CHAPTER 4

PETROGRAPHY AND CLASSIFICATION OF SILCRETE

4.1 DEFINITION AND OCCURRENCE

Silcrete is a hard rock consisting of quartz or chert clasts cemented by silica. Its occurrence is widespread, and deposits have been described in, for example, southern England (Lamplugh, 1902; Clark *et al.*, 1967; Whalley and Chartres, 1976), the Netherlands (Van den Broek and Van der Waals, 1967); South Africa (Summerfield, 1983a, 1983b); the southern United States (Hughes, 1963) and in the mid-western United States (Dury and Knox, 1971). The literature on Australian silcrete is extensive (for example Woolnough, 1927; Williamson, 1957; Langford-Smith and Dury, 1965; Exon *et al.*, 1970; Browne, 1972; Langford-Smith, 1978; Van de Graaff, 1983).

4.2 PETROGRAPHY

Silcrete in the Armidale-Uralla region is a diverse material, containing a wide range of clast sizes and shapes. One common type consists of moderately to well sorted sand-sized clasts in a silica cement. The colour of these silcretes is usually white to cream or grey. The degree of cementation varies, resulting in fracture that may be either conchoidal with a smooth fracture surface (Plate 22), or uneven with a rough or sugary surface (Plate 23). Well cemented samples usually exhibit smooth fracture surfaces.

Another common silcrete in the Armidale-Uralla region consists of variably rounded quartz or chert pebbles in a matrix of quartz sand (Plates

24-30). The sand and pebbles are cemented by silica to form a hard material that usually fractures through pebbles rather than around them. There are good exposures of this silcrete type on hilltops 11 km southwest of Armidale (Plate 31). These exposures are contiguous with basalt remnant deposits. The pronounced rounding of pebbles in these silcretes indicates possible transport in streams. Despite the usual strong silicification of these pebbly silcretes, the silica cement in many samples has weathered more rapidly than the pebbles it is binding. For this reason exposures of these cemented poorly sorted sediments often have portions of rounded pebbles standing in relief above the quartz sand matrix (Plates 32, 33).

At several sites in the Armidale-Uralla region, silcrete contains ferruginous glaebules. The glaebules do not appear to have been impregnated by the silica cement. These silcretes usually also contain sorted sand or small pebbles (Plates 34, 35).

Iron-staining is a feature of silcrete at several sites in the Armidale-Uralla region. Silcrete near Thomas Lagoon (Armidale sheet GR 581185) is iron-stained in parallel bands. These iron-stained bands are intercalated with bands of silcrete that are relatively free of iron (Plates 36, 37). The attitude of the iron-stained bands is variable, but they tend towards sub-horizontal bedding. The cause of this variable iron-staining is unknown, but it may be due to localised temporal variations in the movement and iron content of groundwater, as similar silcrete was not found in this study, or reported by others, elsewhere in the Armidale-Uralla region. As similar silcrete has not been found near other lagoons in the region, it is unlikely that the banded iron-staining is directly related to the conditions of impeded drainage that led to the development of Little Lagoon or Thomas Lagoon.

Another silcrete, quite different to those described above, has formed on some of the Palaeozoic chert beds in the Armidale region. This silica-cemented brecciated chert has developed by the infilling with microcrystalline silica, of fractures in chert bedrock. It consists of silica-cemented poorly sorted angular chert clasts, formed where the chert bedrock began disintegrating prior to silicification. In some cases weathered fragments moved only millimetres before being fixed by silicification (Plates 38, 39). The silica-cemented chert bedrock occasionally grades into unaltered bedrock over distances of less than a metre (Plate 40). Some weathered exposures have been preserved in the transition phase between chert bedrock and silica-cemented brecciated chert (Plate 41).

4.2.1 QUARTZ GRAINS

Microscopic examination of silcrete quartz grains in thin section, revealed marked differences in extinction patterns and fluid inclusion abundance between samples. For example, examination of Samples 056, 280 and 289 (Appendix F) using an empirical quartz grain classification scheme (Folk, 1968), gave the following results.

Sample 056 (silica-cemented sorted clasts; Plates 34-34): 67% of the quartz grains (n=111) have straight to slightly undulose extinction with abundant fluid inclusions; 17% have straight to slightly undulose extinction with few fluid inclusions.

Sample 280 (silica-cemented poorly sorted clasts; Plates 24-25): 87% of the quartz grains (n=103) have straight extinction with few fluid inclusions; 8% have straight extinction with abundant fluid inclusions.

Sample 289 (silica-cemented sorted clasts; Plates 36-37): 55% of the quartz grains (n=108) have straight to slightly undulose extinction with few fluid inclusions;39% have straight to slightly undulose extinction with abundant fluid inclusions.

These results typify the range of extinction/fluid inclusions characteristics of silcrete in the Armidale-Uralla region. Straight to slightly undulose extinction is almost ubiquitous, and the abundance of fluid inclusions varies greatly. In most samples though, grains with few fluid inclusions outnumber those where fluid inclusions are plentiful. On the basis of these extinction/fluid inclusion characteristics, some tentative conclusions can be drawn about sources of the quartz grains. These conclusions are discussed in Section 8.4.

4.3 EXISTING CLASSIFICATION SCHEMES

There have been few attempts to produce classification schemes for silcrete. Two attempts are those of Smale (1978) and Wopfner (1978). Both were devised with reference to Australian silcretes. Wopfner (1978) based his classification on studies of silcretes in northern South Australia and adjacent regions, as well as inspections of silcrete in South Africa and Europe. Smale's (1978) scheme was based on comparison studies of silcrete in northern South Australia and southern Africa. A description of the two schemes follows.

4.3.1 SMALE (1978)

Smale identified five types of silcrete, mainly on petrographic grounds.

1. Terrazzo type. Smale (1978) considered this the commonest type. He named it for its similarity to man-made terrazzo cement stone. Terrazzo silcrete consists of quartz grains in a matrix of 'cherty, cryptocrystalline or opaline silica'. The quartz grains are irregular in shape and degree of rounding and often have solution cavities which according to Smale (1978) 'clearly indicate that the original sediment underwent a period of silica solution'.
2. Conglomeratic silcrete. This type consists of irregularly shaped though sometimes well rounded fragments of terrazzo silcrete, in a characteristically brick-red to brown siliceous cement. Conglomeratic silcrete is a reworked silcrete.

Plate 22. Silica-cemented sorted clasts (0.1-0.3 mm rounded to sub-rounded quartz sand, cryptocrystalline cement, smooth subconchoidal fracture). Dark grains are larger quartz clasts (Armidale sheet GR 598159).

Plate 23. Silica-cemented sorted clasts (0.1-0.3 mm rounded quartz sand, cryptocrystalline cement, 'sugary' fracture surface). Distinctive fracture surface is the result of incomplete silicification (Gostwyck sheet GR 608070).

Plate 24. Silica-cemented poorly sorted clasts (0.5-2 cm quartz clasts, quartz sand matrix, cryptocrystalline cement). Rounding of some clasts suggests transport in stream prior to silicification. Zoning in large quartz clast is almost certainly the result of successive stages of crystal growth, and is not related to silicification. (Dumaresq sheet GR 674266).

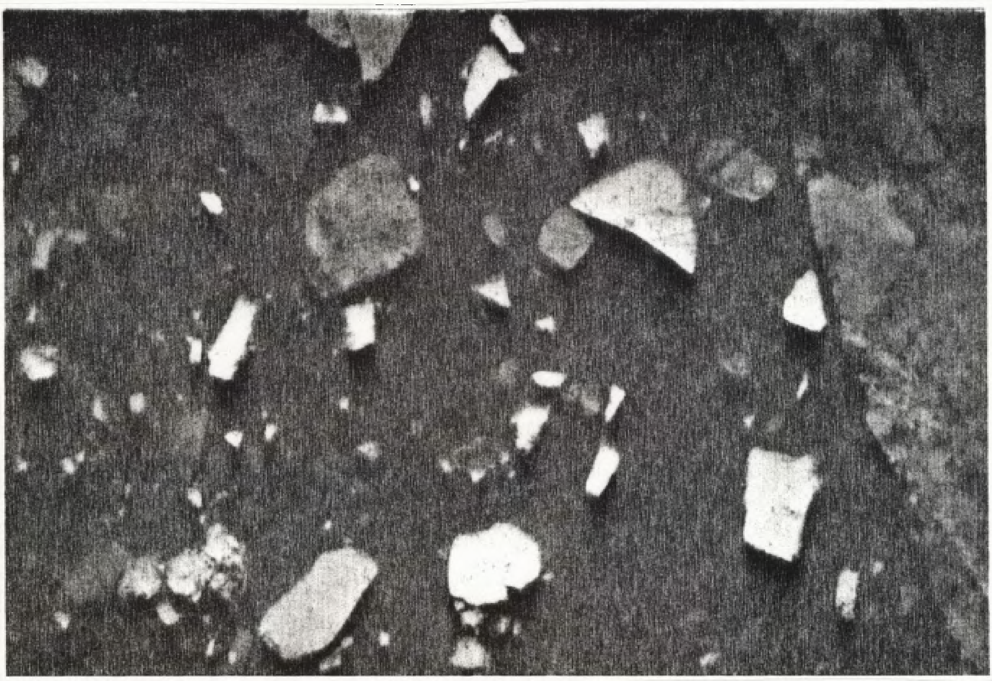

Plate 25. Photomicrograph of Sample 280 shown in Plate 24 (crossed nicols). Actual width of field is 2.5 mm. Sample contains fractured and re-silicified quartz clasts, such as the one visible on the right of the Plate, in a cryptocrystalline matrix containing a suspended fabric of subrounded to subangular quartz grains. Suspended fabric is probably the result of progressive solution of finer grains, and their replacement by cryptocrystalline silica.

Plate 26. Silica-cemented poorly sorted clasts (0.1-0.7 mm rounded quartz clasts, sand matrix, cryptocrystalline cement). Darker grains are quartz and chert. Sample is from site near Sample 056, within an extensive area of variably cemented, silicified and ferruginised sediments (Armidale sheet GR 656227).

Plate 27. Silica-cemented poorly sorted clasts (1-6 mm angular quartz clasts, occasional rounded quartz clasts to 12 mm, sand matrix, cryptocrystalline iron-stained cement). Sample shows bedding, but was not in situ, so no conclusions can be drawn regarding depositional environment. (Dumaresq sheet GR 682254).

Plate 28. *Silica-cemented sorted clasts (1-2 mm subrounded quartz clasts, sand matrix, cryptocrystalline cement, uneven fracture). Uneven fracture through clasts indicates strong cementation (Dumaresq sheet GR 627304).*

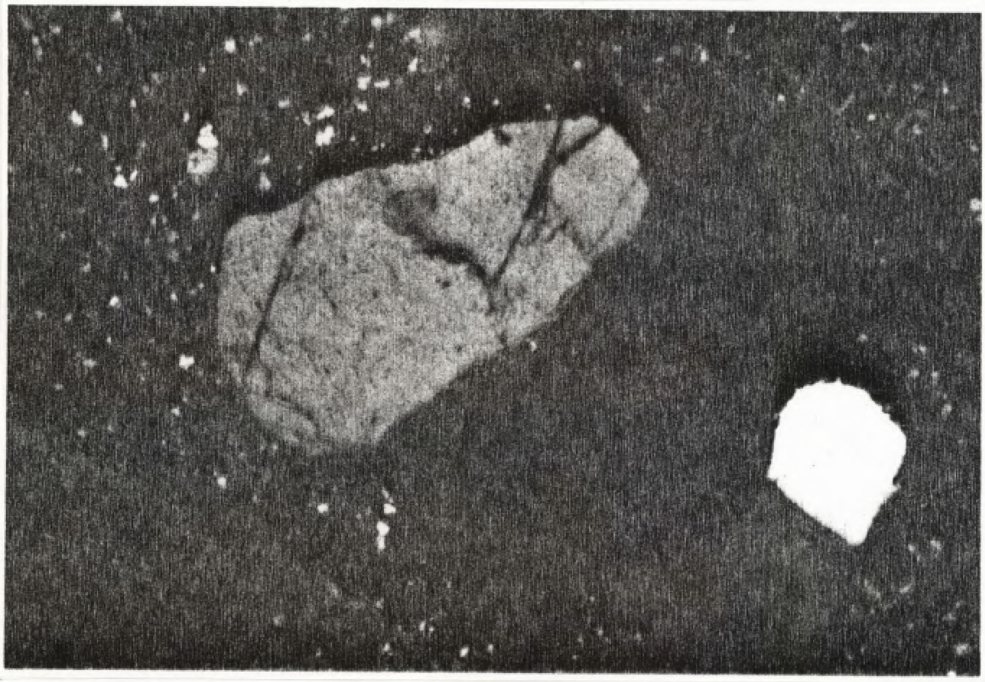

Plate 29. *Photomicrograph of Sample 278 in Plate 28, showing interlocking rounded quartz grains and microcrystalline cement (crossed nicols). Clustering of quartz grains is common in this sample, and may be the result of aggregation during the early stages of silicification. Quartz overgrowths, as in the grain at bottom right, are rare. Many grains have diffuse margins and advanced solutional embayment, though these features are not visible in this Plate. Large grain at bottom right is weathered feldspar. Actual width of field is 3.5 mm.*

Plate 30. *Silica-cemented sorted clasts (1-2 cm rounded quartz clasts, in a matrix of angular quartz grains and iron-stained cryptocrystalline silica cement). This indicates fluvial transport of quartz clasts to achieve rounding and sorting, prior to silica cementation in an iron-rich environment. Sample collected from ground surface, within an area of variably cemented sand and gravel (Dumaresq sheet GR 671251).*

Plate 31. *Silica-cemented sorted clasts on hilltop 11 km southwest of Armidale (Armidale sheet GR 625148). Silcrete contacts basalt in foreground of photograph. Mount Duval (Section 5.7.9; Plate 56) is visible in the distance.*

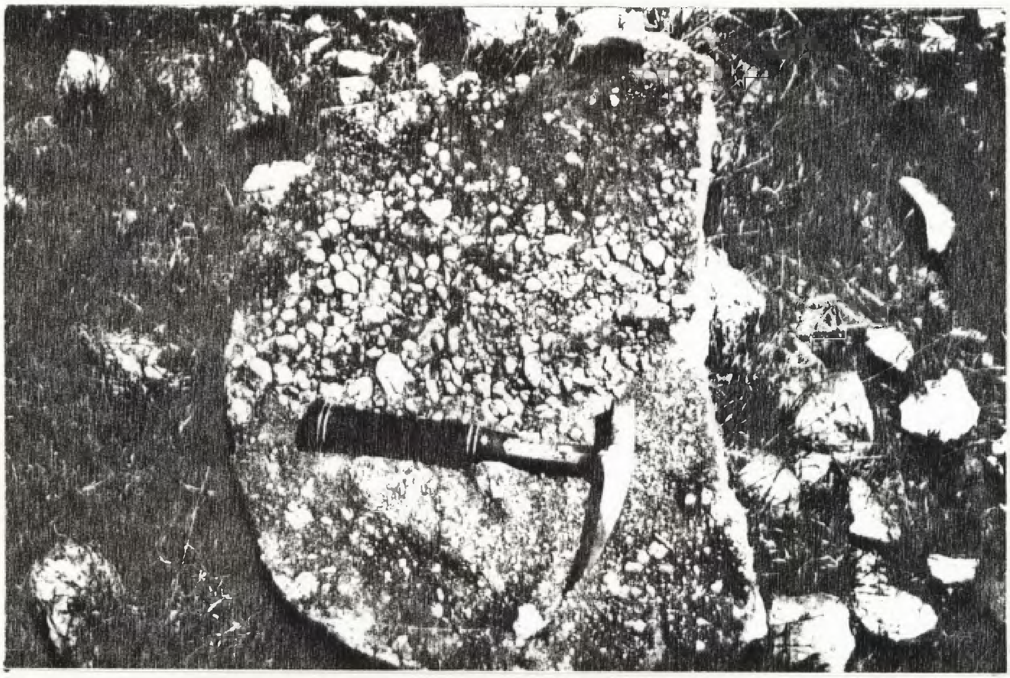

Plate 32. Silica-cemented poorly sorted clasts in boulder (1-3 cm rounded to subrounded quartz clasts, sand matrix). Bedding of in situ exposures of silcrete at this site is sub-horizontal, and consists of beds of alternating clast size, rather than a general trend to larger or smaller clasts. This suggests deposition of clasts under fluctuating fluvial conditions. No overall imbrication trend is evident. Site is 4 km east of eastern boundary of Map 1 (Armidale sheet GR 712098).

Plate 33. Field situation of silcrete shown in Plate 32, 12 km south of Armidale. Hill in background behind house is basalt, and illustrates the characteristic close field relationship between silcrete and basalt.

Plate 34. *Silica-cemented sorted clasts (1-2 mm rounded to subrounded quartz clasts, quartz sand matrix, 0.2-0.6 mm iron-rich nodules) Sample is from site near Sample 051, within an extensive area of variably cemented, silicified and ferruginised sediments (Armidale sheet GR 656227).*

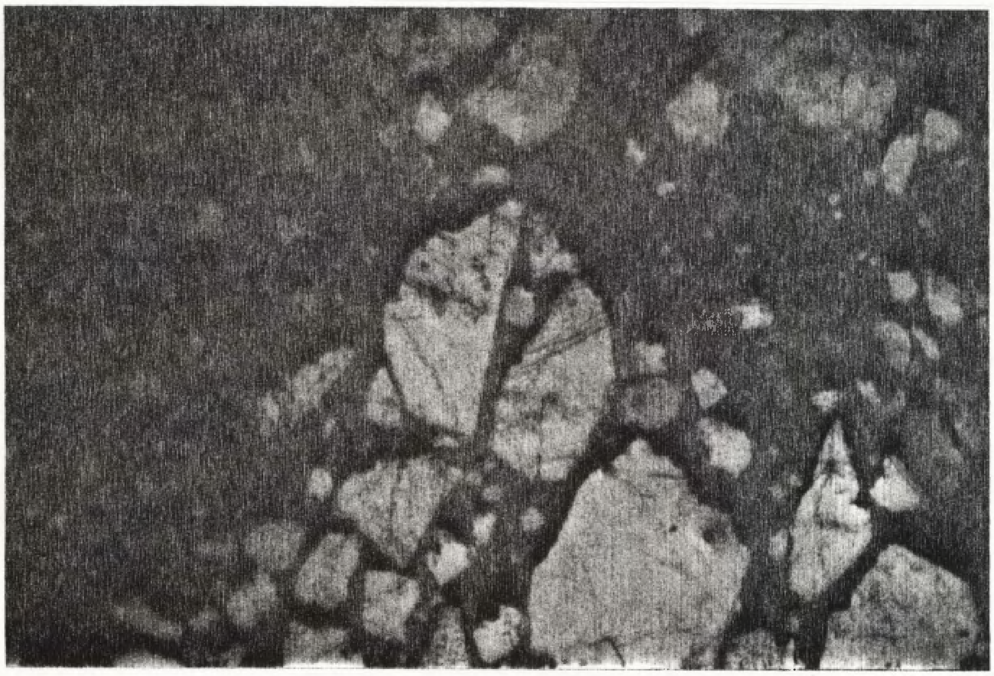

Plate 35. *Photomicrograph of Sample 056 shown in Plate 34 (ordinary light). Actual width of field is 3.5 mm. The ferricrete nodules are not silicified, and contain varying quantities of poorly sorted 0.05-0.2 mm angular quartz fragments. This suggests they are from a different source to the sorted grains in the matrix quartz, and indicates a probable inherited (transported) origin. Some matrix quartz grains in matrix have intergrown with chalcedony before partial rounding, indicating intergrowth in a silica-active environment, then transport, before final cementation. Most grains have few fluid inclusions and either straight or slightly undulose extinction, suggesting predominant vein provenance. There are occasional feldspars. There is no evidence of widespread in situ fracturing and recementation of quartz grains, though paired grains in centre of Plate may be an exception. Silica cement is cryptocrystalline.*

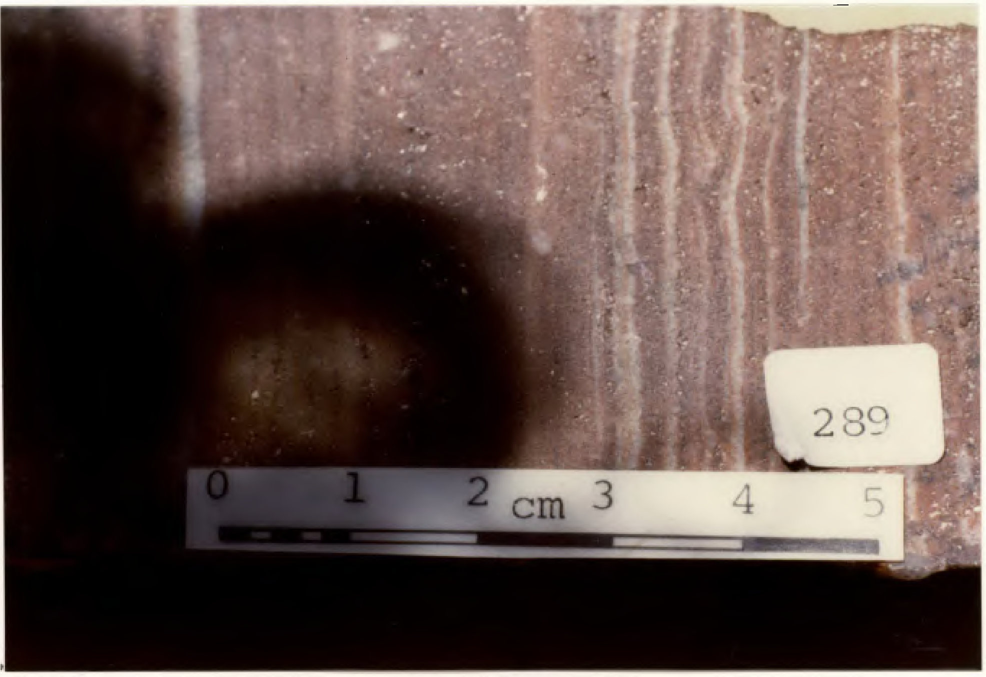

Plate 36. *Silica-cemented sorted clasts (0.1-0.2 mm subrounded quartz sand, cryptocrystalline cement, iron-staining in parallel bands). Band orientation is variable, but there is a tendency to sub-horizontal bedding (Armidale sheet GR 581185).*

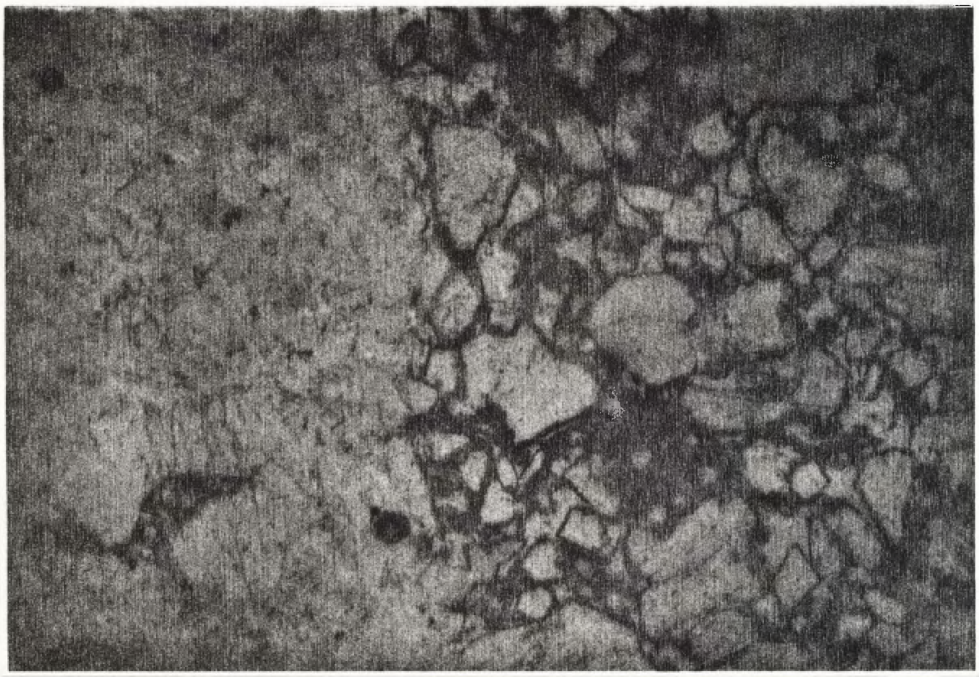

Plate 37. *Photomicrograph of Sample 289 shown in Plate 36 (ordinary light), showing the contact between alternating bands of iron-stained and unstained silica cement. Solutional embayment and etching of quartz grains is visible to right of centre of Plate. Some quartz grains have been fractured and recemented almost in situ, moving less than 0.05 mm before recementation, and preserving continuity of extinction and fluid inclusion characteristics. Iron-staining is not confined to spaces between grains; it penetrates microfractures in grains, and in many cases appears to form a rind around quartz grains, that has been subsequently overgrown with additional quartz. Thus many of the grain outlines apparent under ordinary light, are shown under crossed nicols to actually be the original grain portion of a larger grain consisting of original grain, iron-stained rind and optically continuous quartz overgrowth. The same feature is found less obviously in the unstained layers of the sample. The formative history appears complicated, but may have involved formation of iron-stained rinds in an iron-rich environment, followed by overgrowth development under silica-rich conditions. The varying iron content of the bands may have resulted from fluctuations in the iron content of groundwater during the later stages of silicification. Quartz grain extinction/inclusion characteristics indicate probable mixed granitic and vein provenance (Section 8.4).*

Plate 38. Silica-cemented brecciated chert (1-20 mm angular black chert clasts, sand matrix, cryptocrystalline cement) The chert clasts have been silica-cemented almost in situ (Armidale sheet GR 550208)

Plate 39. Photomicrograph of Sample 281 shown in Plate 38 (ordinary light). Actual width of field is 3.0 mm. Fractures in bedrock on right side of Plate are infilled with microcrystalline silica. There is no clear evidence of progressive replacement of the chert by silica.

Plate 40. in situ silica-cemented brecciated chert, in chert bedrock 20 km south of Armidale, at 'North Mihi' (Figure 2). Site is 5 km southeast of southeast corner of Map 1 (Gostwyck sheet GR 713012).

Plate 41. In situ silica-cemented brecciated chert, showing transition phase between chert bedrock and silica cemented chert breccia (Dumaresq sheet GR 648288).

3. Albertinia silcrete. Named after a quarry of the material near Albertinia in South Africa. This silcrete has little or no clastic component and is almost entirely composed of siliceous cement similar to that found in terrazzo silcrete.
4. Opaline and fine-grained massive forms. These are 'essentially homogeneous rocks, presumably purely of chemical origin, with no detrital components' (Smale, 1978). Included in this group are the layers of opal at Coober Pedy in South Australia.
5. Quartzitic silcrete. These silcretes are petrographically similar to sedimentary orthoquartzite, a sedimentary rock consisting of silica-cemented quartz sand. According to Smale (1978) the crucial difference is that quartzitic silcrete is formed at the surface. This distinction is unsatisfactory in practice, as sedimentary orthoquartzite can now be found at the surface after exposure by erosion. Orthoquartzite can be petrographically similar to silcrete formed by subaerial cementation, and thus it can be difficult to conclusively identify quartzitic silcrete. This illustrates a major problem involved in classifying by genesis.

4.3.2 WOPFNER (1978)

Wopfner based his classification scheme on studies of silcrete in northern South Australia and adjacent regions. The classification considered matrix mineralogy, texture, retention of host-rock texture, and thickness and type of associated profile.

GROUP I

matrix: crystalline quartz
- 1) irregular crystalline
- 2) optical continuity with framework quartz

Habit:
- a) blocky
- b)bulbous - pillowy

Retention of host-rock texture: In 1a and 2a

Profile: Overall kaolinisation of underlying rocks.

GROUP II

Matrix: cryptocrystalline quartz
- 1) massive
- 2) pisolitic [sic] - pseudopebbly
- 3) laminated -'schlierig'

Habit:
- a) columnar, polygonal - prismatic
- b) platy
- c) botryoidal
- d) pillowy ('Knollenstein')

Retention of host rock texture: None

Profile: Intense kaolinisation of underlying rocks, usually with zone of brecciation between kaolinised portion and silcrete.

GROUP III

Matrix: amorphous (opaline) cristobalite-tridymite (opal C-T)

Habit:
- a) breccious
- b) conglomeratic
- c) replacements and infillings

Retention of host rock texture: Invariably perfect

Profile: No specific profile but association with gypsum and alunite (Wopfner, 1978).

4.3.3 LIMITATIONS OF EXISTING CLASSIFICATION SCHEMES

Wopfner's (1978) scheme outlined the characteristic clast components of his three groups of silcretes and emphasised the replacement origin of much silcrete, but did not include clast description in the final classification. This is a disadvantage as it makes detailed sample description difficult within the bounds of the classification scheme. A major drawback of Wopfner's (1978) classification is that:

> No specific consideration is given to the components of the framework, as these are largely incidental, their size depending on the type of host-rock material already present at a given locality prior to the commencement of the process of silicification at that place. Experience has shown that the composition of the host-rock has little influence on the resulting type of silcrete (Wopfner, 1978).

Wopfner's decision to ignore non-matrix material in his classification scheme is unfortunate because this clastic component can provide evidence of the types and intensities of processes operating before the formation of the silcrete. For example rounded, well sorted pebbles indicate the presence of a fluvial environment prior to silicification. Despite stating that the non-matrix material in silcrete is relatively unimportant, Wopfner (1978) discussed the characteristic pebble or grain components of each of each of his three groups of silcrete.

The desirable contents of a classification scheme will depend on the use to which the scheme is to be put. Wopfner (1978) stressed silcrete matrix as the most important characteristic of silcrete, claiming it is diagnostic of the 'formational environment and diagenetic conditions' of the silcrete. The resulting classification scheme is of limited value as a means of fully describing the petrology of silcrete because it fails to categorise the grain/pebble (framework) component of the silcrete.

Smale's (1978) classification considered clast size, but silcrete in the Armidale-Uralla region often contains a mixture of sand and large clasts in siliceous cement (Plates 24, 26 30). These silcretes are transitional between the terrazzo and conglomeratic types of Smale (1978), and do not fit easily into any one of Smale's classes. The difference between Smale's classes is not always clear. For example, from his descriptions of Albertinia and Opaline silcretes, these two classes appear almost identical.

4.4 CLASSIFICATION OF SILCRETE

Regardless of the proposed use of any silcrete classificaton scheme, it should describe silcrete petrography, as a basis for comparing different silcretes and investigating their genesis and landscape significance. The scheme presented here consists of three classes, subdivided according to five criteria. It is primarily a petrographic classification, and is intended to enable identification and comparison of any silcrete.

There are three main types of silcrete in the Armidale-Uralla region.

1. Silica-cemented sorted clasts
2. Silica-cemented poorly sorted clasts
3. Silica-cemented brecciated chert

These types form the basis of the three part classification.

1. Silica-cemented sorted clasts. This silcrete usually consists of moderately to well-sorted quartz clasts of sand to pebble size in silica cement. Some samples consist of sorted clasts of pebble size in a matrix of sorted sand. Colour is usually white or cream to grey. Fracture is usually either conchoidal with a smooth fracture surface, or uneven giving a rough or sugary surface.
2. Silica-cemented poorly sorted clasts. This silcrete consists of unsorted or poorly sorted quartz clasts of sand to pebble size in silica-cement. In some samples a finer sand component may form a matrix around clasts of pebble size. As with cemented sorted clasts fracture is variable, and depends on the degree of cementation of the clasts.

   The roundness of particles in silica-cemented poorly sorted clasts is variable, depending on the amount of physical and chemical weathering of the particles prior to cementation. Some samples contain well rounded clasts, strongly suggesting that clasts were transported in streams before silicification. Other samples contain angular clasts that have probably moved only a short distance since initial fracturing. The variation in clast roundness is far greater in cemented unsorted clasts than in cemented sorted clasts, and the latter are usually more rounded. This it to be expected since clasts are both sorted and rounded during transport in streams.

   Both sorted and poorly sorted silica-cemented clasts have commonly been referred to as grey billy (David, 1887; Browne, 1972; Taylor and Smith, 1975). The term has been used to refer to such a wide range of materials that it is of little value as a precise descriptor, and its use in this thesis is avoided.

3. Silica-cemented brecciated chert. This silcrete consists of unsorted, angular chert clasts, in microcrystalline cement that infills voids and fractures between clasts. In the Armidale-Uralla region, silica-cemented brecciated chert has formed within partly weathered Palaeozoic bedrock. The texture and appearance of the host rock is usually preserved. Where weathering and fracturing of the host rock is further advanced, silica-cemented brecciated chert can grade into silica-cemented poorly sorted clasts over a distance of a metre or less.

Once a sample has been allocated to one of these three classes, details can be given of the following attributes.

1. Clast size and size range.
2. Presence or absence of a finer matrix surrounding larger clasts in the sample.
3. Nature of the silica cement: crystalline; microcrystalline; cryptocrystalline.
4. Nature of fracture: conchoidal; sugary; uneven; smooth.
5. Colour: white; grey; pink; cream.

Using this classification scheme, a sample consisting of well sorted and rounded 6-10 mm quartz pebbles in a white-grey, quartz sand rich, silica cement that has no crystal structure visible in microscope thin section, and exhibiting smooth fracture through clasts in the sample, would be described as: silica-cemented sorted clasts (6-10 mm quartz clasts, sand matrix, cryptocrystalline cement, smooth fracture). A sample consisting of angular and poorly sorted 1-12 mm black chert clasts, in a sand-free and iron-stained silica cement, exhibiting microscopic crystal structure, with sub-conchoidal fracture through the sample, would be described as: silica-cemented poorly sorted clasts (angular 1-12 mm black chert clasts, microcrystalline iron-stained cement, subconchoidal fracture).

The operation of this scheme of silcrete classification can be seen in the descriptions of silcrete samples shown in Plates 22-41. Its aim is to provide sufficient identifying data so that silcrete in the Armidale-Uralla region can be described, and its origin and significance discussed.

CHAPTER 5

THE ARMIDALE-URALLA REGION

5.1 INTRODUCTION

The aim of this chapter is to describe the geomorphology and surface geology of the Armidale-Uralla region shown in Map 1. This description of the landforms and materials of the mapped study area is a basis for the landscape interpretation in following chapters.

5.2 TECTONIC FRAMEWORK

The geomorphic development of the New England region began in the mid-Permian Period, when the island arcs, inter-arc basins and ocean trenches comprising the region were deformed and welded onto the Australian craton (Korsch and Harrington, 1981). This tectonic activity extended from about 255 to 230 my.

From this time much of the New England plateau was above sea level, and erosion products from higher areas were deposited in sedimentary basins. Sediment in these basins dates to the early Permian. In the case of the Clarence-Moreton Basin for example, Triassic sediments were deposited in a very shallow marine to terrestrial coastal swamp environment (Korsch, 1978, 1980).

During the period 200-90 my, the east coast of Australia probably extended further east than is now does, and there was a plate boundary within 200 km of the present east Australian coastline (Jones and Veevers, 1983a). This plate boundary then migrated east (Jones and Veevers, 1983a), forming the

Tasman Sea, an event thought to have taken place 80-60 my ago (Hayes and Ringis, 1973; Weissel and Hayes, 1977).

The opening of the Tasman Sea involved the separation of the Lord Hoew Rise and New Zealand from eastern Australia, and was the result of sea floor spreading associated with the eastward movement of the tectonic plate. The eastern highlands and Main Divide are thought to have originated at about the time the plate boundary began its eastward migration. This uplift was accompanied by the onset of basaltic volcanism along the eastern highlands. There is some evidence that the highlands and Main Divide are migrating westwards: the old (90-45 my) basalts all lie east of the present Main Divide (Jones and Veevers, 1983a). If these earlier volcanic episodes accompanied phases of highland development, as is thought likely (Grimes, 1980; Jones and Veevers, 1983a), then the eastern highlands and Main Divide are moving east. As Jones and Veevers (1983a) suggest, the rate of migration may have slowed through the Cainozoic, and may now be negligible, as appears likely in the Armidale-Uralla region (Section 9.5).

The idea (Ollier, 1978a) that vertical tectonism involving tension, uplift and volcanism, was the main process operating in eastern Australia after the opening of the Tasman Sea, may well be correct. But is is probably an oversimplification to argue (as Ollier, 1982a has done) that the modern eastern scarp and highlands are the direct result of continental rifting. Although the eastern scarp is a fairly uniform distance from the present coast along the length of eastern Australia, it is a highly variable distance from the actual continental edge (Jones and Veevers, 1983a; Bureau of Mineral Resources, 1979). It is this edge, rather than the present coastline, that marks the site of continental rifting, and the variations in distance between the eastern scarp and the continental edge makes a direct causal relationship unlikely.

5.3 TOPOGRAPHY

The Armidale-Uralla region lies between the steeply dissected scarp and gorge country to the east of the New England plateau, and the more gently sloping, low relief of the country to the west of the plateau. The landscape consists of undulating plateaus and hills with several higher landforms such as Mount Duval, Little Duval, Bald Knobs and Arthurs Seat. The regional relative relief is about 400 m, but apart from these higher landforms, the relative relief is only about 100 m. Slopes to 30° occur on the margins of the plateau, but are generally far less, about 0-3° on the plateau tops and 2-15° on the valley sides.

Ten kilometres west of Armidale is the crest of the 'Great Dividing Range'. This feature is neither great nor a range (Ollier, 1978a), but it is the drainage divide between the east flowing coastal rivers and the west flowing rivers of the Murray-Darling river system. In the Armidale region this Main Divide consists of undulating plateau country with slopes commonly only 0.5-2.0°. Isolated hills along the Main Divide have slopes of 20-25°, but nowhere is there a discernible range along the drainage divide.

5.4 DRAINAGE

The Armidale-Uralla region is drained east of the Main Divide by Saumarez Creek, Dumaresq Creek and Dog Trap Creek, three tributaries of the Macleay River. The portion of the Armidale-Uralla region west of the Main Divide is drained by tributaries of the Gwydir River (Map 2). The gradient of rivers of the western system increases close to the Main Divide. For example analysis of mapsheets at 1:25,000 scale show the Gwydir River has a gradient of about 2 m/km at a distance of 30-40 km from the Main Divide, but tributaries of this river close to the Main Divide have gradients of up to 90 m/km.

Rivers flowing to the east coast from the Main Divide have variable gradients. Gradients of 2-5 m/km are common in the plateau areas of the eastern highlands. In the gorge country along the eastern scarp of the highlands, river gradients are often in excess of 200 m/km.

Floodplains associated with rivers in the Armidale region of the eastern highlands are poorly developed. For example, the floodplain of Dumaresq Creek in the vicinity of Armidale is rarely wider than 150 m. One reason for this is that rivers close to divides have low maximum discharges.

Streams in the Armidale-Uralla region show varying degrees of adjustment to local base levels. Streams on the plateau areas of the Armidale-Uralla region show good adjustment, with low gradients of 2-5 m/km and an absence of knickpoints (abrupt changes in longitudinal profile). In the gorges of the eastern scarp, adjustment is poor, and river gradients are steep and variable (up to 200 m/km) with major knickpoints at the gorge heads.

5.4.1 SAUMAREZ CREEK

Saumarez Creek is the largest single drainage system in the Armidale-Uralla region. With its tributary Lambing Gully, Saumarez Creek drains an area of 200 km^2, almost half the mapped area. The trend of Saumarez Creek in the Armidale-Uralla region is south to southeast. In the northern half of this area the valley of Saumarez Creek is only 5-7 km wide between interfluves. Despite this restricted width the valley contains a definite zone of impeded drainage, indicated in Map 2 by the arrowed drainage lines. In this zone there are several small (0.25-3.0 km^2) areas of internal drainage centred on lagoons that are dry in times of drought (Map 2; Figure 2).

The drainage pattern of Saumarez Creek is dendritic, and compressed by the narrow valley and by the low relief in the area of impeded drainage referred to above. In the upper reaches of Saumarez Creek the drainage pattern becomes parallel, around a linear southwest-trending basalt remnant approximately 5 km long and 0.5-2.0 km wide. These parallel tributaries flow southwest, and have developed along the strike of the underlying, steeply dipping ($60-80^{o}$) Sandon Beds. Exposure of Mount Duval by erosion, and extrusion of basalt during the Tertiary have modified this pattern. As a result, the parallel tributaries either side of the southwest-trending basalt remnant now originate in dendritic gullies on the Mount Duval Adamellite.

In the southern half of the Armidale-Uralla region the valley of Saumarez Creek is up to 14 km wide, and Lambing Gully flows northeast to Saumarez Creek, almost normal to the trend of the Main Divide (Map 2).

The northern sections of Saumarez Creek in the Armidale-Uralla region are mainly on chert and sandstone of the Sandon Beds. The central and southern sections cross ferricrete and Tertiary basalt. The central section of the Armidale-Uralla region contains the area of impeded and localised internal drainage discussed above, here called the Saumarez-Arding area.

5.4.2 DUMARESQ CREEK

The area of the Dumaresq Creek basin included in the mapped Armidale-Uralla region is 70 km^2. The headwaters of Dumaresq Creek are on Mount Duval Adamellite, except for several minor tributaries that rise on Tertiary basalt. Dumaresq Creek flows almost southwest then southeast across the Armidale study area. The initial southwesterly trend of the Creek is a result of drainage development on the Mount Duval diapir. The lack of lineations in the Mount Duval diapir, and its shape and orientation in the landscape have enabled the development of this dendritic pattern in the headwaters. Once off the Mount Duval Adamellite, the main channel of Dumaresq Creek turns through almost 90^o and flows southeast across rocks of the Sandon Beds. This flow direction is approximately normal to the strike of the steeply dipping Sandon Beds. It is likely this flow was superimposed on the Sandon Beds as overlying Tertiary basalt was removed by erosion.

The Dumaresq Creek valley does not contain areas of markedly poor drainage or well developed parallel drainage such as those that characterise Saumarez Creek. Despite this there are minor examples of parallel drainage where tributaries downstream of the headwaters of Dumaresq Creek cross rocks of the Sandon Beds. The valley of Dumaresq Creek is 3-7 km wide in the Armidale-Uralla region, and widens progressively downstream.

5.4.3 DOG TRAP CREEK

Dog Trap Creek and its tributaries rise in the Tertiary basalt-capped hills east of Uralla, and drain 55 km^2 of the southern portion of the Armidale-Uralla region. The upper tributaries flow south to southwest along the strike of the Sandon Beds, but at the southern margin of the Armidale-Uralla region Dog Trap Creek turns and flows southeast to east across the grain of the Sandon Beds. This change in drainage direction is probably due to drainage disruption by Tertiary basalts just outside the southern boundary of the Armidale-Uralla region.

5.4.4 GWYDIR RIVER TRIBUTARIES

These tributaries drain 95 km^2 of the Armidale-Uralla region on the western side of the Main Divide. The main tributaries from north to south include Teatree Creek, Blackfellows Gully, Reedy Creek, Spring Creek, and Rocky Creek. The headwater gullies of Teatree Creek flow in parallel channels to the west before joining the main south-flowing creek, which then turns and flows to the west. North of Uralla, Spring Creek flows north before joining Reedy Creek and flowing west. With these exceptions the drainage pattern is dendritic and directed to the west.

The Gwydir River tributaries all rise on the basalt and ferricrete that mantle the Main Divide. Except for Rocky Creek at Uralla, which flows onto the Uralla Granodiorite, all the tributaries flow onto rocks of the Sandon Beds. There is some evidence of bedrock control of drainage in the streams draining the west of the Main Divide. An unnamed gully 0.5 km west of Spring Creek (Armidale sheet GR 530151) flows between Uralla Granodiorite and contact metamorphosed Sandon Beds for 1 km, before turning onto the granodiorite. The apparent absence of bedrock control on some of the other streams west of the Main Divide is probably the result of the steep gradient of the streams, and their initiation on, and superimposition from, fairly homogeneous and level-bedded Tertiary basalt across the grain of the Sandon Beds.

The gradient of the streams on the western side of the Main Divide is up to 110 m/km, measured along 1 km segments, and is usually at least 50 m/km. These streams are much steeper than those draining the eastern side of the Main Divide. On the east of the Main Divide gradients usually vary from 10 to 30 m/km. An exception is the headwaters of Dumaresq Creek on Mount Duval, where gradients measured over 1 km reach 170 m/km.

5.5 DRAINAGE DIVIDES

5.5.1 THE MAIN DIVIDE

The Main Divide runs north-south through the Armidale-Uralla region (Map 2). In cross-section the Main Divide is asymmetric, with steeper slopes occasionally up to 20° on the western fall, but generally gentle to moderate slopes of less than 10° on the eastern side.

The course of the Main Divide is ill-defined in places because of the generally low relief; and sinuous where streams either side of the Divide have cut headward.

The Main Divide is capped by Tertiary basalt for most of its length in the Armidale-Uralla region. The elevation of the Divide is 1170 m in the north of the Armidale-Uralla region, falling to 1060 m in the central region and rising again to 1130 m in the south. This fall in the elevation of the Main Divide from the northern and southern ends of the Armidale-Uralla region toward the central region, is reflected in the bedrock underlying the basalt along the Main Divide (Figure 7).

5.5.2 SECONDARY DIVIDES

The drainage divide between Saumarez and Dumaresq Creeks runs west of south then east of south through the northern half of the Armidale-Uralla region. The course of this divide is sub-parallel to, and about 5 km east, of the Main Divide. The Saumarez-Dumaresq divide is more sinuous than the Main Divide. This may be a result of differential erosion on the more varied lithology along the Saumarez-Dumaresq divide.

The Saumarez-Dumaresq divide has an elevation of 1300 m in the extreme north of the Armidale-Uralla region, falling to 1067 m in the central part of the region. Much of this divide is capped with basalt, and as with the Main Divide, the fall in elevation from the north of the Armidale-Uralla region is mirrored in the sub-basaltic topography (Figure 8).

In the southern half of the Armidale-Uralla region, the divides between Lambing Gully and Saumarez Creek, and between Lambing Gully and Dog Trap Creek, run east to northeast from the Main Divide. They terminate where Lambing Gully and Dog Trap Creek meet Saumarez Creek. The divide between Saumarez Creek and Dog Trap Creek leaves the Main Divide at an elevation of 1097 m (Gostwyck sheet GR 561067), and rises to 1128 m on the basalts of Big Ridge (Gostwyck sheet GR 616085), before falling to 1000 m near the confluence of Dog Trap Creek and Saumarez Creek. The divide between Lambing Gully and Saumarez Creek leaves the Main Divide at an elevation of 1067 m (Armidale sheet GR 554138) and crosses the southern sections of the Saumarez-Arding ferricrete area, falling to 1000 m near the junction of Lambing Gully and Saumarez Creek.

5.6 LAGOONS

The topography of the Armidale-Uralla region is of sufficiently low relief for several areas of internal or impeded drainage to have formed. These areas contain seasonally dry lagoons on or very close to the major divides (Map 2;

Plate 42. Tanglewood Lagoon, looking northwest. The lagoon margin is delineated by the dips in the fence line and the darker vegetation on the lagoon floor. Photograph was taken prior to rains in April-May 1983 (Dumaresq sheet GR 655250).

Plate 43. Barley Field Lagoon, looking to the north. Photograph taken after the April-May 1983 rains (Gostwyck sheet GR 555091).

Plates 42, 43).

The origin of the lagoons in New England has been linked to drainage disruption by warping (Andrews, 1910); conversion of volcanic craters to crater lakes (Cotton, 1909); impeded drainage across a Tertiary planation surface (Voisey, 1957; Warner, 1971); and deflation during late Pleistocene dry conditions, of soil and clay upstream from a sill of exhumed ferricrete or silcrete pavement (Walker, 1979)

Ten lagoons occur in the Armidale-Uralla region. Seven are on or very close to the Main Divide, the other three are on the divide between Saumarez and Dumaresq Creeks. The lagoons are all in areas of low relief and poor drainage, and until heavy rains in April and May 1983, had been dry for several years because of drought.

5.6.1 FARM LAGOON

Farm Lagoon is situated at Dumaresq sheet GR 620256, 1.7 km east of the Main Divide. With a water diameter of nearly 500 m when full, Farm Lagoon is the largest in the Armidale-Uralla region The water depth has been known to reach 2.8 m (owner of 'Lagoon Farm', pers. comm.). Farm Lagoon is supplied with water from a catchment of 3 km2 on the south and west sides of the lagoon, and its natural overflow to Saumarez Creek was on the northeast margin of the lagoon. The bed of Farm Lagoon has very recently been scraped to deepen it, and the excavated material has been used to consolidate the northeast margins of the lagoon, blocking this natural outflow.

The inflow margins of Farm Lagoon are on ferricrete and silcrete, and the old natural outflow zone is on colluvium and alluvium. The level floor of the lagoon contains fine silt and black cracking clay.

5.6.2 UNNAMED LAGOON AT 'PRIMROSE HILL'

This unnamed lagoon, here called Primrose Hill Lagoon, is 200 m east of the

Main Divide, at Dumaresq sheet GR 587282. The lagoon has dimensions of 300 m by 200 m, and is oriented east-west. It has a catchment of about 1 km2 to the north, south and west of the lagoon. Drainage is to Saumarez Creek by a natural outlet at the northeast corner. A narrow (50-100 m) band of colluvium surrounds most of the lagoon. This colluvium abuts ferricrete and basalt on the catchment margins of the lagoon, and rocks of the Sandon Beds on the eastern outlet side. The level floor of the lagoon is fine silt and black cracking clay.

5.6.3 UNNAMED LAGOON NEAR 'SAUMAREZ' AIRSTRIP

This unnamed lagoon, here called Saumarez Airstrip Lagoon, is located at Armidale sheet GR 595212, and has dimensions of 150 m by 200 m. Saumarez Airstrip Lagoon was originally supplied with water from a 1 km2 catchment to the south and west, but embankments on the road adjacent to the western edge of the lagoon have greatly decreased the catchment. The lagoon is 2.5 km east of the Main Divide, and overflow drainage is to Saumarez Creek by a natural outlet on the northeast margin. The level floor of the lagoon contains fine silt and black cracking clay, and the margins are entirely on ferricrete.

5.6.4 THOMAS LAGOON

Thomas Lagoon is located at Armidale sheet GR 581185. The lagoon is 1.1 km east of the Main Divide and has dimensions of 150 m by 250 m. Thomas lagoon flows to Saumarez Creek by a drain cut from the eastern margin, though its natural overflow was to the northeast. Drains cut across the catchment of Thomas Lagoon have reduced the area of the catchment from about 1.5 km2 to its present area of 1 km2 on the south, west and southeast of the lagoon. The western margin of Thomas Lagoon is on silcrete, the remaining margins are on ferricrete. The level floor of the lagoon is fine silt and black cracking clay.

5.6.5 LITTLE LAGOON

This lagoon is situated 0.6 km east of the Main Divide at Armidale sheet GR 577187. The lagoon receives water from a catchment of 1.0 km2 to the west and southwest, which it shares with Thomas Lagoon. Little Lagoon has dimensions of 200 m by 150 m. It has a level floor composed of fine silt and black cracking clay. A drain cut from the northeast margin drains Little Lagoon to Thomas Lagoon. This drain is largely superfluous because Little Lagoon is almost completely filled with sediment, and is capable of carrying only a few centimetres of water before overflowing over its low eastern margin. Little Lagoon has probably acted as a sediment trap for Thomas Lagoon, and has been filled with sediment that would otherwise have been deposited in Thomas Lagoon.

5.6.6 STRAHLE LAGOON

Strahle Lagoon is located at Armidale sheet GR 570177. The lagoon is located 200 m east of the Main Divide, and receives water from a catchment of 0.5 km2 to the south and west. The lagoon has dimensions of 200 m by 150 m, and overflows from the northeast margin. The southeast margin of Strahle Lagoon is on silcrete, the remaining margins are on ferricrete. The level floor of the lagoon contains fine silt and black cracking clay. Strahle Lagoon is now almost filled with sediment. Raised margins are still visible on the west and south edges of the lagoon, but the northeast margins are barely higher than the lagoon floor. In June 1983, when most lagoons in the Armidale-Uralla held 0.8-1.5 m of water, Strahle Lagoon was almost dry, almost all the water having drained over the northeast margins of the lagoon.

5.6.7 BARLEY FIELD LAGOON

Barley Field Lagoon is situated on the Main Divide at Gostwyck sheet GR 555091. The lagoon has dimensions of 200 m by 200 m and is supplied with water by a catchment area of 0.25 km^2 to the south and west. As with the other lagoons in the area the level floor of Barley Field Lagoon contains fine silt and black cracking clay. The southern margin of Barley Field Lagoon in on silicified and ferruginised sediments, and the remaining margins are on ferricrete. The natural overflow of Barley Field Lagoon is to the north. A water race was constructed from Barley Field Lagoon during the gold mining era to supply water to the Sawpit Gully mining area 5 km west of the lagoon (Davis, 1886).

5.6.8 UNNAMED LAGOON NEAR TANGLEWOOD ROAD

This unnamed lagoon, here called Tanglewood Lagoon, is located at Dumaresq sheet GR 655250, 100 m east of the drainage divide between Saumarez and Dumaresq Creeks. Tanglewood Lagoon is sub-circular, with dimensions of 200 m by 250 m, and is fed by a 0.5 km^2 catchment to the north, south and west. The lagoon has no well defined overflow zone, but may have overflowed to the northeast. The lagoon margin is on basalt and ferricrete and the level floor comprises fine silt and chocolate-brown cracking clay. Basalt outcrops at the western end of the lagoon floor. Although Tanglewood Lagoon has not been artificially drained, it carried only centimetres of water in June 1983 when most other lagoons in the Armidale region contained 0.8-1.5 m of water.

5.6.9 UNNAMED LAGOON AT 'GREEN WATTLE FARM'

This unnamed lagoon, here called Green Wattle Farm Lagoon, is located at Armidale sheet GR 638223, on the drainage divide between Saumarez and Dumaresq Creeks. Green Wattle Farm Lagoon has dimensions of 150 m by 250 m, and is fed by a catchment of 0.5 km^2 surrounding the lagoon. The margin of Green Wattle Farm Lagoon is on ferricrete and colluvium, and has no well defined outlet zone. The floor of the lagoon is ferricrete.

5.6.10 UNNAMED LAGOON AT 'WYANBAH'

This unnamed lagoon, here called Wyanbah Lagoon, is situated at Armidale sheet GR 652202, 50 m east of the drainage divide between Saumarez and Dumaresq Creeks, and directly across the New England Highway from Armidale Airport. The lagoon is sub-circular with a diameter of 250 m, and is fed by a catchment of 0.25 km2 to the south and west. The margins of the lagoon are on ferricrete and basalt, and a 1 m ferricrete profile is exposed on the northern margin of the lagoon. There is no well defined outlet zone, and the floor of the lagoon is silcrete and dark brown cracking clay.

The characteristics of lagoons in the Armidale area are summarised in Table 1.

TABLE 1. CHARACTERISTICS OF LAGOONS IN THE ARMIDALE-URALLA REGION

LAGOON NAME	GRID REF	Km OFF DIVIDE	LAGOON SIZE (m)	APPROX. CATCHMENT AREA (km^2)	CATCH-MENT ORIENT	MARGIN MATERIAL	OVER-FLOW ORIENT
Farm	D:620256	1.7 E	500x500	3.0	S,W	ferr,sil colluv	NE
Primrose Hill	D:587282	0.2 E	200x300	1.0	N,S,W	colluv, on ferr, bas,Sandon Beds	NE
Saumarez Airstrip	A:595212	2.5 E	150x200	1.0	S,W	ferr	NE
Thomas	A:581185	1.1 E	150x250	1.5	S,W	ferr,sil	N
Little	A:577187	0.6 E	200x150	1.0	W,SW	ferr,sil	E
Strahle	A:576173	0.2 E	150x200	0.5	S,W	ferr,sil	NW
Barley Field	G:555091	0	200x200	0.25	E,S,W	ferr,sil	N
Tanglewood	D:655250	0.1 E	250x250	0.5	N,S,W	ferr,bas	none
Green Wattle Farm	A:638223	0	150x250	0.5	N,S,E,W	ferr,bas	none
Wyanbah	A:652202	0.05 E	200x250	0.25	W,S	ferr,bas	none

(D=Dumaresq 1:25000 sheet; A=Armidale, G=Gostwyck 1:31680 sheets)
(ferr=ferricrete, sil=silcrete, colluv=colluvium, bas=basalt)