Palaeontological correlation of Cenozoic marine deposits of the southeastern, southern and western coasts, Cape Province

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Cenozoic calcareous units of the Cape southeast, south and west coasts have been correlated by means of macropalaeontology. The Alexandria and Salnova Formations of the Algoa Group are correlated, respectively, with the De Hoopvlei and Klein Brak Formations of the Bredasdorp Group. The west coast deposits have previously been dated by means of vertebrate fossil remains, amongst other methods. This enables confirmation of the ages of the various formations (Neogene for the Alexandria and De Hoopvlei Formations and Quaternary for the Salnova and Klein Brak Formations) along the southeastern and southern coasts, as determined by means of correlation with sea-level curves.

Introduction

Outcrops of Cenozoic marine and marine-related (aeolian) deposits are present along most of the southern African coastline. Siesser (1972) and Ruddock (1973) applied the terms 'Cainozoic coastal limestones' and 'Tertiary limestones', respectively, as collective names for these deposits. Whilst Ruddock's term was used for calcareous deposits confined to the southeast coast, Siesser's term included the coastline between Saldanha and East London. In the past, attempts have been made to correlate these 'limestones' of the west, south and southeast coasts. Wybergh (1919, p.63-64), on discussing the age of the 'Bredasdorp beds', made the following comments: 'As far as they go, therefore, the fossils point to an age intermediate between the Alexandria beds, which are now shown to be of Mio-Pliocene age, and the Recent period'. It is, however, clear that he based the younger age mainly on the fossils which he collected from the Port Beaufort locality, '..... being species now living on the south coast .....'. The marine deposit at this locality, which is situated well below 30 m above sea-level, are now known to belong to the Quaternary Klein Brak Formation. Both Tertiary and Quaternary marine deposits were at that stage collectively treated as one unit, viz. the 'Bredasdorp beds'. Later workers such as du Toit (1954), Spies et al. (1963) and Siesser (1972), amongst others, tentatively correlated these 'limestones' of the west, south and southeast coasts, mainly on the grounds of lithological similarities.

Because regional discontinuities separate these deposits along the southern African coastline and its hinterland, different stratigraphic names are used for similar deposits (Figure 1). Along the southeastern coast, the deposits constituting the newly defined Algoa Group were recently subdivided into six formations (Table 1) by Le Roux (1988), mainly on the basis of palaeontological, age, and lithological characteristics, thus rationalising and replacing all previously used non-standard terms. Five formations (Table 1) constituting the Bredasdorp Group were also recently defined for the calcareous Cenozoic deposits along the south coast by Malan (1989). Although names such as 'Saldanha Formation' (Tankard, 1975), 'Varswater Formation' (Hendey, 1974), 'Alexander Bay Formation' (Haughton, 1932; Stocken, 1978); 'Dorcasia Limestone' (du Toit, 1954; Siesser, 1972) and others are used in the literature for various west coast deposits, confusion still surrounds the definitions thereof. Tankard (1976), for example, used names such as 'Langebaan Limestone Member' and 'Velddrif Shelly Sand Member' which he considered as constituents of the 'Bredasdorp Formation'. These names and subdivisions clearly need revision according to the latest work along the southeast and south coasts, respectively, by Le Roux (1988) and Malan (1989). The use of the name 'Bredasdorp Group' (which has undergone a rank change from 'formation' status) is presently limited to deposits along the south coast. Pether (1986) tested and revised the findings of Carrington & Kensley (1969) (who subdivided the marine deposits into so-called 'complexes'), Tankard (1975) and Hendey (1981a, b).
Table 1  Classification and correlation of Algoa and Bredasdorp Group sediments

<table>
<thead>
<tr>
<th>Age</th>
<th>ALGOA GROUP</th>
<th></th>
<th>BREDASDORP GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Marine</td>
<td>Aeolian</td>
<td>Marine</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holocene</td>
<td></td>
<td>Schelm Hoek Fm</td>
<td></td>
</tr>
<tr>
<td>Pleistocene</td>
<td>Salnova Fm</td>
<td>Nahoon Fm</td>
<td>Klein Brak Fm</td>
</tr>
<tr>
<td>Pliocene</td>
<td>Alexandria Fm</td>
<td>Nanaga Fm</td>
<td>De Hoopvlei Fm</td>
</tr>
<tr>
<td>Miocene</td>
<td>Palaeocene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eocene</td>
<td>Bathurst Fm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Unit not yet approved by SACS

and subdivided these west coast deposits into so-called 'packages', according to their respective heights above sea-level and their relation to specific transgression/regression cycles. Three of these 'packages', the 90m, 50m and 30m packages were identified. These subdivisions, however, lack definition according to the Lithostratigraphic Code and would need amendment in future.

Palaeontological correlation of southeast and south coast deposits

Palaeogene
Along the southeast coast scattered, isolated, outcrops of Palaeogene marine deposits (the Bathurst Formation of Maud et al., 1987) are present east of the Kowie River in the vicinity of Birbury. Isolated outcrops occur at Pato's Kop (on plateau on eastern bank of Great Fish River), Needs Camp (upper quarry) and near Kids Beach, respectively, (Figure 2), the latter locality being a new finding by Le Roux (1989).

The absence of calcareous deposits of Palaeogene age in the Bredasdorp Group is the result of either non-deposition or complete erosion prior to deposition of the De Hoopvlei Formation.

Neogene
Index fossils of the Neogene Alexandria Formation, according to Le Roux (1986; 1989), include the extinct Glycymeris borgesi* (Cox, 1946), Cardium edgari Newton, 1913, Notocalista schwarsi (Newton, 1913), Pirenella stowi Newton, 1913, Cypraea sietsmansii Liltved & Le Roux, 1988, Tivela baini Newton, 1913, Melapium patersonae Newton,
1913 and Calyptraea kilburni Krensley & Pether, 1986. The presence of these fossils, amongst other criteria (Le Roux, 1988), is used to distinguish the Neogene Alexandria Formation from the younger Quaternary Salnova Formation.

A recent palaeontological examination of the De Hoopvlei Formation in the vicinity of Bredasdorp yielded typical Alexandria index fossils such as Glycymeris borgesi, Cardium edgari, Notocallista schwarzi, Pirenella stowi, Tivela baini, Melanippe patersonae and Calyptraea kilburni. Furthermore, exotic (West African) species such as Thais haemastoma (Linne, 1767) and Arca noae (Linne, 1758), which were recently reported from the Alexandria Formation (Le Roux, 1987c), have now also been found in the De Hoopvlei Formation. This is indicative of differences in the extent of Neogene and present marine-biogeographical provinces. The burrowing echioid Echinodiscus colchoesterensis Smuts, 1988, which is in all probability the predecessor to the modern-day E. bisperforatis, is common to both the Alexandria and De Hoopvlei Formations. The oyster (Crassostrea margaritacea (Lamarrk, 1819)) acme zone which, according to Le Roux (1987b) normally occurs at the base of the Alexandria Formation in the form of a basal oyster-shell conglomerate (clasts exclusively oyster shells), was recently found in the same stratigraphic setting at Aasvoelkrans (along the Salt River) in the De Hoopvlei Formation.

A confident confirmation of palaeontological correlation between the Alexandria and De Hoopvlei Formations, as tentatively suggested by Du Toit (1954) and Spies et al. (1963) has now been established.

Ruddock (1973), after Mountain (1962) lists Glycymeris pilosa (synonyms G. borgesi Cox, 1946; G. africana Cox, 1939 and G. australo-ficana King, 1953) from the Bushfontein Formation at Needs Camp Upper Quarry. This record is regarded as extremely dubious for the following reasons: G. borgesi is a very common species in the Neogene deposits (Alexandria Formation) and therefore well-known to the author. Not a single specimen has been found at the Needs Camp locality by the author, or in the extensive collections from that locality presently housed in the Albany Museum. According to Lock (1972), who searched the museum at the Department of Geology at Rhodes University, the identification was done from a cast which has, apparently, since been mislaid. The author has identified a single specimen of Cardium sp. (not C. edgari) from the Needs Camp deposit, a cast of which could easily have been confused with Glycymeris sp.

**Quaternary**

Extinct fossils of the Salnova Formation such as Duplicaria oioosa Kilburn & Tankard (1975), Pupa daviesi Kilburn & Tankard (1975) and Gastrana fibrosa Kilburn & Tankard (1975), (Le Roux, 1989) as well as species of the so-called ‘Swartkops fauna’ such as Cerithium scabridum rufonodosum (E.A. Smith, 1899), Cantharidus suevensis fulioni (Sowerby, 1889) and Monilea obscura ponsonbyi (Sowerby, 1888) must have appeared after the Neogene since their remains are absent in the Alexandria Formation.

These characteristic fossils, with the exception of Gastrana fibrosa, have also been identified in the Klein Brak Formation. In addition to these extinct fossil species, the following extant exotic species are also common to both formations:

<table>
<thead>
<tr>
<th>West African Province</th>
<th>Indo-Pacific Province</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panopaea glycymeris (Borm, 1890)</td>
<td>Anodonta edentula (Linne, 1758)</td>
</tr>
<tr>
<td>Loripes mirula (Sowerby, 1889)</td>
<td>Pseudostomatella orbiculata</td>
</tr>
<tr>
<td>Tellina madagascariensis</td>
<td>(A. Adams, 1850)</td>
</tr>
<tr>
<td>Melapium hawthornei</td>
<td>Polinices taimulus (Swainson, 1840)</td>
</tr>
<tr>
<td>Nuculana bicuspisada (Gould, 1845)</td>
<td>Tapes subcarius (Lamarrk, 1818)</td>
</tr>
<tr>
<td>Felania diaphana (Gmelin, 1791)</td>
<td>Nuculana bicuspidata</td>
</tr>
<tr>
<td>Leporomeis kenuxei (Dunker, 1853)</td>
<td></td>
</tr>
</tbody>
</table>

It would thus appear that there were considerable fluctuations in marine-biogeographical provinces during the Quaternary (cf. Le Roux, 1987a). Extant warm water mollusc species, normally associated with species of the ‘Swartkops fauna’, characterise fossil assemblages from estuaries/lagoonal facies associated with the 6–8 m shoreline (Le Roux, 1987a). This warm period probably coincides with the well-documented period of higher temperatures at c. 120 000 B.P. (Kilburn & Tankard, 1975). The extant form of the burrowing echioid is common to both the Salnova and Klein Brak Formations, thus indicating evolution from the extinct Echinodiscus colchoesterensis to the extant form E. bisperforatis during the Pleistocene (i.e. post-Pliocene to pre-Holocene).

The palaeontological correlation of the Salnova and Klein Brak Formations, as tentatively implied by Davies (1971) and Tankard (1975) has now been confirmed.

**Correlation with west coast deposits**

**Palaeontological evidence**

Some of the index fossils from the Alexandria Formation have also been reported from west coast deposits (Tankard, 1975; Krensley & Pether, 1986). These include Glycymeris borgesi, Cardium edgari, Notocallista schwarzi and Calyptraea kilburni. The first mentioned three have been recorded from the deposits at Ysterplaat to which a Pliocene age can be assigned (see ‘Ages’). Notocallista schwarzi is also present in the 50m package. Calyptraea kilburni, together with two other extinct fossils, viz. Nucella praecingulata (Haughton, 1932) and Melapium hawthornei Krensley & Pether (1986) are common to the Alexandria Formation, the 50m package and the 30m package. It is, however, absent in deposits below 30m along the southeast coast.

One index fossil from the Salnova Formation, viz. Gastrana fibrosa, is also present in Quaternary west coast deposits (Kilburn & Tankard, 1975). Exotic species of the West African Province common to the south/southeast and west coast Quaternary deposits include Panopaea glycymeris, Loripes mirula, Tellina madagascariensis, Venerupis dura, Nuculana bicuspisada and Felania diaphana.

**Corresponding sea-levels**

The sea-level curve (Figure 3) presented by Le Roux (1989) for the southeast coast is based mainly on local onshore evidence and now also applies to the south coast. The earliest Neogene transgression/regression cycle started in the Middle...
Miocene and ended in the Late Miocene/Early Pliocene. During this cycle the marine planation of the coastal platform took place while the Alexandria Formation presently situated above c. 120 m, was deposited. Two cycles are recognised for the Pliocene, while at least four are indicated for the Quaternary. The first Pliocene cycle had a transgressive maximum of about 120 m, thereby eroding all possible Late Miocene Alexandria deposits below that height. At least three stillstands occurred during the ensuing regression during which the Alexandria Formation below 120 m was deposited. The next cycle (Late Pliocene) reached about 60 m with at least one significant stillstand during the ensuing regression. The Early Pleistocene cycle turned at c. 30 m. Marine and paralic deposits formed during the Neogene (i.e. above 30 m above sea-level) constitute the Alexandria Formation, whereas those of the Quaternary (i.e. below 30 m above sea-level) belong to the Salnova Formation (Le Roux, 1989).

The three 'packages' of Pether (1986) are correlated with the post-Miocene cycles of Le Roux (1989) in the following way: the 90 m and 50 m packages are, respectively, being correlated with the Early Pliocene (120 m) and Late Pliocene (60 m) cycles. Pether (1986) distinguished the 30 m package, which clearly refers to a single stratigraphic unit deposited during a single regressive sea-level period, from later Pleistocene marine deposits at lower elevations. These Quaternary west coast deposits (the 30 m package and later Pleistocene deposits) are correlated with the collective Quaternary (30 m) cycles (see Figure 3) which apply to the south/southeast coast. Elevation differences between the correlated units is probably the result of differential diastrophism.

Ages

Newton (1913), on account of similarities of certain Alexandria fossils with those of European and South American species, assigned a Mio-Pliocene age to the Alexandria formation. This age was generally accepted by subsequent workers. However, McMillan (in Stear, 1987; Rust et al., 1989), assigned a Pleistocene age to the bulk of the Alexandria Formation on the grounds of micropalaeontological data. This age is in clear disagreement with the data presented here.

According to Pether (1986), the 90 m 'Package' contains vertebrate fossils of Mio-Pliocene aspect such as Cerothorium praecox, Hippotragus, gomphothere, creodont, ostrich (large sp.), seal, large-toothed cetacean, shark teeth (including Carcharodon cf. megalodon), and various fish teeth (including Labrodon siromeri). Hendey (1981a,b) correlated the '75-90 m Complex' of Carrington & Keesley (1969), (i.e. the 90 m Package of Pether, 1986), in Namaqualand with the Early Pliocene Varswater Formation at Langebaanweg. This formation was dated by means of vertebrate fossils, the mammalian fauna being comparable with the more securely dated East African faunas (Hendey, 1970, 1974; Hooijer, 1972). The Varswater Formation is in turn coupled to the Early Pliocene transgressive sea-level. Pether (1986) considered the mineralised, fragmentary, abraded and commonly bio-eroded nature of the vertebrate fossils as suggestive of them being remané fossils, thus predating or being contemporaneous with the enclosing deposit. The youngest of these Mio-Pliocene fossils therefore constrain the age of the deposit and indicate that this unit is at least Early Pliocene in age and that the ensuing 50 m package should be Pliocene or younger.

The presence of remains of Equus capensis in the 50 m package suggests (Pether, 1986) that this package cannot predate the c. 2.0 Ma mammalian dispersal event in Africa of Lindsay et al.(1980). The age inferred by Hendey (1981a,b) for the Baards Quarry fluviatile deposits (which contain Equus) in the southwestern Cape, was by implication confirmed by Pether (1986). He considered the 50 m package to be Late Pliocene in age and correlated it with the regressive portion of sea-level cycle Q1 of Vail & Hardenbol (1979) and Beard et al. (1982). Consequently, the 30 m package must reflect a subsequent high sea-level, and is thus correlated with cycle Q2 in the Early Pleistocene (Pether, 1986).

A Neogene age for the deposit at Ysterplaat (which contains the Alexandria index fossils Glycymeris borgesi, Cardium edgari and Notocallista schwarzi), was indicated by the presence of fossil penguin material (Olson, 1985). This could generally substantiate the Neogene age of those parts of the Alexandria and De Hoopvlei Formations which contain these fossils (i.e. below 60 m), as opposed to the Pleistocene age for the relevant parts of these formations as indicated by McMillan (in Stear, 1987; Rust et al., 1989).

Conclusion

The Alexandria and Salnova Formations of the Algoa Group (southeast coast) have been positively correlated with, respectively, the De Hoopvlei and Klein Brak Formations of the Bredasdorp Group (south coast). This is accomplished by means of index and other diagnostic molluscan fossils common to both groups. These criteria, supplemented by corresponding sea-level information, also allow the southeast/south coast deposits to be correlated with similar west coast deposits. Since the age of the latter sediments were established from mammalian vertebrate remains, amongst other criteria, the essential link to substantiate the age of the

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**Figure 3** Neogene sea-level curve for the southeast coast (after Le Roux, 1989 - figure 12.1). Horizontal scale not proportional.
Alexandria/De Hoopvlei Formations as determined by correlating with sea-level curves (Le Roux, 1989), is provided.

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