New Pleistocene and Holocene stratigraphic units in the Yalgorup Plain area, southern Swan Coastal Plain

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Abstract

Within the area of Yalgorup Plain (amended from the Yoongarillup Plain) between Mandurah and Bunbury, there are a variety of fossiliferous limestone, aeolian limestone, and quartz sand units. Three new Pleistocene formations are recognised: the Tims Thicket Limestone, the Myalup Sand, and the Kooallup Limestone. These formations, previously part of the Tamala Limestone, underlie distinct Pleistocene landforms and comprise distinct shore-parallel systems formed by coastal progradation, interrupted by subaerial unconformities. They represent sedimentation during the Pleistocene, which was dominated by cuspatate forelands, barriers, and wave-built platforms.

The western edge of the Yalgorup Plain is bordered by Holocene barrier dunes which are a geomorphic extension of the Leschenault Peninsula barrier. Various Holocene formations underlie the barrier in the Yalgorup region. Generally, they can be assigned to the Safety Bay Sand, Becher Sand, Bridport Calci lutite, and Leschenault Formation, and to the Preston Beach Coquina, a new unit formally defined in this paper. Four types of large-scale standard Holocene stratigraphic sequences can be recognised in this region: Type 1, prograded bank, beach, beachridge sediments; Type 2, prograded shoreface to beachridge sediments; Type 3, retrograded barrier dune sediments overlying estuarine lagoonal sediment; and Type 4, retrograded barrier dune sediment unconformable on Pleistocene sediment. These standard sequences can be used to help unravel the Holocene history of the barrier dunes in the Yalgorup area, and specifically between Preston Beach and the Bouvard Reefs.

Introduction

The western part of the Swan Coastal Plain between Mandurah and Bunbury contains Pleistocene limestone (McArthur & Bettenay 1960; Playford et al. 1976), linear wetlands and estuarine lagoons, and a shore-parallel Holocene barrier dune system (Searle & Semeniuk 1985; Semeniuk 1985). Within this area is the Yalgorup Plain (amended here from the Yoongarillup Plain), a Pleistocene to Holocene surface developed on a variety of fossiliferous limestone, aeolian limestone, and quartz sand. Previous drilling in this area was conducted by Commander (1988).

Recent research has delineated a range of new Pleistocene to Holocene stratigraphic units in this area, which are described in this paper. Recognition of these new units has provided a tool to unravel the local Pleistocene and Holocene coastal history, as described in Semeniuk (1995a,b). Stratigraphic and geomorphic patterns derived from the Pleistocene terrain in the region show that there are distinct shore-parallel tracts of Pleistocene landforms that developed by coastal progradation, interrupted by subaerial unconformities. Sedimentation was dominated by narrow beachridge plains and cuspatate forelands (Semeniuk 1995a). Defining a new Holocene stratigraphic unit in the region has also aided in the recognition of four key stratigraphic sequences that help unravel coastal history.

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formed by Pleistocene marine progradation that are restricted palaeogeographically to the Mandurah-Bunbury area (Semeniuk 1990). At the time of this first amendment (Semeniuk 1990), the opportunity also existed to rectify the name, but this was not done. The term “Yoongarilup”, deriving from the locality of Yoongarilup, south of Busselton, should refer to features in that region, and not to those restricted to the coastal tract between Bunbury and Mandurah. At present, following extended usage from the Busselton area into the Mandurah-Bunbury area by McArthur & Bartle (1980), and later amendment by Semeniuk (1990), the term “Yoongarilup Plain” now refers to a coastal plain quite removed from its origin. Following the results that clarify the Pleistocene palaeogeography in this region (Semeniuk 1995a), I propose that the situation be now rectified: firstly; that the term Yoongarilup Plain be restricted to the Busselton area; and secondly, that the term “Yalgorup Plain”, derived from the local region (Semeniuk 1995a), I propose that the occurrence of limestone form discontinuous rocky reefs and islands (the Bouvard Reefs). Another line of former reefs, the Buffalo Reefs, occurs buried under Holocene dunes to the south (Semeniuk 1995a). Generally, there are no prominent limestone ridges or rocky reefs, buried or otherwise, in the central part of the area.

The age of the Plain is concluded to be Pleistocene, for the following reasons; 1, the formations that underlie the plain abut or overlie other units in the area are generally conceded to be Pleistocene in age (e.g. the Bassendean Sand, and the yellow sand and limestone that underlies the Mandrah-Eaton Ridge); 2, radiocarbon ages for the limestones at various sites returned ages >30–40,000 years.

**Pleistocene lithologies**

Ten types of sedimentary rock and sediment in the Pleistocene sequences occur in this region. These are (limestone terminology follows Dunham 1962):

1. Shelly/bioturbated calcarenite: fine to medium grained, bioturbated to structureless, skeletal quartz grainstone, with abundant calcareous algae and invertebrate skeletons. Shell locally present and randomly oriented by bioturbation;

2. Bioturbated foraminiferal calcarenite: fine to medium sand grainstone of calcareous algae, invertebrate skeletons, quartz, shell grit, whole molluscs, and abundant granule-sized foraminifera (Marginopora); bioturbation consists of vertical burrows 3–4 cm diam, penetrating downwards for 50–75 cm, otherwise bioturbation shows general swirling;

3. Laminated and cross-laminated marine calcarenite: medium grained skeletal quartz grainstone, generally without shell beds; conspicuously laminated, cross-laminated and trough-bedded;

4. Laminated to cross-laminated beach calcarenite: skeletal quartz grainstones, with variable structure and texture, but forming a set vertical sequence, usually over 2.0–2.5 m. Mollusc shells present (Donax most common); sedimentary structures and two diagnostic cephaleopods distinguish four subfacies (Semeniuk & Johnson 1982) – lower part is trough-bedded, medium to coarse grained, with local shells, middle zone is medium to coarse grained, with oriented shell, and low inclined cross-lamination, then there is medium grained calcarenite, with bubble-sand structures, and upper part is crudely layered to bioturbated to structureless, medium to coarse grained, with diagnostic cephaleopods Sepia and Spirula;

5. Cross-laminated to structureless calcarenitic aeolianite: large scale cross-laminated to structureless fine to medium grained skeletal quartz grainstone; cross-lamination sets 2–5 m high; calcarete rhizoconcretions and pipes common;

6. Calcrlted limestone: this limestone is mainly calcrite in sheet-like form, 20–30 cm thick, or massive, within and on top of the parent limestone, or coating.
pipes; lateral and vertical relationships and gradations, and palimpsest grains and textures indicate parent lithology was aeolianite;

7. Indurated, bored limestone: limestone varies from aeolianite to shelly limestone, and may also be calcitized; key features are induration by calcite cements (fine grained calcite, sparry calcite, calcarete), borings and pot-holes; borings are 1 cm diameter or less; limestone surface may be fissured, with local pot-holes some 10–30 cm diameter, and veneered with rounded limestone gravel and shells of Ninella, Marmarstoma, Littorina, limpets, barnacles;
8. Shelly calcilutite: structureless lime mudstone to skeletal lime mudstone;
9. Quartz sand: yellow, grey, or white, medium grained, and well to poorly sorted; grains mostly quartz, with some felspar and minor heavy minerals; quartz sand in this area is largely structureless (cf. Glassford & Semeniuk 1990); and
10. Shelly terrigenous mud: dark grey, structureless terrigenous mud with estuarine shells.

Some general features about these lithologies are noted here. All limestones are generally white, cream, tan to buff in colour. Grainstones are weakly to strongly cemented by sparry calcite, depending on location relative to the water table. Most limestones also are variably weakly indurated by calcrite, and additionally may be stained by iron oxides. Molluscs in the fossiliferous limestones (Table 1) are typically assemblages from seagrass bank environments (cf. Logan et al. 1970; Semeniuk & Searle 1985; Semeniuk 1995a). Calcreted limestone is a rock type best developed at unconformity surfaces, and indicates major subaerial exposure. Indurated, bored limestone (often with a gravel veneer of limestone lithoclasts and shells) is at unconformity surfaces, and indicates major subaerial exposure.

**Pleistocene formations**

Pleistocene limestones and quartz sand form distinct tracts of terrain on the Yalgorup Plain. Three new formations are described here to facilitate interpretation tracts of terrain on the Yalgorup Plain. Three new formations are described here to facilitate interpretation of the regional Quaternary history and palaeogeography. They are lithologically distinct from the Tamala Limestone, but they can be identified readily as distinct units by their lithology, stratigraphy and geography. They are lithologically distinct from the Tamala Limestone at its original location (Logan et al. 1970), at its type section (Playford & Low 1972), and from the calcarenitic aeolianite regarded as Tamala Limestone in the central Swan Coastal Plain of the Perth Regional area (Fairbridge 1953; Klenowski 1976; Gazzard 1983, 1986). Pleistocene limestones that comprise the offshore limestone ridges and the deeper sections of the Quaternary profile are left undifferentiated at present.

The new Pleistocene formations are:

3. Kooallup Limestone: a Late Pleistocene shoaling sequence of submarine, beach and aeolian calcarenites;
2. Myalup Sand: quartz sand, mostly grey to white, generally sandwiched between the Tims Thicket Limestone and Kooallup Limestone;
1. Tims Thicket Limestone: a shoaling sequence of submarine, beach and aeolian calcarenites deposited earlier in the Pleistocene.

The features of these formations are summarised in Table 2. The stratigraphy and relationships between the units are shown in Figures 2 & 3.

<table>
<thead>
<tr>
<th>BIVALVIA:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anodonta perleia</td>
</tr>
<tr>
<td>Brachidontes ustulatus</td>
</tr>
<tr>
<td>Callucina lacetula</td>
</tr>
<tr>
<td>Chlamys aspernissus</td>
</tr>
<tr>
<td>Chionery cardiodies</td>
</tr>
<tr>
<td>Divulcina cumingi</td>
</tr>
<tr>
<td>Dona francisensis</td>
</tr>
<tr>
<td>Electrona georgiana</td>
</tr>
<tr>
<td>Eucrassatella sp</td>
</tr>
<tr>
<td>Glycemeris strialularis</td>
</tr>
<tr>
<td>Gomphina undulosa</td>
</tr>
<tr>
<td>Hemidona chapmani</td>
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</tbody>
</table>

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<tr>
<th>GASTROPODA:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acteocina sp</td>
</tr>
<tr>
<td>Amalda monilifera</td>
</tr>
<tr>
<td>Amblychilasp oblonga</td>
</tr>
<tr>
<td>Astralium squamiferum</td>
</tr>
<tr>
<td>Bedeva paivae</td>
</tr>
<tr>
<td>Bittium graniarum</td>
</tr>
<tr>
<td>Bulla quoyii</td>
</tr>
<tr>
<td>Calyptraeus calyptraeformis</td>
</tr>
<tr>
<td>Canthurus lehmanni</td>
</tr>
<tr>
<td>Canthurus lepidus</td>
</tr>
<tr>
<td>Canthurus sp</td>
</tr>
<tr>
<td>Clanculus sp</td>
</tr>
<tr>
<td>Collisella onychitis</td>
</tr>
<tr>
<td>Cominella tasmanica</td>
</tr>
<tr>
<td>Conus anenome</td>
</tr>
<tr>
<td>Dicathais orbita</td>
</tr>
<tr>
<td>Drupa sp</td>
</tr>
<tr>
<td>Ethminolia vitiliginea</td>
</tr>
<tr>
<td>Gibbula lehmanni</td>
</tr>
<tr>
<td>Gibbula preissana</td>
</tr>
<tr>
<td>Haminoea brevis</td>
</tr>
<tr>
<td>Hippi conicus</td>
</tr>
<tr>
<td>Hippi foliaceus</td>
</tr>
<tr>
<td>Leioptyrga octona</td>
</tr>
<tr>
<td>Mangelia sp</td>
</tr>
</tbody>
</table>

Most identifications based on standards identified by G W Kendrick (Western Australian Museum) as cited by Semeniuk & Searle (1985); supplementary identifications from Roberts & Wells (1981) and Wells & Bryce (1985).

All molluscs listed, except for the gastropod Parcanassa are also present in Holocene seagrass assemblages, cf Semeniuk & Searle (1985).

**Tims Thicket Limestone**

**Definition and characteristics:** The Tims Thicket Limestone is a Pleistocene fossiliferous and non-fossiliferous calcarenite cropping out along the eastern Yalgorup Plain. Its lower to middle part is fossiliferous marine, and its uppermost part is aeolian.

**Derivation of name:** Tims Thicket area in the northern Yalgorup National Park.

**Type section:** A disused quarry at 32°39’06” 115°37’36”, along Tims Thicket Road.

**Distribution:** The formation is restricted to the Yalgorup Plain area, and crops out almost along the entire length of the eastern part of the Plain (Fig 1). It also is intersected in cores underlying Holocene units.
Table 2
Limestone members in Pleistocene formations in the Yalgorup coastal area

<table>
<thead>
<tr>
<th>FORMATION</th>
<th>MEMBER</th>
<th>LITHOLOGY</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>KOOALLUP LIMESTONE</td>
<td>LAKESIDE MEMBER</td>
<td>cross-laminated to structureless, fine and medium calcarenite</td>
<td>aeolianites</td>
</tr>
<tr>
<td></td>
<td>BELLEVUE MEMBER</td>
<td>white to cream shelly/ bioturbated calcarenite, laminated cross-laminated</td>
<td>submarine to beach zone facies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>shelly calcarenite/coquina, laminated to cross-laminated beach calcarenite</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SPRINGHILL MEMBER</td>
<td>calcilutite and shelly calcilutite</td>
<td>submarine basin facies</td>
</tr>
<tr>
<td>TIMS THICKETT LIMESTONE</td>
<td>WHITE HILL ROAD MEMBER</td>
<td>cross-laminated to structureless, fine and medium calcarenite</td>
<td>aeolianites</td>
</tr>
<tr>
<td></td>
<td>CLIFTON DOWNS MEMBER</td>
<td>white to cream shelly/ bioturbated calcarenite, bioturbated foraminiferal</td>
<td>submarine to beach zone facies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>limestone, laminated cross-laminated marine calcarenit</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>laminated to cross-laminated beach calcarenite</td>
<td></td>
</tr>
</tbody>
</table>

Thickness and geometry: At the type section, the formation has been logged as 9.1 m thick. Regionally, the unit is a ribbon to wedge, some 60 km long, up to 5 km wide and 5–10 m thick.

Lithology: The sequence of limestone at the type section (from 1 at the base to 5 at the top) is:

1. cross-laminated to structureless calcarenitic aeolianite: 2.0 m thick;
2. laminated to cross laminated beach calcarenite: 2.0 m thick;
3. laminated and cross laminated marine calcarenite: 1.3 m thick;

Table 3
Description of Holocene stratigraphic units in the Yalgorup coastal area

<table>
<thead>
<tr>
<th>SEDIMENT UNIT</th>
<th>STRUCTURE</th>
<th>LITHOLOGY</th>
<th>HOLOCENE DEPOSITIONAL ENVIRONMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety Bay Sand</td>
<td>large scale cross laminated to structureless</td>
<td>white, cream, orange fine and medium sand</td>
<td>dune</td>
</tr>
<tr>
<td>(aeolian facies)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety Bay Sand</td>
<td>laminated to bedded; seaward sloping layers</td>
<td>white, cream, yellowish medium and coarse sand and shelly sand</td>
<td>beach</td>
</tr>
<tr>
<td>(beach facies)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preston Beach Coquina</td>
<td>bedded to crudely layered</td>
<td>white, cream, yellowish, &amp; tan shell beds, shell grit, shelly sand, and coarse to medium sand</td>
<td>subtidal shoreface to beach</td>
</tr>
<tr>
<td>Becher Sand</td>
<td>structureless, bioturbated crudely layered</td>
<td>grey sand and shelly sand; shells from seagrass assemblage</td>
<td>subtidal seagrass bank</td>
</tr>
<tr>
<td>Bridport Calclutite</td>
<td>structureless to bioturbated; shell layers</td>
<td>grey calcilutite and shelly calcilutite</td>
<td>deep subtidal basin</td>
</tr>
<tr>
<td>Leschenault Formation</td>
<td>structureless, bioturbated, crudely layered</td>
<td>grey sand, mud, muddy sand, locally shelly; estuarine shells</td>
<td>estuarine sand and mud flats</td>
</tr>
</tbody>
</table>

1 Data from Semeniuk (1983), Semeniuk & Searle (1985, 1987), and this paper.
Figure 2A. Stratigraphy of transects. Legend to transects.
Figure 2B. The stratigraphy of the transects 1–4, 7.
Figure 3. Summary of stratigraphic relationships between the Pleistocene formations (from Semeniuk 1995a).
2. bioturbated foraminiferal calcarenite: 1.8 m thick;  
1. shelly/bioturbated calcarenite with seagrass assemblage  
biota: 2.0 m thick; unconformable on yellow quartz sand.  

The bioturbated foraminiferal calcarenite is laterally  
equivalent to shelly/bioturbated calcarenite and lami-  
nated and cross-laminated marine calcarenite. The  
limestone types in the formation are in a shoaling-upward  
sequence, with seagrass bank lithofacies and the later-  
ally equivalent sand wave lithofacies and bioturbated  
foraminiferal calcarenite lithofacies passing up into a  
beach sequence and then into a beachridge/dune se-  
quence. Within the beach facies, the subfacies are also in  
a shoaling sequence: trough cross-bedded calcarenite  
passes up into laminated calcarenite with  
foraminiferal calcarenite lithofacies passing up into a  
beachridge/dune sequence. The natural lithologic se-  
contains  

in Table 1. The upper part of the unit, the beach facies,  
compared with the Holocene seagrass bank assemblage  
seagrass bank environments. The molluscs are listed and  
molluscan and foraminiferan fossils, indicative of  
to non-fossiliferous aeolian be the basis of recognising  
the calcarenites from fossiliferous submarine to littoral  
limestones. It is proposed that the broad separation of  
part of fossiliferous limestones passing up into aeolian  
view, the formation consists of a distinctive mid-lower  
calcarenite lithofacies passing up into a beach sequence  
with seagrass bank lithofacies and the laterally equiva-  

Stratigraphic relationships: The formation  
unconformably overlies older Pleistocene limestone at  
depth, abutting and pinching out unconformably to east  
against yellow sand and limestone that underlie the  
Mandurah-Eaton Ridge, and pinches out downdip  
(westwards) as a natural palaeogeographic synoptic sur-  
fac. In its eastern parts, it is unconformably overlain by  
the Myalup Sand filling karst features on the limestone;  
in its western parts it is unconformably overlain by Ho-  
locene sediment.  

Fossils: Lower to middle parts of the formation contain  
molluscan and foraminiferan fossils, indicative of  
seagrass bank environments. The molluscs are listed and  
compared with the Holocene seagrass bank assemblage  
in Table 1. The upper part of the unit, the beach facies,  
contains Donax spp, Paphies sp, Sepia spp, and Spirula  
spirula.  

Members in the formation: The natural lithologic se-  
quence in the formation reflects a sequence of shoaling,  
with seagrass bank lithofacies and the laterally equiva-  
lent sand wave lithofacies and bioturbated foraminiferal  
calcarenite lithofacies passing up into a beach sequence  
and then into a beachridge/dune sequence. In a broad  
view, the formation consists of a distinctive mid-lower  
part of fossiliferous limestones passing up into aeolian  
limestones. It is proposed that the broad separation of  
the calcarenites from fossiliferous submarine to littoral  
to non-fossiliferous aeolian be the basis of recognising  
two members in the formation, as follows (Table 2):  

White Hill Road Limestone Member: upper part of  
formation consisting of aeolian calcarenite. The area  
along White Hill Road, south of Mandurah, exposes  
good sequences of this member, with relict  
beachridge patterns evident (see figure 5 of Semeniuk  
1995a). The type location for the member is the same  
as for the formation.  

Clifton Downs Member: lower to middle part of  
the formation consisting of fossiliferous marine  
calcarenite passing up into fossiliferous laminated  
beach calcarenite, exposed in the Clifton Downs area,  
east of Lake Clifton. The type location for the mem-  
er is the same as for the formation. Additional quarry  
reference sites are located along Tims Thicket Road in  
the Tims Thicket area.  

Myalup Sand  

Definition and characteristics: The Myalup Sand is a  
predominantly grey to white quartz sand unit between  
the Tims Thicket Limestone (below) and the Kooallup  
Limestone (above). There are local thin lenses of  
limestone in the formation.  

Derivation of name: Myalup Swamp, in the southern  
Yalgorup Plain area, east of Binningup.  

Type section: Sand ridge at 32°58'00" 115°42'57", south  
of the Yalgorup National Park.  

Distribution: The formation is restricted to the Yalgorup  
Plain, cropping out almost along the entire length of its  
eastern and middle part. It also is intersected in core in  
this area.  

Thickness and geometry: Where intersected in core and  
trenches, the formation has variable thickness from 5–15  
m thick. Regionally, the unit is a ribbon to shoe string,  
some 60 km long, up to 5 km wide and 5–15 m thick.  

Lithology: The type section, 15 m thick, is generally  
structureless grey to white quartz sand, mainly fine to  
medium sand-sized, and poorly sorted. The formation  
becomes progressively more iron-stained in the upper  
3–4 m. Though quartz rich, it also contains minor  
feldspar. The upper parts of the formation may be  
stained yellow. Locally, there are carbonate-rich lenses,  
<1 m thick, located 2–3 m below present mean sea level.  
It was not generally possible to differentiate facies in the  
quartz sand sections of the Myalup Sand.  

Stratigraphic relationships: Contact with the  
underlying Tims Thicket Limestone is sharp and uncon-  
formable, marked by prominent karst in the limestone.  
Contact with the overlying Kooallup Limestone is sharp  
and unconformable, with the base of the limestone trunc-  
aturing the ridge-and-depression sequence in the Myalup  
Sand which pinches out under the limestone. In the de-  
pressions on the Myalup Sand, there is an overlying  
undifferentiated suite of Pleistocene to Holocene shelly  
Spirula Spirula  

Kooallup Limestone  

Definition and characteristics: The Kooallup Limestone is a  
Pleistocene fossiliferous and non-fossiliferous  
calcarenite that crops out along the western zone of the  
Yalgorup Plain. Subsurface sections may contain local  
calcitutite lenses. The lower to middle part of the forma-  
tion is fossiliferous, and the uppermost part is aeolian.  

Derivation of name: Kooallup Lagoon, east of Lake  
Preston and north of Myalup.  

Type section (type locality): Quarry, east of Lake  
Preston, in the southern part of Yalgorup Plain area, at  
32°02'46" 115°42'36".  

Distribution: The formation is restricted to the Yalgorup  
Plain area, cropping out almost along the entire length of  
the western part of the Yalgorup Plain. Additionally,
it has been intersected in core underlying Holocene units in this region.

**Thickness and geometry:** At the type section, the formation is 10.8 m thick. Regionally, the unit is a ribbon to wedge, some 60 km long, up to 5 km wide and 5–16 m thick.

**Lithology:** At the type section, there are four types of limestone, in stratigraphic order, from 1 at the base to 3 at the top, these are:

1. laminated and cross laminated marine calcarenite and shelly/biota: 6 m.
2. laminated to cross laminated beach calcarenite: 2 m thick.
3. laminated calcarenite and calcilutite: 1.8 m thick.
4. laminated to cross laminated marine calcarenite and shelly/biota: 6 m.

In a section further south from the type section, the same sequence of limestones occurs but are underlain by calcilutite:

1. laminated calcilutite (5 m thick); unconformable on an older un-named shelly marine limestone.
2. laminated to cross laminated beach calcarenite: 2 m thick.
3. laminated and cross laminated marine calcarenite: 9 m thick.

In general, the Kooralup Limestone sequences exhibit shoaling: seagrass bank facies, and the laterally equivalent sand wave facies, are overlain by beach and then beachridge/dune facies. The beach sequence progresses from subtidal to supratidal, with preservation of bubble structures and shells of *Donax, Sepia,* and *Spirula.* Locally, in former inter-ridge marine depressions, there are lenses of calcilutite.

**Stratigraphic relationships:** The formation unconformably overlies an older as yet un-named Pleistocene limestone at depth, and pinches out unconformably to the east against the Myalup Sand. To the west, it pinches out downdip as a natural palaeogeographic surface, or abuts a buried ridge that is the extension of the Bouvard Reefs system.

**Fossils:** The fossil within the Kooralup Limestone is similar to that in the Tims Thicket Limestone. The lower to middle parts of this formation contain molluscs (Table 1) and foraminifera, derived from seagrass bank environments. The upper part of the unit, the beach facies, contains *Donax* sp, *Paphies* sp, *Sepia* spp, and *Spirula spirula.*

**Members in the formation:** As for the Tims Thicket Limestone, the sequence in the Kooralup Limestone reflects shoaling, with (local basin calcculites and) seagrass bank lithofacies passing up into beach facies and then into a beachridge/dune facies. The sequences essentially form a fossiliferous lower to middle part, and a non-fossiliferous (aeolian) upper part. It is proposed that this broad separation of limestones be the basis of recognising three members in the formation, as follows (Table 2):

**Lakeside Limestone Member:** upper part of formation consisting of aeolian calcarenite. The type location for the member is the same as for the formation; additionally, the pits and quarries around the Lakeside property east of Lake Preston, and the eastern shore of Lake Preston exposes good sequences of this member.

**Bellevue Limestone Member:** lower to middle part of formation consisting of fossiliferous marine limestones and fossiliferous laminated beach calcarenite. The type location for the member is the same as for the formation; additionally, local pits and quarries in the area of the Bellevue property, along the northeastern shore of Leschenault Inlet, expose good sections of this member.

**Springshill Limestone Member:** lower part of the formation consisting of calcilutite and shelly calcilutite. A local lens of this calcilutite occurs at depth under the Springshill property (located 2 km SE of Binningup). The type section for the member is Core Site 2, Transect 7 (Fig 2). [Note that use of the Springshill Limestone Member is to be distinguished from the previous use of the term Spring Hill, as two words, for the Palaeozoic Spring Hill Limestone in the Bonaparte Basin; though not formally defined to date in the Bonaparte Basin, the Spring Hill Limestone was first used by Druce 1963].

**Distribution:** An additional feature in the Kooralup Limestone is a south to north facies change; to the south, beachridge and dune facies above the seagrass bank and beach facies are quartz sand rich; to the north, they are more carbonate-grain rich. This transition is related to major inputs of quartz sand from two sources in the south: erosion of the Mandurah-Eaton ridge (with concomitant net northwards longshore drift), and the Collie, Preston and Wellesley rivers transporting quartz from the dunes further east.

**Pleistocene palaeogeographic units**

The Pleistocene formations are restricted to distinct, mappable tracts of country that represent discrete phases of coastal sedimentation, progradation, and geomorphic history in this region. In effect, their distribution reflects accretionary stages of the Swan Coastal Plain between Mandurah and Bunbury. In this context, they have been assigned palaeogeographic names to highlight their discrete palaeogeographic character (Semeniuk 1995a). The distribution of the Pleistocene formations in relationship to the Pleistocene landform units are as follows (Semeniuk 1995a):

1. **Youdaland:** the most eastern and oldest Pleistocene landform unit on the Yalgorup Plain, underlain by the Tims Thicket Limestone; the name derives from Youda, between Tims Thicket and Mandurah;
2. **Myalup Sand Shelf and Myalup Sand Ridge:** a sand shelf system that separates the Mandurah-Eaton Ridge from Kooralupland, and a linear ridge system generally sandwiched between the Youdaland and Kooralupland, respectively, and underlain by the Myalup Sand; the name derives from Myalup Swamp, between Myalup and Binningup; and
3. **Kooralupland:** the most western and youngest Pleistocene landform unit on the Yalgogup Plain, underlain by Kooralup Limestone; the name derives from Kooralup Lagoon, located to the east of Lake Preston.

The evolution of the Yalgorup (coastal) Plain is interpreted to have taken place in several stages related to sealevel still-stands in the Pleistocene (Semeniuk 1995a):

1. formation of an older Pleistocene limestone beachridge plain (Youdaland), within which there was shoaling from...
marine seagrass carbonate sedimentation to beach to beachridges/dunes;

2. accumulation of quartz rich coastal sand barriers (Myalup Sand Shelf and Myalup Sand Ridge);

3. formation of a younger Pleistocene limestone beachridge plain (Koallupland) within which there was, again, shoaling from marine seagrass carbonate sedimentation to beach to beachridges/dunes.

Thus the overall progressive accretion of the Yalgorup Plain records, with subaerial interruptions (Fig 3): 1. sedimentation and progradation in a coastal setting partly behind offshore rocky reefs; 2. changes in style from cuspatc foreland and shoreface accretion to coastal barriers; and 3. alternation in sedimentation from carbonate-rich to quartz-rich. The results also provide several insights into the Quaternary history of the Perth Basin in southwestern Australia in regards to the alternations of carbonate/siliciclastic sedimentation in general, the control of the geometry of coastal sediment bodies by ancestral topography such as the offshore limestone ridges, the longevity of the limestone ridge ancestral topography, and the age structure of the Pleistocene coastal plains (Semeniuk 1995a).

**Holocene stratigraphy**

Much of the western edge of the Yalgorup Plain is bordered by Holocene barrier dunes. Though these are a geomorphic extension of the Leschenault Peninsula barrier (Semeniuk 1985), stratigraphically they present a different Holocene history to elsewhere. Various Holocene sediment types occur in this area and, generally, they can be assigned to previously defined formations. However, one unit remains undescribed, and is formally defined in this paper as the Preston Beach Coquina. The sediment types and their assigned formations are summarised in Table 3.

**Preston Beach Coquina**

**Definition and characteristics:** The Preston Beach Coquina is the name proposed for light-coloured, bedded, laminated, cross-laminated shell gravel and sandy sand along the shoreface of the Leschenault-Preston Sector, and in the subsurface.

**Derivation of name:** Preston Beach, south of Mandurah.

**Type section:** Preston Beach at 32°52′57″ 115°38′40″.

**Distribution:** The unit is widespread along the coastal zone of the Leschenault-Preston Sector, and additionally forms isolated units in the subsurface in other coastal sectors further north.

**Thickness and geometry:** The unit is up to 6-7 m thick. Regionally along the Leschenault-Preston Sector, the unit will appear as a discontinuous ribbon, some tens of kilometres long, up to 100-200 m wide and 6-7 m thick. Elsewhere it forms lenses, some 1-3 m thick, and hundreds of metres wide.

**Lithology:** At the type section, the formation is a light-coloured (yellowish, tan, buff, to cream), bedded, crudely layered, to locally laminated, to cross-laminated deposit of shell gravel, shell grit, shelly sand, and sand. Sand grains are quartz, or quartz, bioclasts and lime-

**stratigraphic relationships:** The formation overlies a variety of units, depending on locality and the extent of erosion along its base: it has an erosional contact with both the Becher Sand and Leschenault Formation, and an unconformable contact with Pleistocene sediment and sedimentary rock. The formation is overlain conformably and gradationally by dune deposits of the Safety Bay Sand. Laterally, the unit may pass into shelly sand and sand of the beach facies of the Safety Bay Sand. It may also pass laterally into Becher Sand.

**Fossils:** Molluscan shell remains in the formation include: Donax spp, Glycymeris sp, Mactra sp, and Donacilla sp, and in the uppermost part, Spirula spirula and Sepia spp.

**Age:** Radiocarbon ages show that the unit is wholly Holocene. In the Leschenault-Preston Sector, its age is 5455 14C yrs BP to present (Semeniuk 1995b). Elsewhere, such as at Quinns Rock, it is older, but still Holocene.

**Distribution:** The Preston Beach Coquina is a distinctive, widespread shell gravel unit formed in high energy beach to shoreface settings. The dominant, and consistent shell gravel content serves to separate it from other marine and strand units such as the Becher Sand and the beach facies of the Safety Bay Sand, respectively.

**Holocene sedimentary sequences**

In coastal southwestern Australia, there are four main large-scale standard Holocene stratigraphic sequences (Semeniuk 1995b, and Fig 4):

Type 1, prograded bank, beach, beachridge system composed of a shoaling sequence of subtidal basin sediment, seagrass bank sediment, beach sand, and dune sand;

Type 2, prograded shoreface to beachridge system composed of a shoaling sequence of shoreface shell/sand, beach sand/shell, and dune sand;

Type 3, retrograded barrier dune system composed of dune sand overlying estuarine lagoonal sediment; and

Type 4, retrograded barrier dune system composed of dune sand unconformable on Pleistocene sediment.

Each type tends to be localised in a specific sector of coast. Type 1 occurs in settings of cuspatc forelands behind barrier limestone reefs, ridges and islands, such as the Rockingham-Becher system (Searle et al. 1988) and the Whitfords Cusp (Semeniuk & Searle 1986). Type 2 occurs along the modern shore face of the Leschenault-Preston barrier (e.g. Preston Beach). Type 3 occurs in the Leschenault Peninsula area (Semeniuk 1985), and Type 4 occurs in the northern part of the Leschenault-Preston Sector and in coastal sectors further north (Semeniuk et al. 1989).

**Barrier dune stratigraphy, Yalgorup area**

The standard Holocene stratigraphic sequences have been used to help unravel the Holocene history of the barrier dunes in the Yalgorup area, and specifically between Preston Beach and the Bouvard Reefs. The Holocene stratigraphy under the barrier dunes here is complex;
Figure 4. The four standard Holocene stratigraphic sequences in the southern Perth Basin (from Semeniuk 1995b).
the marine Holocene record begins with a Type 1 sequence, which is sharply overlain by a Type 3 sequence, with a final capping of Type 2 sequence (Semeniuk 1995b). The sedimentary sequence records dramatic coastal changes associated with rising Holocene sealevels; simple seagrass bank, beach, beachridge sedimentation/progradation was abruptly terminated, and succeeded by development of a barrier dune with its associated barred lagoon. The sequence developed is interpreted to be a response to seas rising into a bathymetrically complex area. The area between Preston Beach and Bouvard Reefs, being in a transition zone between a coastal sector of complex bathymetry to the north and one of simple bathymetry to the south, had the potential to record differing styles of Holocene sedimentation in response to varying sealevel (Semeniuk 1995b).

References


Fairbridge R W 1953 Western Australian Stratigraphy. Text Book Board Publication, University of Western Australia, Perth.


Gozzard J R 1983 Fremantle Part Sheets 2033 I and 2033 IV, Perth Metropolitan Region, 1:50,000 Environmental Geology Series, Geological Survey of Western Australia, Perth.

Gozzard J R 1986 Perth, Sheet 2034 II and part 2034 III and 2134 III, Perth Metropolitan Region, 1:50,000 Environmental Geology Series, Geological Survey of Western Australia, Perth.


Semeniuk V 1995a The Quindalup System and its implication for sealevel history reconstructions in Southwestern Australia. Journal of the Royal Society of Western Australia 70:35–47.


Semeniuk V & Cresswell I D 1989 The Quindalup Dunes: the regional system, physical framework and vegetable habitats. Journal of the Royal Society of Western Australia 71:23–47.
