Executive summary

The Coega IDZ, situated inland of Algoa Bay about 20km to the northeast of Port Elizabeth (Eastern Cape Province) is underlain by sedimentary rocks that range in age from *c.* 470 million years ago to the present. These sediments are assigned to ten rock successions within the Palaeozoic Table Mountain Group, the Mesozoic Uitenhage Group and the Caenozoic Algoa Group *plus* unnamed alluvial deposits of Tertiary / Quaternary age. Most of these rock units contain fossil heritage of some sort but in most cases this is very limited. The notable exceptions are three marine successions – the Sundays River Formation of Early Cretaceous age (*c*. 136 Ma = million years old), the Alexandria Formation of Miocene / Pliocene age (*c*. 7-5 Ma), and the Salnova Formation of Mid Pleistocene to Holocene age (< 1 Ma). Important but rare fossils of dinosaurs and plants are also known from the Early Cretaceous Kirkwood Formation, but so far only outside the study area. Levels of bedrock exposure within the Coega IDZ are generally very low due to extensive cover by superficial drift (*e.g.*soil, alluvium, *in situ* weathering products) as well as by surface calcrete (pedogenic limestone) and dense vegetation. Man-made excavations such as road and railway cuttings, stormwater drainage channels, reservoirs and quarries, of which there are a considerable number within the Coega IDZ, often provide the best opportunities to examine and sample fresh, potentially fossiliferous bedrock.

During the course of the present field study, carried out over ten days in February – March 2010, over one hundred natural and artificial exposures of sedimentary rocks within or very close to the Coega IDZ were examined for palaeontological heritage (GIS data for these sites is listed in an Appendix). The fossil heritage of each of the ten main stratigraphic units occurring in the Coega IDZ has been assessed on the basis of (a) the scientific literature and (b) fieldwork carried out for the present study. The palaeontological sensitivity of each unit as it occurs in the Coega IDZ has been estimated and is summarized in Table 1. This table also outlines the specialist palaeontological mitigation that is recommended in the case of future developments that involve excavations into these stratigraphic units.

Future developments within the Coega IDZ will have to be individually assessed beforehand in terms of their likely impact on palaeontological heritage. The impact of these developments and the need, if any, for palaeontological mitigation can now be quicky assessed on the basis of this palaeontological report when used in conjunction with the relevant geological maps. The key factors to consider here are (a) the location of the proposed development, (b) the extent (depth, volume) of the bedrock excavations involved, and (c) the palaeontological sensitivity of the stratigraphic units affected.

Palaeontological mitigation is not necessary in the case of stratigraphic units with a low palaeontological sensitivity (*e.g.* Peninsula Formation, Nanaga, Nahoon and Schelm Hoek aeolianites). Specialist palaeontological mitigation is especially recommended for substantial excavations into the Kirkwood, Sundays River and Salnova Formations which all have a proven fossil record of high scientific importance. The Alexandria Formation is also known to be richly fossiliferous, and a number of the key fossil localities within this unit are situated in the Coega region. However, field evidence suggests that much of this lime-rich succession has been diagenetically altered in the Coega area so that most new excavations expose few or no fossils of value. Unless rich fossil remains, such as seen at the main Coega limestone quarry, are encountered during excavation, palaeontological mitigation is therefore not automatically recommended in the case of the Alexandria Formation (Note that this unit covers a large percentage of the Coega IDZ).

Palaeontological mitigation generally concerns the construction phase rather than the operational phase of a development, unless this development involves ongoing excavation of bedrock (*eg* mining). Where it is recommended, mitigation by a qualified palaeontologist should entail (a) the field examination of new bedrock excavations, (b) the recording of sedimentological and palaeontological data, (c) the judicious sampling of fossil material and (d) recommendations for any further action required to safeguard fossil heritage. It is important that the opportunity to mitigate is given while the bedrock excavations are fresh and *before* they are infilled, covered over or degraded by weathering and plant growth. Before development starts a realistic programme of mitigation should therefore be negotiated between the developer and the palaeontologist contracted for the project to maximize the scientific and conservation benefits of the work while minimizing disruption of the construction programme.

Environmental control officers responsible for developments within the Coega IDZ should: (a) be alerted to the palaeontological sensitivity of several geological units in the area, (b) familiarize themselves with the sort of fossils that might be encountered during development through museum displays and using this report, and (c) alert SAHRA and a professional palaeontologist should significant fossil remains be exposed during excavations.

Ten localities of exceptional geological or palaeontological interest within or very close to the Coega IDZ - Geosites GS1 to GS10 - have been listed in Table 2. The table outlines their scientific interest and makes more or less specific recommendations for action in each case. In general, these sites should be safeguarded from development as far as possible. Any unavoidable development directly affecting these sites will require palaeontological mitigation which should be commissioned in the planning stage before development commences.

It must emphasized that management and conservation of palaeontological heritage within the Coega IDZ must extend beyond the protection of the handful of geosites listed in Table 2. Palaeontological heritage is not site-specific but related to entire geological units (*eg* formations). The distribution of these formations is indicated on published geological maps (*e.g.* 1: 50 000 scale maps) and these must be consulted in conjunction with the present report in order to assess the necessity for palaeontological mitigation for a particular development.

Given the palaeontological interest of the Coega region and the number of large scale bedrock excavations being carried out within the Coega IDZ, or envisaged for the future, it is recommended that a palaeontologist be commissioned by the Coega Development Corporation to briefly review potential or actual impacts on palaeontological heritage here once a year. This work would probably entail a one- to two-day site visit, a review of relevant background documentation for future projects and written report for the Coega Development Corporation and SAHRA.

Fossil heritage in the Coega area has considerable educational potential for schools, universities and the general public. It is therefore recommended that the Coega Development Corporation consider establishing a small, informative display of local fossils with suportig materials (*e.g.* maps, reconstructions, leaflet). This educational project would also provide a useful resource for training ECOs involved in developments in the Coega IDZ and would benefit from collaboration with concerns outside the Coega IDZ such as nearby brick pits.

Structure of this report

The palaeontological heritage of the ten different sedimentological units represented in the Coega IDZ – as shown on geological maps - is briefly outlined in **Section 1**. The stratigraphic position and age of these units is shown in Fig. 1. Their distribution within the Coega region is shown in the geological map in Fig. 2.

Section 2 introduces the geology of the study area, lists the handful of fossil heritage impact studies that have already been conducted here, and outlines the scope of work for the present palaeontological heritage review.

The fossil heritage within each sedimentary formation within the Coega IDZ is described in more detail in **Section 3** on the basis of (a) the palaeontological literature and (b) field observations made during the present field study.

Section 4 includes a summary of the estimated palaeontological sensitivity of each geological unit at Coega, based on the literature and recent fieldwork. Recommendations for palaeontological mitigation required in the case of future developments that may intersect these formations are summarized in Table 1. A list of proposed geosites warranting special protection is provided in Table 2.

Extensive references to the geological and palaeontological literature relevant to the Coega area are given in **Section 5**.

A tabulation of geological and fossil sites examined in the course of fieldwork, together with their GPS co-ordinates, is presented in the **Appendix**.

NB **This report needs to be read and used in conjunction with the published geological maps of the Coega area listed in Section 2. A small scale map of the Coega IDZ provided by the Coega Development Corporation (Pty) Ltd is included at the end of the report.**

1. Summary of Coega IDZ palaeontological heritage

The Coega IDZ is situated inland of Algoa Bay about 20km to the northeast of Port Elizabeth (Eastern Cape Province). The area is underlain by a wide spectrum of sedimentary rocks that span an age range of some 470 million years. These sediments are assigned to the Palaeozoic **Table Mountain Group**, the Mesozoic **Uitenhage Group** and the Caenozoic **Algoa Group** *plus* unnamed alluvial deposits of Tertiary / Quaternary age. They have been geologically mapped at 1: 250 000 and 1: 50 000 scales. Most of the rock units contain fossil heritage of some sort but in most cases this is very limited. The notable exceptions are three marine successions – the Sundays River Formation of Early Cretaceous age (*c*. 136 Ma = million years old), the Alexandria Formation of Miocene / Pliocene age (*c*. 7-5 Ma), and the Salnova Formation of Mid Pleistocene to Holocene age (< 1 Ma). Levels of bedrock exposure within the Coega IDZ are generally very low due to extensive cover by superficial drift (*e.g.*soil, alluvium, *in situ* weathering products) as well as by surface calcrete (pedogenic limestone) and dense vegetation. Man-made excavations such as road and railway cuttings, stormwater drainage channels, reservoirs and quarries, of which there are a considerable number within the Coega IDZ, often provide the best opportunities to examine and sample fresh, potentially fossiliferous bedrock.

Fluvial quartzites of the Mid to Late Ordovician **Peninsula Formation** (**Op**) (Table Mountain Group) crop out only at Coega Kop where they are extensively quarried for building and road material. A limited range of trace fossils (*e.g.*burrows, trackways) are recorded from this unit elsewhere within the Cape Fold Belt and its overall palaeontological sensitivity is low.

Two Early Cretaceous formations within Uitenhage Group – the Kirkwood and Sundays Formations - underlie most of the Coega IDZ at depth but are often mantled by younger Algoa Group rocks. They occur at or near the surface along the margins of the Coega River Valley and its northern tributary the Brakrivier (Small coastal outcrops are also known, *e.g.* at Hougham Park). Levels of exposure are very low, with the exception of a few erosional gullies, clay quarries (mostly disused and overgrown) *plus* new and old road and railway cuttings. The fluvial to estuarine **Kirkwood Formation** (**J-Kk**) of the Algoa Basin consists of multi-hued, reddish-brown to grey-green mudrocks with subordinate greenish-grey sandstones. The formation has a moderate to high (occasionally very high) palaeontological sensitivity. It is famous for its plant fossils - mainly gymnosperms and ferns, including locally abundant petrified wood - as well as its rare but palaeontologically significant dinosaur remains. The Kirkwood dinosaur fauna includes a small range of gigantic sauropods, juvenile iguanodonts, stegosaurs and small-bodied theropods. Most species are only known from isolated bones and teeth, however. Apart from a single small fragment of bone, no fossils were recorded from the Kirkwood Formation during this study. Extensive recent excavations into these beds for stormwater channels in IDZ Zone 5 and new road cuttings west of Coega (not to mention large cuttings in the Portnet area) were not checked for fossil material while they were still fresh – an unfortunate lost opportunity in palaeontological heritage terms.

Grey to greenish-grey mudrocks and subordinate calcareous sandstones of the **Sundays River Formation** (**Ks**) were laid down in a range of estuarine to offshore marine shelf settings. Of the dozen or more natural and artificial exposures of these sediments examined within the Coega IDZ, mostly along the eastern escarpment of the Coega River Valley, almost all yielded a range of shelly invertebrate fossils. The palaeontological sensitivity of this

formation is therefore rated as high (*NB* Huge numbers of scientifically valuable fossils are inevitably lost during brick making in the Swartkops and Coega Valleys on the outskirts of the IDZ). The Sundays River fossil faunas mainly consist of concentrations of thick-shelled bivalve mollusks (*e.g.*free-living and cemented oysters, strongly ornamented trigoniids, large elongate girvillellas) together with much rarer gastropods and ammonites and locally abundant trace fossil assemblages within non-calcareous silty sandstones. Apart from spirorbid worm tubes, the majority of the shelly fossils occur within dense shell beds (*coquinas*) at the base of storm-generated sandstones. It is noteworthy that several previously unrecorded invertebrate groups have recently been discovered within the Sundays River Formation of the Coega IDZ region. These include current-orientated scaphopod mollusks (tusk shells) from Bontrug 301 (IDZ Zone 14) collected by the author during this study and fossil crabs embedded, together with fine plant debris, in rich calcareous nodules from the main Coega brick pit (pers. comm., Dr Billy de Klerk, Albany Museum, Grahamstown, 2010). The new Bontrug fossil site also yields thin sandstones containing carpets of well-preserved nuculid and other bivalves as well as abnormally high concentrations of small branching corals (probably reworked) associated with a peculiar pebbly conglomeratic bed.

Five separate formations of the Late Caenozoic Algoa Group are mapped within the study area. Their geological complexity reflects deposition during an interval of fluctuating climate, global sea levels and episodic uplift of the South African subcontinent. Limestone-rich estuarine to coastal marine sediments of the **Alexandria Formation** (**Ta**) overlie the greater part of the Coega IDZ, with an average thickness of 7-10m. Locally they contain a rich diversity - over two hundred taxa - of Miocene / Pliocene marine fauna. These are mainly bivalves and gastropods, but there is also a wide range of rarer groups such as flat sea urchins ("sea pansies"), corals, brachiopods (lamp shells), barnacles, crabs and sharks' teeth. Several of the most prolific collecting localities for the Alexandria fauna that are mentioned in the palaeontological literature are situated within the Coega IDZ, but most of these are shallow, abandoned and overgrown quarries that no longer yield abundant fossil material. One officially designated stratotype locality for the Alexandria Formation east of Coega has already been destroyed by new road development. In both palaeontological and sedimentological terms, the most interesting exposures of the Alexandria Formation by far are seen in the upper (limestone) quarry at Coega. A wide range of sedimentary facies (rock types) are seen here, including cross-bedded channeled conglomerates, flat-bedded beach sands, coquinites (fine shell hash) and probable estuarine muds, among others. Unfortunately, many of these features are already being covered over by ongoing quarry rehabilitation. The conglomeratic basal portion of the Alexandria succession, here as elsewhere, is typically rich in disarticulated fossil oysters and other robust mollusc shells (*e.g.Glycimeris*, cowries and large gastropods). In the Grassridge area (IDZ Zone 14) the basal conglomerate sometimes consists largely of fossil oyster shells. The Alexandria Formation is also very rich in trace fossils of various sorts. Laminated beach sands are frequently riddled with invertebrate burrows, such as the distinctive pellet-lined crustacean burrow *Ophiomorpha* that is well seen at the main Coega limestone quarry as well as at the NW end of the stormwater channel running beneath the N2 in IDZ Zone 5. Elegant vase-shaped cavities (*Gastrochaenolites*) were excavated into the firm sea bed by boring bivalves following the initial transgression of the Miocene seas across the Algoa coastal plain. They are well seen at the contact of the Alexandria and Sundays River Formations in the main Coega quarry as well as the Alexandria / Kirkwood contact in the railcutting north of the N2 (Zone 5). A remarkable range of delicate borings made by sponges, polychaetes and other invertebrates are preserved in exquisite detail in shell moulds that are embedded within

upturned blocks of basal Alexandria conglomerate near the western edge of the Coega limestone quarry. These blocks are the subject of ongoing research by Dr Billy de Klerk and colleagues and need to be safeguarded.

Despite its unusally rich fossil record, in practice the palaeontological sensitivity of the Alexandria Formation is very variable, ranging from high to low. Apart from the more robust species such as oysters and *Glycimeris*, many fossil shells are fragmentary and unidentifiable. Examination of several deep stormwater drainage trenches and reservoirs within the Coega IDZ shows that usually much of the succession has been secondarily calcretised by circulating groundwater, normally destroying most fossil remains in the process. They are sometimes preserved as fossil moulds (impressions) and occasionally coquinites with scattered, well-preserved shells are found. On the whole, however, the impact of these voluminous stormwater trenches and reservoirs on Alexandria palaeontological heritage appears to be remarkably low.

Karstic (*i.e.* solution) weathering of the extensive Alexandria Formation limestone plateau has led to the formation of a distinctive reddish-brown, pebbly residual soil that was previously assigned to a separate stratigraphic unit, the so-called **Bluewater Bay Formation** (**T-Qb**). It infills numerous solution cavities in the upper surface of the Alexandria limestones and on the 1: 250 000 Port Elizabeth geological sheet it is mapped across large expanses of the IDZ. The only fossils recorded from this unit so far are sparse freshwater mussels and land snails. NE-SW trending zones of larger-scale (*c*. 50-100m) depressions known as *dolines* are clearly seen in aerial and satellite images as rounded grassy patches within darker thicket vegetation. These features are also formed by solution of the underlying limestone, are often infilled with clay-rich soils and may form pans after rain. New road construction in Coega IDZ Zone 6 has transected one of these deep doline infills which comprises several meters of dark, mottled soil with carbonaceous plant rootlets. Moist grassy pans might be expected to attract game, but no mammal bones or teeth were observed within the doline infill.

The youngest highly fossiliferous marine succession within the Coega IDZ is the **Salnova Formation** (**Qs**) of Mid Pleistocene to Recent age. It crops out intermittently along the coastline from the Marine Growers abalone farm northeastwards to Mellville. The formation comprises a spectrum of well-indurated sandy and conglomeratic beach deposits that form low rocky benches close to modern sea level and are locally rich in marine shell remains. A geologically important stratotype section for the Salnova Formation has been identified at Hougham Park . Here the conglomeratic and sandy Salnova beds unconformably overlie the Sundays River Formation and are overlain in turn by consolidated aeolianites of the Nahoon Formation. A comparable (but even larger) range of marine invertebrates to that seen in the older Alexandria Formation has been recorded from the Salnova Formation. However, many of these taxa are mainly found in finer-grained, estuarine facies that are not well exposed in the Coega IDZ itself (Some are seen at the important stratotype locality for this formation located within the Portnet area near the Salnova saltworks). The majority of the Salnova fossil and subfossil species are still alive, though some warm-loving species like the gigantic “geoduck” clam *Panopea* no longer occur naturally in the Algoa Bay area. The overall palaeontological sensitivity of the Salnova Formation is judged to be high, although many occurrences are not especially shell-rich or contain mainly fragmentary remains.

Three separate successions of calcareous dune sands (*aeolianites*) are recognized within the upper part of the Algoa Group. For the most part these sediments contain only sparse fossil remains – notably several extant genera of land snails such as *Achatina* and *Tropidophora* –

and their overall palaeontological sensitivity is low. The oldest, and topographically most elevated, aeolianites are assigned to the **Nanaga Formation** (**T-Qn**) of Pliocene to Early Pleistocene age. They are usually semi-consolidated, are often stained a deep reddish-brown and may show large scale dune cross-bedding (excellent examples are seen in N2 roadcuts between Colchester and Grahamstown). Recent re-mapping of the Coega IDZ has revealed a narrow band of Nanaga sands overlying Alexandria Formation limestones inland of the modern dune cordon. Deep trenching through surface calcretes near Hougham Park has exposed spectacular vertical sections through column-like megarhizoths - the densely concentrated, calcretised root casts of dune plants (*e.g.*shrubs, small trees). These trace fossils are embedded within pale brown, unconsolidated dune sands that are mapped within the Nanaga Formation. Possible calcretised termite nests with a spongy fabric are also seen here. Several genera of fossil land snails, including *Achatina*, *Tropidophora* and probable *Natalina* are abundant within the sandy matrix. Relict patches of more typical, orange-red Nanaga aeoliantes are scattered further inland across the Alexandria Formation and older rocks. An example is seen near the western entrance to the main Coega brick quarry; here partially calcretised and apparently unfossiliferous orange-hued aeolianites overlie pebbly conglomerates of “Bluewater Bay” – type facies.

Small exposures of Mid to Late Pleistocene aeolianites of the **Nahoon Formation** (**Qn**) are currently only mapped just east of the Coega River mouth, within the Portnet area. These outcrops may well have been obliterated by later development at the Ngqura Port. However, further, more extensive representatives of the Nahoon Formation have been identified during this study in the Sea Arc / Marine Growers region as well as directly overlying the Salnova Formation stratotype E succession at Hougham Park and further northeastwards along the coast. Here buff, well-consolidated aeolian sands situated just a few meters above sea level contain abundant terrestrial snail shells (*Achatina*, *Tropidophora*), occasional storm-tossed coquinite intraclasts and sparse marine shells (*e.g.Turbo*, oysters). Embedded within them are sparse human artifacts of quartzite, some of which are referable to the Middle Stone Age (Dr Lita Webley, pers. comm., 2010). The Nahoon beds are planed off by a well-developed wave-cut platform (possibly reflecting the Eemian sea level highstand during the last interglacial, *c*. 120 000 BP) and are overlain by ancient storm beach gravels and younger dunes of the Schelm Hoek Formation. Low coastal cliffs towards Mellville are built of several cycles of Nahoon Formation dune sands separated by palaeosols and contain pervasive calcretised rhizoliths.

Unconsolidated to semi-consolidated, well-vegetated dune sands along the modern coastline of Algoa Bay are assigned to the **Schelm Hoek Formation** (**Qw**). Good examples of vertically sectioned dunes showing large scale aeolian cross-bedding are seen in the active sand quarries near the Sea Arc factory site and at Sonop (Coega Zone 10). Apart from the usual concentrations of wind-deflated dune snails (notably superabundant *Tropidophora* and *Natalina* here), a range of subfossil remains can be seen, especially in deflation hollows. Among these are millipede exoskeletons, small mammal and reptile bones, fragments of charcoal, buried mats of plant roots and incipient rhizocretions . Shell middens of oysters and other edible marine shells situated close to the shoreline are attributable to Late Stone Age (and probably later) humans and will be considered in more detail under archaeological heritage.

A range of elevated river terrace and channel conglomerates (Pliocene / Pleistocene High Level Gravels) and younger silty alluvial deposits at low elevations occur along both sides of the Coega River Valley. So far they have proved unfossiliferous.

2. Introduction, previous studies and brief

The Coega IDZ is situated on the coastal plain inland of Algoa bay *c.* 15-25km to the northeast of Port Elizabeth, Eastern Cape Province. The area comprises a low-relief coastal plateau mantled by sand dunes along the coast and traversed by the shallow NW-SE valley of the Coega River and its tributaries (*e.g.*dry valley of the Brakrivier). The only prominent topographic feature is the rugged quartzitic hill of Coega Kop (146 m asl).

Apart from the modern coastal sand dunes, most of the Coega IDZ landscape is mantled by dense vegetation – primarily mesic succulent Sundays Thicket along the valley slopes and drier Coega Bontveld on the calcareous plateau. Natural exposures of bedrock are therefore confined to occasional erosional dongas and low limestone cliffs along the steeper Coega Valley sides, small craggy outcrops on Coega Kop, as well as narrow rocky benches, low calcareous sandy cliffs and dunes in the coastal zone. Fresh exposures of the older geological units are for the most part only found in roadcuts, borrow pits, limestone quarries and clay-pits, as well as an extensive network of storm water channels and reservoirs. Most of these excavations have been made in recent years following the establishment of the Coega IDZ. Older excavations such as clay pits and limestone quarries, several of which have yielded important fossil material in the past, are in many cases already overgrown and difficult to access. Ongoing rehabilitation involving infilling of many of these excavations with rock waste, rubble and cleared vegetation further restricts opportunities to study the bedrock and to record fossils.

The geology of the Coega IDZ has been mapped at 1: 250 000 scale (sheet 3324 Port Elizabeth) and, more recently, at 1: 50 000 scale (sheets 3325DA Addo, 3325DC & DD, 3425 BA Port Elizabeth). Geological explanations to these maps, including brief palaeontological data, are provided by Toerien and Hill (1989) and Le Roux (2000) respectively. Older sheet explanations by Haughton (1928) and Engelbrecht *et al.* (1962) are also relevant, as is the unpublished report on the geology of the Coega IDZ by Goedhart and Hattingh (1997).

The Coega IDZ is entirely underlain by a range of terrestrial, coastal and marine sedimentary rocks that extend from modern times back to the Early Cretaceous Period, some 470 or so million years ago (Figs. 1, 2). These sediments are assigned to three major geological successions: (1) the Early Palaeozoic **Table Mountain Group** comprising Ordovician (*c*. 450 Ma) fluvial sandstones and quartzites of the Peninsula Formation that are only seen at Coega Kop; (2) the Mesozoic **Uitenhage Group** that was deposited within the Algoa Basin in a range of fluvial, estuarine and shallow marine settings during the Late Jurassic to Early Cretaceous Periods (*c*. 150-130 Ma), and (3) the Late Caenozoic **Algoa Group** that accumulated along the coast of Algoa Bay over the last seven million years in estuaries, lagoons, rocky and sandy shores, and aeolian dune fields. A rich fossil record has been found in several of the marine sedimentary formations found here, notably the Early Cretaceous Sundays River Formation, the Late Tertiary Alexandria Formation, and the Pleistocene Salnova Formation. The terrestrial formations tend to be far less fossil rich on the whole, but important fossil material – notably dinosaurs and plants in the Early Cretaceous Kirkwood Formation – may potentially be found here as well.

The distribution of outcrops of these various sedimentary formations are outlined in the published 1: 250 000 geological map sheet 3324 (Fig. 2). Please note that modifications to this map are shown in the more recent and detailed 1: 50 000 scale geological maps listed above which should be used in conjunction with this report.

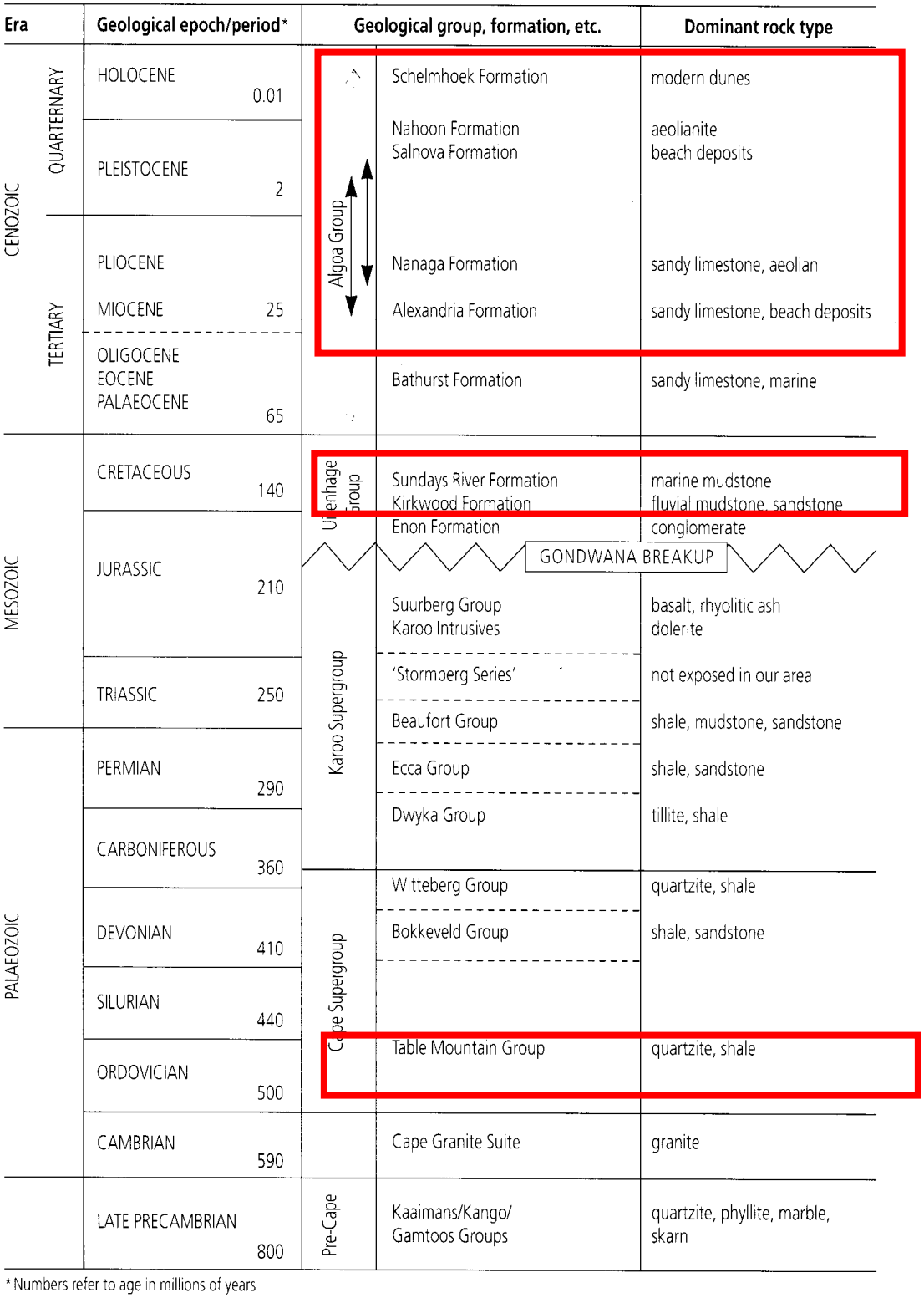

Fig. 1. Stratigraphic table of geological units represented on the South Coast of th Eastern Cape (modified from Rust 1998). The three main sedimentary successions that occur within the Coega IDZ – the Table Mountain, Uitenhage and Algoa Groups - are outlined in red. Note that these successions are separated by significant time gaps of tens to hundreds of millions of years.

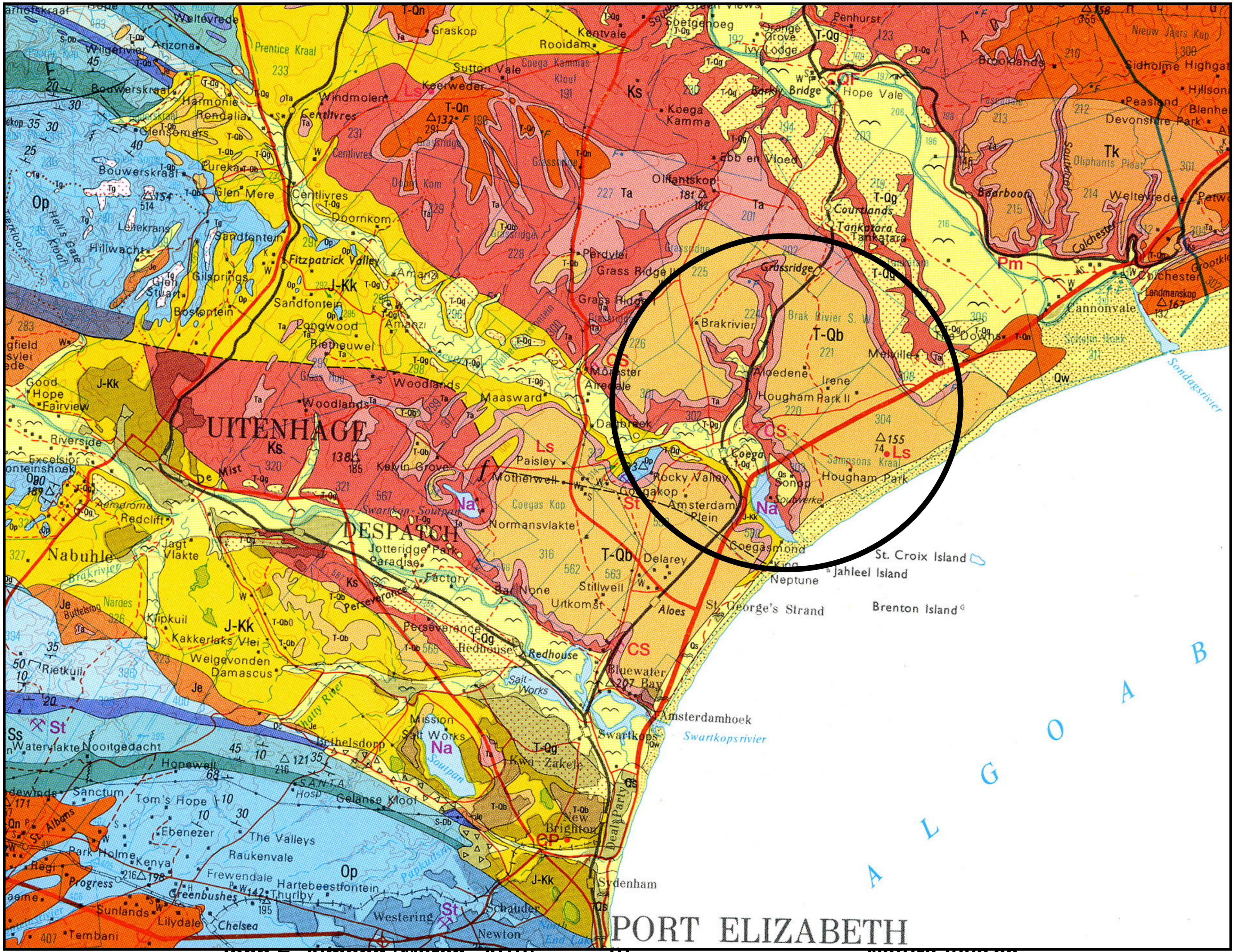
UITENHAGE
DESPATCH
PORT ELIZABETH
ALGOA B
Weltevrede
Arizona
Wilgerivier
Bouwerskraal
Harmonie
Rondalia
Glensomers
Eureka
Glen Mere
Leliekrans
Hillwacht
Sandfontein
Gilsprings
Glen Stuart
Bostontein
Graskop
Kentvale
Rooidam
Sutton Vale
Keerweder
Windmolen
Centlivres
Prentice Kraal
Doornkom
Fitzpatrick Valley
Amanzi
Longwood
Rietheuwel
Woodlands
Maasward
Koega Kamma
Ebb en Vloed
Olifantskop
Perdvlei
Grass Ridge
Grassridge
Brakrivier
Monster
Aloedene
Irene
Hougham Park II
Hougham Park
Sampsons Kraal
Coega
Rocky Valley
Coegakop
Amsterdam Plein
Coegasmond
Sonop
Soutwerke
Paisley
Motherwell
Coegas Kop
Normansvlakte
Delarey
Stillwell
Uitkomst
Bar None
Aloes
St. George's Strand
Neptune
St. Croix Island
Jahleel Island
Brenton Island
Bluewater Bay
Amsterdamhoek
Swartkops
Swartkopsrivier
Redhouse
Hedhouse
Perseverance
Factory
Jotteridge Park
Paradise
Kelvin Grove
De Mist
Kakkerlaks Vlei
Welgevonden
Damascus
Klipkuil
Nabuhle
Redcliff
Jagt Vlakte
Riverside
Excelsior
Good Hope
Fairview
Rietkuil
Waterylakte
Nooitgedacht
Hopewell
Sanctum
Tom's Hope
Ebenezer
The Valleys
Raukenvale
Frewendale
Hartebeestfontein
Greenbushes
Thurlby
Chelsea
Westering
Schauder
Newton
Sunlands
Lilydale
Tembani
Progress
Kenya
Park Holme
St. Albans
Gelanse Kloof
Bethelsdorp
Mission
Salt Works
Kwa-Zakele
New Brighton
Sydenham
Deal Party
Salt Works
Penhurst
Soetgenoeg
Orange Grove
Ivy Lodge
Barkly Bridge
Hope Vale
Courtlands
Tankatara
Brooklands
Sidholme
Highgate
Hillsons
Peasland
Devonshire Park
Baarboom
Weltevrede
Colchester
Cannonvale
Landmanskop
Melville
Dows
Nieuw Jaars Kop
Sondagsrivier
T-Qb
T-Qg
T-Qn
J-Kk
Ks
Ta
Tk
Op
Je
Qw
Qs
Na
Ls
St
CS
CP
Pm

Fig. 2 (preceding page). Extract from 1: 250 000 scale geological sheet 3324 Port Elizabeth (Council for Geoscience, Pretoria, 1991). The position of the Coega IDZ is very approximately indicated by the black circle (See also map of the Coega IDZ at the end of this report).

The outcrops of major stratigraphic units are shown including the Peninsula Formation (Op, pale blue), Kirkwood Formation (J-Kk, yellow), Sundays River Formation (Ks, cerise), Alexandria Formation (Ta, pink), "Bluewater Bay Formation" (T-Qb, buff) and coastal dune sands (Qw, pale yellow). Note that later 1:50 000 scale mapping has considerably refined this scheme. For example, the Bluewater Bay Formation is no longer regarded as a separate formation but as a residual soil developed on the Alexandria Formation. Outcrops of Sundays River Formation are now recognized on the southern margins of the Coega River Valley. Tertiary / Quaternary aeolianites of the Nanaga Formation (T-Qn, orange) are now mapped inland of the modern dune sands along the coast of the Coega IDZ.

2.1. Previous palaeontological heritage studies in the Coega IDZ

Fossil collections have been made by a number of previous workers from sediments of the Mesozoic Uitenhage Group and the Caenozoic Algoa Group in the Coega coastal region between the Swartkops and Sundays Rivers. Extensive references to earlier palaeontological work are given by Engelbrecht *et al*. (1962), Cooper (1981) and in Sections 3 and 5 of this report. Much of this fossil material is now in the collections of the Albany Museum, Grahamstown and Iziko: South African Museum, Cape Town. Brief reference to fossil biotas within all the various formations occurring in the study area is made in the very useful report on the geology of the Coega river mouth and adjacent IDZ by Goedhart and Hattingh (1997) as well as in the relevant geology sheet explanations (Engelbrecht *et al*., 1962, Toerien & Hill 1989, Le Roux 2000).

To the author's knowledge, only a handful of palaeontological impact studies have been carried out within the Coega IDZ so far, despite the considerable level of recent, ongoing and proposed development in this area. These studies are mostly very brief and comprise the following:

- A palaeotological impact assessment of the administration craft basin area and the additional container berths area in the Port of Ngqura by Dr Billy de Klerk (2007). Note that this report is extremely brief (two pages) and does not aim to assess the whole Portnet area in palaeontological heritage terms. For example, it does not cover the substantial recent cuttings into the Kirkwood Formation along the western edge of the Coega estuary, small outcrops of Nahoon Formation aeolianites just east of the Coega River Mouth (perhaps since destroyed by development), and key exposures of the Salnova Formation on the eastern side of the estuary that were formally designated as one of the stratotypes of this sedimentary unit by Le Roux (1991).

- A short (four-page), undated palaeontological impact assessment by Robert Gess for a proposed chlor-alkali and salt plant in the coastal zone (Algoa Group) whose precise location is unclear since there is no map.

- A 2001, ten-page desktop study for a proposed electrical transmission line between Poseidon Substation and Grassridge Substation, the latter lying within the northern IDZ. The report (without figures) is available on the Internet but the authorship is unclear.

- Two short (9-10pp) desktop studies by the present author dated 2008 for proposed developments in Zone 6 of the Coega IDZ (Exxaro Alloystream Managanese Project and Kalagadi Manganese Smelter).

2.2. Scope of work for this study

The present palaeontological heritage assessment was commissioned as part of a comprehensive heritage assessment of the Coega IDZ by Eastern Cape Heritage Consultants cc (Jefferies Bay) on behalf of the Coega Development Corporation (Pty) Ltd. The agreed scope of work for the present palaeontological heritage study was defined as follows:

Phase 1 – preparation

preparation of desktop study on fossil heritage of study area based on:

- review of all relevant palaeontological and geological literature, including geological maps, previous reports
- location and examination of fossil collections from study area
- data on proposed development provided by the developer

Phase 2 – fieldwork

- detailed field examination of representative natural and artificial exposures of potentially fossil-bearing sediments
- recording of observed fossils and associated sedimentological features of palaeontological relevance (photos, maps, aerial or satellite images, GPS co-ordinates, stratigraphic columns)
- judicious sampling of fossil material, where warranted

Phase 3 – curation & analysis

- curation in an approved respository (museum or geological survey collection) of any fossil material collected
- photography and provisional identification of fossils
- analysis of stratigraphy, age and depositional setting of fossil-bearing units

Phase 4 – final report & feedback

- illustrated, fully-referenced review of palaeontological heritage within study area based on desktop study and new data from fieldwork and analysis
- identification and ranking of highlights and sensitivities to development of fossil heritage within study area
- specific recommendations for further palaeontological mitigation (if any)
- recommendations and suggestions regarding fossil heritage management on site, including conservation measures as well as promotion of local fossil heritage (*e.g.*for public education, schools)

During the course of the present field study, carried out over ten days in February – March 2010, over one hundred natural and artificial exposures of sedimentary rocks within or very close to the Coega IDZ were examined for palaeontological heritage (see Appendix). The land administered by PortNet (Nguqura Port, Coega estuary and adjacent coastal areas) as well as private Offit land embedded within IDZ Zone 14 were specifically excluded from the present study. However, an abandoned clay pit and a shallow limestone quarry within the Offit land was visited for comparative purposes.

3. Palaeontological heritage of Coega IDZ formations

NB Please refer to the Appendix for GPS co-ordinates of the localities mentioned in the text.

3.1. TABLE MOUNTAIN GROUP

The Palaeozoic Table Mountain Group underlies much of the Port Elizabeth area. It is represented within the Coega IDZ only by the Peninsula Formation which forms Coega Kop as well as several small islands offshore (Jahleel, St Croix and Brenton).

3.1.1. Peninsula Formation (Op)

The Peninsula Formation is a predominantly fluvial succession of Mid to Late Ordovician age (c. 450-470 Ma) with minor shallow marine to estuarine intercalations. It was laid down by extensive networks of braided streams on the margins of the ancient Supercontinent Gondwana ((Broquet 1992, Hiller 1992, Thamm & Johnson 2006). The Peninsula Formation succession consists of pale grey, massive (*ie* unlaminated) to flat- and cross-bedded sandstones and quartzites (*ie* well-cemented sandstones) with minor quartz pebble conglomerates and occasional thin (<1m), lenticular mudrocks.


h

Fig. 3. Major quarry exposure of pale quartzites of the Peninsula Formation at Coega Kop. Potentially fossiliferous mudrocks or heterolithic units (interbedded sandstones and mudrocks) are not seen here.

Largely due to its great age and terrestrial setting, the fossil record of the Peninsula Formation is very sparse and its palaeontological sensitivity is correspondingly low (Almond *et al*., 2008). Body fossils (shells, bones *etc*) are unknown from this formation, although impressions of rounded mudflakes and fossil trackways have occasionally been

misinterpreted as moulds of shells. So far only a modest range of trace fossils (*ie* fossilized burrows, tracks *etc* – records of past animal behaviour) have been recorded from the Peninsula Formation, mostly in association with heterolithic subunits (*ie* interbedded sandstones and mudrocks) that are attributed to shallow marine or estuarine settings. They include Ordovician forms of the trilobite burrow *Cruziana* (*Rugosa* Group), arthropod trackways attributed to trilobites and water scorpions (eurypterids), complex annulated "worm burrows" of the ichnogenus *Arthrophycus*, a small range of horizontal burrows (*Palaeophycus etc*), *Skolithos*-dominated "pipe rock", and the large (up to 25cm wide) cyclindrical burrow *Metaichna* (Almond 2008c). Recent work on comparable Early Palaeozoic trace fossil assemblages suggests that they formed in estuarine as well as fully marine settings (Buatois & Mangano, 2007). Age-diagnostic organic-walled microfossils such as acritarchs are likely to occur in finer mudrocks within the marine-influenced, heterolithic parts of the succession, but these fossils have yet to be successfully isolated.

3.1.2. Peninsula Formation in the Coega IDZ

Within the Coega IDZ the Peninsula Formation is only exposed in small craggy outcrops on the slopes and peak of Coega Kop (Loc 111) as well as in various large quarries excavated into its slopes (Figs. 3 and 4). Note that Coega Kop would have formed an offshore island, comparable to the modern St Croix and neighbouring islands, when the Algoa Basin was flooded by shallow seas in the Late Tertiary (Alexandria Formation) times. Large storm quartzite boulders whose surfaces are covered with percussion marks pointing to a high energy storm beach setting can still be seen on the slopes of Coega Kop (Fig. 63). Brief inspection of Peninsula Formation quartzites on the slopes of Coega Kop did not reveal any fossils. Given the low palaeontological sensitivity of this unit, and its huge outcrop area within the Cape Fold Belt, no special palaeontological mitigation is recommended. Analysis of any dark, freshly-exposed mudrocks for microfossils may prove worthwhile in future.

Fig. 4. Craggy outcrops of Peninsula Formation quartzites on Coega Kop (NE peak).

3.2. UITENHAGE GROUP

The Uitenhage Group is a 3.5km thick succession of Mesozoic fluvial, estuarine and marine sediments spanning the Late Jurassic to Early Cretaceous Periods (*c.* 150-125 Ma). It is best represented on land in the Algoa Basin as well as on the adjacent continental shelf (Shone 2006; Figs. 5, 6 and 7).

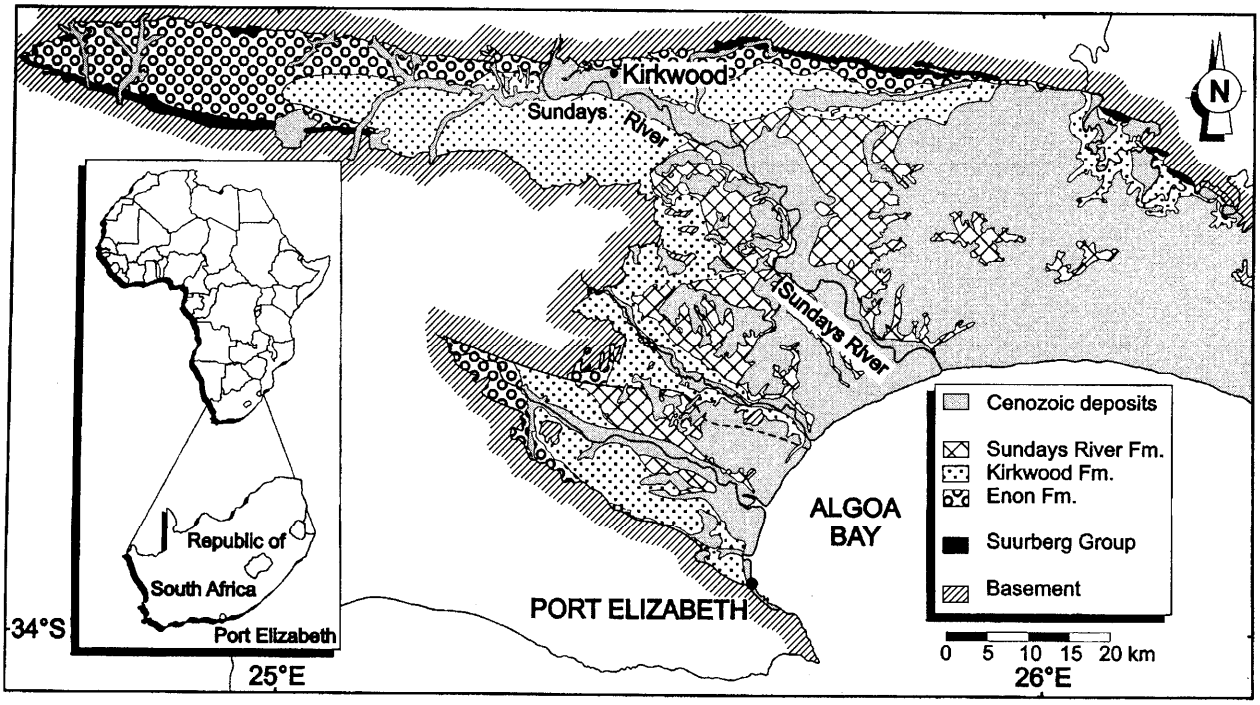

Fig. 5. Outcrop map of the main formations of the Mesozoic Uitenhage Group within the Algoa Basin (From Gomez *et al.,* 2006b). Note the extensive cover by Late Caenozoic sediments of the Algoa Group close to the coast.

3.2.1. Kirkwood Formation (J-Kk)

The Kirkwood Formation in the Coega IDZ area comprises readily-weathered silty mudrocks and subordinate sandstones of fluvial origin and Early Cretaceous (Berriasian / Valanginian) age that crop out along the southwestern slopes of the Coega River Valley. Key geological accounts include those by Rigassi & Dixon (1972), Winter (1973), McLachlan & McMillan (1976), Tankard *et al.* (1982), Dingle *et al.,* (1983) and Shone (1976, 2006). Early geologists called these rocks the "Variegated Marls" referring to the distinctive reddish-brown, pinkish and greenish-grey colour spectrum shown by the sediments (*NB* "marl" is a misnomer, technically referring only to calcareous, clay-rich mudrocks). Another older name for the same succession was the "Wood Beds", referring to the abundant petrified wood recorded in the Algoa Basin and elsewhere (see fossil record below).

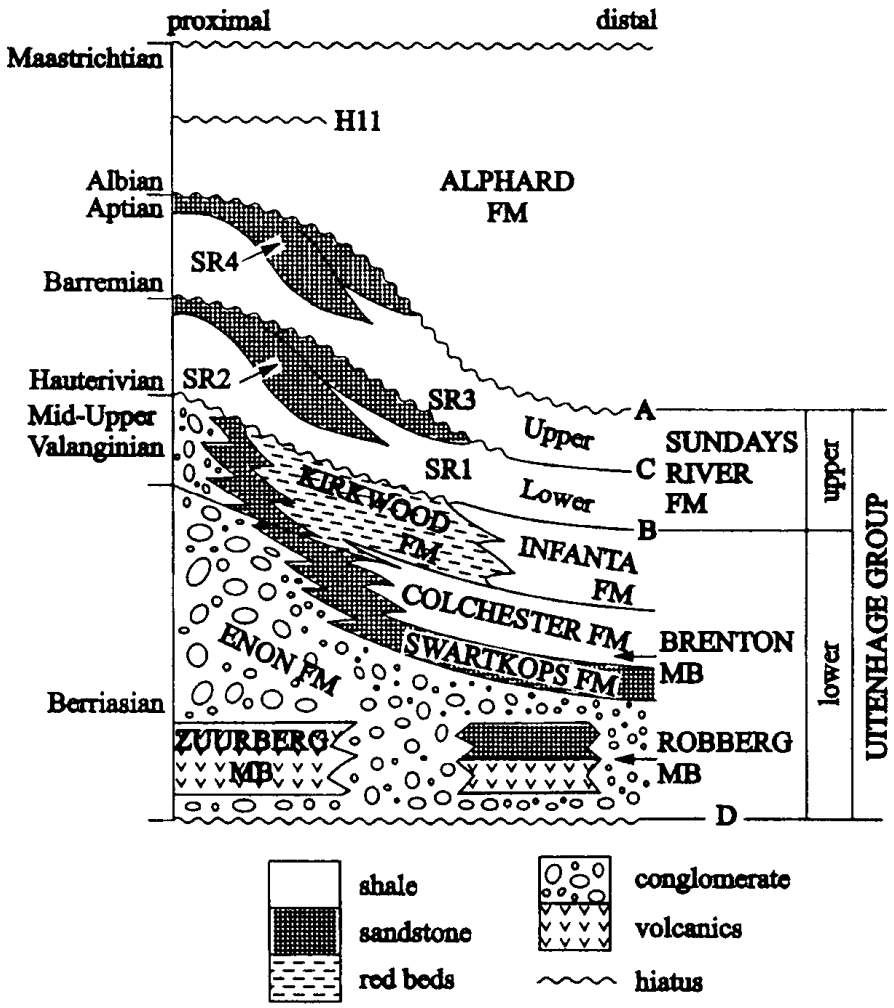

Fig. 6. Stratigraphic column for the Uitenhage Group. Only the Early Cretaceous Kirkwood and Sundays River Formations occur near surface within the Coega IDZ (From Gomez *et al.,* 2006b). The stratigraphical relationships between the various formations and their ages are still under discussion.

At the time that these Uitenhage sediments were being deposited, some 140 million years ago, Africa and South America – previously united within the West Gondwana supercontinent - were starting to pull apart. Uplift, faulting and erosion of the youthful southern African continent led to the rapid deposition of huge amounts of alluvium by systems of meandering rivers and estuaries fringing a new Mediterranean-sized seaway that was opening up in the southern Cape area (Fig. 7). Well-preserved calcrete-rich palaeosols (fossil soils) within the Kirkwood alluvium suggest that prevailing climates were semi-arid, warm to hot, with a low seasonal rainfall of 100-500mm / year (Frost 1996; Fig. 13a). This pattern is supported by the abundance of leathery- and small-leaved plants in the fossil flora, while well-developed seasonal growth rings are preserved in at least some fossil woods (Fig. 8).

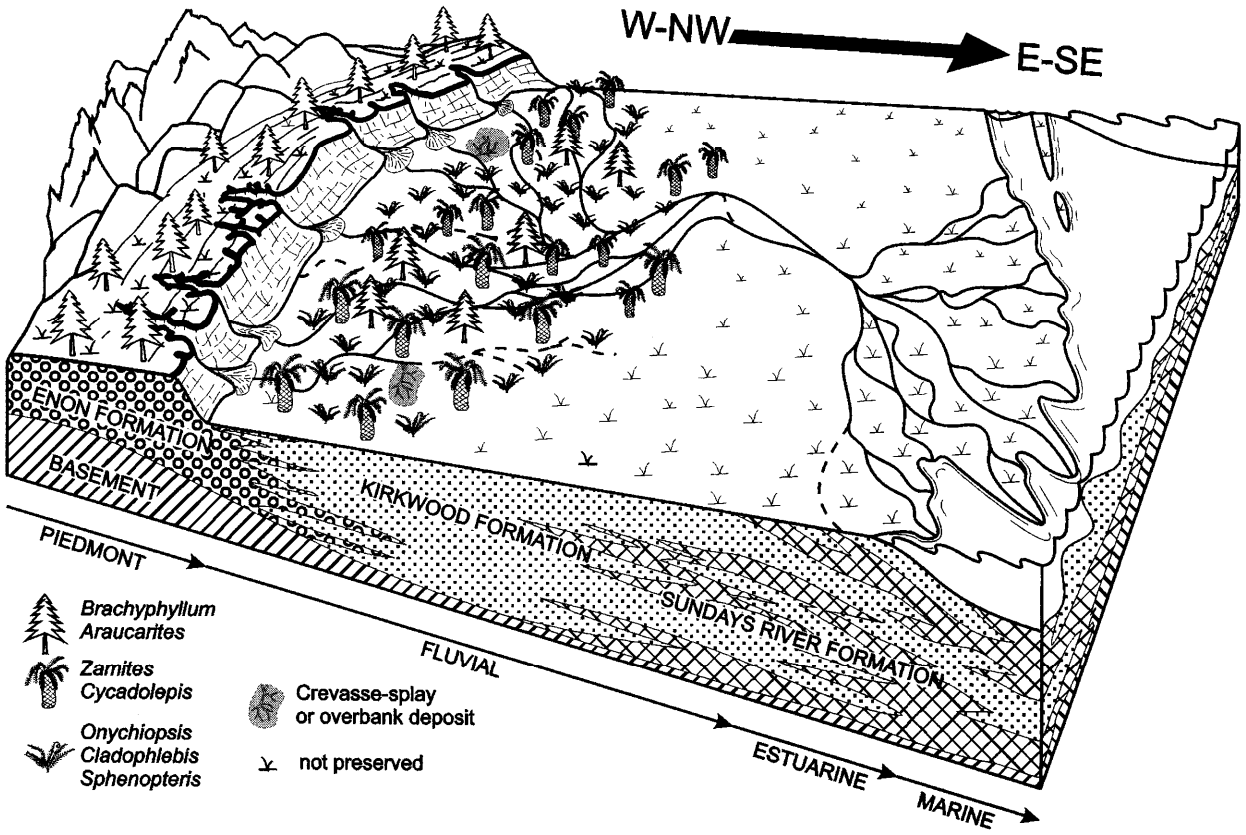

Fig. 7. Reconstruction of the depositional settings of the Uitenhage Group in the Algoa Basin (From Gomez *et al.,* 2006b). The plants shown are mainly ferns and gymnosperms. Note interfingering of Sundays River and Kirkwood facies shown here.

3.2.1.1. Palaeontological record of the Kirkwood Formation

The Kirkwood Formation is the most palaeontologically productive unit in southern Africa that yields terrestrial biotas of Early Cretaceous age. Its overall palaeontological sensitivity is rated as high (Almond *et al.* 2008). Fossils include vascular plants (including concentrations of petrified logs, lignite beds, charcoal), tetrapod vertebrates (notably dinosaurs) and freshwater invertebrates, among others (Du Toit 1954, McLachlan & McMillan 1976, Toerien and Hill 1989, Le Roux 2000 and further references listed below). Recent palaeontological research has yielded a number of new dinosaur taxa, for the most part from the Algoa Basin to the northeast of Port Elizabeth, but also from the Oudtshoorn Basin of the Little Karoo (De Klerk 2008, Rubidge *et al*., 2008).

The palaeobotanically famous "Variegated Marls" and "Wood Beds" of the Kirkwood Formation in the Eastern Cape have yielded a diverse fossil flora. Woody vegetation was dominated by gymnosperms including conifers such as *Araucaria* and *Podocarpus* (Fig. 8), extinct cycad-like bennettitaleans like *Zamites* (Fig. 9), as well as true cycads. In addition there are charophytes (stoneworts, an advanced group of freshwater algae), bryophytes (liverworts) and pteridophytes such as ferns (Tate 1867, Seward 1903, Haughton 1928, 1935, Du Toit 1954, Engelbrecht *et al*. 1962, McLachlan & McMillan 1976, 1979, Brown 1977a, 1977b, Anderson & Anderson 1985, Bamford 1986, MacRae 1999, Almond *et al*. 2008). Angiosperms (flowering plants), which first radiated during this period, are not represented,

however. Plant microfossils include pollens, spores and cuticular fragments, while amber and charcoal are locally common (Scott 1971, 1976a, 1976b, Gomez *et al*., 2002a, b). So far no inclusions such as fossil insects have been recorded within the amber, which represents the oldest Cretaceous material recorded from Gondwana.

Cretaceous dinosaurs have been collected from the Kirkwood Formation of the Algoa Basin since the mid nineteenth century and a number of exciting new finds have been made recently. Most of the Kirkwood dinosaur fossils found so far are highly fragmentary, however. The earliest discoveries, in 1845, were of the stegosaur *Paranthodon* from Bushman's River Valley and represent some of the first dinosaur finds made anywhere in the world (Atherstone 1857, Owen 1876, Galton & Combs 1981, De Klerk 1995, 2000).

The gigantic remains – mainly isolated vertebrae, leg bones and teeth - of several different titanosaurid and diplodocid sauropods are known from the Algoa and Oudtshoorn Basins (Rich *et al*., 1983, De Klerk 2008). These include the poorly-known *Algoasaurus* from Dispatch near Port Elizabeth (a possible camarasaurid), most of whose bones were made into bricks before they could be rescued (Broom 1904), and huge bones from the Calitzdorp area that were originally described as a giant plesiosaurus (Hoffman 1966). Disarticulated remains of numerous juveniles (hatchlings) of a primitive iguanodontian were discovered recently near Kirkwood (Forster & De Klerk 2008 and paper in press). The most completely preserved Kirkwood dinosaur is the small coelurosaur therapod *Nquebasaurus* (De Klerk *et al*., 2000; Figs. 10 & 11); recent studies suggest this form may in fact be more closely related to the bird-like dinosaurs or alvarezsaurids (B. De Klerk, pers. comm., 2010). At least one other theropod, a basal tetanuran, is known from fragmentary remains in the Kirkwood Formation (Rich *et al*., 1983, Mateer 1987, Forster *et al*., 2009). Other vertebrate fossil groups from the Kirkwood Formation include frogs, crocodiles, turtles, sphenodontid and other lizards, mammals and freshwater fish such as garfish (De Klerk *et al*., 1998, Rich *et al*., 1983, Ross *et al*., 1999).

Non-marine invertebrate fossils in the Kirkwood Formation are represented by freshwater or estuarine molluscs (*e.g.*unionid bivalves), rare insects such as beetles, and several groups of small crustaceans including ostracods (seed shrimps), conchostracans (clam shrimps) and notostracans (tadpole shrimps) (Haughton 1935, McLachlan & McMillan 1976, Dingle *et al.* 1983, MacRae 1999, Rich *et al*. 1983, Ross *et al*. 1999, Mostovski & Muller 2010). Trace fossils include borings into petrified tree trunks that are variously attributed to bivalves (*Gastrochaena*) and insects (possibly beetles).

Fig. 8. Blocks of silicified wood from the Kirkwood Formation (Collections of Albany Museum, Grahamstown). Well-developed growth rings in some specimens suggest a highly-seasonal climate. Other fossil woods lacking growth rings may be preserved as casts.

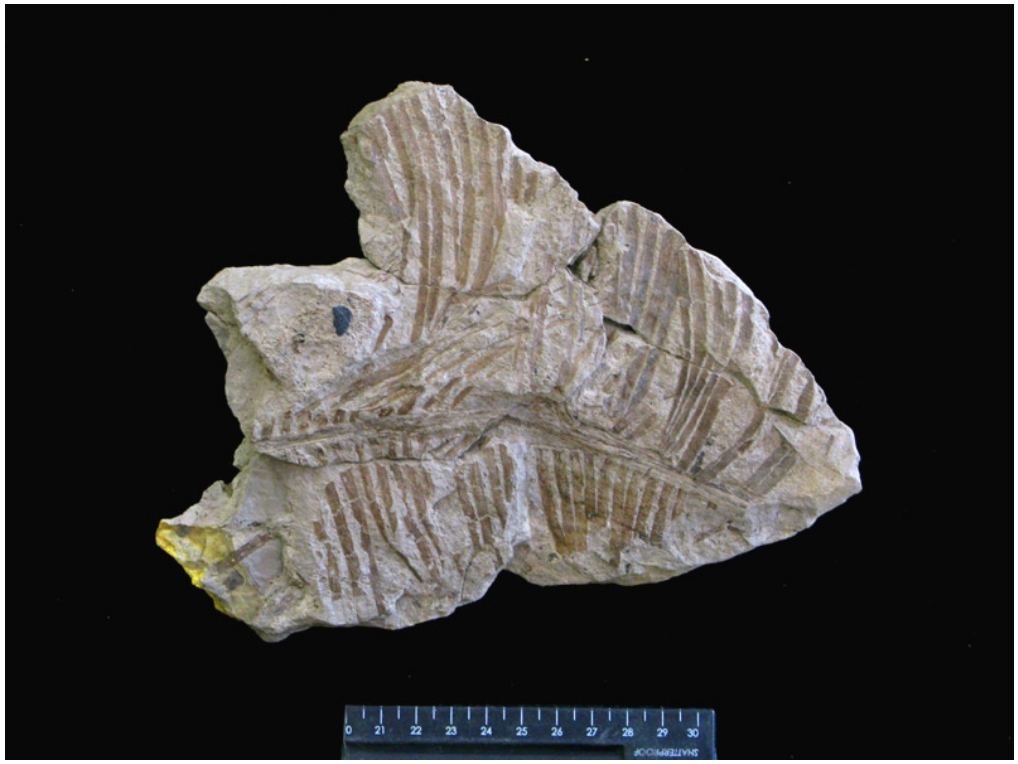

Fig. 9. Compression fossil of a pinnate, sclerophyllous (leathery) leaf of the bennettitalean *Zamites* from the Kirkwood Formation (Albany Museum, Grahamstown). Bennettitaleans were an extinct group of cycad-like gymnosperms of the Mesozoic Era.

Fig. 10. Well-articulated skeleton of the small (*c.* 1m long) predatory theropod dinosaur *Nquebasaurus* from the Kirkwood Formation of the Algoa Basin (W. de Klerk, Albany Museum, Grahamstown).

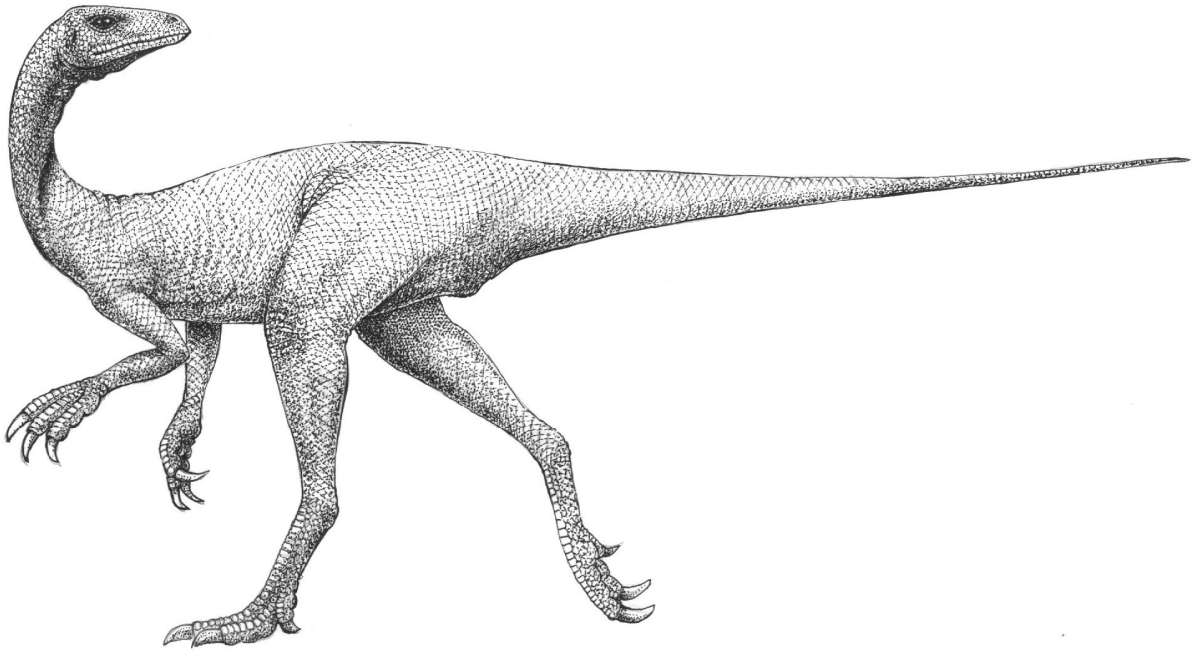

Fig. 11. Reconstruction of *Nquebasaurus* or "Kirky" (W. de Klerk, Albany Museum).

3.2.1.2. Kirkwood Formation in the Coega IDZ

The 1: 250 000 geological map (Fig. 2) indicates a continuous band of Kirkwood rocks cropping out along the western edge of the Coega River estuary and inland to Coega Kop and beyond. However, later remapping at 1: 50 000 scale referred quarry and railway cutting exposures on slopes south and southwest of Salnova hamlet to the Sundays River Formation. In the course of this study, the presence of pinkish or reddish-brown hued mudrocks – as seen for example in the railway cutting and several quarries mentioned below - was taken to identify the Kirkwood as opposed to Sundays River Formation. In either case, the Kirkwood Formation underlies the Alexandria Formation over much of the southwestern IDZ (Zones 1-5) and these Early Cretaceous rocks will be intersected by deeper (> 7-10m) excavations in this area.

Dark mudrocks containing marine, estuarine and freshwater invertebrates are known from the so-called Colchester Member within the lower Kirkwood Formation to the southwest of the Coega IDZ (Rigassi & Dixon 1972, McLachlan & Anderson 1976, Dingle *et al.,* 1983). This unit is regarded by some authors as a separate formation underlying the Kirkwood Formation (*e.g.*Dingle *et al*., 1983; Fig. 6). "Marine fossils" from the "Wood Beds" in a borehole at Coega Kop mentioned by Engelbrecht *et al.,* (1962) and McLachlan and Anderson (1976, fig. 4) may belong to the Colchester Formation which lies deep below the surface here and is unlikely to be affected by development.

Because of its soft-weathering nature, few exposures of the Kirkwood Formation are available in the Coega IDZ. They comprise: a few small quarries on Swarte Koppen 302 south and west of Coega (Locs 11, 12, 26), roadcuts along the old R102 (Locs 18, 19) and along the new tar road just west of Coega (Loc 17), recently excavated stormwater drainage channels and reservoirs in Zone 5 just north of the N2 (Locs 3-7, Fig. 6), deep railway cuttings southwest of the marshalling yard in the same area (Fig. 13, Loc 8), as well as stormwater channels and occasional erosion dongas in the northern sector of Zone 1 to the south of the N2 (*e.g.* the butterfly reserve area, Locs 34-35). Extensive fresh cuttings through Kirkwood sediments have also been made recently along the western edge of the Coega estuary salt flats as part of the port development, but these lie on Portnet land outside the study area.

Apart from a small fragment of unidentified bone at Loc. 4, no fossils were recorded from the Kirkwood Formation within the Coega IDZ during this study. Most Kirkwood fossil localities in the literature (*cf* review by McLachlan & Anderson 1976) are situated towards the northern edge of the Algoa Basin, well outside the Coega IDZ, where different palaeoenvironmental conditions more conducive to fossil preservation may well have prevailed. Fossil remains are more likely to be found in recent excavations, before surface wash and weedy vegetation have obscured the freshly exposed sediments. The extensive Kirkwood cuttings along the new tar road west of Coega (Loc 17, Fig. 13a), along the western edge of the Coega estuary saltpans, as well as in the deep stormwater drainage reservoir in IDZ Zone 5 (Loc 4) are already partially degraded or covered over. They represent a serious lost opportunity in palaeontological terms because these exposures were not examined for fossils while or soon after they were made.

Fig. 12. Gently dipping reddish-brown mudrocks and greenish-grey sandstones of the Kirkwood Formation overlain unconformably by limestones of the Alexandria Formation (Loc. 6).

Fig. 13. Alexandria Formation limestones unconformably overlying variegated sandstones and mudrocks of the Kirkwood Formation (Loc. 8). Note irregular erosional contact between the Algoa and Uitenhage Groups here.

Good exposures of the unconformable sedimentary contact between the Late Tertiary Alexandria Formation and underlying multi-hued mudrocks and greenish sandstones of the Kirkwood Formation are seen at:

- Low cliff face (Loc 6) situated at the northern end of a stormwater tunnel underneath the N2 (Figs. 12, 98). This is Geosite GS7 listed in Section 4.
- Deep railway cutting SW of the marshalling yard (Loc 8), adjacent to the N2 (Figs. 13, 99). This is Geosite GS8 listed in Section 4.

These exposures are of geological interest and should be safeguarded from further development if at all possible. Both localities are also of palaeontological interest for the well-developed bivalve borings (*Gastrochaenolites*) in the first case and the abundant crustacean pellet burrows (*Ophiomorpha*) in the second (See Alexandria Formation palaeontology).

Fig. 13a. Deep and extensive new roadcut through the Kirkwood Formation west of Coega (Loc 17) showing pinkish-brown mudrocks. Rows of white calcrete nodules towards the base of the exposure (arrow) are palaeosols or fossil soil horizons reflecting semi-arid climates in the Early Cretaceous.

3.2.2. Sundays River Formation (Ks)

The Sundays River Formation is of Early Cretaceous (Valanginian-Hauterivian) age, *ie* around 136 Ma (million years old; Fig. 6). It comprises a thick (up to 2km) succession of grey sandstones, siltstones and finer-grained mudrocks that are often highly fossiliferous (Shone 2006). Depositional settings range from estuarine through littoral (shoreline) to marine outer shelf (McMillan 2003). These beds are differentiated from the older Kirkwood Formation by (a) the absence of reddish-hued mudrocks, (b) the presence of prominent-weathering calcareous sandstones, and (c) the frequent occurrence of fossil marine shells. These last are commonly, but not invariably, associated with the thin sandstone beds, many of which are tempestites. Key geological accounts of the Sundays River Formation include those by Du Toit (1954), Rigassi & Dixon (1972), Winter (1973), McLachlan & McMillan (1976), Tankard *et al.* (1982), Dingle *et al.,* (1983), McMillan (2003) and Shone (1976, 2006). For the Coega area the geological sheet explanations by Haughton (1928), Engelbrecht *et al.* (1962), Toerien and Hill (1989) and Le Roux (2000) are most relevant.

3.2.2.1. Palaeontological record of the Sundays River Formation

In palaeontological terms the Sundays River Formation contains one of the most prolific and scientifically important marine biotas of Mesozoic age in southern Africa. Fossils have been recorded from the Sundays River beds in the Algoa Basin since the early nineteenth century (1837). Cooper (1981) provides a good review of the earlier literature. Important collections were made, for example, by the famous Eastern Cape geologists W.G. Atherstone and A.G. Bain (see Sharpe 1856; Fig. 14) and there has been a long history of palaeontological publications dealing with the Sundays River fauna since then. Among the key papers are those by Sharpe (1856), Kitchin (1908), Spath (1930), Du Toit (1954), Engelbrecht *et al*. (1962), Haughton (1969), McLachlan & McMillan (1976, 1979), Klinger & Kennedy (1979), Cooper (1981, 1991), Dingle *et al*. (1983), McMillan (2003) and Shone (1986, 2006). An accessible, well-illustrated account of Sundays River fossils has recently been given by MacRae (1999). The ammonites and microfossils are of particular biostratigraphic importance, while the foraminiferans (a group of protozoans) are useful for palaeoenvironmental analysis (See extensive discussion in McMillan 2003).

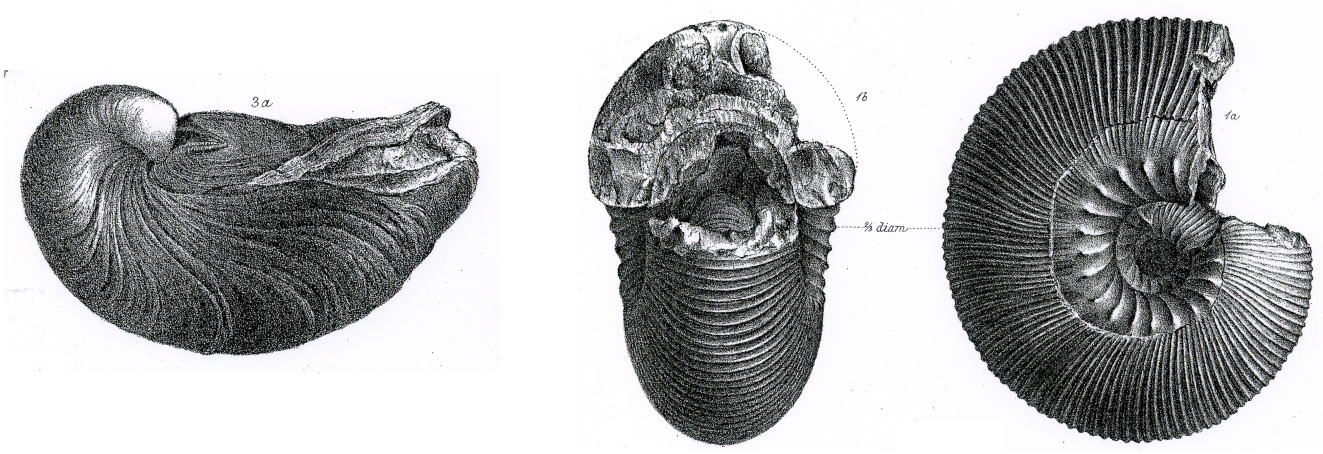

Fig. 14. Early illustrations of Sundays River fossils – the oyster *Aetostreon* (left) and the ammonite *Olcostephanus* (right) from an early publication by Sharpe (1856).

The main invertebrate macrofossils recorded from the Sundays River Formation are a rich variety of mollusks. These include several cephalopod subgroups - mainly ammonites, *plus* much rarer nautiloids and belemnites. The cephalopod fauna has been revised recently by Cooper (1981, 1983) and is dominated by a series (14 spp.) of strongly ribbed, coiled ammonites of the Genus *Olcostephanus* (Figs. 14, 15, 26), also well known from Early Cretaceous marine faunas elsewhere in the world. Interestingly, clear examples of well-developed sexual dimorphism (male and female shells of different size and form) as shown in this genus. Much rarer partially coiled ammonites (*Distoloceras*) and straight-shelled, obliquely ribbed forms (*Bochianites* Fig. 49) also occur.

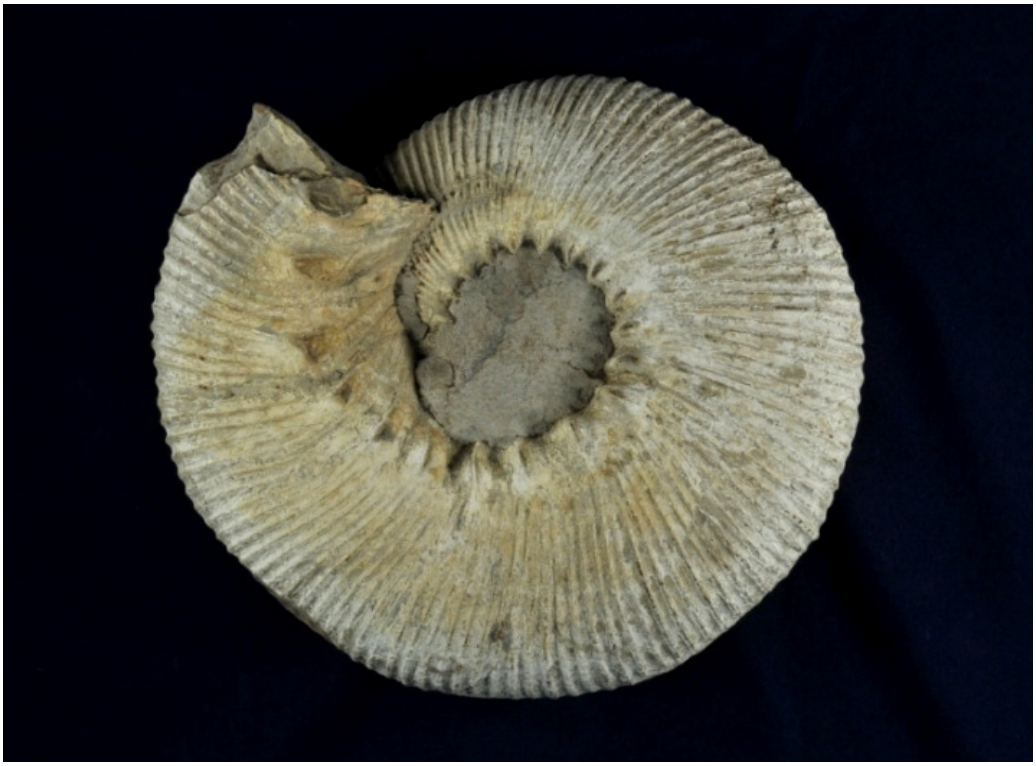

Fig. 15. Well-preserved specimen of the ammonite *Olcostephanus* from the Sundays River Formation (Albany Museum, Grahamstown). This is a macroconch (female) and *c*. 25cm across.

The Sundays River mollusks include a number of mainly small-bodied gastropods (*c*. 6 genera, including limpets), and over forty genera of bivalves (mussels, clams *etc*). In terms of abundance as well as biodiversity the bivalve mollusks are also the dominant group. The commonest form is the thick-shelled "Devil's toenail" oyster *Aetostreon* (previously known as *Exogyra* or *Gryphaea*) which is often preserved in dense coquinas (shell beds) at the base of storm sandstones (Figs. 14, 19, 24, 27). Some of the other bivalves, such as the strongly – ribbed or knobbed trigoniids (eleven species in seven genera, recently revised by Cooper, 1979, 1991 Figs. 18, 29) and the elongate-shelled *Gervillella* (Figs. 17, 29) – all shallow infaunal forms - are also quite substantial (20-30cm long or more) with robust shells. Encrusting oysters cemented onto shells, rocks or hardgrounds are common (Fig. 20). Dense storm-transported accumulations of scaphopod mollusks (tusk shells) have been discovered recently in the Sundays River Formation, in this case from the Coega IDZ (Fig. 31). Most of these South African fossils are badly in need of taxonomic and palaeobiological revision (*cf* recent work on similar-aged South America mollusks by Lazo 2007 and earlier papers; Fig. 16).

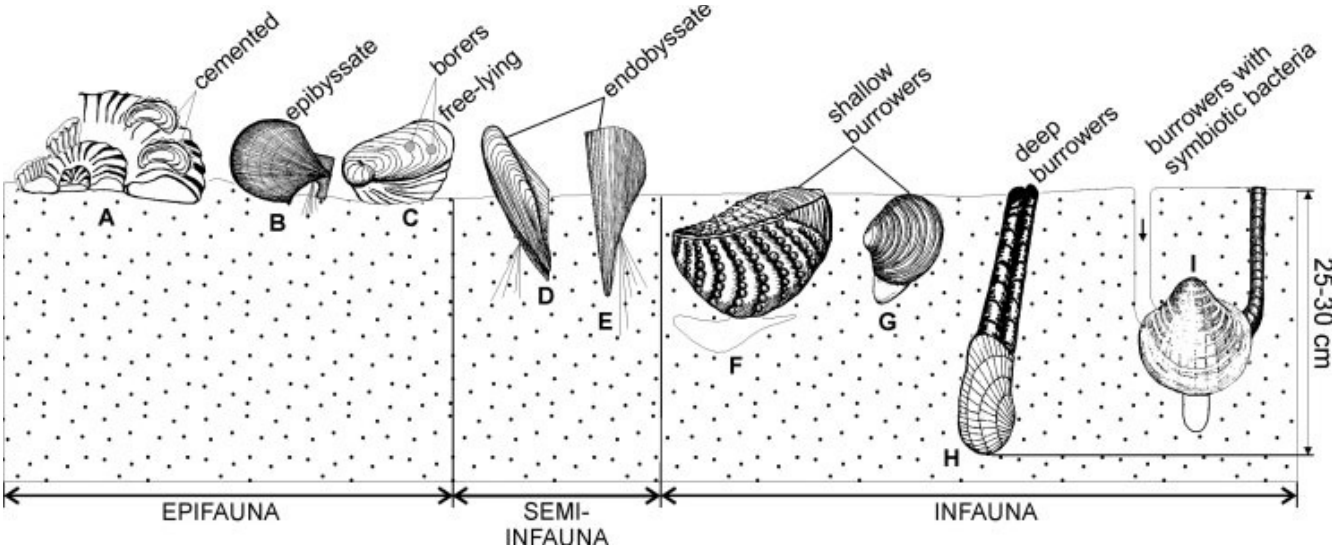

Fig. 16. Reconstructed life orientations of common Early Cretaceous bivalves from the southern hemisphere (from Lazo 2007). They include: A - cemented oysters (*Amphidonte*) B – epibyssate clams (*Mimachlamys*) C – free-lying oysters (*Aetostreon*) D, E – partially buried *Gervillella* and *Pinna* respectively F, G – shallow burrowing trigoniids (*Steinmanella*) and astartids (*Eriphyla*) H, I – deep burrowing *Pholadomya* and *Sphaera*. Most of these genera are represented in the Sundays River biota.

Fig. 17. The large, thick-shelled, semi-infaunal bakevelliid bivalve *Gervillella* from the Sundays River Formation (Iziko Museums, Cape Town).

Fig. 18. The knobbly, thick-shelled burrowing trigoniid bivalve *Steinmanella* from the Sundays River Formation in the main Coega brick pit (shell length 10cm).

Fig. 19. Well-preserved specimen ("Devil's toenail") of the common free-living oyster *Aetostreon* from the Sundays River Formation, main brick pit at Coega.

Fig. 20. Block of calcareous sandstone (14 cm across) encrusted with cemented oysters (possibly *Amphidonte*), Sundays River Formation, main brick pit, Coega.

More minor invertebrates – including stenohaline as well as euryhaline taxa - from the Sundays River Formation are solitary and branching colonial corals (Fig. 33), tube-dwelling serpulid polychaetes (Fig. 25), bryozoans, echinoderms (usually fragmentary crinoids or sea lilies, ophiuroids or brittle stars, sea cucumbers, regular echinoids) and shrimp-like crustaceans. However, more intensive collecting from these beds is likely to reveal further invertebrate taxa. This is suggested by the recent discovery of two new crustaceans (including several specimens of strongly tuberculate crabs) within Sundays River concretions (Dr Billy de Klerk, pers. comm., 2010), the scaphopods or tusk shells mentioned earlier, and recent new records of beetle remains south of Addo (Mostovski & Muller 2010). Sundays River trace fossils are poorly studied, but are locally abundant. They range from dense banks of cylindrical intrasediment burrows to a range of borings into wood, shells and hardgrounds (*ie* cemented substrata on the sea floor including, for example, exhumed early diagenetic concretions). A spectrum of microfossils from this stratigraphic unit include foraminiferans, ostracods, dinoflagellates and land-derived pollens and spores (Dingle *et al*., 1983, McMillan 2003). Among the rarer microfossil groups recorded are radiolarians, shrimps, and fragments of echinoderms (ossicles of crinoids, ophiuroids, holothurians and echinoids).

The Sundays River beds contain sparse, often unidentifiable plant fossils such as fragments of driftwood (sometimes insect- or perhaps mollusk-bored), leaf and twig debris, amber (fossil resin), lignite, charcoal and the reproductive structures of charophyte algae (stoneworts). Fossil vertebrates from the Sundays River Formation are very rare indeed. The best-known example is the partial skeleton of a 3m-long plesiosaur (an extinct group of large marine reptiles), *Leptocleidus capensis* (Figs. 21, 22). This comes from the famous, but poorly-localized, site of Picnic Bush on the Swartkops River near Port Elizabeth (Andrews 1910; see MacRae 1999 for good illustrations). Isolated dinosaur bones and teeth have also been mentioned, though several earlier records probably stem from the older Kirkwood Formation.

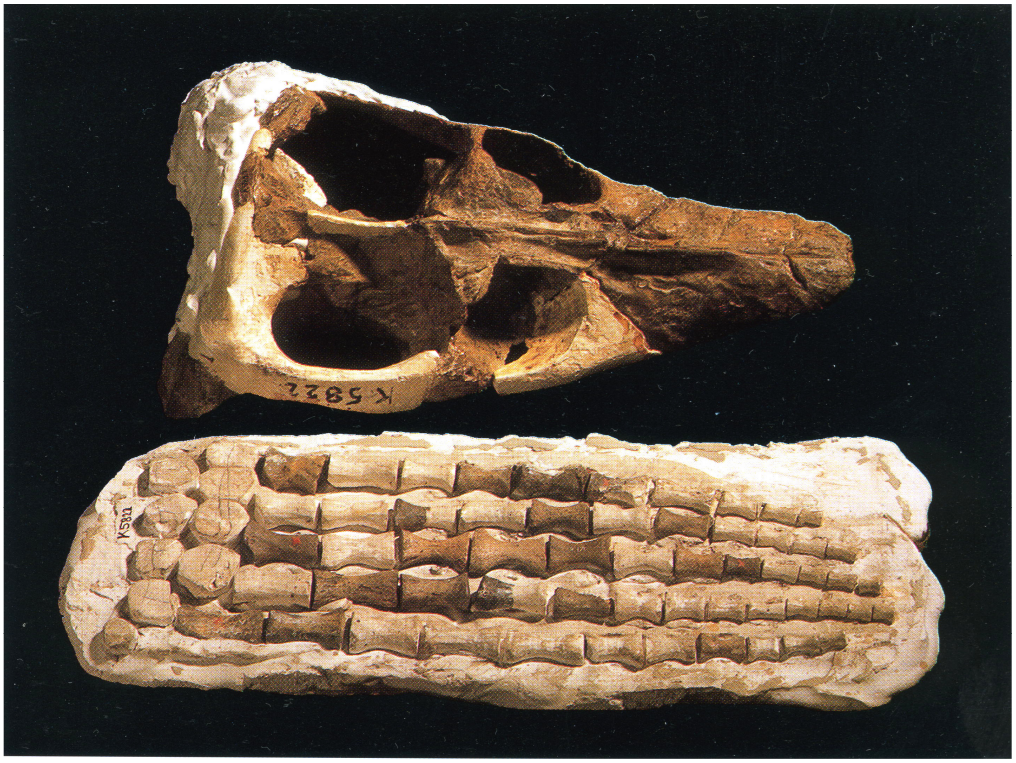

Fig. 21. Skull and flipper of *Leptocleidus capensis*, a 3m-long plesiosaur (marine reptile) from the Sundays River Formation at Picnic Bush on the Swartkops River near Port Elizabeth (From MacRae 1999).

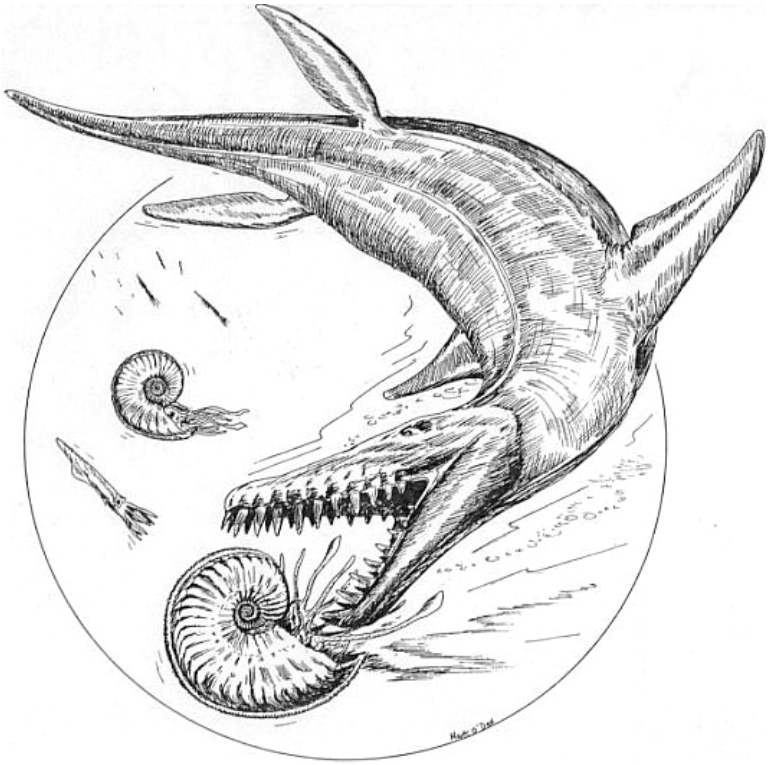

Fig. 22. Artist's reconstruction of a Cretaceous plesiosaur hunting ammonites.

Despite the long history of palaeontological work on Sundays River fossils, there has been little systematic collection of fossils – especially macrofossils - from these beds in recent decades and most taxa remain poorly studied (*e.g.*most invertebrate groups, apart from the ammonites, trigoniid bivalves and foraminiferans). The Coega area – notably the Coega Brick Pits just west of the Coega IDZ – has been sampled extensively by palaeontological groups over the years for micro- and macrofossil remains. Much remains to be done even here, however, and a lot of palaeontologically interesting material is undoubtedly being destroyed in the currently active brick pits in the region.

3.2.2.2. Sundays River Formation in the Coega IDZ

The Sundays River Formation underlies most of the central and eastern sectors of the Coega IDZ, from the southwestern side of the Coega River Valley eastwards. Natural exposures of these readily-weathered, fine-grained sediments are rare, however, due to extensive cover by younger sediments of the Algoa Group (notably the Alexandria Formation), drift deposits (*e.g.*soil, alluvium, colluvium) and dense thicket vegetation. The narrow outcrop area of the clay-rich Sundays River beds along the slopes fronting the Coega River Valley is largely obscured by dense mesic thicket that is readily apparent on aerial and satellite images. Here bedrock is only accessible in a few erosional dongas and gullies as well as in more extensive exposures within active or abandoned brick pits near Coega and in the Grassridge / Morester area to the north. These brick pits have yielded numerous important fossils over the years that are represented in museum collections (*e.g.*Albany Museum, Grahamstown, Iziko: South African Museum, Cape Town). However, little or no palaeontological monitoring of such pits over long intervals has undoubtedly led to the destruction of vast amounts of potentially valuable fossil heritage. Fossil collecting sites mapped by Cooper (1981, his fig. 1 therein) in the study region include the main brick pit southeast of Coega (Locs 20-23), the smaller North and South Tossies quarries due east of Coega (Locs 36-39), the abandoned quarry on Offit land due north of Coega (Locs 27-28) as well as one or more active pits in the Morester area on farm Webedachtsfontein 300 outside the Coega IDZ (Sheet 3325DA Addo).

During the present study exposures of Sundays River Formation were examined for palaeontological heritage at the localities briefly listed below. Most sites proved fossiliferous to some extent. The great majority of shelly invertebrate fossils observed were found in association with thin, calcareous sandstone horizons that weather out as prominent ledges or benches from the gentler mudrock slopes. The mudrocks themselves (generally olive green to grey siltstones) appear to be fossil-poor on the whole. Ovoid calcareous mudrock concretions up to several decimeters in diameter are common at certain horizons within the mudrocks. Several were broken open in search of fossils, but without success; however, it is known that such concretions do indeed yield well-preserved fossils in some cases (*e.g.*new crustaceans discovered by Dr Billy de Klerk, Albany Museum) and a more intensive examination of such nodules may well yield palaeontological dividends.

Brief notes on the main Sundays River Formation exposures within the Coega IDZ follow.

Fig. 23. View from the west across the main brick pit at Coega (Locs 20-23).

(a) Main brick quarry SE of Coega (Locs 20-23, Figa. 23, 92; *NB* this is Geosite 1 in Section 4). Thin, laterally-persistent to lenticular calcareous sandstones on the eastern face of this deep quarry contain dense assemblages of intact and broken up mollusk shells. These shells occur especially towards the base of the sandstone which is often preferentially calcified (Fig. 24). These shell beds or *coquinas* were probably generated by episodic storm events that exhumed and concentrated mollusks living on or within the sea bed. They are strongly dominated by the distinctive toenail-shaped shells of the oyster *Aetostreon* that lived freely on the sea bed, weighted down by its heavily thickened lower (left) valve (Figs. 14, 16, 19). Other robust bivalves recorded here include large knobbly trigoniids (Genus *Steinmanella*; Fig. 18) and elongate *Gervillella* (Fig. 17), both shallow infaunal forms, as well as irregular-shaped, flattish encrusting oysters (possibly *Amphidonte*; Fig. 20). The western face of the quarry is far less fossiliferous, with the exception of numerous tightly-coiled tubes of serpulid (spirorbid) polychaetes that weather out of the mudrocks or are occasionally seen embedded in the surface of calcareous concretions (Fig. 25). Elsewhere in this formation spirorbids are often seen encrusting molluscs shells. Silty impure sandstones (probably estuarine) on the quarry floor show wave ripple lamination and contain dense assemblages of trace fossils, including horizontal, oblique and vertical burrows. Isolated fragments of unidentifiable fossil wood (and perhaps bone) were also found here. Grey mudrocks towards the base of the eastern face of the quarry have recently yielded several specimens of fossil crab with a distinctive tubercular ornamentation; these have not been recorded previously from the Sundays River Formation and are currently being studied by Dr Billy de Klerk of the Albany Museum, Grahamstown (pers. comm., 2010).

Fig. 24. Prominent-weathering calcareous sandstone (*c*. 25c thick) within the Sundays River Formation at the main Coega brick pit. Note dense concentration of articulated and disarticulated shells (mainly of the oyster *Aetostreon*) towards the base of the bed.

Fig. 25. Washed-out calcareous tubes of spirorbid polychaete worms, Sundays River Formation, Coega brick pit (Loc 23). The coiled shells shown are up to 1cm across.

In a small, largely hidden gully just to the south of the main Coega brick pit (Locs 70-71) highly bioturbated (*ie* burrowed) silty sandstones, a few well-preserved specimens of the bivalve *Aetostreon* as well as two prized specimens of the characteristic, strongly-ribbed Sundays River ammonite *Olcostephanus* were recorded, these last weathering out of a calcareous shell-rich sandstone (Fig. 26). The apparent rarity of ammonites in the main pit is probably due to over-collection by visiting palaeontologists. Small (male) microconchs and larger (female) macroconchs of *Olcostephanus* have been collected here in the past and are frequently found on the conveyor belts of active brick pits in the Coega Valley (Dr Billy de Klerk, pers. comm., 2010). Many of these attractive ammonites are apparently sold (illegally) to local fossil enthusiasts.

Fig. 26. Specimen of the strongly-ribbed ammonite *Olcostephanus* which has weathered out of a calcareous sandstone bed of the Sundays River Formation in the Coega Quarry area (Loc. 70).

(b) Tossies Quarry South due east of Coega (Locs 36-37). This quarry has now been largely infilled with rubble and brushwood and no fossils were found here. A clear sedimentary contact between the conglomeratic, shell-rich base of the Alexandria Formation and the underlying grey-green Sundays River mudrocks is exposed in the upper, eastern part of the quarry (Figs. 58a, 58b, 96). Given its stratigraphic interest, it is recommended that this face is kept free of rubble so that it is accessible for geologists to study in future (See Geosite GS5, Section 4)..

(c) Tossies Quarry North on the southern side of the Brakrivier Valley (Locs 38-39). As with the previous locality, the main quarry has been almost complete back filled, so no *in situ* Sundays River bedrock is accessible. Disturbed slabs of grey-green silty sandstone here contain abundant dispersed fragments of fossil wood and black charcoal. Sundays River

sediments exposed in a hidden gully just to the north of the main quarry (Loc 40, Figs. 27, 97) include a calcareous sandstone bed containing a typical *Aetostreon*-dominated shelly coquina. As well as numerous specimens of the common oyster *Aetostreon* (Fig. 27), well-preserved specimens of trigoniids, *Gervillella*, concentrically-ribbed astartid bivalves (*Herzogina*?) and the rare, radially-ribbed Cretaceous limpet *"Patella" caperata* (Fig. 28) are also recorded here. This locality is useful for palaeontological education and research purposes and should be safeguarded (See Geosite GS6, Section 4).

Fig. 27. Abundant shells of the oyster *Aetostreon* weathering out of a fossiliferous calcareous sandstone in the Sundays River Formation (Loc. 40).

(d) Dry dam between Tossies Quarries (Locs 42-44). Disturbed blocks of typical shell-rich Sundays River calcareous sandstones are variously scattered or heaped up in this area. Several contain well-preserved examples of Early Cretaceous mollusks such as flattish encrusting oysters and free-living toenail-shaped oysters (*Aetostreon*), *Gervillella*, trigoniids such as *Trigonia tatei*, and rare gastropods.

Fig. 28. Specimen of the rare, radially-ridged limpet *"Patella" caperata* from the Sundays River Formation (Loc 40). The limpet (top right) is 3cm across.

(e) Abandoned brick quarry, Offit land (Locs 27-28, Figs. 58a, 95; this is Geosite 4 in Section 4). This locality is of stratigraphic as well as palaeontological interest in that the sharp contact between the Alexandria Formation and underlying Sundays River mudrocks is clearly exposed. Additionally, an unusal, deeply-incised erosional channel at the base of the Alexandria limestones is seen in the northwestern corner of the quarry. Rich mollusk beds are exposed along the edge of a prominent bench on the eastern side of the quarry (Fig. 29). The shells here, both intact and fragmentary, are exposed on the top of the bed and appear to have been winnowed out and concentrated by storm activity, although erosional down-wasting may also be partially responsible. They include numerous well-preserved specimens of trigioniids, *Gervillella* as well as free-living and cemented oysters like *Aetostreon* and (?) *Aphidonte*. The latter encrusts other shells, some of which must therefore have been exposed on the seabed for some time before burial. Slightly lower down in the succession a tempestite sandstone bed contains a well-cemented lower layer of finely broke up shell hash.

(f) Brakrivier Valley (Loc. 32). Non-calcareous, wave ripple-laminated grey-green sandstones are exposed in a small but deep donga on the southeastern flank of the dry valley. No fossils were recorded here.

(g) Chetty River banks, southeast of the Coega brickworks (Loc 33, Fig. 30). This locality is mainly of sedimentological interest, since no fossils were recorded here. The tabular succession displays clear small-scale (few cm), upward-coarsening cycles of greenish sandstone to greyish siltstone that in turn form part of larger upward-shallowing cycles. Well-developed wave ripple lamination is seen within the sandstone units.

Fig. 29. Dense, winnowed and perhaps down-wasted concentration of mollusk shells, including *Gervillella* and *Steinmanella*, at the top of a storm sandstone, Offit brick pit (Loc. 28).

Fig. 30. Upward-thickening and –coarsening succession (shallowing cycle) within the Sundays River Formation, banks of the Chetty River (Loc 30).

(h) Dongas and eroding slopes close to the Butterfly Reserve in Zone 1 (Locs 34-35). This locality is primarily of stratigraphic interest since no fossils were recorded here. Reddish-hued Kirkwood mudrocks containing pedogenic calcrete nodules (*ie* terrestrial sediments) are overlain by greenish-grey sandstones that can probably be attributed to the shallow marine / estuarine Sundays River Formation. If correct, this is one of the few sites within the Coega IDZ where the contact between these two units can be examined. A *possible* rubbly sandstone breccia occurs close to the inferred contact, supporting the idea that the Sundays River overlies the Kirkwood with an erosional unconformity (See discussion in McMillan 2003).

(i) Small abandoned quarry on the eastern banks of the Coega River Valley, close to the N2 (Loc 66). Mudrocks, wave-rippled sandstones and calcareous concretions of the Sundays River Formation are exposed here. Fossils include thick-shelled bivalves (*e.g.*trigoniids) embedded in disturbed blocks of calcareous sandstone.

(j) Erosional gullies on the eastern slopes of the Coega River Valley, farm Bontrug 301 (Sector 14 of Coega IDZ, Locs 103-108). Thin sandstones weathering out of the northern and southern face of this gully contain dense carpets of well-preserved small bivalves, both on their upper surface and internally (Fig. 32). Most of these mollusks are probably deposit-feeding nuculoids ("nut shells") that have been winnowed out of bottom muds (or perhaps driven out by bottom anoxia) but a few other forms are present. Towards the northeastern end of the deepest gully (Loc 108) thin coquinas dominated by small, curved tusk shells (Mollusca, Class Scaphopoda) are found at the base of a tempestite sandstone. The delicate tusk shells show a pronounced current-orientation (Fig. 31). This is the first record of this molluscan subgroup form the Sundays River Formation (They are, however, already known from the much younger Algoa Group). Slightly to the northwest (Loc 133), at a lower stratigraphic level within the Sundays River Formation, occurs an unusual, well-consolidated pebbly conglomeratic bed within a narrow gully. This rock type has not been observed elsewhere in the Coega IDZ. The upper surface of the conglomerate, which is unfortunately poorly exposed here, contains sparse fragments of fossil wood as well as numerous specimens of a branching coral (Fig. 33), a fossil group that is generally rare in the Sundays River beds. At this stage it is unclear whether the corals are in growth position or, as appears more likely, have been ripped up and transported from elsewhere and then incorporated into the conglomerate by a high-energy event (*e.g.*storm surge).

(k) Low coastal bench at the Salnova Formation stratotype E locality, Hougham Park (Locs 84-85). This locality is of considerable stratigraphic importance as one of the stratotypes (*ie* selected keystratigraphic sections) designated by Le Roux (1991) for the Pleistocene Salnova Formation (See Algoa Group, Section 3.3.3. and Geosite GS10, Section 4). It is also of interest since the unconformable, erosional contact between the conglomeratic base of the Salnova Formation and the underlying, gently dipping beds of the much darker, finer-grained Sundays River Formation are clearly seen (Figs. 34, 77, 78, 101). This erosional contact represents some 130 million years of "lost" geological time (Fig. 1). The upper portion of the Cretaceous unit is extensively fractured and shot through with calcrete veins here, and no fossils were recorded here.

Fig. 31. Small slab of Sundays River Formation sandstone showing aligned scaphopods or "tusk shells" (*c.* 1.5cm long). These represent a new mollusc group for this formation and were first discovered in the Coega IDZ (Bontrug area, Loc 108).

Fig. 32. Carpets of small bivalves covering sandstone bedding planes in the Bontrug area (Loc 132), Coega IDZ.

Fig. 33. Concentrated fragments of branching corals from an unusual conglomeratic bed in the Sundays River Formation, Bontrug area (Loc 133).

Fig. 34. Coastal outcrop of calcrete-veined Sundays River Formation erosionally overlain by basal conglomerates of the Pleistocene Salnova Formation, Hougham Park (Loc 84).