BUNBURY - BUREKUP

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

WESTERN AUSTRALIA 1. 50 000 URBAN GEOLOGY SERIES

SHEET 2031 III AND PART OF SHEET 2031 II

URBAN GEOLOGY OF THE BUNBURY - BUREKUP SHEET

The aim of this urban geology survey is to provide information for those concerned with aspects of land planning, material and water supply, rural, urban, industrial or transport development. The intention is to point out geological factors which may affect planning on a broad, rather than specific basis. Detailed site investigations will still be required but it is hoped that this information will provide a useful framework for such further work.

The Bunbury sheet and the mapped portion of the Burekup sheet represent just over 586 km2 of land surface. A variety of land uses in the area includes residential and light industrial development; pastoral, dairy and market-garden agriculture, some irrigated; State Forests; and the production of titanium dioxide, mainly for pigments. A few acres of natural vegetation remain, particularly on sand dunes south of Bunbury. The City of Bunbury covers some 13 km2 and a further 17 km2 are occupied by smaller townsites at Australind, Eaton, Boyanup, Brunswick Junction, Bunnup and Dardanup. Nearly 38 km2 of State Forest occur within the sheet area. Major roads radiate from Bunbury and, with two railway lines, provide distribution routes from the international airport to the southwest of the state. A power station adjacent to the harbour feeds electricity into the state's grid system.

The geology of the Collie sheet, which includes Bunbury and Burekup, was mapped in 1963 by Lowry and in 1975-6 by Wilde and Walker, all of the Geological Survey. Maps were published as 1:250 000 preliminary editions in 1973, covering the coastal plain, and in 1979, covering the whole sheet. The Bunbury and Burekup area was remapped in 1979 for this urban geology edition, by Riggs of the Survey, using 1:40 000 aerial photography (dated 1977) and closely spaced traverses. East of the Darling Scarp the work of Wilde and Walker was used with very minor modification, mainly on the scarp face. Text data were provided by Riggs, Wilde, Commander and Mather, of the Geological Survey.

PHYSIOGRAPHY

As can be seen from the inset physiographic diagram, the mapped area extends from the Darling Scarp westwards across various coastal plain units to the Indian Ocean. A small portion of the Blackwood Plateau occurs in the southeast of the map area, separated from the coastal plain by the low Whicher Scarp, a marter erosion feature. The Darling Scarp is the fault-controlled western margin of an ancient plateau which lies just to the east of the mapped area. The coastal plain, and in 1979, covering the whole sheet. The Bunbury and Burekup area was remapped in 1979 for this urban geology edition, by Riggs of the Survey, using 1:40 000 aerial photography (dated 1977) and closely spaced traverses. East of the Darling Scarp the work of Wilde and Walker was used with very minor modification, mainly on the scarp face. Text data were provided by Riggs, Wilde, Commander and Mather, of the Geological Survey.

The coastal plain is characterized by a broad, level, alluvial belt with lines of sand dunes and limestone ridges on its seaward side. Former shoreline lagoons are now represented by strings of lakes and seasonal marshes immediately inland from the active coastal dune system. The piedmont zone represents an even rather shoreline formed during a period of active erosion and sediment deposition.

STRATIGRAPHY

Rocks of Archaean age crop out in the eastern portion of the mapped area, widely covered by a thin mantle of rock weathering debris or a thicker laterite profile. On and west of the Darling Scarp are localized areas of Cretaceous sediments and basalt and widespread Quaternary sediments.

ARCHAEAN

Quartzite is the most abundant of the metasedimentary units. It occurs as isolated rafts or boudins in gneisses between Collie River and Ottrey Brook. The rock is a medium, even-grained metamorphosed orthoquartzite with scarce muscovite or the green chromo-mica, fuchsite, along foliation surfaces.

Near the headwaters of Henty Brook is an area of layered hornblende gneiss in which hornblende is the chief mafic mineral. Quartz, and microcline and plagioclase feldspars are major constituents, with minor biotite. Within the hornblende gneiss zone are localized rafts of amphibolite; finely banded quartzites; white and grey quartzose gneisses; and pink and grey, coarse-grained foliated gneiss.

The most common rock-type in the metamorphic sequence is a fine to medium-grained layered gneiss, composed of quartz, microcline, plagioclase, biotite and, locally, garnet. Foliation is emphasised by varied amounts of biotite in the rock which is generally pink and white or grey and white. Within the unit boundaries shown on the map, many rock-types may be found locally, including white and grey granitic, sheared augen gneiss; foliated and slickensided pink granite; blue-grey gabbro; orthoquartzite; migmatite; blue-grey and green amphibolite; and dark-green hornblendite.

Included in this group is a series of mylonites in a shear zone crossing Henty Brook northeast of Mostray. A typical representative is a fine-grained rock containing rounded clasts of quartz and microcline, and lozenge-shaped clasts of green hornblende and sphene. The matrix is mainly quartz and feldspar with minor amphibole or biotite.

The gneisses are widely covered by a thin sheetal soil with abundant fragments of relatively fresh rock reflecting the immediate bedrock.

Augen gneiss occurs as a coarse-grained, mesocratic rock and has developed from granites by cataclasis and metamorphic recrystallization. Isolated rafts of leucocratic, even-grained granite are presumably remnants of a parent material. The gneiss consists of quartz, microcline, oligoclase, biotite and some hornblende, surrounding microcline augen. Enclosed in the unit are elements of melanocratic feldspathic amphibolite, dark-grey hornblende gneiss; and pink and white quartzo-feldspathic gneiss.

Near Ferguson is a **porphyritic granite gneiss** which probably represents an intermediate metamorphic stage from granite to augen gneiss. It is a coarse-grained rock with abundant tabular megacrysts of microcline set in an identical matrix to that of the augen gneiss described above. The biotite shows a strong foliation fabric and there is a marked gneissic recrystallization of the feldspar matrix.

Porphyritic granite occurs as a narrow remnant band near Mostray and is assumed to be the main parent material for the augen and porphyritic gneisses. The granite is a pink and grey, coarse-grained rock with pink, tabular microcline phenocrysts comprising up to 70 per cent of the rock. The phenocrysts are strongly aligned and set in a granular groundmass of microcline, oligoclase, quartz, and biotite. The unit encloses an area of medium-grained, blue-grey hornblendite with greenish feldspar clasts.

PRECAMBRIAN

Numerous veins and segregations of quartz occur within the metamorphic and granite terrains and are too small to show at this map scale. Close to the Darling Scarp the veins mainly trend north to northeast and are subparallel to the regional foliation. The veins are locally iron stained but are otherwise barren of minerals apart from the crystalline, opaque white and cream quartz.

A discontinuous but persistent body of **foliated pegmatite** occurs near the eastern margin of the mapped area. It consists of quartz, microcline, albite and muscovite, with local minor concentrations of tourmaline and rarer minerals. The pegmatite is subparallel to the regional foliation and is variously deformed and folded.

Mafic dykes of tholeiitic dolerite composition are widespread in Archaean rocks, mainly with a northerly trend. The dolerite is medium-grained and blue-grey. It occurs as distinct intrusions 1 m to 10 m wide, from a few tens of metres to several hundred metres in length. The primary mineralogy is plagioclase (andesine-labradorite), augite, hornblende, minor quartz, and accessory apatite, sphene and pyrite. Fretted phenocrysts of white feldspar up to 3 mm diameter are locally common. Many dykes show some alteration, for example, saussuritization of plagioclase and breakdown of pyroxene to fibrous amphibole. Quartz-feldspar-epidote veining is common.

CRETACEOUS

Bunbury Basalt crops out on the shore at Bunbury and underlies parts of the coastal plain around and south of that city. It consists of at least two lava flows of porphyritic tholeiitic basalt which is locally vesicular and displays columnar jointing. Vesicles and cracks are commonly filled by a greenish calcic plagioclase. It is a fine-grained, dark-grey to blue-grey rock, tending to rounded weathering patterns. Near Gelorup, south of Bunbury, the basalt occurs at shallow depth beneath eluvial and alluvial soils and clays. An exposure in the aggregate quarry shows at least one darker grey feeder dyke some 3 m wide. Bunbury Basalt is believed to have filled valleys eroded into the Jurassic Yarragadee Formation (now concealed).

The **Moxicar Beds** are poorly exposed at three localities and may occur elsewhere under the pisolitic laterite capping as seen near Moxicar. At the type area, the beds consist of 9 m of poorly sorted, ferruginous, feldspathic sandstone, some cross-bedded. Some 800 m north east of the type locality, a clay pit has exposed 11 m of sediments also considered to be part of the Moxicar Beds. These are horizontally bedded and include white and mottled yellow, brown, orange-brown and reddish-purple siltstones, red and brown sandy clays and plastic clays, pale-grey clay, mottled kaolinised sandstone and conglomerate; thin layers of hard iron-cemented sandstone. Several small springs and seeps occur above the iron-cemented layers, the water causing extensive staining downslope. It is probable that a similar sequence of sediments occurs towards the type section where only the harder, ferruginous layers crop out. The deposit is a shallow-water to pisolic sequence and is correlated with the Donnybrook Sandstone to the south.

CAINOZOIC

Cainozoic **laterite** is widespread on the Blackwood and Darling Plateaux, forming a dissected capping over granite and yrongor rocks. The laterite is chiefly massive and cemented but ranges from well lithified to loose and earthy. It may be either pisolitic or vesicular and is often associated with a residual laterite gravel derived from the parent material by weathering. The iron-cemented rock is from 1 m to 6 m thick, overlying a white, cream or dusky pallid zone of clays, sandy clays and mudstones. A white or yellowish, clayey sand is widespread at the surface, contains pebbles of quartz and laterite, and is probably a weathering product of sandy laterite. Two levels of laterite surface are recognised, separated by a distinct topographical break of several metres, suggesting two phases of lateritization.

QUATERNARY

The oldest Pleistocene deposit in the area is the **Yoganup Formation**. In the type area to the south it is a shoreline deposit consisting of a basal conglomerate and a well-sorted sand foreshore. The conglomerate is not recognised in the Burekup area, and it is clear that the foreshore environment has undergone modification, as the sand here is poorly sorted, ranging from very fine to coarse grained. Also in contrast to the type area where rounded grains predominate, some 60 per cent of grains in this area are subrounded and just under 40 per cent subangular. In general, only about 2 per cent rounded grains are encountered in the Burekup area suggesting major dilution of the shoreline deposit by colluvial and alluvial admixture.

The sand is off-white at surface, grading through cream to yellow, orange and brown with increasing depth. Pebbles and cobbles of granitic, laterite and water-rounded quartz are found in the sand, and feldspar grains are common. Very fine-grained heavy minerals, especially ilmenite, are a widespread accessory and in one locality north of Paradise Creek a magnetic ilmenite-rich layer has been cemented by goethite and forms a marked low ridge. Other heavy minerals include zircon, epidote, rutile and rare garnet and blue tourmaline. The quartz grains are mainly rounded, some clear translucent and most are coated with an iron-oxide film.

The Yoganup Formation occurs in two distinct geomorphic environments: north of Paradise Creek it forms part of a distinct shelf; south of that creek it occurs at the base of the shelf.

Sediments of the Guildford Formation, locally known as "Darlamup Loam", form the broad, slightly undulating plain immediately west of the Darling Scarp. Mainly alluvial, the formation includes some shallow-water and estuarine lenses and consists of sandy and plastic clays, clayey sands, and silts which grade from one to the other both laterally and vertically. In some areas a semi-lithified laterized clay is seen at the water table suggesting active lateriation at present. The clays are predominantly mottled in shades of orange and brown, although red, grey and green horizons occur. The sand is fine to medium grained or rarely very coarse, mainly subangular and some subrounded. Pebbles of quartz or laterite are locally abundant and rare surface skins of very fine-grained heavy minerals attest to the reworking of Yoganup Formation or colluvial sands immediately up-slope. Adjacent to the Busselman dunes (see below), the Guildford Formation is widely covered by a thin layer of washed or blown sand up to 50 mm thick. A basal sand layer is known from borehole information.

The upper stratum of the formation is, in many places, marked by a spring-line where water percolating through the overlying sands encounters the impermeable clayey horizon. Near river valleys, Guildford Formation sediments tend to grade into the river sediments and, unless marked by an erosional break, are impossible to differentiate.

Busselman Sand forms the easternmost and oldest of three dune systems which are roughly parallel to the coast. The sand is fine to medium grained, in places coarse, grey to off-white at surface, passing through cream and pale buff to yellow at depth. A pink, coarser layer occurs in some areas and is probably a local beach sand. Between Gelorup and Busselton north of Ferguson or colluvial sands immediately up-slope. Adjacent to the Busselman dunes (see below), the Guildford Formation is widely covered by a thin layer of washed or blown sand up to 50 mm thick. A basal sand layer is known from borehole information.

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Tamala Limestone with its associated sand, forms the Spearwood Dunes physiographic unit. In general, these dunes are higher than the Busselman Dunes, have steeper slopes, especially on their eastern edge, and occur in more continuous ridges. As the two sands are almost identical in physical and chemical character, and in the general absence of fossil evidence, these physiographic differences are the main criteria for distinguishing the two geological units.

The limestone is principally a lithified eolian calcarenite, although minor marine, shelly lenses and zones of bright, white chalk are encountered. The fawn calcarenite varies in hardness from friable to completely lithified and in quality from low to moderate (from 30 to 70 per cent $CaCO_3$). The high impurity is a medium to coarse quartz sand with rare feldspar and fine limonite. Deposition evidence ranges from indistinct to very definite horizontal bedding and to well-defined cross-bedding, suggesting shallow off-shore to eolian conditions, backed by accumulating sand dunes. Fossil traces include root casts and moulds, infilled burrows of worms and indistinct mollusc and gastropod casts. Although not shown on the map south of Bunbury, limestone occurs in the subsurface, in places beneath a very shallow sand cover.

The sand element is mainly derived from the calcarenite by decalcification on weathering, although there is some evidence for a separate, eolian origin for a few strata. In these instances, dune bedding is preserved and many sand grains are pitted and polished. Generally, the sand does not show any bedding features and the fine to medium grains are frosted, subangular to subrounded, and poorly to moderately sorted. Off-white near surface, the sand becomes yellow with increasing iron-oxide coating at depth and is characteristically bright orange within a matrix or two of limonite. Beneath the iron coating, most grains are colourless, a few are yellow, orange or pink.

A minor erosion scarp at Mostray and a shallow shelf near Australind in this sand element attest to a Quaternary shoreline one or two metres above the present sea level.

Collcovinn is widespread on hill slopes in the east and southeast of the mapped area and consists of fine to coarse-grained material. Typically found in shades of brown and orange, clay, silt and sand form the matrix to pebbles and cobbles of quartz, laterite and various crystalline rocks depending on location. The unit includes some alluvially reworked material in narrow watercourses and some outwash from Yoganup Formation from which it is usually distinguished by the absence of rounded grains. Colluvial sand grains are mainly subangular with lower amounts of angular or subrosed grains. Very fine-grained ilmenite is a common accessory mineral. In places, the colluvium grades downwards into eluvial sandy, kaolinitic clays and has presumably derived from laterite at no great distance. Field relationships suggest the colluvium probably began forming in the Pleistocene and is still being deposited.

Lagoonal deposits occur in Bunbury and on the shores of Leschenault Inlet and are encountered beneath both the inlet and the peninsula to the west. The deposits are brown and black silts and mud, and lenses of very fine-grained sand on flats fringed with samphire. Sea-grass filaments are common in the muds, and shallow-marine, Holocene shells are locally abundant. To the north of the mapped area, fossils dating from Middle to Late Pleistocene are found in this unit. Two small areas of mangrove mud banks are possible remnants of a more extensive cover during a warmer climate.

Alluvium is found in all valleys in the map area, in places too localized to show at this scale. Landforms within the unit are river flats and terraces, and natural levees. An attempt has been made to separate two different ages of deposition but this is not always possible where one unit grades into another. South of Bunbury, the area mapped as Holocene alluvium is almost entirely reworked clayey sand of the Guildford Formation and probably thinly overlies undisturbed elements of that formation. Some Holocene reworking has occurred in the sand associated with Tamala Limestone near Australind.

Grain sizes vary from very fine, mainly in river terraces and banks, to very coarse in watercourses. Sediment types include clay, silt, sand and pebbles in various admixtures and shades of browns, creams and grey, generally in loosed deposits grading one into another. The younger terraces include units of gelatinous muds and are prone to flooding, being on average one metre lower than the older terrace. Near Minninup, alluvium overlies a recent shoreline marked by a marine shell bed, about two metres above present sea level.

Swamp deposits occur in two distinct environments : one parallel to and immediately inland of the most recent dune line; and the other in scattered interdunal depressions in the two Pleistocene sand units. The deposits are typically dark grey or brown, fine sands or silts with varied but significant amounts of peat. Some diatomaceous earth is recorded near Lake Beridup and probably occurs in small amounts elsewhere. Most swamps are ephemeral and appear in the dry season as playas or areas of closed hydrophytic vegetation. Quartz grains are mainly subangular but range from angular to rounded, reflecting the varied parent materials. Many swamps are surface expressions of a shallow water table but some represent a perched water table on an impermeable clay layer.

Safety Bay Sand is the youngest geological unit and is still forming from material washed up from the ocean floor and then blown inland as hummocky dunes. It is a cream, calcareous quartz sand in which shell fragments make up 10 to 80 per cent of the whole. The quartz is fine to medium grained, angular to subrounded, mainly clear and colourless, with some iron-stained grains. Shell fragments are confined to subrounded and coarser grained than the accompanying quartz. Very fine-grained accessory heavy minerals include ilmenite, zircon, garnet, rutile, hornblende, and tourmaline, and are locally concentrated on the beach and in hollows within the dunes. The ironpoke basal layers are partly lithified to a friable calcarenite commonly displaying dune bedding.

ECONOMIC GEOLOGY

CLAY

Plastic clay, for tile manufacture, is extracted from lenses in the generally sandy clays of the Guildford Formation at Waterloo. It is also used to give pre-firing strength during brick-making with sandy clays from the same pit and with various Cretaceous clays and kaolinised sediments from a pit north of Mostray.

DIATOMACEOUS EARTH

As mentioned above, diatoms have been recognised in swamp deposits near Lake Beridup but no assessment has been made of the quality or quantity of the material. It is likely that minor amounts of diatomaceous earth occur in many of the swamps in the area.

GRAVEL

Small gravel pits have been opened in several localities on the Darling and Blackwood Plateaux and along the Darling Scarp. They exploit the pisolitic and massive lateritic gravels which are used for road construction as a sub-base or as the wearing surface of minor roads. Most pits are used for only a short time before being abandoned.

HEAVY MINERAL SAND

Local Holocene concentrations of heavy minerals occur in the Safety Bay Sand. One such concentration has been mined out in Koombana Bay, producing 376 000 t of ilmenite, zircon and monazite. Other deposits at Koombana Bay and Minninup contain a further 500 000 t of minerals but are not economic at present.

A second, early Pleistocene shoreline runs parallel to the Bussell Highway, and heavy mineral deposits have been located north and south of Strathan. The southern block yielded 1 274 000 t of ilmenite, zircon, leucoxene and monazite in 1978 when mining ended. The northern block has presently unreconnoitred, inferred resources of some 1 500 000 t of minerals.

The Yoganup Formation has the geotechnical properties of a loose sand, though a low vertical face may stand unsupported for a short time. The material is permeable, settlement could occur under load and it requires protection against erosion.

The Guildford Formation has a wide variety of geotechnical properties because of the variable clay content. Natural density is moderate to high, and permeability is low except in sand-rich parts of the formation. Alternate wetting and drying will cause the clay to swell and shrink which makes foundation conditions poor unless special precautions are taken to keep the moisture content constant. Low cut slopes are generally stable, although slides may occur in shallow cuts where there is seepage. Drainage disposal is generally difficult.

Busselman Sand, which is generally moderately to well graded and cohesionless except where it contains minor clay or silt, has a moderately high natural density, is very permeable and well drained, and is not subject to shrinkage. It may be moderately well consolidated beneath a loose surface cover which can be remoulded when dry and cleared of vegetation. Drainage disposal is only a problem where the sand is thin and mixed with underlying clays, or in areas of shallow water table. The thickness and degree of consolidation of the sand, and the depth to water table, need to be established during site investigation.

Areas mapped as Busselman Sand overlying Guildford Formation will generally have the geotechnical properties of the latter.

Tamala Limestone, where it is predominantly calcarenite, includes material ranging from soft to hard depending on the degree of cementation. The harder material is slightly porous and permeable, of medium natural density and high to medium compressive strength. Solution cavities occur irregularly and some are filled with unconsolidated sand. Some zones of root cast are present with high porosity, and these zones may lead to severe settlement under load.

The softer, less-cemented material has a higher porosity and permeability and a lower density and compressive strength than the harder, well-cemented rock. Both harder and softer types and zones of unconsolidated sand occur together in an irregular way, which makes the detailed determination of geotechnical properties difficult. Steep cuts are commonly stable.

The unit composed predominantly of sand is partly consolidated, has a high natural density, high permeability, and no cohesion or shrinkage. Some settlement can be expected beneath foundations. Subsurface pinnacles and thin sheets of dense, hard limestone are locally encountered and, where present, will increase excavation costs. Drainage-disposal characteristics are good.

Colluvium, because it is an unconsolidated mixture of different soils and rock fragments, has extremely variable geotechnical properties. Disturbed slopes are likely to be unstable and to require protection against erosion. Seepage and stormwater drainage disposal characteristics depend on clay content.

The lagoonal deposits are highly variable, low-lying and generally saturated. They are expected to have poor geotechnical properties which because of rapid lateral changes in lithology are difficult to predict.

Alluvium, because of its various lithologies, has a wide range of engineering properties. Foundation conditions are generally poor, irregular settlement under load being typical.

A near-surface water table in some cases would adversely affect building stability and is a problem with excavation and drainage.

The swamp deposits are made up of variable, poorly-consolidated material with unsatisfactory engineering properties. The deposits will settle irregularly under load and have low bearing capacity. The near-surface water table would impede excavation and drainage and deter building activity.

Safety Bay Sand is a porous, cohesionless or poorly lime-cemented, permeable material that is unstable in excavations and prone to wind erosion when vegetation is removed. Settlement, sometimes uneven, is common under load but can be controlled by compaction and stabilization.

ENVIRONMENTAL GEOLOGY

Soil erosion has created problems, mainly on the steeper slopes in the eastern part of the mapped area. The erosion is essentially caused by one of three human activities : gravel extraction, agricultural clearing, or road building.

Abandoned gravel pits act as compacted catchments for rainfall which then runs from the lower floor of the pit in volumes far exceeding the natural capacity of adjacent absorbant soils or watercourses. This excess flow causes gullying, which increases in length and breadth with succeeding rainfalls. In some pits near Joshua Creek, attempts have been made to revegetate abandoned workings by planting eucalypts. Deep ripping, preferably along the contour, is required to slow run-off until vegetation is established and to provide suitable sites for natural revegetation. Some form of groundcover or mulch/ growth should be planted initially to reduce surface evaporation and provide a long-term brake on run-off. On steeper pit slopes, contour bunds leading to sumps are essential to prevent gullying and to reduce the amount of silt carried downslope.

Clearing forest for pasture on steep slopes has had similar effects to gravel extraction, except that unconsolidated soils are exposed to water erosion. Consideration should be given to leaving stands of trees or shrubs along the contour, at least until pasture grasses are fully established, to lessen the incidence of gullying.

A few gravelled roads on slopes are built with cuttings and embankments which tend to be free of vegetation for one or two growing seasons and are thus prone to erosion. Remedies could be similar to those for improved drainage, contour bunding, terracing, or seeding to produce an initial groundcover among which native plants could re-establish.

Mineral-sand mining at Strathan has been completed with rehabilitation of the mined land. Processed sands and slimes were remined and shaped into gently sloped dunes and have been sown with pasture grasses and cereals. It is expected that the land will be returned to regular agricultural use after a few seasons' growth.

Proposals for mining in general in the area are viewed favourably if elementary environmental concern is applied. Sites should be inviisible from main roads or centres of population. Provision must be made to prevent silt running on to roads or adjacent property, and access roads should either be suitable for mine traffic or be upgraded, probably at the miner's expense. It should also be realised that mining is only an interim land-use and that rehabilitation to an acceptable subsequent land-use, generally agriculture, is the responsibility of the miner.

Sites for rubbish disposal may be found within the thicker sand units throughout the area. Mined-out sand pits may provide convenient sites for disposal, as sand for covering layers of rubbish is generally available within or close to the pit. Disposal sites for industrial waste may be located in similar areas, provided no groundwater extraction is carried out nearby. Effluent from a plant at Australind is currently pumped to Safety Bay Sand dunes on the coast, and its effects on the ocean and inlet are closely monitored to minimize any damage to the environment.

Further information may be obtained from the Geological Survey of Western Australia, Mineral House, Perth.

PRECAMBRIAN ROCKS

These rocks are predominantly granitic types comprising gneisses, porphyritic and even-grained granites. They include minor quartz lenses and veins and remnants of sedimentary rocks, now quartzite. Widespread mafic dykes intrude all rock types. The rocks are hard and dense when fresh or slightly weathered and make good building foundations. When weathered they become softer and less dense, but the felsic rocks are still adequate for foundations if minor buildings if normal preparation procedures for foundations in clay are followed. In the case of the mafic rocks, weathering products are usually more prone to swelling and shrinking with alternate wetting and drying than those of granitic rocks. This makes poor foundation material, unless special precautions are taken to keep the moisture content constant. The rocks are usually intersected by fractures or joints, some of which may be open and stained with iron oxide or other weathering products. These structures, quartz veins and shear zones, particularly on the face of the Darling Scarp, provide channels for percolating water and contribute to the instability of slopes, excavations and engineering structures.

The softer and less dense products of weathering, particularly those from mafic rocks, tend to be unstable on steep slopes and in excavations, especially in winter. They may provide suitable material for the construction of impervious embankments, but individual material testing is necessary.

Both granitic and mafic rocks, when hard and dense in their fresh or slightly weathered state, are suitable for road construction, railway ballast, breakwater construction, and building aggregate. In fresh rocks the widespread foliation is not a geotechnical problem.

CRETACEOUS ROCKS

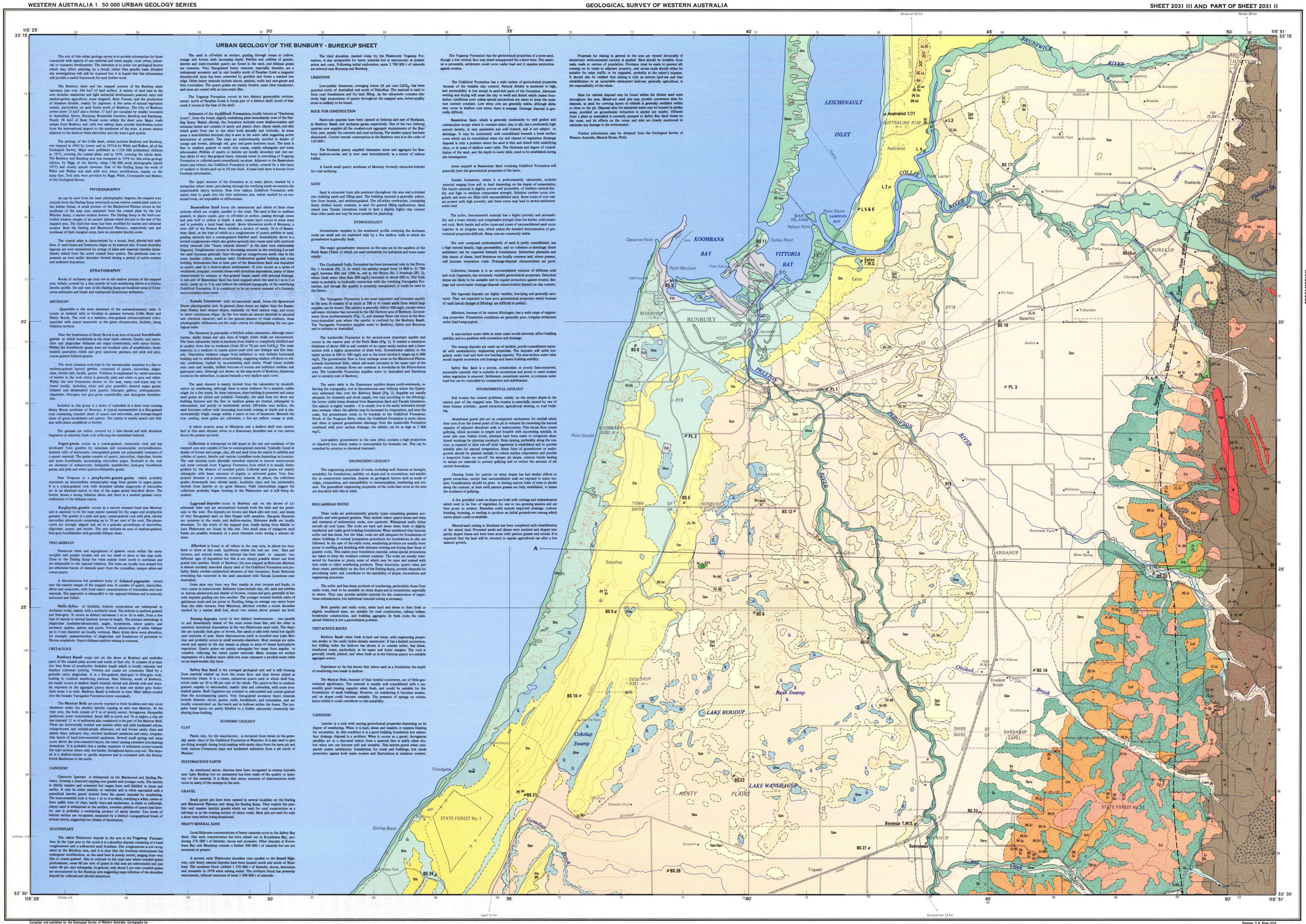
Busbrey Basalt when fresh is hard and dense, with engineering properties similar to the mafic dykes already mentioned. It has a limited occurrence, but drilling under the harbour has shown it to contain softer, less dense, weathered zones, particularly at its upper and lower margins. The rock is generally closely jointed, and when fresh as in the Gelorup quarry is a suitable aggregate source.

Experience so far has shown that where used as a foundation the depth of weathering over basalt is shallow.

The Moxicar Beds, because of their limited occurrence, are of little geotechnical significance. The material is usually well consolidated with a reasonably good bearing capacity when fresh, and would be suitable for the foundations of small buildings. However, on weathering it becomes weaker, and on slopes could become unstable. The presence of springs on certain layers within it could contribute to this instability.

CAINOZOIC

Laterite is a rock with varying geotechnical properties depending on its degree of weathering. When it is hard, dense and massive, it requires blasting for excavation. In this condition it is a good building foundation but subsurface drainage disposal is a problem. When it occurs as a gravel, ferruginous pisolitha set in a clay-sand matrix form a material that is stable when dry, but when wet can become soft and unstable. This laterite gravel when compacted makes satisfactory foundations for roads and buildings, but needs protection against both water erosion and fluctuations in moisture content.



REFERENCE

			PROBABLE MAXIMUM THICKNESS (m)	
PHANEROZOIC	CAINOZOIC	QUATERNARY (HOLOCENE)	Qhs	20	SAFETY BAY SAND : Mobile dunes
				40	Calcareous quartz sand dunes
			Qhw	7·5	Swamp deposits, mainly peaty sand
			Qhy	3	younger river terraces
			Qha	7·8	Alluvium older river terraces
		QUATERNARY (PLEISTOCENE TO HOLOCENE)	Qd	7·3	Laporonal deposits, mud, silt, shell beds
			Qc	3	Colluvium, some eluvial soils
		PLEISTOCENE	Qhs	30	Sand associated with Tamala Limestone, high dunes
			Qsf	40	TAMALA LIMESTONE : eolian and marine calcarenite
			Qpb	15	BASSENDEAN SAND : low rounded dunes
			Qgb	5	Thin Bassendean Sand over Guildford Formation
			Qpu	20	GUILDFORD FORMATION : mainly alluvial sandy clay
			Qpry	15	YOGANUP FORMATION : younger element
			Qpr	12	YOGANUP FORMATION : including ferruginised limenite layer
	MESOZOIC (CRETACEOUS)		Cdl	6	Laterite, lower level
			Cdl	6	Laterite, massive or pisolitic
			Kxb	20 +	MAXICAR BEDS : siltstone and clay overlying arkose
			Kbb	70	BUNBURY BASALT : tholeiitic vesicular basalt
	PRECAMBRIAN (INDETERMINED)		d	10	Mafic dykes, dolerite or gabbroic
			pf	50	Pegmatite dykes and veins
			q	10	Quartz dykes and veins
ARCHAEAN			Agp	300	Porphyritic granite
			Arp	? 1000	Porphyritic granite gneiss
			Axa	1500	Augen gneiss
			Ash	3000	Quartz-feldspar-biotite (-garnet) gneiss, in places beneath eluvial cover
			Ash	400	Quartz-feldspar-hornblende (-biotite) gneiss
			Aqc	120	Quartzite, metamorphosed orthoquartzite

SYMBOLS

Geological boundary
- Accurate
- Approximate
- Inferred

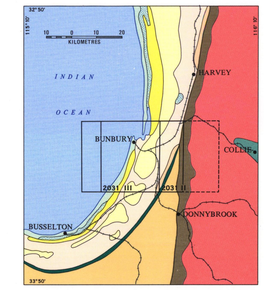
Fault
Strike and dip
- Bedding 30
- Foliation 40
- Vertical foliation
Shear zone
Bore borehole ≥ 100 m BS 17
Quarry or pit
- Active
- Abandoned or inactive
Mineral occurrence
- Clay Cl
- Diatomaceous earth Dt
- Gravel Gr
- Heavy-mineral sand Hm
- Limestone Ls
- Rock for aggregate Rc
- Sand Sd

Highway
Major road
Minor road
Track
Railway
Local Authority boundary
Townsite boundary
State Forest boundary
Powerline
Homestead
Horizontal control
Benchmark, height accurate FSS 28.358 m
Contour in metres
Watercourse

The representation on this map of a rock does not necessarily imply right of way

TABLE 1 . MAIN AQUIFERS

AGE	FORMATION	THICKNESS (m)	HYDROGEOLOGY
QUATERNARY	TAMALA LIMESTONE	40	Good supplies, mostly fresh
	BASSENDEAN SAND	15	Moderate to good supplies, fresh to brackish
	GUILDFORD FORMATION	20	Poor to moderate supplies, fresh to saline
	YOGANUP FORMATION	15	Good supplies, fresh
UNCONFORMITY			
CRETACEOUS	LEEDERVILLE FORMATION	300	Major aquifer. Good supplies of fresh water
	BUNBURY BASALT	70	Aquiclude
UNCONFORMITY			
JURASSIC	YARRAGADEE FORMATION	200–500	Major aquifer. Large supplies of fresh water
	COCKLESHELL GULLY FM	400	Potential for large supplies of fresh water at Bunbury but saline at depth



PHYSIOGRAPHIC DIAGRAM

- Quindalup Dunes
- Spearwood Dunes
- Bassendean Dunes and interdune swamps
- Major wetlands
- Pinjarra Plain
- Collie Basin
- Darling Scarp
- Whicher Scarp
- Piedmont Zone
- Darling Plateau
- Blackwood Plateau

Compiled and published by the Geological Survey of Western Australia. Cartography by the Geological Mapping Section, Department of Mines. Topographic base from compilations by the Department of Lands and Survey.
Copies of this map may be obtained from the Geological Survey of Western Australia, 66 Adelaide Tce., Perth.
Printed by the Government Printing Office, Perth.

Geology : E.R. Riggs 1979

FIGURE 1

POTENTIOMETRIC HEAD IN LEEDERVILLE AND YARRAGADEE FORMATIONS

- Leederville Formation
- Bunbury Basalt
- Bunbury Basalt, concealed
- Yarragadee Formation
- Archaean rocks
- Exploratory borehole
- Potentiometric head, metres above A.H.D.
- in Yarragadee Formation
- in Leederville Formation
- Syncline

FIGURE 2

WATER TABLE ELEVATION AND DISTRIBUTION OF QUATERNARY AQUIFERS

- Watercourse
- Swamp
- Exploratory borehole
- Water table contour, metres above A.H.D.
- Bunbury Basalt
- Tamala Limestone and Safety Bay Sand
- Bassendean Sand and underlying Guildford Formation
- Guildford Formation
- Yoganup Formation
- Superficial deposits absent or thin

INDEX TO ADJOINING SHEETS

DECLINATION DIAGRAM

DIAGRAMMATIC SECTION A-B

SCALE V/H = 2

A
B
SEA