz clasts are mostly fine grained, 0.1mm and less, but range up to almost 2mm. Embayment of quartz clasts is common and often deep. Many grain boundaries are diffuse but are mostly sharp. Undulatory extinction is commonly observed. The proportion of fine matrix to clasts is high, over 50% in much of the section. Clay is present in much of the section but is thinly diffused and rarely obscures matrix.

Accessories are very fine and difficult to diagnose but are present throughout the section. Probably Zircon and Glauconite. Opaque minerals are very rare, fine shreds of graphite present in certain fields.
Sample No. 53.1

Locality: Bendalong, The ML53 Deposit.

Hand specimen description: Compact, grey, intensely indurated silcrete with sub-conchoidal fracture.

Thin-section description:
This section is composed of sub-rounded to acicular quartz clasts up to 2mm set in a finer groundmass of finer grained quartz clasts.

The quartz clasts are extremely poorly sorted and a wide range of grain size from more than 2mm to less than 0.1mm. Smaller grains than 0.05mm are considered to be part of the matrix as their boundaries are more diffused with surrounding smaller particles. Diffused edges of clasts are common, but rarely is the complete boundary diffused. Slightly to deeply embayed portions of grains are common but voids containing fine grained quartz are very rare.

Rare composite grains are of all grain sizes. Metamorphic rock fragments are common.

This section was cut perpendicular to the upper surface to show if there were any special features associated with the "cockade" structures present in the section. No unusual features were observed. Rare accessory zircon and graphite is present.
Sample No: 57

Locality: Windellama, the Croker Deposit.

Sample site: Quarry face.

Hand specimen description: Dense, indurated pale grey silcrete, rich in large clear quartz clasts set in abundant pale grey apparently amorphous matrix.

Thin section description:

This silcrete is of coarse rounded to angular quartz clasts in a finer grained quartz matrix. The clasts range in size from 0.5 to 2mm. The distribution of quartz particles is bimodal as there are few between 0.1 and 0.5mm. The fine grained matrix of interlocking, lobed quartz is sparse and in some fields the fabric resembles that of a metaquartzite.

Many grain boundaries are sharp but diffuse boundaries and moderately embayed margins are common.

Most quartz is plutonic but metamorphic quartz is present.

Rare opaque minerals and fine grained zircon is present. Anatase rich concentrations occur in embayments and irregular zones of the matrix.
Sample No: 59
Locality: Nerriga, the Oallen Deposit.
Sample site: Random surface cobble.

Hand specimen description: Saccharoidal, moderately indurated pale grey silcrete. Odd clasts up to 5mm diameter but mainly coarse sand size particles present having an uneven fracture similar to quartzite.

Thin section description:

This rock is composed of rounded to angular quartz clasts set in a matrix of finer quartz clasts and sparse interlocking quartz. The quartz clasts in general range up to 1mm in diameter and the most common size range is between 0.1 and 0.2mm (one large elongate metamorphic quartz clast is 7mm long). Most quartz contain fine vacuoles and are plutonic but metamorphic quartz particles are also present.

The matrix is sparse and variably silicified. Much of it is finely porous. Where the matrix is of fine clasts the porosity is high, up to 10% and where the matrix is of finer, interlocking quartz grains, the porosity is very low. The porous zones are scattered throughout the section.

Rare, fine grains of zircon are present throughout the section. Carbon flakes are common but not abundant and are restricted to the more compact fields of the section.
Sample No:  60

Locality :  Nerriga, The Oallen Deposit.

Location :  Upper surface of sand.

Hand specimen description:

The silcrete is saccharoidal, friable, and pale.

Thin-section description:

The silcrete is composed of rounded to subangular quartz clasts of from less than 10 microns to .5 m in diameter. The clasts are most commonly of plutonic quartz typically with fine vacuoles or inclusions.

Undulatory extinction is rare. The quartz clasts are relatively well-sorted, especially in the most common size, i.e., about .1mmillimetre. Clast distribution is even, clast grain boundaries are generally sharp, embayment is rare and limited corrosion and overgrowth of quartz is not present.

Metaquartzite rock fragments are unusually rare. Authigenic quartz matrix is not common, the matrix is mainly of finer quartz clasts. The section is porous and colourless in plain polarised light except for common irregular shreds of opaque limonite. Accessory zircon is present.
Localities: Nerriga, The Oallen Deposit

Sample site: Random, surface cobble.

Macroscopic description: Pale, saccharoidal, moderately friable silcrete.

Thin section description:

The section is composed of rounded to sub-angular quartz clasts, up to 0.8 mm set in a variable matrix of finer clasts and microcrystalline quartz. Although coarser clasts are common, the modal diameter is between 0.1 to 0.2 mm. Composite, sutured metaquartzite clasts greater than 1 mm in diameter occur, but it is difficult to delineate the boundaries of these clasts. None greater than 0.8 mm were observed with certainty. Composite metaquartzite-like areas were common. Embayment and corrosion of clasts was common, especially in the more compact zones of the sections. No ironstaining was observed. The matrix was fine, microcrystalline, adjoining and merging into the diffused grain boundaries of clasts in some areas (up to 25% of the section). In most fields examined, the matrix was sparse, although almost always present in small regions. In general the rock is porous, but fairly well silicified, especially in separate, elongate zones.

Rare, commonly fine grained accessory zircon is evenly distributed throughout the section. Fine flecks of carbon are common, of variable size (up to 0.2 mm) throughout the section.

Rare zones of sparse anatase or clay were observed in parts of the matrix.
Sample No:    79

Locality:       Bendalong, ML12 deposit.

Sample site:    Eastern part of deposit. Random sample from quarry production in 1969.

Hand specimen description:    Compact, highly indurated silcrete with scattered pores of 0.5 to 1.0mm throughout. Cloudy white quartz clasts of up to 5mm diameter in grey to blue-grey rock. The fracture is sub-conchoidal.

Thin section description:

This section is composed of rounded to angular quartz clasts of up to 1mm in diameter, and most commonly between 0.1 and 0.3mm set in a sparse fine grained matrix of interlocking quartz grains.

Most quartz is plutonic which is clear and with fine vacuoles but metamorphic quartz is common but not abundant. Clasts are poorly sorted. Most clast margins are interlocked with surrounding finer clasts or matrix. Composite clasts of silcrete and metamorphic rock fragments are present.

The matrix is of variable sized quartz grains which are mainly about 10 microns, and without any contamination.

The section is not porous, with rare elongate accessory zircon.
Sample No: 83

Locality: Tallong, the Caoura Road Deposit

Sample site: Upper surface of seam, at eastern end of deposit

Hand specimen description: Poorly sorted silcrete resembles a porphyritic igneous rock. Glassy angular smoked quartz clasts up to 2mm set in a fine grained sub-vitreous conchoidally fractured pale grey matrix. Parts of the rock appear to be weathered, with zones of differential induration.

Thin section description:

This section is distinctly banded with alternating ironstained zones and ironstain-free zones. The section is composed of large (2 to 3mm) rounded and subrounded quartz clasts with sub-rounded to very angular finer (0.1 - 0.3mm) quartz clasts set in a matrix of variable sized interlocking quartz. The clast margins, especially those of grains less than 0.2mm are diffuse and intergrown with surrounding finer matrix quartz grains. Sharp grain boundaries are not common and embayment of quartz grains is rare and limited.

The quartz is mainly plutonic but metamorphic quartz is also present. The grain size distribution is uneven. One large rounded silcrete pebble and several gneissic quartzite fragments are present.

The matrix is sparse and unevenly distributed. It is composed of 10 to 20 micron interlocking quartz grains. The ironstained bands mentioned obscure much of the matrix in parts of the section. The section has low porosity and where the matrix is not obscured, sparse rare zircon can be observed.
Sample No. 84

Locality: Tallong, the Caoura Road deposit
Sample Site: Upper surface of large slab in creek bed.

Hand specimen description: Yellow-brown banded, intensely indurated silcrete with a vitreous lustre and conchoidal fracture. A weathered outer zone of up to 4mm is slightly friable. The weathering has produced a banding parallel to the margins. Fine quartz clasts are contained in a finer matrix.

Thin-section description:

This rock is finely banded due to grainsize distribution. The rock is fine grained and of sub-rounded to angular quartz clasts ranging in size up to 0.5mm but most commonly below 0.2mm. Most quartz is plutonic with rare metamorphic quartz. The clasts are set in a matrix of finer quartz grains, commonly less than 10microns. The quartz grain boundaries are mostly sharp without extensive intergrowth between margins and matrix. Iron-staining occurs in bands perpendicular to the laminations. Opaque minerals, probably carbon are distributed sparsely throughout the section. Porosity is low.
Sample No: 87

Locality: Bungonia, The Stockyard Deposit.

Sample site: Not known. The sample was collected by Mr. M.V. Anderson in 1973. The sample was selected as it is part of a plant root fossil. It was hoped that some original structures would be evident in thin section.

The specimen is basically a silcrete although some plant traces are present. The specimen is part of a cylinder about 25mm in diameter. The fracture surface is earthy and small, irregularly distributed residual linear elements are present within the cylinder. The outer surface has some "growth lines" preserved. The colour is very pale grey.

Thin section description:

The section is made up of fine angular to acicular quartz clasts (up to 0.5mm) in a brown obscure matrix of finer quartz and clay, anatase and carbon mixture of variable proportions. The clasts are commonly etched or embayed but do not show edges which are clearly fused with surrounding finer grained quartz. This is in accordance with the friable nature of this material.

Linear and curvilinear concentrations of brown clay, carbon and anatase occur in parts of the section. These elements are similar to the "colloform structures" observed in many other silcretes but are considered here to be plant fossil traces.

The irregular distribution and organisation of these elements implies mobility of the supporting medium within the fossil root outer surface. Rare fine metaquartzite clasts are present in the section. Very fine zircon was observed as an accessory mineral and small irregular flecks of charcoal occur throughout.
Sample No. 102

Locality: Bendalong, the Beach Deposit

Sample site: Upper surface of seam, about 10m from beach.

Hand specimen description: Indurated, grey silcrete.

Thin-section description:
This rock is composed of quartz clasts which range in grain size from 20 microns to 1mm, with most grains being 0.1 to 0.2mm. The clasts are sub-rounded to sub-angular and mostly of plutonic quartz. Metamorphic quartz grains are present but rare. Grain size distribution is uneven and in some fields most clasts are about 0.1mm but in general the clast sorting is poor. Grain boundaries are commonly sharp but are also commonly intergrown with surrounding grains.

The matrix is sparse, due to the poor sorting and interlocking of grains.
Sample No. 107.

Locality: Bendalong, Headland Deposit.

Hand specimen description: Dense, indurated, dark grey silcrete.

Thin-section description:
This rock is composed of sub-rounded to very angular quartz clasts in a matrix of finer clasts and microcrystalline quartz. Clasts up to 1mm are present and the grainsize is evenly distributed down to sub-microscopic matrix components. Many quartz clast grain boundaries are diffuse and embayment of the clasts is common. Parts of the section are finely porous and clay and anatase is unevenly distributed through the section. Moderate iron-staining is present throughout the section. Metamorphic quartz is common but most quartz is plutonic. Accessories may have been obscured by iron-staining but appeared to be sparse.
Sample No: 116

Locality: Tallong, the Caoura Homestead Deposit.

Sample site: Selected from quarry face as being typical of face.

Hand specimen description: Dense, compact, intensely indurated, tending to saccharoidal, pale buff silcrete.

Thin section description:

This rock is composed of sub-rounded to angular quartz clasts ranging in size from 10 microns to 1mm set in a sparse matrix of interlocking finer quartz (10 microns down to 5 microns).

The grainsize distribution is relatively evenly distributed but may be slightly bunodal with fewer grains between 0.1 and 0.3mm. Most quartz is plutonic with fine vacuoles or clear but metamorphic quartz is present. Sorting is very poor.

The clast margins are commonly intergrown with surrounding matrix or clasts.

Silcrete and metamorphic rock fragments are present, commonly appearing to have been partly fragmented and then intergrown with the surrounding medium.

The section is slightly to considerably porous being up to 25% in some fields. Rare opaque fragments, probably carbon, are scattered throughout the section, as were rare fine zircon granules.
Sample No. 118

Locality: Bungonia, the Stockyard Deposit

Hand specimen description: White to yellow friable fine grained silty sandstone.

Thin-section description:
This rock is composed of rounded to angular quartz clasts of up to 0.5mm diameter, but most commonly about 0.1 to 0.2mm. There is a sparse, scattered matrix which is turbid, partly iron-stained and contains some chalcedony. Thin overgrowths are present on most clasts. The section is very porous. The sorting is better than for silcretes. The quartz is mainly plutonic but metamorphic grains are common. Rare embayments are present. Rare opaque hematite particles are present throughout. Accessories were difficult to detect but one subhedral, isotropic granule resembled spinel, which is rare as a detrital mineral. This rock is a sandstone, not a silcrete.
Locality: Bungonia, the Stockyard Deposit

Sample site: Spur at northern end of deposit, surface outcrop.

The surface of the specimen is pale grey, darkened with organic matter; the fracture is sub-conchoidal and the surface is very pale grey. The rock is massive, compact and dull in lustre. It is made up of coarse (up to 4mm) rounded to subangular transparent quartz clasts in a fine-grained, aphanitic matrix. The clasts are randomly oriented, unevenly distributed and poorly sorted. The texture is similar to that of the silcrete at the Morris Deposit. Anatase-rich zones occurs as shadow-like darker areas on the lower side of each clast.

Thin-section description:

The rock contains sparse, irregularly distributed, rounded to sub-angular coarse quartz clasts, with smaller irregular, angular even-grained quartz clasts set in an even grained, coarse matrix of interlocking quartz. The matrix grain size is predominantly 0.02 to 0.03mm (coarse silt).

The clasts range from 0.3mm to 4mm and are commonly embayed. Some have one or more edges with diffuse boundaries which tend to merge with the surrounding matrix. Almost all clasts have anatase-rich "shadows" of varying area.

Commonly these are from ten to twenty percent of the area of the adjoining clast. Some deep embayments are also filled with anatase. The "shadows" are always on the stratigraphically lower side of the clasts. Rare clasts are elongate schistose quartz composites. Adjoining grains of these metaquartzite fragments are cemented together by secondary quartz.

Clasts with grain size less than 0.3mm tend to be more angular than larger clasts. Fine acicular quartz fragments were observed. The matrix is coarser than that observed in silcrete from the Morris Deposit but otherwise similar in morphology, colour and sorting.

The clasts are similar in size and distribution to those at the Morris Deposit except that in this specimen no quartz euhedra were observed, and the anatase-rich "shadows" appeared to be on the lower side of the clasts. This is in contrast to the Morris Deposit where bypyramidal quartz euhedra were observed.
The quartz clasts commonly contain parallel and sub-parallel continuous lines of fine (less than 10 micron) bubbles. Undulatory extinction is common in quartz clasts.

In plane polarised light, the section is mainly colourless, with evenly distributed opaque zones of limonite (yellow to brown in reflected light) and fine grained anatase.

Rare zircon observed as an accessory and as an inclusion.

The fabric of this specimen is characteristic of the north-western lobe of the Stockyard Deposit and very similar to the north-western lobe of the Morris Deposit.
Sample No. 124

Locality: Bungonia, the Old Feltham Deposit.

Hand specimen description: An indurated, grey silcrete which is sub-vitreous with a sub-conchoidal fracture and irregular friable weathered zones. Quartz clasts occur up to 2mm but most are less than 1mm.

Thin-section description:
This section is composed of rounded to sub-angular quartz clasts which are well sorted in parts or set in a matrix of interlocking quartz grains. Certain fields resemble a fine grained (0.1mm) metaquartzite. The grainsize ranges from less than 5 microns to 1mm with the modal size from 0.1 to 0.2mm.

The section porosity is low with the regions between subspherical quartz grains being filled with an opaque material, probably mainly carbon. Most quartz is plutonic with rare metamorphic quartz. There are several composite metaquartzite grains. Although parts of the section are a silty-sandstone, overall this silcrete is low in porosity and moderately well silicified. Rare zircon is the only accessory mineral observed.
Sample No: 130


Sample site: Southern edge of deposit, upper surface of seam.

Hand specimen description:
This rock is composed of medium to coarse angular fragments of transparent quartz in a matrix of cream-white, earthy, slightly friable silcrete. Some exposed clasts look to be parts of terminated quartz prisms. Clasts are not as coarse or sparse as in other silcrete from this deposit.

Thin section description:
This silcrete is composed of a wide range of sizes and shapes of clasts rarely larger than 1 mm in diameter in a brown matrix, the texture of which is partially obscured by fine interstitial vacuoles. Sizes of clasts range down to matrix size but the matrix is nevertheless distinct. This is due to the small number of clasts compared to many other silcretes, although the number in this rock is more numerous than for typical silcrete from this deposit.

Smaller clasts are typically angular to acicular while larger clasts are angular to rounded, many having deep embayments. These rarely tend to parallel actual or possible crystalline faces. Some clasts contain lines of fine bubbles.
Sample No: 132


Sample site: Near northern edge of outcrop, 55m from end of north-west lobe of outcrop. Chosen as being typical of that part of the deposit. To the north-west the silcrete becomes more dense, whiter, with sparse clasts. To the south the silcrete is progressively less dense, more sandy.

Hand specimen description:
The specimen is made up of abundant coarse clasts, mainly of transparent quartz and rarely of translucent, white metaquartzite, in a matrix of pale grey fine grained quartz. The metaquartzite clasts are sparse but more abundant than in most silcretes examined. The specimen is pale grey in bulk except for the upper 3 to 15mm which is pale buff. Where pale grey the fracture is conchoidal and the fracture surfaces sub-vitreous. Where the silcrete is pale buff the fracture is earthy, except for the fracture surfaces of those quartz clasts which were also fractured.

Thin section description:
In thin section, this silcrete is made up of a wide size range of quartz clasts in a fine grained matrix. The clast sizes range from 2mm down to 10-20 microns. The matrix nevertheless is distinct from the fine grained clasts. Rare clasts are metaquartzite composites. The quartz clasts are of a large variety of shapes from rounded, but deeply embayed, to angular and acicular. Smaller clasts are commonly angular. Edges of clasts are embayed, sharp or diffused with the matrix. Both sharp and diffused edges may occur on the one clast. The section is very slightly porous throughout, more so in the ironstained upper zone. The porosity in the lower, unstained zone is extremely fine, of largely unconnected pore spaces. Many clasts contain lines of very fine bubbles. Rare accessory zircon is present. Very little anatase was observed.
Sample No: 133

Locality: Bungonia, The Morris Deposit

Sample site: North western end of outcrop. Chosen as appearing typical of this part of the deposit.

Hand specimen description:

This rock is white and typical of the northern lobes of the outcrop. It is composed of sparse, large transparent quartz clasts, in a white sub-vitreous matrix. The clasts are up to 4mm in length and some appear to have been split and the interspace filled by the matrix. Embayment of clasts is visible without optical aids and thin cream coloured cusps on the lower side of clasts. This unusual petrological type of silcrete is characteristic of the Morris deposit.

Thin section description:

Quartz clasts from 20 microns to 2mm are set in a uniform grainsize matrix of tightly interlocking, lobed crystalline quartz grains. The clasts are relatively sparse, compared to silcretes from other areas. A wide variety of clast shapes exist from acicular, to angular, sub-angular and well rounded. Many, especially larger, rounded clasts are deeply embayed and vidided. The embayments are filled with finer matrix material with fine granular anatase clustered around the diffused edges of the embayment or split through the clast. Large, rare clasts have a shape which could be interpreted as being a section of a terminated quartz crystal.

The grainsize of the matrix itself is about 10 microns. The interspaces between the irregular quartz fragments appear to be pore spaces as these zones behave as an isotropic medium, even when fine granular anatase is present.

The only accessory mineral observed was the fine brown granular anatase, observed in embayments and as a thin cusp on the lower side of most clasts.
Sample No: 135

Locality: Bungonia, The Jerrara Creek Deposit.

Sample site: Lower seam at western end of ridge. Chosen at random from the limited outcrop.

Hand specimen description:

This silcrete is grey-buff with an irregular fracture with a slightly saccharoidal texture. Macroscopically, it appears to be composed of a uniform grainsize, rather similar in texture to a metaquartzite, lacking the "terrazzo" texture of many other silcretes. This silcrete is tough, not friable.

Thin section description:

Microscopically as well as megascopically this silcrete appears similar to a metaquartzite and lacks the distinctive "terrazzo" texture common to most silcretes examined.

It is composed of fairly uniform sized sub-angular and angular to acicular quartz clasts. The intergranular spaces are either vacant or filled with smaller grains of quartz. The clasts are up to 0.5mm in diameter but are most commonly about 0.15mm. Clast edges are interlobed with surrounding finer quartz grains to which they are fused. The intergrain boundaries lack the thin "glassy" fusion lines observed in typical coarse metaquartzites from Cooma and Lithgow.
Sample No: 136

Locality: Bungonia, The Jerrara Creek Deposit.

Sample site: Chosen as being typical of the seam in this region (Fig.92) From centre of face (Fig.32).

Macroscopically this specimen is pale grey with an earthy fracture surface and is moderately friable. It is composed of sparse sub-rounded transparent quartz clasts in a matrix of very fine silty matrix and fine quartz clasts. Many fine incipient fractures were observed.
Sample No. 138

Locality: Bungonia, the Jerrara Creek Deposit.

Hand specimen description: A friable, pale grey siltstone with bimodal grainsize distribution and clear quartz clasts similar to silcrete.

Thin-section description:
A fine grained, buff coloured section with one clast of 1mm diameter. This section is composed of fine, sub-rounded quartz clasts less than 0.1mm in diameter. The matrix is an amorphous, cloudy, brown material containing obscure fine grained quartz fragments. The clay and anatase-rich matrix obscures the basic fabric of the rock.
Sample No. 139

Locality: Windellama, the McGaw Deposit

Sample site: North-eastern edge of deposit, upper part of seam.

Hand specimen description: Iron-stained, yellow-brown conglomeratic highly indurated silcrete with clear quartz clasts up to 2mm. Larger clasts are sub-rounded but most are angular.

Thin section description:
This rock is composed of angular to sub-rounded quartz clasts up to 2mm in diameter. The grainsize distribution is evenly distributed from 2mm down to about 20 or 10 microns. Most quartz is plutonic with rare metamorphic quartz clasts. Some grain boundaries are sharp and some margins are intergrown with surrounding matrix. Deep embayments are common but not abundant.

The matrix grainsize is less than 10 to 20 microns, mostly less than 5 microns and virtually free of contamination by anatase except for isolated anatase concentrations. Overall, porosity is low but up to 30% in zones. Accessory minerals are mainly scattered, opaque limonite particles.
Sample No. 141

Locality: Windellama, the McGaw Deposit

Sample site: North-western edge of deposit.

Hand specimen description: Yellow-brown iron-stained, conglomeratic silcrete with clear quartz clasts up to 2mm diameter. The rock is compact and highly indurated.

Thin section description:
This section has two zones, one which has a minor yellow iron-staining throughout and the other which is rich in titania (anatase or leucoxene). In general, the section is composed of sub-rounded to angular quartz clasts of up to 2mm diameter set in a matrix of finer grained, (less than 5 microns) interlocking quartz grains.

Most quartz is plutonic but metamorphic quartz, some gneissic, is abundant. The grainsize distribution is even. Most grain boundaries are sharp, but parts of margins are commonly intergrown with the matrix surrounding them. Limited embayment is present. Silcrete and metaquartzite rock fragments are sparse but present.

In the anatase-rich part of the section the matrix is obscured and porosity overall is low.

The main accessory minerals present are anatase and limonite. Diffuse and opaque concentrations of anatase are present throughout the section.
Sample No. 142

Locality: Tallong, the Badgery Lookdown Deposit.

Sample site: West of creek bed, upper surface of rock

Hand specimen description: White, "porcellanite-like" rock with sub-vitreous lustre and conchoidal fracture.

Thin-section description:
This rock is composed of sub-rounded to angular quartz clasts ranging in grain size from 20 microns up to 2mm. The sparse matrix is almost entirely chalcedony, in places obscured by interstitial micropores. Even quartz overgrowths of 5 to 10 microns present on almost all clasts throughout the section. The grain size distribution is even and inter-clast volume is small, although up to 20% locally. Porosity is low, intergranular volume is occupied by chalcedony. Most quartz is plutonic but metamorphic quartz is present. Rare embayment of quartz clasts is present.

Matrix grain size is generally less than ten microns. Rare, elongate subhedral zircon is present in the section.
Sample No:  Cl
Locality:    Rock Flat
Sample site: From Newbold Quarry adjacent to Rock Flat Creek, about 22km south of Cooma, N.S.W.

Hand specimen description:  Not available. This sample was selected from the high silica quartzite.

Thin section description:

This rock is composed of interlocking quartz grains of up to 0.5mm in diameter but most commonly from 0.1 to 0.2mm in diameter with sparse interstitial quartz grains of about 0.05mm. The quartz particles are generally equant and of plutonic quartz.
Sample No: C2

Locality: Rock Flat

Sample site: From Newbold Quarry adjacent to Rock Flat Creek, about 22km south of Cooma, N.S.W.


Thin section description:

This section is composed of interlocking quartz grains of about 0.2 to 0.3mm in diameter with rare grains of up to 1mm. Most grains are equant plutonic quartz but elongate and metamorphic quartz grains are present. Zones of fine grained (less than 10 microns) interlocking secondary quartz are present. The white band in hand specimen is a strain zone, rich in fine vacuoles and undulose extinction.
Sample No: L1

Locality: Marrangaroo, near Lithgow.

Sample site: Newbold Quarry.

Hand specimen description: Not available. Quartzite.

This section is composed of equant, interlocking plutonic quartz grains of from 0.1 to 0.5mm in diameter. Some interstitial quartz grains of about 0.05mm are present as well as intergranular veins and zones of kaolinite. Some sparse black needlelike or dendritic material could be Braunite or Pyrolusite (high Mn²⁺ in chemical analyses).
Sample No: L2
Locality: Marrangaroo, near Lithgow
Sample site: Newbold Quarry.
Hand specimen description: Quartzite.

This section is of equant interlocking quartz grains of from 0.1 to 0.5mm diameter. The quartz is plutonic and rich in fine vacuoles. Some interstitial kaolinite is present.
No. 1: Bendalong Headland Deposit:- This is a green, yellow, grey and pink clay. The yellow zones are translucent, the green parts non-plastic with grey and pink clay being semi-plastic.

No. 2: Bendalong Headland Deposit:- This is a grey and pink plastic clay. The grey clay contains slickenside zones. The pink clay contains dark red iron-stained zones and coarse rounded quartz pebbles.

No. 3: Bendalong Headland Deposit:- This is a pale grey, fine grained partly silicified silstone. It is composed mainly of quartz with up to 20% clay.

No. 4: Bendalong Headland Deposit:- This is an off-white partly silicified silstone.

No. 5: Bendalong Headland Deposit:- An off-white silty clay.

No. 6: Bendalong Headland Deposit:- Silcrete Seam 3. This is an off-white friable clayey silstone.

No. 7: Bendalong Headland Deposit:- Silcrete Seam 3. This consists of iron-stained nodules and ironstone pebbles loosely bound in a yellow-brown quartz-rich silt.

No. 8: Bendalong Headland Deposit:- A pale grey, sandy friable siltstone which occurs between silcrete Seams 2 and 3. The silt appears to contain less than 10% clay.

No. 9: Bendalong Headland Deposit:- This pale grey sand occurs between silcrete seams 2 and 3 and contains abundant etched quartz clasts of up to 1mm diameter and quartz clasts which have a yellow surface iron stain.

No. 10: Bendalong Headland Deposit:- This sand which also occurs between silcrete seams 2 and 3 is medium grained with off-white silt and clay. The quartz clasts appear to have been partly etched. Some larger rounded quartz clasts have an abraded, frosted surface texture. The more abundant 0.5 to 1mm clasts have a resinous, irregular surface appearance.

No. 10A: Bendalong Headland Deposit:- A pale grey siltstone with some silcrete characteristics such as floating texture and evidence of semi-fluid behaviour during lithification occurs as silcrete seam 2.
No. 11: Bendalong Headland Deposit:— An off-white to pale grey, friable, nodular silcrete which appears to be typical of seam one. The silcrete contains coarse quartz clasts up to 2mm diameter.

No. 12: Bendalong Headland Deposit:— This is a dark grey, carbonaceous, poorly-developed soil from the base of seam 2 at Section D. Fragments of silicified pale buff sandstone are present in the soil.

No. 13: Bendalong Headland Deposit:— A grey-brown, poorly developed soil which has developed over the silcrete sequence at Section D.

No. 13B: Bendalong Headland Deposit:— A poorly-silicified, off-white nodular silcrete occurs near the top of seam 2, Section D, with large, rounded quartz clasts.

No. 14: Bendalong Headland Deposit:— This is an off-white, partly silicified siltstone with some clay.

No. 17: Bendalong Headland Deposit:— A pale grey silcrete which is indurated and with floating texture, nodular external surface occurs at the top of seam 3 in Section D.

No. 18: Bendalong Headland Deposit:— This is a pale grey sandy siltstone.

No. 20: Bendalong Headland Deposit:— This is a pale grey slightly friable fine silty sandstone with some silcrete features such as the floating texture and the incipient jointing phenomena where discrete blocks of semi-fluid silcrete appear to have been fused during formation.

No. 21: Bendalong Headland Deposit:— An off-white to pale grey silt with very little clay occurs at Section D.

No. 22: Bendalong Headland Deposit:— This is a coarse sand with sub-rounded clasts with quartz silt and up to 10% clay.

No. 23: Bendalong Headland Deposit:— This is a red-yellow siliceous laterite containing large sub-rounded quartz clasts.

No. 24: Bendalong Headland Deposit:— This is a coarse sand with abundant quartz silt and clay.
No. 25: Bendalong Headland Deposit:- A pale grey to buff siltstone with quartz clasts and minor clay occurs about 2m from the top of Section D.

No. 26: Bendalong Headland Deposit:- A pale buff very fine even-grained sand occurs above sample No. 25.

No. 27: Bendalong Headland Deposit:- This is a mustard-coloured silt containing some clay.

No. 28A: Bendalong Headland Deposit:- A nodular, pale grey, friable siltstone, with the typical silcrete "floating texture", occurs as the upper seam at Section D.

No. 29: Bendalong Headland Deposit:- This is a pale grey, friable, fine grained silcrete with a "floating texture" and irregular incipient jointing.

No. 30: Bendalong Headland Deposit:- This is a grey friable fine sandstone.

No. 31: Bendalong Headland Deposit:- An off-white silty clay occurs just below the upper silcrete seam at Section D.

No. 32: Bendalong Headland Deposit:- This is a silty moderately indurated silcrete with some clay throughout.

No. 33: Pattimore Lagoon Deposit PML3:- This is a tabular 15mm thick siliceous ironstone fragment from a vein above the upper silcrete and below the basalt. The upper part is more intensely indurated than the lower. The lower surface has the "incipient jointing" noted in Samples 29, 45 which gives an appearance of discrete blocks having been pushed together in a semi-solid state.

No. 35: Pattimore Lagoon Deposit:- A brown and yellow iron-laterite occurs in the silcrete-sand sequence. Coloured banding is in a vertical plane.

No. 36: Pattimore Lagoon Deposit:- A silty, slightly iron-stained coarse, poorly sorted sandstone occurs as a resistant bed about a metre below the basalt. It is moderately friable.

No. 37: Pattimore Lagoon Deposit:- This is a pale grey, friable siltstone.
No. 39: Pattimore Lagoon Deposit:- A friable grey sandy siltstone occurs above the lower silcrete seam.

No. 43: Bendalong ML20 Deposit:- This is a nodular, friable silcrete with a floating texture.

No. 45: Bendalong ML17 Deposit:- This is composed of rounded silcrete pebbles in a more recent silcrete. Lower in the sample the pebbles are partly fused with the enclosing later silcrete. This is similar to the "jointing" present in samples 29,33. Where the silcrete appears to have been in semi-fluid state neither slump nor slickensiding structures are present such as are found in clays associated with the silcretes in this region. This sample is pale grey and intensely indurated with a dull lustre.

No. 47: Bendalong ML15 Deposit:- This is a fine grained silcrete with sub-conchoidal fracture sub-vitreous lustre, floating texture and is intensely indurated. It has quartz clasts up to 2mm in diameter and variably iron-stained zones and a thin white friable weathered veneer.

No. 48: Bendalong ML15 Deposit:- This rock is identical to No. 47 but has a "cockade" structure on the upper surface.

No. 49: Bendalong ML31 Deposit:- This is a fine grained, intensely indurated grey silcrete with fine sub-orthogonal red iron-stained traces. The pattern of these is reminiscent of that of the laterite "box-work" common at the western margins of this deposit.

No. 54: Bungonia Stockyard Deposit:- This is a mixed type of silcrete with dark, fine grained silcrete with a conchoidal fracture grading into a paler, more friable siltstone.

No. 55: Bungonia Stockyard Deposit:- A pale grey silcrete with a floating texture occurs in seam 2. It is very compact and intensely indurated.

No. 56: Bungonia Stockyard Deposit:- This is a coarse, partly weathered and iron-stained silcrete with abundant, rounded quartz clasts. A floating texture is present throughout.
No. 58: Windellama Croker Deposit:- This is a pale grey, friable, silcrete with a "pumice-like" outer surface. Planes similar to bedding occur in a vertical plane. It has a floating texture with rare quartz clasts up to 4mm in diameter.

No. 59: Windellama Croker Deposit:- This is a coarse grained grey silcrete typical of the indurated silcrete from the deposit. Abundant coarse quartz clasts are set in a fine grained matrix.

No. 62: Bendalong ML12 Deposit:- This buff to pink micaceous siltstone was found about 3m below the surface in MLA490 just east of ML12. It contains a fennestellid fossil similar to those found in the Permian marine sediments at Warden Head, Ulladulla, (coll. G.B. Brink).

No. 63: Bendalong ML31 Deposit:- This is a pale grey, fine grained intensely indurated silcrete with sub-conchoidal fracture and a floating texture.

No. 64: Bungonia Old Feltham Deposit:- This is a siliceous laterite containing a "derived" Permian pecten-like pelecypod fossil found at the base of a tree near the south-eastern edge of the deposit. The fragment had apparently been brought to the surface by the tree root growth (fig. 29), (coll. M.V. Anderson).

No. 65: Bendalong ML53 Deposit:- This is a pale grey silcrete with a quartzite rather than floating texture. It has abundant plant fossil traces and rare rounded quartz grains up to 4mm in diameter, (coll. M.V. Anderson).

No. 66: Tallong Caoura Homestead Deposit:- This is a pale grey to brown and black intensely indurated silcrete with a quartzite texture and quartz clasts up to 2mm diameter and abundant plant fossil traces (coll. M.V. Anderson).

No. 67: Bungonia Old Feltham Deposit:- Granular, brown, partially weathered granodiorite.

No. 68: Bungonia Old Feltham Deposit:- This is a kaolinised in situ., weathered granodiorite which occurs on the western edge of the deposit. It is friable and granular.
No. 69: Bungonia Old Feltham Deposit:- This is a grey and yellow sandy clay rich in fossil plant fragments from just above the in situ weathered granodiorite at the western edge of the deposit.

No. 70: Bungonia Old Feltham Deposit:- This is a buff to dark grey intensely indurated silcrete with a floating texture.

No. 72: Bungonia Old Feltham Deposit:- This is a white silty kaolinitic clay from below the lower silcrete seam.

No. 73: Bungonia Old Feltham Deposit:- This is a white kaolinitic clay with coarse quartz clasts throughout. Both 72 and 73 are transported weathered granodiorite products.

No. 74: Bungonia Old Feltham Deposit:- This is a friable white to brown clayey sandstone.

No. 75: Bungonia Old Feltham Deposit:- This is a fine grained sand.

No. 76: Bungonia Old Feltham Deposit:- This is a variable grain size silcrete in which some zones are very fine grained with a conchoidal fracture and other zones are more quartzitic. There are irregular, pale, friable weathered zones.

No. 77: Bungonia Morris Deposit:- This is a very pale grey, intensely indurated silcrete with coarse quartz clasts in a very fine grained white ("Porcellanite-like") matrix. This is the best macroscopic example of "floating texture" observed in the study. The clasts are rounded, angular, almost acicular, shattered, deeply embayed with some rare beta quartz outlines. The distribution of the clasts is uneven, there are large areas, up to 4cm² where there are no visible clasts in the matrix (coll. J.G. Olliver).

No. 78: Bungonia Morris Deposit:- This white silcrete has a quartzitic texture because the matrix is more coarse and clasts are smaller. It has an almost saccharoidal appearance but with a resinous lustre and is intensely indurated.

No. 80: Bungonia Stockyard Deposit:- A number of cobbles from a stockpile (22/11/73). Most are fine grained with a sub-conchoidal fracture, dull lustre and fine irregular yellow veins which are probably anatase-rich zones. The silcrete has a floating texture and is indurated (coll. J.G. Olliver).
No. 82: Bungonia Stockyard Deposit:- A ferruginous, partly silicified poorly-sorted sandstone which occurs below the lower silcrete seam.

No. 82: Tallong Caoura Road Deposit:- This is a variable iron-stained, very fine grained silcrete with a floating texture, greasy lustre and conchoidal fracture. Several fine plant fossil traces.

No. 86: Tallong Caoura Road Deposit:- Identical to No. 85.

No. 103: Bendalong Beach Deposit:- This is a fine-grained laterite with some fine grained dark red cross-cutting, sub-orthogonal veins. This is similar to typical "box-work" in many laterites.

No. 104: Bendalong ML4 Deposit:- This is a pale grey to brown indurated silcrete with a quartzite texture, dull lustre.

No. 105: Bendalong ML4 Deposit:- This is a fine grained silcrete which is intensely indurated, has a sub-conchoidal fracture, quartzitic texture and dull lustre. It is grey with brown iron-stained areas throughout. Grainsize is even and there are fine irregular voids.

No. 106: Bendalong ML21 Deposit:- This pale grey silcrete is fine-grained with a quartzitic texture and is compact and intensely indurated.

No. 108: Bendalong ML30 Deposit:- This is a pale grey fine-grained silcrete with rare coarse quartz clasts up to 4mm diameter. Concentric faint iron-staining and a thin veneer of friable weathered material are present.

No. 109: Bendalong ML36 Deposit:- This silcrete is friable, slightly iron-stained with a dull lustre and floating texture.

No. 110: Bendalong ML36 Deposit:- This rock is a siliceous laterite with some silcrete characteristics. It is made up of concentric zones and at the centre is a dull red iron-stained, fine-grained silcrete with discrete buff zones. The floating texture is present. Surrounding this red zone is a yellow zone which appears to be less siliceous but has fine bands and patches of paler siliceous material. The outer zones is finer grained, compact, brown siliceous laterite up to 4mm thick.
No. 111: Bendalong ML36 Deposit:- A largely iron-stained silcrete with rare pale grey zones is from a thick seam at the southern end of the deposit. It is intensely indurated with floating and quartzitic textures.

No. 112: Bendalong ML7 Deposit:- This is an intensely indurated grey silcrete with a floating texture, sub-conchoidal fracture and a coarse matrix. Bands of pink iron-staining are present as well as evidence of semi-fluid blocks having been partially fused. Rare fine-grained zones have a conchoidal fracture and sub-vitreous lustre.

No. 113: Tallong Caoura Homestead Deposit:- A pale grey silcrete with vitreous lustre, conchoidal fracture, floating texture and large quartz clasts in the upper parts occurs on the surface at the western side of the deposit. The quartz pebbles are greater than 10mm in diameter (fig. 20).

No. 114: Tallong Caoura Homestead Deposit:- This is a dark grey silcrete with a coarse matrix and coarse quartz clasts.

No. 115: Tallong Caoura Homestead Deposit:- This is a brown silcrete with a sub-vitreous lustre, conchoidal fracture and floating texture.

No. 117: Tallong Caoura Homestead Deposit:- This is a white, very fine grained, porcellanite-like silcrete with conchoidal fracture and sub-vitreous lustre. A thin black vitreous zone occurs on one surface of the sample and on another is a 1cm friable, saccharoidal weathered zone.

No. 120: Bungonia Stockyard Deposit:- A dark grey intensely indurated silcrete with a coarse matrix and coarse quartz clasts occurs in the north-western extremity of the deposit.

No. 121: Bungonia Stockyard Deposit:- A friable, pale grey, nodular sandstone occurs at the north-eastern edge of the deposit. It has a floating texture and is probably the lateral extension of seam 2.

No. 122: Bungonia Old Feltham Deposit:- This is a pale grey, intensely indurated silcrete with quartz clasts up to 2mm diameter. There are irregular weathered friable zones.
No. 123: Bungonia Old Feltham Deposit:- This is a pale grey silcrete with a coarse matrix and quartz clasts up to 5mm in diameter. It has a sub-conchoidal fracture and irregular weathered, friable zones.

No. 125: Bungonia Old Feltham Deposit:- This is a pale buff silty sandstone with a floating texture and coarse rounded quartz clasts.

No. 126: Bungonia Old Feltham Deposit:- This is a white sandstone with a clay matrix.

No. 127: Bungonia Old Feltham Deposit:- This silcrete is indurated, pale buff to grey with a coarse matrix.

No. 128: Bungonia Morris Deposit:- A slightly friable sandstone with a floating texture and white clay matrix occurs at the eastern side of the deposit.

No. 129: Bungonia Morris Deposit:- This is a pale grey, intensely indurated silcrete with coarse quartz clasts in a fine grained matrix. Rare beta quartz sections and deeply embayed quartz clasts are visible macroscopically.

No. 134: Bungonia Jerrara Creek Deposit:- This is a white silty sandstone.

No. 137: Bungonia Jerrara Creek Deposit:- This is a pale grey clay.

No. 140: Windellama McGaw Deposit:- This buff, brown indurated silcrete has a variable grain size with rounded quartz clasts ranging up to 3mm in diameter. It is variable iron-stained pink and brown with an uneven to sub-conchoidal fracture and dull lustre.
3 maps
1 copy of publication.