THE LITHOSTRATIGRAPHY OF CENOZOIC DEPOSITS ALONG THE SOUTH-EAST CAPE COAST AS RELATED TO SEA- LEVEL CHANGES

BY

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of the degree of Master of Science at
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DECLARATION

I the undersigned hereby declare that the work contained in this thesis is my own original work and has not previously in its entirety or in part been submitted at any university for a degree.

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ABSTRACT

Cenozoic sediments along the south-east coast of the Cape Province have been studied intermittently for more than a century by various authors. In this presentation the literature is reviewed and many ambiguous stratigraphic subdivisions and definitions are clarified.

The Cenozoic deposits can be classified, according to origin, as marine, aeolian and fluvial. The marine deposits, being either beach, nearshore, estuarine or lagoonal deposits associated with transgressive/regressive shorelines, are now subdivided on the grounds of distinct lithological, palaeontological as well as age differences into the Palaeogene **Bathurst**, Neogene **Alexandria** and Quaternary **Salnova Formations**. The Late Pliocene to Early Pleistocene **Nanaga Formation**, the Middle to Late Pleistocene **Nahoon Formation** and the Holocene **Schelm Hoek Formation** constitute the coastal aeolian deposits. All the marine and marine-related (aeolian) formations, which are characterised by calcareous clastics, have been grouped together in a newly defined **Algoa Group**. Fluvial deposits are subdivided into the **Martindale, Kinkelbos, Bluewater Bay, Kudus Kloof** and **Sunland Formations**.

The various deposits are correlated with different stands of sea-level through geological time. The earliest Cenozoic transgression/regression cycle started in the Early Palaeocene and reached the highest recorded altitude for the

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era. The Bathurst Formation was probably deposited during this regression. A second lesser transgression/regression cycle occurred in the Late Eocene to Early Oligocene. As far as is presently known, no deposit in the outcrop area of the Algoa Group can be definitely related to this cycle. The next cycle, which reached a transgressive maximum of c. 250 m, started in the Middle Miocene and terminated in the Early Pliocene. Marine planation of the coastal platform took place during the transgression, whilst the Alexandria Formation presently situated above 120 m, was deposited during the regression. The Early Pliocene transgression is considered to have reached a maximum present-day elevation of c. 120 m, during which the 120 m marine bench and "Humansdorp Terrace", amongst others, were carved. The Alexandria Formation presently situated between 60 and 120 m, was deposited during the Late Pliocene regression, which experienced several relatively long stillstands which probably account for the 106 m, 90 to 100 m and 84 m benches. Even the 60 m- and 52 m-shorelines could have been formed during this regression. Preliminary palaeontological evidence, however, suggests that the 60 m-shoreline represents a transgressive maximum of a subsequent cycle followed by a regression with at least one significant stillstand at 52 m. The Alexandria Formation situated between c. 60 and 30 m, was probably deposited during this regression, which also saw the deposition of the Bluewater Bay, Kinkelbos and Kudus Kloof Formations.

During the Quaternary transgression/regression cycles, of which at least four are indicated, the Salnova Formation

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(absent above 30 m) was deposited. The Nahoon Formation, which is also extensively developed on the continental shelf, was deposited during the last two Pleistocene glacials, when sea-levels receded to less than -100 m. The Schelm Hoek Formation, which is still being deposited, originated from the transgressive maximum of the Flandrian transgression at the start of the Holocene.

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OPSOMMING

Senosoiese sedimente langs die suidooskus van die Kaapprovinsie is periodiek deur verskeie outeurs vir meer as 'n eeu bestudeer. In hierdie aanbieding word die literatuur saamgevat en vele dubbelsinnige stratigrafiese onderverdelings en definisies opgeklaar.

Die Senosoiese afsettings kan volgens oorsprong geklassifiseer word as marien, eolies en fluviaal. Die mariene afsettings, synde strand-, nabystrand-, estuarien- of lagunale afsettings geassosieerd met transgressiewe/ regressiewe kuslyne, word nou op grond van kenmerkende litologiese, paleontologiese sowel as ouderdomsverskille onderverdeel in die Paleogeen **Bathurst**, Neogeen **Alexandria** en Kwaternêre **Salnova Formasies.** Die Laat-Plioseen tot Vroeg-Pleistoseen **Nanaga Formasie**, Middel- tot Laat-Pleistoseen **Nahoon Formasie** en die Holoseen **Schelm Hoek Formasie** vorm die kus-eoliese afsettings. Al die mariene en marienverwante (eoliese) formasies, gekenmerk deur kalkige klastiese afsettings, is saamgegroepeer in 'n nuutgedefinieerde **Algoa Groep.** Fluviale afsettings word onderverdeel in die **Martindale, Kinkelbos, Bluewater Bay, Kudus Kloof** en **Sunland Formasies.**

Die onderskeie afsettings word gekorreleer met verskillende seevlakstande deur geologiese tye. Die vroegste Senosoiese transgressiewe/regressiewe siklus het in die Vroeg-Paleoseen begin en die hoogste aangetekende elevasie vir die era

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bereik. Die Bathurst Formasie is waarskynlik gedurende hierdie regressie afgeset. 'n Tweede kleiner transgressie/ regressiesiklus het plaasgevind gedurende die Laat-Eoseen tot Vroeg-Oligoseen. Sover tans bekend, kan geen afsetting in die dagsoomgebied van die Algoa Groep definitief met hierdie siklus in verband gebring word nie. Die volgende siklus, wat 'n transgressiewe maksimum van c. 250 m bereik het, het begin in die Middel-Mioseen en verstryk in die Vroeë Plioseen. Mariene planasie van die kusplatform het gedurende die transgressie plaasgevind terwyl die Alexandria Formasie wat tans bo 120 m geleë is, gedurende die regressie afgeset is. Die Vroeg-Plioseen transgressie het waarskynlik 'n maksimum huidige hoogte van c. 120 m bereik, waartydens o.a. die 120 m branderstoep en "Humansdorpterras" gekerf is. Die Alexandria Formasie tans geleë tussen 60 en 120 m, is afgeset gedurende die Laat-Plioseen regressie. Hierdie regressie het verskeie relatief lang stilstande, wat waarskynlik die 106-m, 90- tot 100-m en 84-m branderstoepe verklaar, ondervind. Selfs die 60-m en 52-m kuslyne kon tydens hierdie regressie gevorm het. Voorlopige paleontologiese getuienis dui egter daarop dat die 60-m kuslyn 'n transgressiewe maksimum van 'n daaropvolgende siklus verteenwoordig, gevolg deur 'n regressie met minstens een beduidende stilstand by 52 m. Die Alexandria Formasie geleë tussen c. 60 en 30 m, is waarskynlik gedurende hierdie regressie gedeponeer, waartydens ook die Bluewater Bay, Kinkelbos en Kudus Kloof Formasies afgeset is.

Gedurende die Kwaternêre transgressie/regressiesiklusse, waarvan minstens vier aangedui word, is die Salnova Formasie

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(afwesig bo 30 m) afgeset. Die Nahoon Formasie, wat ook op groot skaal op die kontinentale bank ontwikkel is, is gedeponeer gedurende die laaste twee Pleistoseen glasiale toe seevlakke tot benede -100 m gedaal het. Die Schelm Hoek Formasie wat tans nog afgeset word, het ontstaan uit die transgressiewe maksimum van die Flandriese transgressie aan die begin van die Holoseen.

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CHAPTER 1 - INTRODUCTION

A coastal plain of variable width adjoins the Southern African coastline (Truswell, 1977). Along the south-east coast, which - for the purposes of this study - is defined as the coastal region between the Groot River and the Kei River (Fig. 1.1), it is relatively broad and largely covered by Cenozoic deposits. These deposits have been studied intermittently for more than a hundred years by various authors (see references). Until relatively recently, the scarcity of datable deposits as well as the low economic potential of Tertiary strata in general, has militated against the systematic stratigraphic study thereof and the development of regionally applicable correlation schemes. Stratigraphic subdivisions and definitions which evolved as a result of this work were not always clear and unambiquous.

In the present study an attempt was made to systemise and revise the stratigraphic nomenclature for the Cenozoic along the south-east coast. In this process it became necessary to define some new formations, whilst others had to be redefined. In the latter case preference was given to established names, where possible, rather than coining new names. The other objectives of this study were to provide an up-to-date reference list and summary of previous work on Cenozoic geology of the area, and to correlate the various formations with existing sea-level curves based on global as well as local observations.

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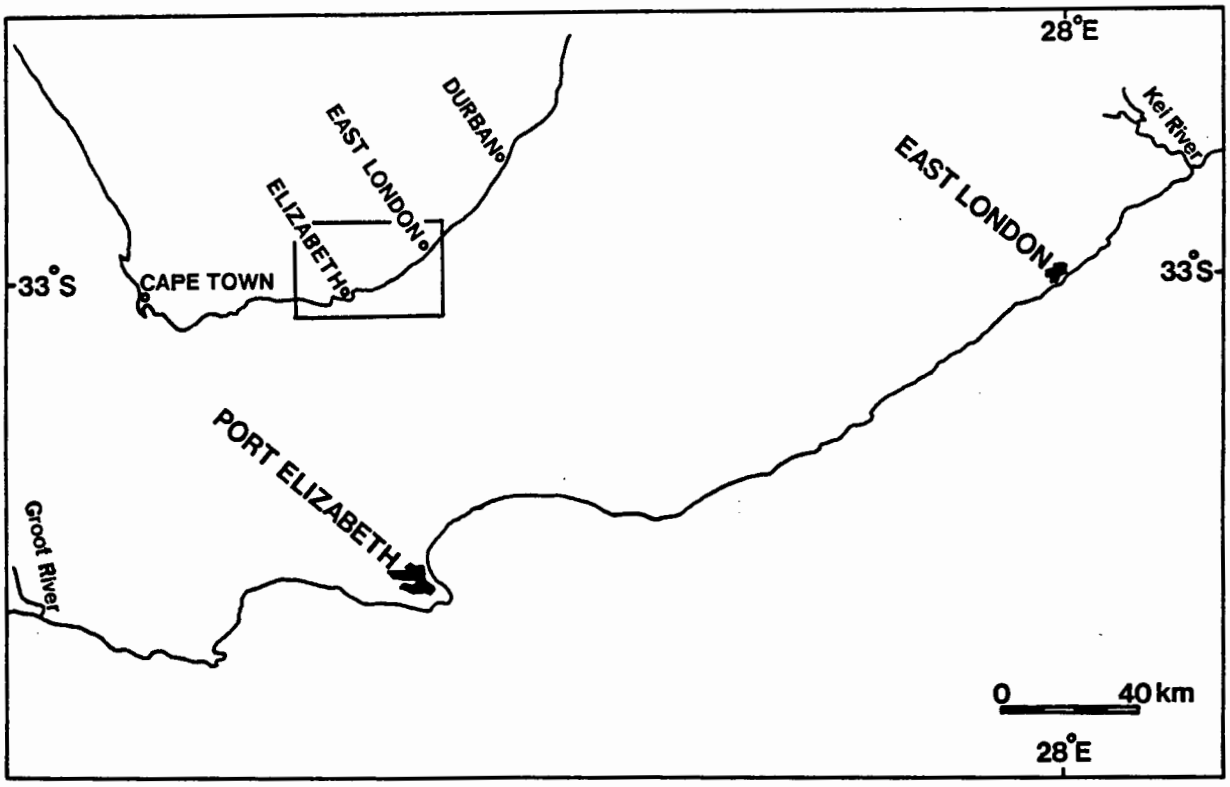

Fig. 1.1 - Index map of study area.

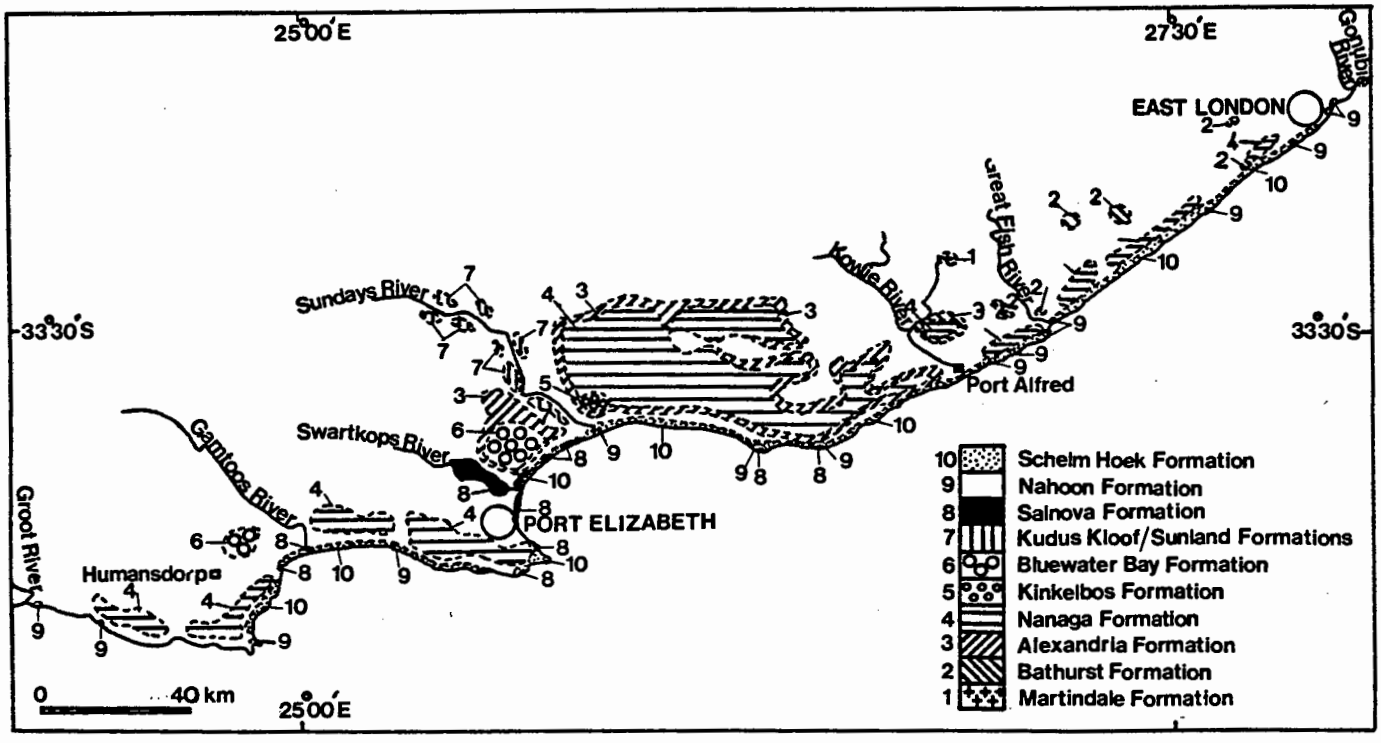

Fig. 1.2 - Schematic distribution of Cenozoic deposits along the south-east coast.

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The Cenozoic deposits in the area (Fig. 1.2) were classified, according to origin, as marine, aeolian or fluvial (see Table 1.1). All clastic-calcareous marine and marine-related (aeolian) deposits along the south-east coast have been included in a newly-defined Algoa Group.

TABLE 1.1 - CLASSIFICATION OF CENOZOIC DEPOSITS ALONG THE SOUTH-EAST CAPE COAST.

Age		ALGOA GROUP		Fluvial
		Marine	Aeolian	
QUATERNARY	Holocene	Salnova Fm	Schelm Hoek Fm	
	Pleistocene		Nahoon Fm	Sunland Fm
			Nanaga Fm	Kudus Kloof Fm Bluewater Bay and Kinkelbos Fm's
TERTIARY	Pliocene	Alexandria Fm		
	Miocene			
	Oligocene			
	Eocene	Bathurst Fm		Martindale Fm
	Palaeocene			

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MARINE DEPOSITS

The marine deposits, being either beach, nearshore, estuarine or lagoonal deposits associated with transgressive/regressive shore-lines, are now subdivided on the grounds of distinct lithological, palaeontological as well as age differences into the **Bathurst, Alexandria** and **Salnova Formations.** Tertiary and Quaternary marine deposits in the area were formerly collectively known as the **Alexandria Formation** (SACS, 1980).

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CHAPTER 2 - BATHURST FORMATION

The Bathurst Formation represents the Palaeogene marine deposits east of the Kowie River at localities such as Birbury, Pato's Kop and Needs Camp (Fig. 2.1).

2.1 LITERATURE REVIEW

The name "Bathurst limestone" was first used by W.G. Atherstone in 1850 (quoted in Schwarz, 1908) and later adopted by Schwarz (1908) for hard, crystalline limestone in the vicinity of Bathurst. Seeley (1891) referred to certain Tertiary marine limestones at Bathurst "from 300 to 400 ft above the sea", containing teeth of Charcharodon and Lamna, and shells of Turritella, Ostrea, Donax and Lucina, which were stated to be preserved in the Albany Museum, Grahamstown. Woods (1908) described some internal casts of a large 'Perna' (presently known as Isognomon sp.) obtained from the upper part of the Needs Camp limestones.

The name "Bathurst limestone" fell into disuse as subsequent authors, e.g. Newton (1913), Haughton (1925), Chapman (1930), Mountain (1946), Du Toit (1954) and SACS (1980), amongst others, incorporated these limestones into the Alexandria Formation.

The presence of the benthic foraminifera Discocyclina pratti, which occur in abundance along with D. varians, persuaded Chapman (1930) to assign a Late Eocene age to the

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outcrops at Birbury. However, after re-examination of the outcrop by Bourdon and Magnier (1969), a younger age was assigned to these deposits on the evidence of a well preserved Miocene assemblage. The presence of poorly preserved Eocene benthic foraminifera in the same deposit was ascribed to reworking. Siesser and Miles (1979) also studied the Birbury microfossils and identified at least 14 species of calcareous nannofossils and six species of planktonic foraminifera. These were mainly Palaeogene forms, plus a few longer-ranging types. None were specifically Neogene. Age ranges of several of the nannofossils and foraminifera, especially Morozovella subbotinae and Chiasmolithus solitus overlap, thus indicating an Early Eocene age for the Birbury deposits.

At the Upper Quarry, Needs Camp, about 6 m of marine 'limestone' is present. The lower part consists of pebbly and fine-grained calcareous sandstone, while the upper part consists mainly of coarse-grained calcareous sandstone. The rocks are generally hard and crystalline. According to Siesser (1971) they are composed of skeletal grainstone rich in molluscs, cirrepeds, polyzoa and coralline algae cemented by microspar. Large 'Perna'(i.e. Isognomon sp.) valves are conspicuous. These rocks were originally considered to be lateral equivalents of the Alexandria Formation (Newton, 1913; Du Toit, 1954) which in turn was thought to be Eocene in age by correlation with the Birbury beds (Haughton, 1925; Chapman, 1930). Lock (1973) reviewed the literature, but despite the presence of Eocene benthic foraminifera, was wary of assigning a Palaeogene age

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to these deposits, probably in view of the allegedly reworked Eocene foraminifera at Birbury (reported by Bourdon and Magnier 1969). According to Siesser and Miles (1979) the ranges of Tertiary nannofossils would indicate an Eocene (probably Early Eocene) age for the Needs Camp Upper Quarry deposit. This would also suggest that the Birbury and Upper Needs Camp outcrops were deposited during the same high stand of sea-level.

The hard crystalline limestone which occurs in the immediate vicinity of Bathurst was previously also considered to be Eocene in age (S.P. Applegate, quoted by Tankard, 1975). Similar limestone occurs in more than thirty isolated outcrops east of the Great Fish River in the Ciskei, mainly clustered around Kenilworth and Pato's Kop north of Bell (Fig. 2.1). These were also considered to be of Eocene age (Maud et al., 1987). The present author sampled most of these outcrops during 1986 for micropalaeontological age determinations by I.K. McMillan (SOEKOR). According to him (pers. comm., 1989) these outcrops, as well as those in the immediate vicinity of Bathurst, are of a post-Eocene age. They are thus excluded from the Bathurst Formation, and belong to the Alexandria Formation. Maud et al. (1987) reported an abundant and fairly diverse assemblage of nannoplankton from the limestone at Pato's Kop (Great Fish River), including 20 different taxa, indicating an age of middle Early Eocene to earliest Middle Eocene.

Limestone resembling the Bathurst-type is exposed on both sides of the Gxulu River, as well as west of Kidds Beach,

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according to Mountain (1974). A newly discovered outcrop near Kidds Beach was confirmed to be of Eocene age (I.K. McMillan - pers. comm., 1989).

Le Roux (1987c) suggested that the Palaeogene calcareous deposits east of the Kowie River, which are rather unlike the Alexandria Formation in its type area, be excluded from the latter. At a meeting of the SACS Task Group on Cenozoic Stratigraphy in 1986, it was suggested that a new formation name should be established for the Palaeogene marine deposits, thus separating it from the Neogene Alexandria Formation. The name "Bathurst Formation" was formally revived by Maud et al. (1987), although the deposits in the immediate vicinity of Bathurst actually belong to the Alexandria Formation.

2.2 LITHOSTRATIGRAPHY

2.2.1 Full Name

Bathurst Formation.

2.2.2 Proposer of Name

Maud et al. (1987).

2.2.3 Stratigraphic Position and Age

The Bathurst Formation represents the oldest (lowermost) formation in the Algoa Group (see Chapter 8). The formation overlies pre-Cenozoic rocks unconformably as a thin veneer on a well-planed wavecut surface. It is in places overlain by calcrete or soil. The age of the

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Bathurst Formation is Palaeogene (probably Eocene, according to Maud et al., 1987 and Siesser and Miles, 1979 - amongst others).

2.2.4 Type Area and Derivation of Name

The type area is situated between the Kowie and Great Fish Rivers in the vicinity of the farm Birbury 206, about 8 km east north-east of Bathurst (Figs. 2.1, 2.2). The unit is named after the village of Bathurst (south-east of Grahamstown), since the majority of representative exposures of the formation occur in the district, and also because the name has some historical connections (see Section 2.1).

2.2.5 Geological Description

Basic concept and unifying features: The formation consists essentially of calcareous sandstone (often indurated and crystalline), conglomerate and limestone containing marine invertebrates (shells) as well as sharks' teeth. It is distinguished from underlying (pre-Cenozoic) units by its highly calcareous nature and from overlying deposits (e.g. calcrete) by its clastic origin. Criteria distinguishing the Bathurst Formation from the other (younger) marine deposits in the Algoa Group are summarised in Table 4.1.

Thickness: 1 - 12 m (average 3 m).

Lithology: **Sandstone** (45 - 82%): Mean thickness 0,5 m, max. 2 m (units moderately tabular to lenticular); fine- to coarse-grained, gritty/pebbly in places; structureless to

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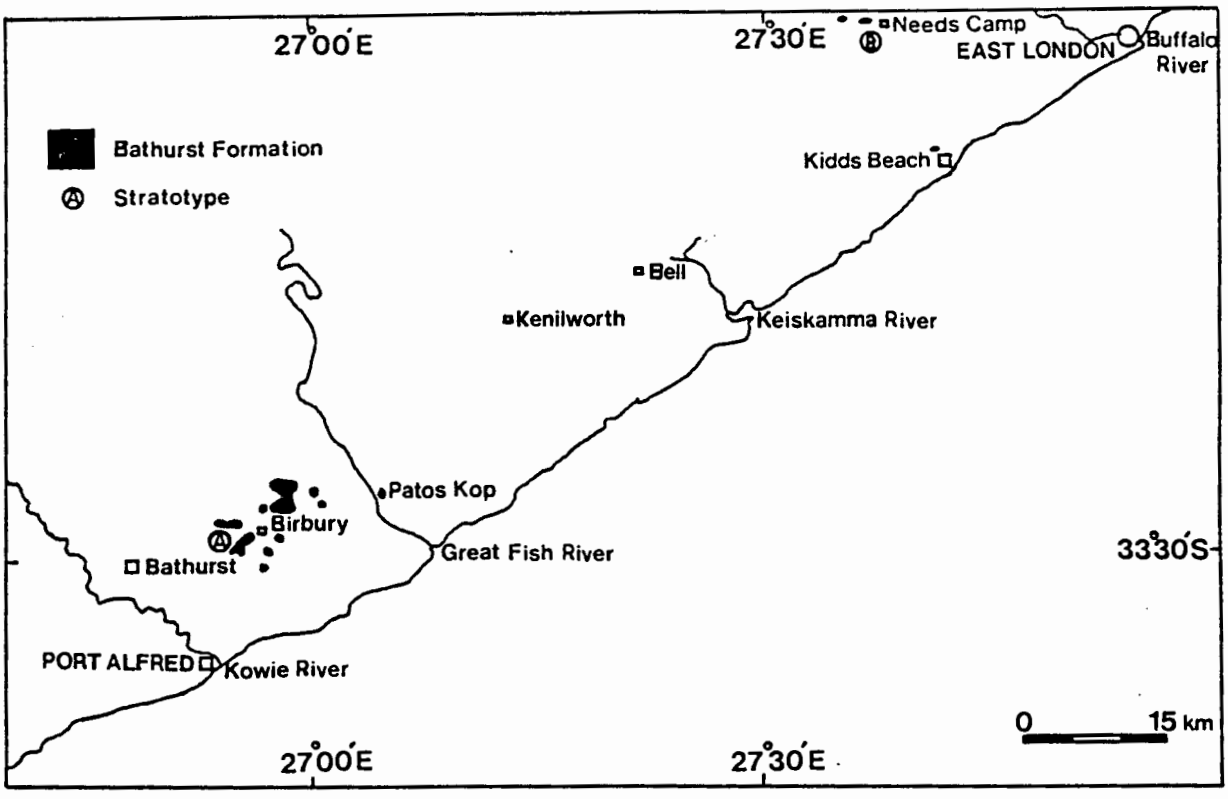

Fig. 2.1 - Distribution of Bathurst Formation and location of stratotypes A and B.

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vaguely horizontally laminated; thin-bedded; yellowish grey (5Y 7/2) to pale greenish yellow (10Y 8/2); calcareous, often glauconitic; moderately to well sorted; well rounded.

Conglomerate (0 - 20%): Mean thickness 0,4 m (units tabular to lenticular); pebbles to cobbles in medium to coarse-grained sandstone matrix; horizontally bedded, thin-bedded (beds moderately lenticular); very light grey (N8) to pale greenish yellow (10Y 8/2), clasts comprise quartz, quartzite, siltstone, sandstone, silcrete (Grahamstown Silcrete Formation), bone (probably derived from Karoo Sequence), and coral (cannibalised from older marine deposits?); clasts discoidal to roller shaped (Zingg classification).

Limestone (40 - 90%): Mean thickness 1,2 m, max. 3,5 m (units moderately lenticular); fine- to coarse grained; structureless to vaguely horizontally laminated; medium bedded; dark yellowish orange (10YR 6/6) to yellowish grey (5Y 7/3); shelly.

Palaeontology: In sandstone, comminuted shell fragments constitute between 10 and 60 per cent of the grains; some unbroken mollusc and brachiopod shells are present. Sharks' teeth normally abundant, especially in conglomerate. Characteristic macrofossil species (not recorded from either the Alexandria or Salnova Formations) include Aturia sp. (a nautiloid cephalopod), Pecten bathurstensis (previously identified as Chlamys bathurstensis, but here placed in the

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genus Pecten because of its equal "ears"), Entolium corneum, Aequipecten sp., Isognomon sp., Terabratulina sp. (a brachiopod) as well as an unidentified echinoid. Sharks' teeth, which are more abundant and represent a wider taxonomic range than those from the Alexandria Formation, include the following species: Charcharodon megalodon, C. angustidens, Oxyrhina desori, Odontaspis macrota and O. elegans (Mountain, 1962). Tankard (1975) reported Otodus obliquus, Odontaspis macrota and O. cuspidata which, according to S.P. Applegate (quoted by Tankard, 1975), also indicate an Eocene age for these deposits.

Genesis: Lithology and fossil (micro and macro) assemblages as well as the physical conditions of the fossils indicate a fairly high energy depositional environment, probably ranging from the shoreface to the foreshore.

2.2.6 **Boundaries**

Upper boundary: Unconformable, sharp. The boundary is defined as the base of surficial calcrete or soil.

Lower boundary: Unconformable, sharp. On crossing the boundary a sharp upward increase in $CaCO_3$-content takes place, due to the presence of abundant marine shell material in the Bathurst Formation.

Lateral boundary: The formation is terminated by erosional cut-offs in the west and east. The inland limit of the formation roughly coincides with the 360 m contour.

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2.2.7 Subdivision

No further subdivision into members has as yet been made.

2.2.8 Regional Aspects

Geographic distribution: Scattered isolated outcrops of the formation occur east of Bathurst in the vicinity of Birbury. Singular outcrops occur at Pato's Kop (on plateau on eastern bank of Great Fish River), Needs Camp (upper quarry) and near Kidds Beach (road cutting) respectively (Fig. 2.1).

Lateral variation: Lithological variations over short distances are typical and conspicuous.

Criteria for lateral extension: Because of the close similarity of sediments of the Bathurst Formation with those of the Alexandria Formation in the area east of the Kowie River, only micropalaeontological age determinations can really determine the true identification of the outcrops.

Correlation: No deposits with a similar age span have yet been identified along either the south-western Cape or the Natal/Zululand coasts. The Cheringoma and Salamanga Formations of Mozambique as well as the Buntfeldschuh Formation of Southern Namibia may be age correlatives.

2.2.9 Stratotypes

Stratotypes were selected at the following localities (Figs. 2.1, 2.2):

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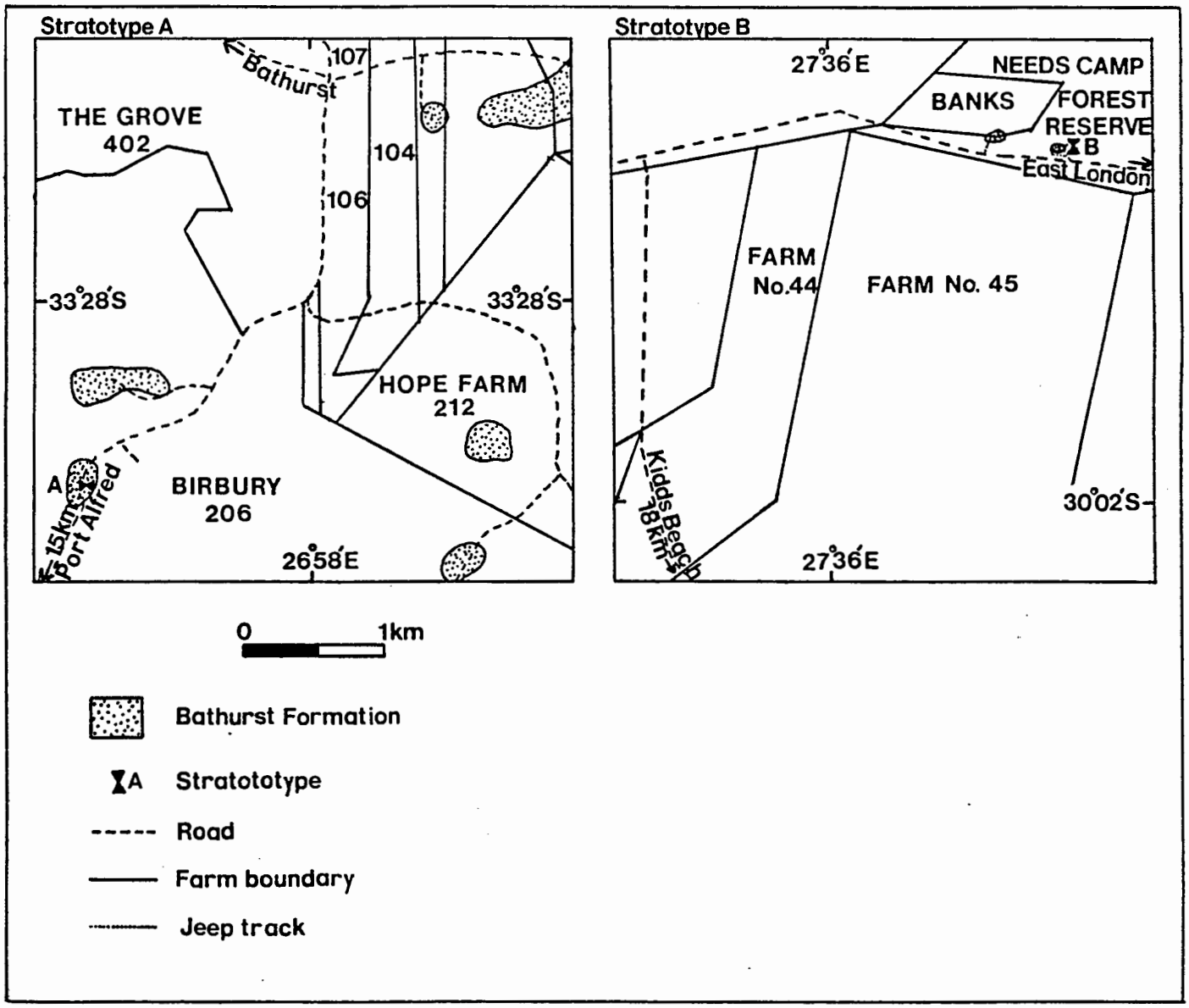

Fig. 2.2 - Location of stratotypes A (Birbury) and B (Needs Camp).

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A. Birbury (holostratotype).

B. Needs Camp (Upper Quarry) (reference stratotype).

A. BIRBURY STRATOTYPE

Kind and rank: Unit holostratotype.

Nature of section: Lower part of section is exposed in a road cutting, while upper part is exposed in a quarry face immediately on top, and continuing with the cutting.

Location: See Figure 2.2.

Accessibility: Good. Next to secondary road.

Lithology: Sandstone (81%), conglomerate (19%) - see columnar section (Fig. 2.3). Second sandstone from base moderately glauconitic.

Structure: No regional structure visible.

Reasons for selection: The section at Pato's Kop (lower boundary not exposed) selected by Maud et al. (1987) as a holostratotype is of a temporary nature only (future quarrying very probable), while the lower portion which has been revealed in a test pit, has been back-filled. It is thus rejected as a stratotype. The Birbury stratotype was selected for the following reasons: Good accessibility, presence of lower boundary, abundance of sharks' teeth, presence of Aturia sp. and Pecten bathurstensis (both

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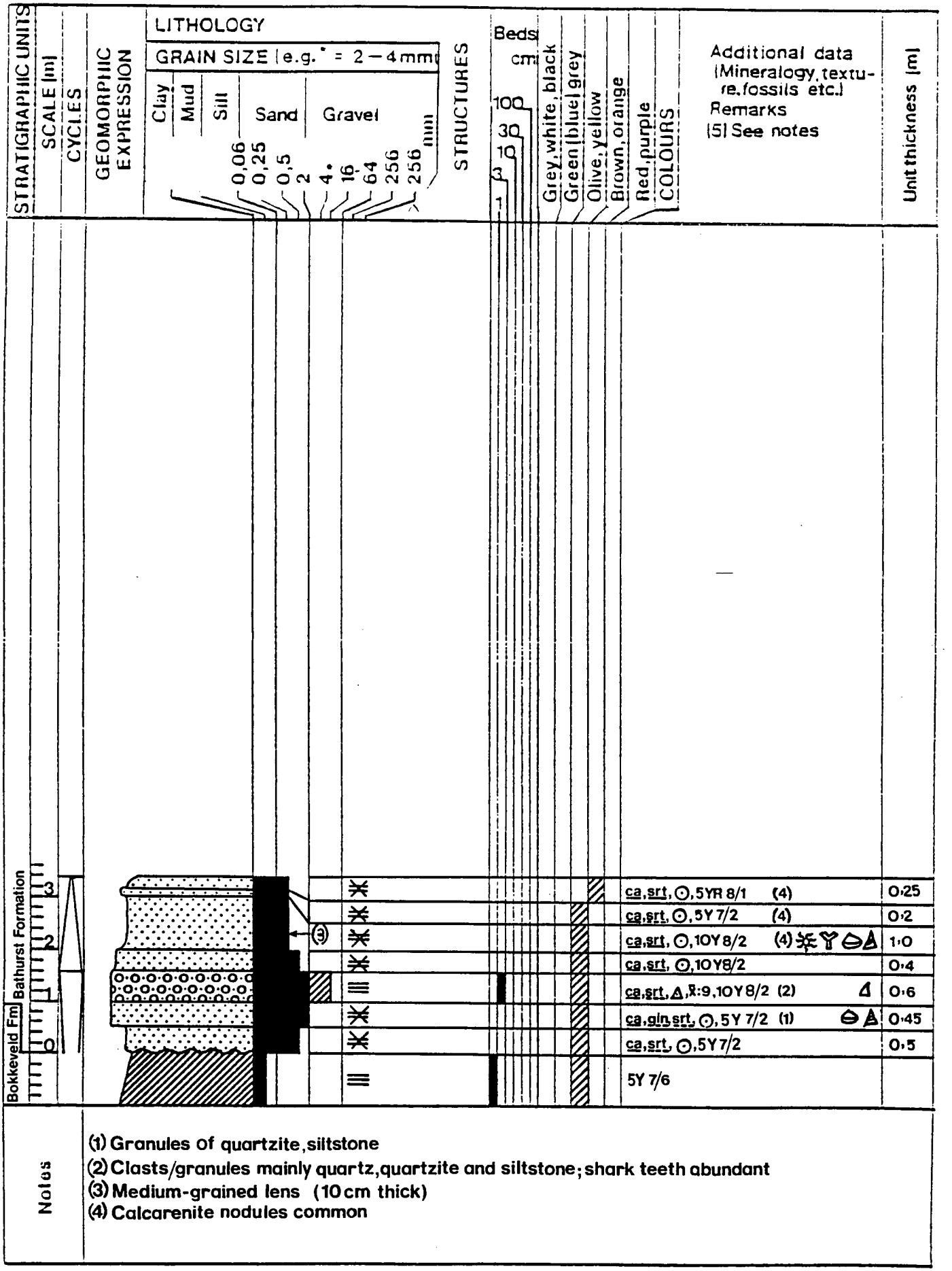

Notes

(1) Granules of quartzite, siltstone
(2) Clasts/granules mainly quartz, quartzite and siltstone; shark teeth abundant
(3) Medium-grained lens (10 cm thick)
(4) Calcarenite nodules common

Fig. 2.3 - Stratotype A (Birbury) of the Bathurst Formation. (For legend, see p. 17)

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LEGEND FOR STRATOTYPE SECTIONS
(for Chapters 2 - 6; 9 & 10)

CYCLES

Δ Fining upward

∇ Coarsening upward

LITHOLOGY, CONTACTS

Palaeosol/Soil horizon

Calc-tufa { .. sandy; — silty }

Limestone (coquinite, caquina) { o pebbly; ⌒ shelly; .. sandy; . clastic; x crystalline }

Calcrete

Conglomerate (calcrete-cemented)

Mudrock

Siltstone

Sandstone (o pebbly)

Conglomerate (matrix-supported)

Conglomerate (clast-supported)

Alternating lithologies

No outcrop

Unconsolidated

Semi-consolidated

Gradational contact

Sharp contact

Eroded contact

BEDS, COLOURS

Left-hand, right-hand lithologies

White, light

STRUCTURES

No visible structure

( ) Vague structure

Horizontal lamination

Wavy bedding

Inclined bedding (beach stratification)

Cross-bedding (general)

Aeolian cross-bedding

Planar cross-bedding

Trough cross-bedding

Herringbone cross-bedding

Imbrication

Slumps

Load casts

Flute casts

Current ripples (aeolian)

Wave ripples

Bioturbation

Horizontal burrows/tubes

Vertical burrows/tubes

ADDITIONAL DATA

Vertebrata

Shark teeth

Fish remains

Invertebrata

Plant remains

Plant roots

Brachiopoda

Bryozoa

Corals

Asteroidea

Echinoidea

Gastropoda

Pelecypoda

Ammonoidea

Nautiloidea

Cirrepedia

Malacostraca

Rounded — well rounded

Subangular — subrounded

Lenticular beds

Lenticular litho-units

Tabular litho-units

$\bar{x}$ Mean, max. size (mm)

[0,8/3] Mean litho-unit thicknesses for left-hand, right-hand lithologies respectively (cm)

ABBREVIATIONS

co: calcareous; fe: ferruginous; gln: glauconitic; hu: humic; f: very fine-grained; f: fine-grained; m: medium-grained; c: coarse-grained; srt: sorted; ( ) slightly; __ moderately; ___ highly; 10YR 8/2: see Rock-color Chart

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Bathurst Formation index fossils; the former being the only nautiloid thus far found in this formation). This outcrop also represents the only measurable section of the formation in the Bathurst district - other outcrops yield only very thin sections (< 1 m) or are only visible in plan view. The site has also been declared a national monument.

Adjacent units: No overlying deposits present. The formation is underlain by Bokkeveld Group sediments (see columnar section - Fig. 2.3).

Boundaries and contact relationships: Upper boundary at this locality is represented by a concrete building foundation (ruin on top of quarry face). Lower boundary exposed in road cutting, taken at base of calcareous sandstone above mudstone of Bokkeveld Group.

B. **NEEDS CAMP (UPPER QUARRY) STRATOTYPE**

Kind and rank: Unit reference stratotype.

Nature of section: Quarry face - fenced in as a national monument - exposing about 2,5 m of the formation.

Location: See Figure 2.2.

Accessibility: Good. Jeep track leads from tarred road to quarry. Off-road vehicle not required.

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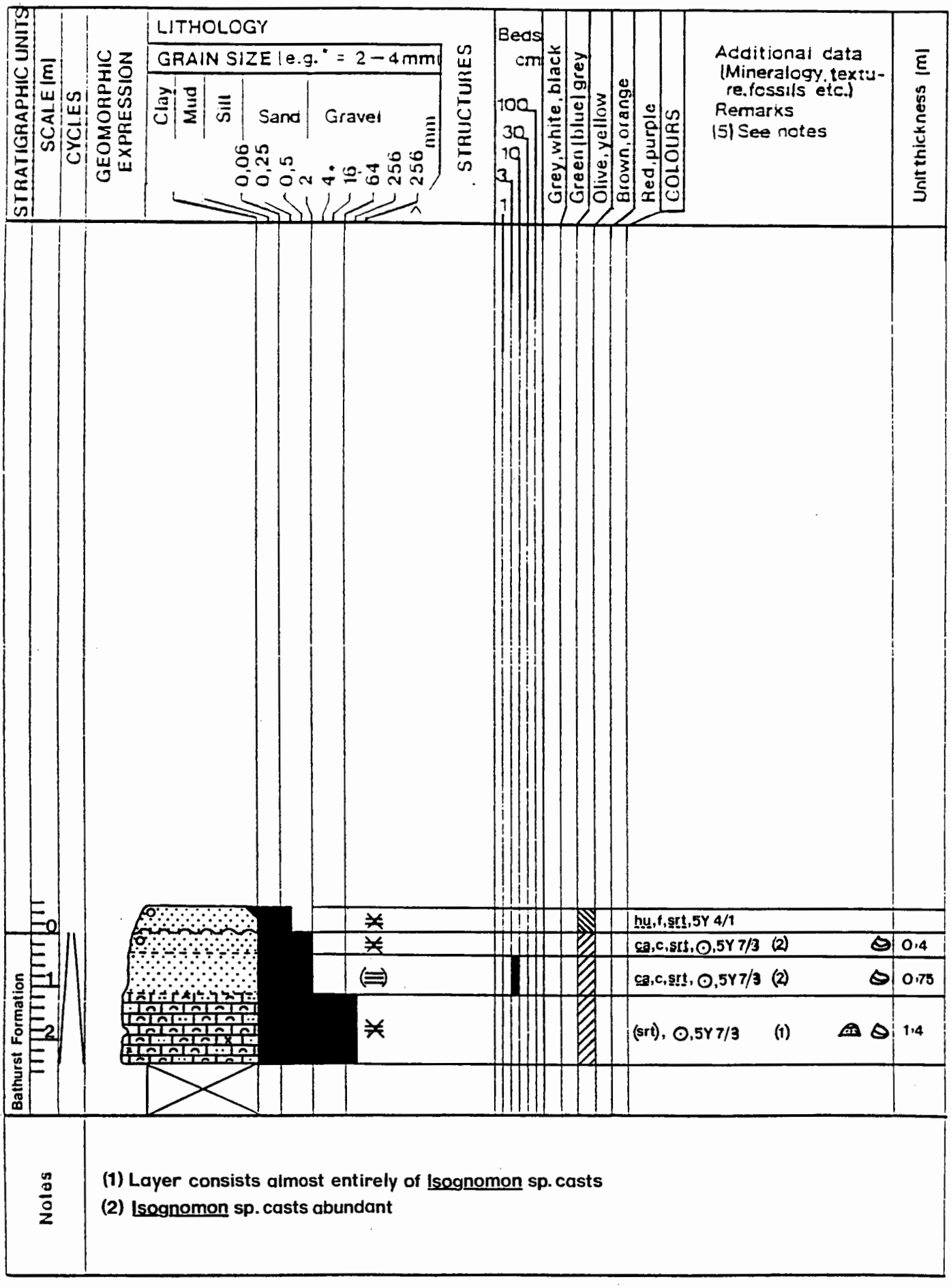

Fig. 2.4 - Stratotype B (Needs Camp) of the Bathurst Formation.

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Lithology: Sandstone (45%), limestone (55%) - see columnar section (Fig. 2.4). Section (both limestone and sandstone) consists almost exclusively of Isognomon casts.

Structure: No regional structure visible.

Reasons for inclusion: Stratotype included because of abundance of Isognomon casts as well as permanent nature of section (fenced in and declared as a national monument).

Adjacent units: The formation is overlain by a soil layer (see columnar section - Fig. 2.4). The underlying formation is not exposed, but it is in all probability a Karoo dolerite sill or the Igoda Formation (Upper Cretaceous).

Boundaries and contact relationships: Upper boundary taken at top of sandstone below base of overlying soil layer. Lower boundary not exposed.

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CHAPTER 3 - ALEXANDRIA FORMATION

The Alexandria Formation represents marine and paralic deposits of Neogene age.

3.1 LITERATURE REVIEW

The earliest contribution on the present-day Alexandria Formation was A.G. Bain's map, published in 1856, wherein he labelled these beds "Tertiary". In a lecture delivered at Grahamstown in 1857, Atherstone gave an account of marine beds that had been recognised along the Bushmans River in 1845. In the same year (1845) he and Dr. R.N. Rubridge examined an area near Oxhoek (a bend in the Bushmans River), where the latter found "Terabratula" sp. as well as "gigantic Ostrea". Whether it was Dr. Atherstone or A.G. Bain who first recognised the marine sediments, is not clear, but since these two collaborators had many joint excursions, credit must probably go to both for recognition of these layers as a separate entity.

Atherstone (1857) used the name "Tertiary shell beds", while Stow (1871) referred to this unit as "Pliocene or Postpliocene Strata of the Interior". In 1885, A. Moulle (quoted by Mountain, 1946) called the same Tertiary sequence the "Albany Formation", a name later also used by Corstorphine (1904). Rogers and Schwarz (1901) described "recent" deposits, "consisting of boulder beds and sands,

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containing many marine shells belonging to recent species, although some, such as a very large Pectunculus, appear to be absent from this part of the coast at the present time". ("Pectunculus" is presently known as Glycymeris borgesi, a diagnostic Alexandria fossil).

Rogers (1906) was the first to realise that the occurrence of these beds at various elevations from "a few feet (on the shores of Algoa Bay) up to some 1,300 ft (Addo Heights)" implied a very considerable period of deposition. He also observed that pebbles were abundant, and realised that parts of the rocks were beach deposits, referring to them as "marine beds of Tertiary or Recent age". Rogers and Du Toit (1909) gave an account of the distribution of the "Tertiary and Recent Deposits", but it was Schwarz (1908) who first used the name "Alexandria Formation". He erroneously considered the blue clay at the mouth of the Swartkops River, which he and Rogers had previously described as belonging to the Sundays River marine beds (now known as the Sundays River Formation), to be possibly the basal member of the Alexandria Formation, mainly on account of its fossil content. As a result of the findings of Lang (1908) in the Lower Quarry at Needs Camp (now known not to be part of the Tertiary marine deposits), Schwarz (1908) considered the Alexandria Formation to be of Cretaceous age: "There is no reason to doubt the determination of the age of the beds as Senonian or Danian, but at the same time the presence of sharks' teeth and the Mollusca of an Eocene type in these South African occurrences makes one at first hesitate".

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Newton (1913), on account of similarities of certain Alexandria fossils from the Albany Museum collected by Atherstone, Schwarz and a Mrs. Paterson, as well as from the British Museum (collected earlier by Atherstone and A.G. Bain), with those of European and South American species, assigned a Mio-Pliocene age to the formation. King (1953) and Haughton (1963), however, considered it to be Pliocene rather than Miocene in age. Wybergh (1920) used the name "Alexandria Series", a name also used by Haughton et al. (1937). Haughton (1925) gave a brief account of the Tertiary deposits of the south-eastern districts of the Cape Province, and on Cape Sheet No. 9 (Port Elizabeth) he distinguished between marine and continental types. The latter was thought to be contemporaneous, in part, with the marine facies of the "Alexandria Beds" towards the coast. Haughton (1925, p. 31) also realised that "the age of the formation is a progressive one, those portions nearer the present coast-line having been deposited at a more recent date than those further inland, on a gradually shelving marine plain down which the sea slowly retreated in a south-easterly direction". Haughton (1928), Amm (1934), Frankel (1936), Haughton et al. (1937) and Mountain (1946) included the overlying aeolian deposits with the marine deposits.

Engelbrecht et al. (1962) and Mountain (1962) were the first to map the marine and aeolian deposits separately. The first-named authors also, for the first time, differentiated between the Tertiary and Quaternary marine deposits. Nevertheless, SACS (1980), after recommendations by Ruddock to the appropriate Task Group in 1977, included both

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Tertiary and Quaternary marine deposits in the Alexandria Formation. Le Roux (1987c), however, proposed that Palaeogene as well as the Quaternary marine deposits be excluded from the Alexandria Formation proper since, in his opinion, they represented separate mappable formations.

Ruddock (1968) and King (1972a) concentrated mainly on geomorphological features associated with the deposition of the Alexandria Formation. Siesser (1972a) correlated the "coastal limestones" on a regional scale, also giving a petrographic description of them, including those of aeolian derivation (Siesser 1972b). Ruddock (1973) gave a summary of certain features of the "coastal limestones", as well as a check-list of marine fossils from these deposits.

3.2 LITHOSTRATIGRAPHY

3.2.1 Full Name

Alexandria Formation.

3.2.2 Proposer of Name

E.H.L. Schwarz (1908).

3.2.3 Stratigraphic Position and Age

The Alexandria Formation unconformably overlies the Mesozoic Uitenhage Group, the Palaeozoic Cape Supergroup or the pre-Cape Gamtoos Group as a veneer on well-planed seaward-sloping platforms. It underlies the Kinkelbos and Nanaga Formations, reddish terrestrial (fluvial) conglomerate/gravel (the Bluewater Bay Formation) and

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calcrete, all of Late Tertiary to Quaternary age. The age of the Alexandria Formation is probably Miocene to Pliocene (Siesser and Dingle, 1981).

3.2.4 Type Area and Derivation of Name

The type area is situated east of the Sundays River, in the vicinity of Colchester (Fig. 3.1). The unit is named after the town of Alexandria, since some of the best representative exposures occur in its district.

3.2.5 Geological Description

Basic concept and unifying features: The formation consists essentially of alternating layers of calcareous sandstone, conglomerate and coquinite, containing a rich assemblage of marine invertebrates. It is distinguished from underlying units by its highly calcareous nature, and from overlying units by the absence of aeolian cross-bedding, calcrete and reddish (terrestrial) silt, sand and gravel. Criteria distinguishing the Alexandria Formation from the other marine deposits in the Algoa Group are summarised in Table 4.1.

Thickness: 3 - 14 m (average 9 m).

Lithology: **Sandstone** (20 - 98%): Mean thickness 1 m, max. 5 m (units moderately tabular to lenticular); fine- to coarse-grained, pebbly in places; horizontally laminated (Pl. 3-1), planar/trough cross-bedded; thin- to medium-bedded; very light grey (N8) to yellowish grey (5Y 7/2 - 5Y

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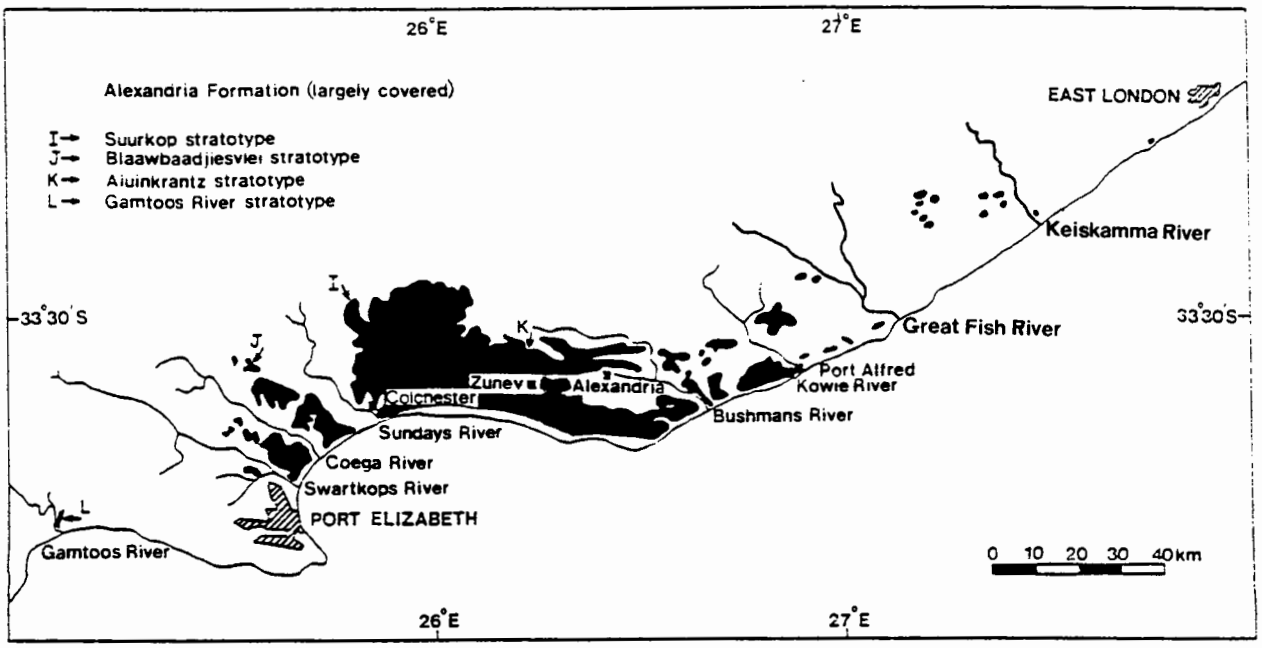

Fig. 3.1 - Distribution of Alexandria Formation and location of stratotypes I - L.

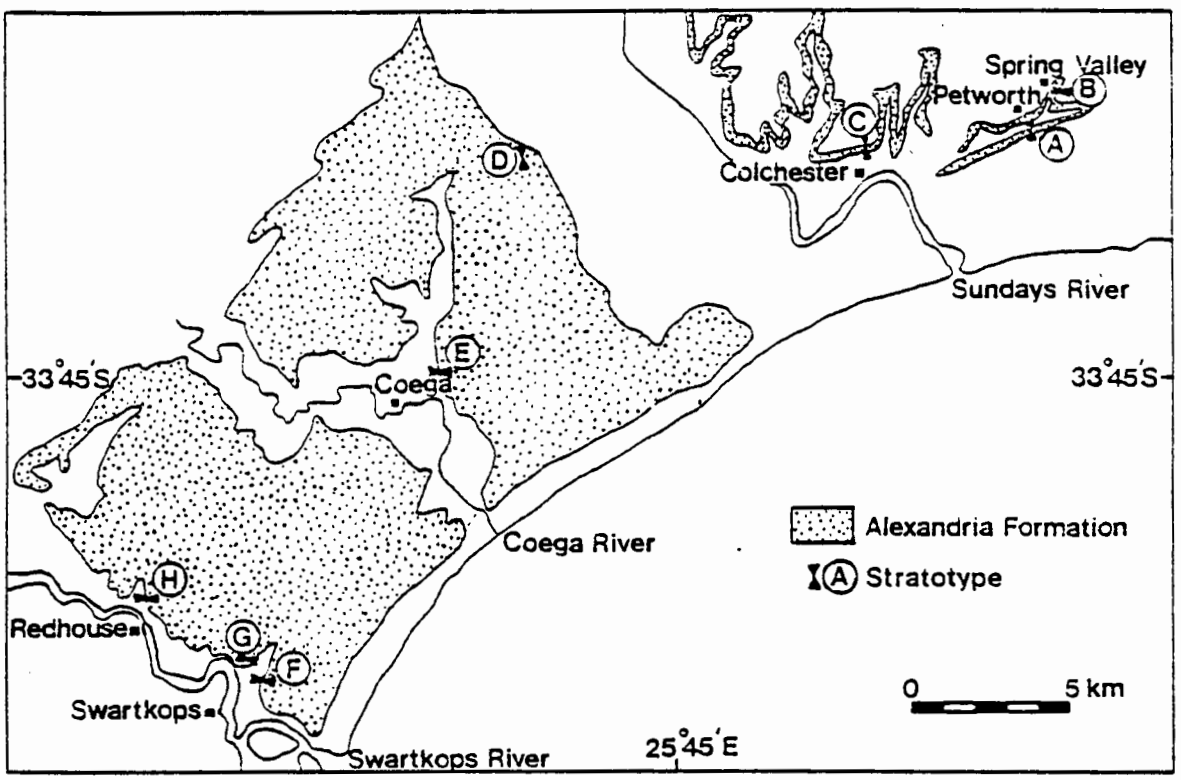

Fig. 3.2 - Location of stratotypes of the Alexandria Formation in the Swartkops - Colchester area.

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8/1); calcareous, often glauconitic; moderately to well sorted; well rounded.

Conglomerate (0 - 80%): Mean thickness 1 m, max. 3,5 m (units tabular to lenticular); pebbles to large cobbles in fine- to coarse-grained sandstone matrix; vaguely horizontally bedded, imbricated; thin- to medium-bedded (beds moderately lenticular); very light grey (N8) to very pale yellowish orange (10YR 8/2); max. clast size 300 mm; clasts comprise (in diminishing order) quartzite (Table Mountain Group), hornfels (Karoo Sequence, metamorphosed), sandstone (Uitenhage Group), shale (Bokkeveld Group); clasts discoidal to roller-shaped (Zingg classification).

Coquinite (0 - 40%): Mean thickness 1 m, max. 3,9 m (units moderately tabular); shell fragments vary in size between 5 and 15 mm, pebbly in places (Pl. 3-2); structureless to horizontally laminated, cross-bedded; very thin- to medium-bedded; greyish yellow (5Y 8/4) to pale yellowish orange (10YR 8/6); moderately sorted; subangular to subrounded.

Palaeontology: In sandstone, comminuted shell fragments constitute between 5 and 50 per cent (average 25 per cent) of the grains; some unbroken pelecypods and gastropods are present. About 70 per cent of coquinite consists of invertebrate remains, usually recrystallised. Oyster shells occur in conglomerate (Pl. 3-3).

More than 170 species of Mollusca, four species of Brachiopoda, at least four species of Echinodermata, a few

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species of Crustacea (e.g. Palaeoscylla sp. - a supposedly extinct species reported by Smuts, 1987), some Coelenterata, as well as some Bryozoa have been reported from the Alexandria Formation (Ruddock, 1973; Le Roux, 1987d). Vertebrate remains include sharks' teeth, fish teeth, as well as fish vertebrae and coprolites. Extinct molluscs include Glycymeris borgesi, Cypraea zietsmani, Tivella baini, Notocallista schwarzi, Cardium edgari, Melapium patersonae, Pirenella stowi, Ostrea redhousiensis and Calyptraea kilburni. The presence of any one of these guide fossils distinguishes the Alexandria Formation from the younger Salnova Formation (cf. Le Roux, 1986a) or the older Bathurst Formation (see also Table 4.1). Exotic species such as the West African Thais haemostoma, Venus verrucosa and Arca noae as well as the Indo-Pacific Vasum cf. truncatum, Amalda optima, Hastula diversa and Melapium cf. elatum indicate differences in the extent of Neogene marine-biogeographical provinces (Le Roux, 1987b). Two ecozones in the Alexandria Formation, namely those of the oyster Crassostrea margaritacea (Pl. 3-4) (within the basal conglomerate) and the sand-dollar Echinodiscus sp. (in the overlying sandstone) have been recognised (Le Roux, 1987d). Depositional environments are inferrable from certain fossils found in situ, e.g. typical estuarine species such as Solen capensis, Loripes clausus and Dosinia hepatica (Le Roux, 1987d). The existence of musselcracker-type fish during the Neogene is indicated by typical perforations on shells of Cypraea zietsmani caused by mulluscivorous fish predation, pointing to an ex-pisce origin of these shells (Liltved and Le Roux, 1988).

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The trace fossils of the Alexandria Formation belong to two marine ichnofacies, namely the Skolithos and Cruziana ichnofacies (Smuts, 1987). The Skolithos ichnofacies contains Ophiomorpha (Pl. 3-5), Skolithos and Monocraterion which indicate energetic littoral to sublittoral environments subject to abrupt erosion/deposition cycles. The Cruziana ichnofacies contains Thalassinoides (Pl. 3-6), Arenicolites and Rosselia and is typical of sublittoral to shallow littoral areas below normal wave base. Common depositional environments of the Cruziana ichnofacies include shallow shelf areas, lagoons, estuaries and bays.

Genesis: Sedimentary structures and lithology, corroborated by biogenic structures and fossil assemblages, point to depositional environments ranging from shoreface and foreshore to lagoonal and/or estuarine.

According to Le Roux (1987a, 1987d) certain fossil species, if found in situ (i.e. not transported), can be used as depositional environment indicators. An estuarine environment for part of the Alexandria Formation was proved by the occurrence of Solen capensis, Loripes clausus, Dosinia hepatica, Assiminea ovata and Nassarius kraussianus. For other portions of the Alexandria Formation the following depositional environments are indicated:

1) Foreshore with sandy beach by Donax serra, Bullia digitalis and Tellina alfredensis.
2) Foreshore with rocky substratum by Patella sp., Diodora sp., Siphonaria sp. and Helcion dunkeri.

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3) Sublittoral by gastropods such as Bullia annulata, Amalda contusa and Melapium elatum as well as Dentalium sp. - an offshore scaphopod.

4) Sublittoral and/or estuarine by Echinodiscus colchesterensis, which is in all probability the predecessor to the modern-day E. bisperforatis (commonly known as "pansy shells" or "sand dollars"). The latter species live in calm, relatively deep-water conditions (10m +), such as found in the sublittoral zone along open coasts or in the deeper, calmer parts of estuaries. At Spring Valley these fossils occur in a flat-laminated sandstone that locally shows hummocky cross-bedding, which is indicative of the sublittoral zone. However, at the same locality E. colchesterensis also occurs in a higher massive sandstone with signs of profuse bioturbation that may be indicative of estuarine conditions.

A dual provenance is indicated for the Alexandria Formation. The intrabasinal provenance is indicated by the presence in conglomerates, of Cape Supergroup and Uitenhage Group clasts, as well as cannibalised Alexandria Formation of earlier deposition. The extrabasinal (Karoo) provenance is manifested by the presence of lidianite, tillite, chert and even dolerite clasts in some conglomerates.

Other aspects: The coquinite, conglomerate and certain sandstones are well indurated and cause the formation to form more resistant ridges on weathering. Vegetation differences (grassy on calcareous Alexandria Formation and

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bushy on underlying clayey Uitenhage Group sediments) facilitate recognition and mapping of the formation.

3.2.6 **Boundaries**

Upper boundary: Unconformable, sharp. The boundary is defined as the base of surficial calcrete or reddish silt and sand (Kinkelbos Formation), or reddish (terrestrial) gravel/conglomerate (Bluewater Bay Formation), or the cross-bedded aeolian Nanaga Formation.

Lower boundary: Unconformable, sharp. On crossing the boundary a sharp upward increase in $CaCO_3$ content takes place, due to the presence of abundant marine shell material in the Alexandria Formation.

Lateral boundary: The formation is terminated by an erosional cut-off in the west. The eastern boundary is provisionally taken at the Igoda River beyond which no typical Alexandria Formation rocks have thus far been found. The northern limit of the formation roughly coincides with the 300-m contour in the area west of the Kowie River, above which coeval silcrete or high-level fluvial gravel may occur. Southwards, the Alexandria Formation may pass below sea-level onto the continental shelf, although it would seem more probable that post-Tertiary (marine) erosion may have removed all but remnants of the Alexandria Formation in the off-shore.

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3.2.7 **Subdivision**

No further subdivision into members has been deemed necessary.

3.2.8 **Regional Aspects**

Geographic distribution: Discontinuous outcrops of the formation occupy a narrow strip between the southernmost mountain ranges and the sea, extending from near Port Alfred to Port Elizabeth, with a few outliers towards the Gamtoos River in the west. A few small isolated outcrops occur east of the Kowie River. Occurrences of "Alexandria Formation" west of 24°E longitude, as shown by SACS (1980, Fig. 7.9.1), are lithologically quite dissimilar to the Alexandria Formation of the type area, being non-calcareous, and should therefore be excluded from this unit.

Lateral variation: Tertiary marine deposits are generally thin or absent on those parts of the coastal plain underlain by the Cape Supergroup. Two of the more important exceptions are Rooikrans on the southern bank of the Bushmans River, where about 6 m of the Alexandria Formation rests unconformably on steeply dipping Bokkeveld and Witteberg rocks, and the area in the vicinity of Alexandria, where the Bokkeveld is unconformably overlain by up to 8 m thick Alexandria Formation. Lithological variations over short distances are typical and conspicuous, e.g. compare stratotypes A to H which are situated within a few kilometres of one another.

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Criteria for lateral extension: East of the Bushmans River poor outcrops result in fragmentary sections, and the limestone at some localities (e.g. near Zuney, west of Alexandria) is atypical of the Alexandria Formation coquinites. However, palaeontological evidence such as the occurrence of the bivalves Glycymeris borgesi, Cardium edgari and Melina gaudichaudi, characteristic of the Alexandria Formation, suggests that these deposits also belong to this formation.

Correlation: Correlation with the De Hoopvlei Formation of the Bredasdorp Group (Malan, in press - a) in the southwestern Cape, as well as with the Uloa Formation in Natal (SACS, 1980) seems warranted. Deposits of similar age probably occur along the west coast.

3.2.9 **Stratotypes**

Stratotypes were selected at the following localities (Figs. 3.1, 3.2, 3.3):

A. Petworth (lectostratotype).
B. Spring Valley (parastratotype).
C. Colchester (parastratotype).
D. Tankatara (reference stratotype).
E. Coega (reference stratotype).
F. Swartkops railway cutting (reference stratotype).
G. Swartkops pillar (reference stratotype).
H. Dassiekrans (Redhouse) (reference stratotype).
I. Suurkop (Addo Park) (reference stratotype).
J. Blaawbaadjiesvlei (reference stratotype).

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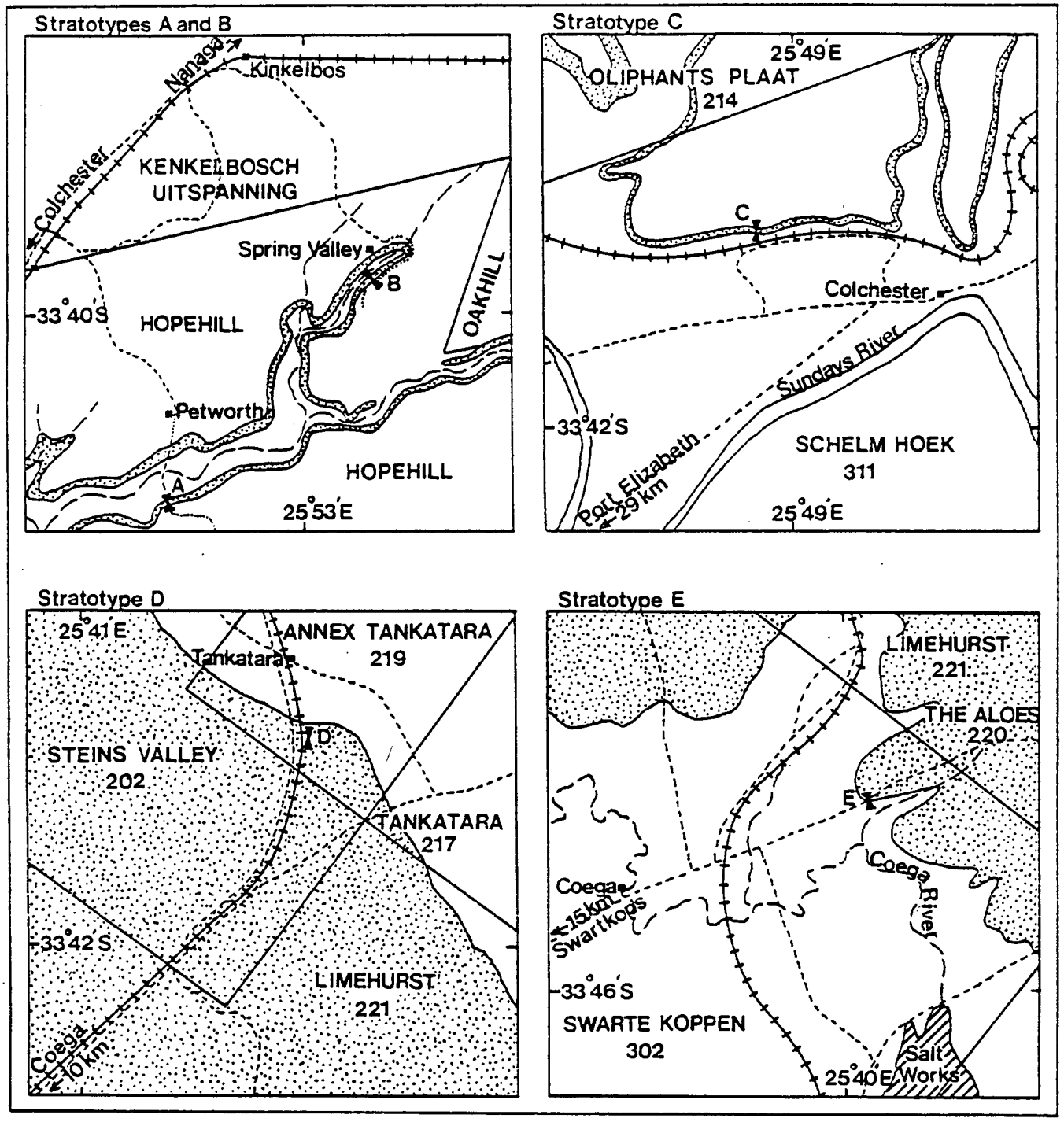

Fig. 3.3a - Location of stratotypes A (Petworth), B (Spring Valley), C (Colchester), D (Tankatara) and E (Coega). (For legend - see Fig. 3. b).

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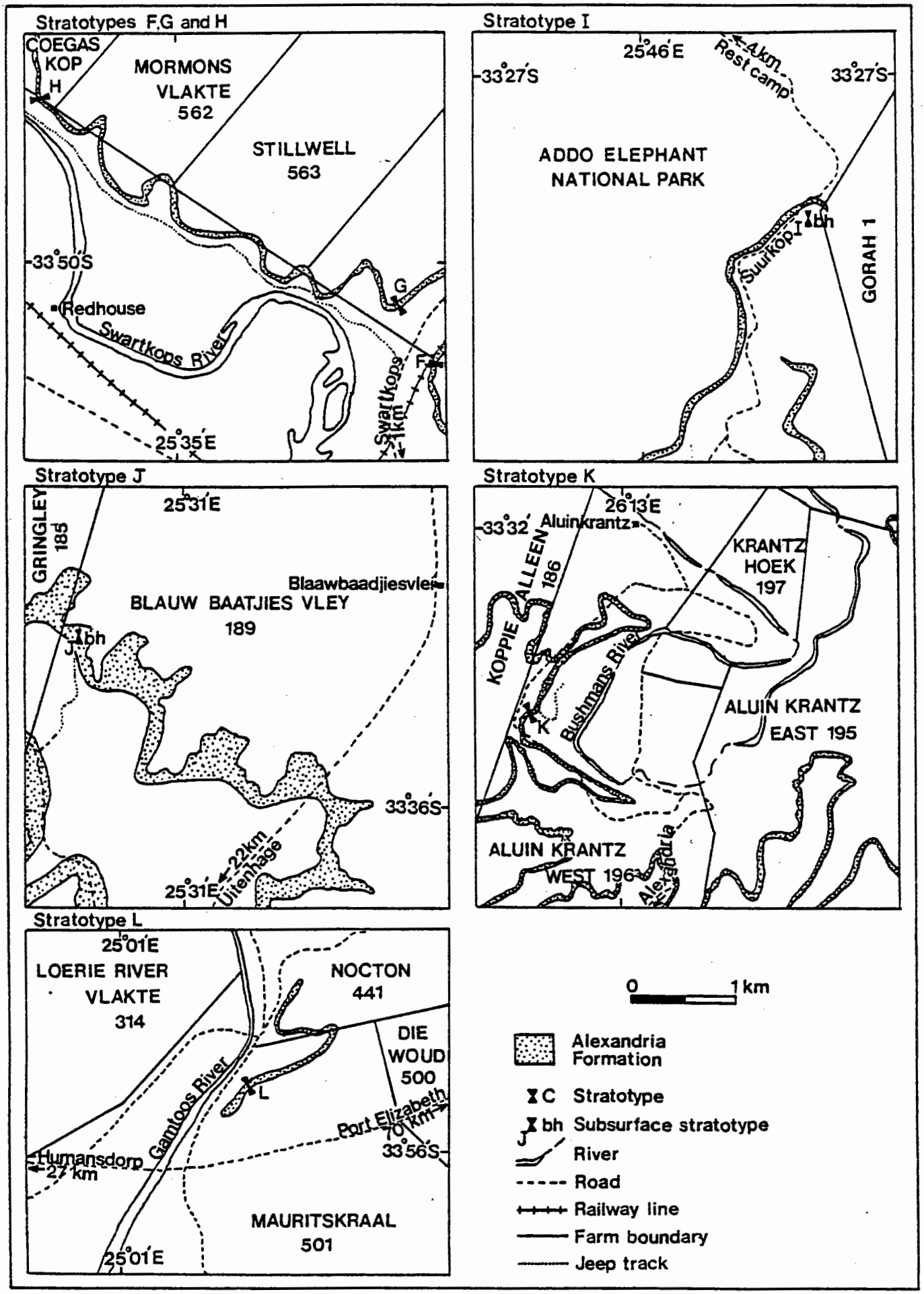

Fig. 3.3b - Location of stratotypes F (Swartkops Railway cutting), G (Swartkops pillar), H (Dassiekrans/Redhouse), I (Suurkop/Addo Park), J (Blaawbaadjiesvlei), K (Aluinkrantz) and L (Gamtoos River).

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K. Aluinkrantz (Alexandria) (reference stratotype).

L. Gamtoos River (reference stratotype).

A. PETWORTH STRATOTYPE

Kind and rank: Unit lectostratotype.

Nature of section: Jeep track cutting which exposes the full thickness of the formation.

Location: See Figure 3.3.

Accessibility: Fair. Jeep track in good condition except after heavy rains when Grootkloof Spruit could be in flood for a day or two. Any vehicle with adequate ground clearance will take one to within 150 m of stratotype.

Lithology: Sandstone (48%), conglomerate (34%) and coquinite (18%) - see columnar section (Fig. 3.4). Herringbone cross-bedding and load casts are present in some sandstone units, which are also slightly ferruginous in places. One of the conglomerates shows inclined bedding (beach stratification). A few dolerite clasts are present. A coquinite-filled trough is present in one of the sandstones.

Structure: No regional structure visible.

Reason for selection: Stratotype selected because of exactly defined line of measurement (jeep track cutting)

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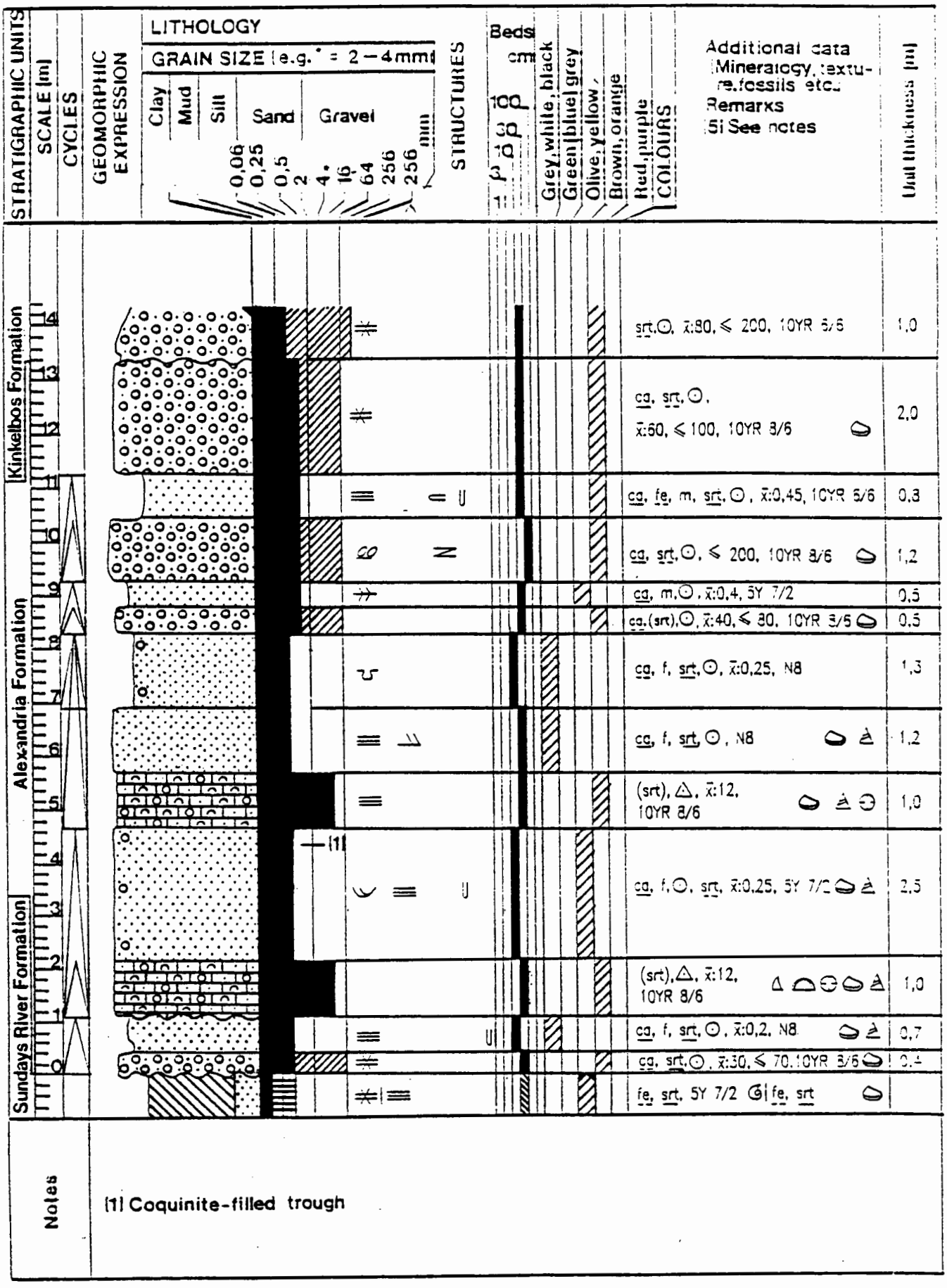

Fig. 3.4 - Stratotype A (Petworth) of the Alexandria Formation.

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as well as above-average thickness.

Adjacent units: See columnar section (Fig. 3.4).

Boundaries and contact relationships: Upper boundary taken at top of fourth thick conglomerate below base of reddish (terrestrial) pebbles in an unconsolidated sandy matrix (Kinkelbos Formation). Lower boundary rather poorly exposed; taken at base of first conglomerate above the greyish mudstone and sandstone of the Sundays River Formation.

B. **SPRING VALLEY STRATOTYPE**

Kind and rank: Unit parastratotype.

Nature of section: Cliff on southern side of incised valley, which exposes almost the full thickness of the formation.

Location: See Figure 3.3.

Accessibility: Fair. Jeep track leads from homestead to top of krantz, but a cautious approach from here is necessary because of loose sand of the overlying Kinkelbos Formation. Any vehicle with adequate ground clearance will reach top of krantz.

Lithology: Sandstone (83%), conglomerate (12%) and coquinite (5%) - see columnar section (Fig. 3.5).

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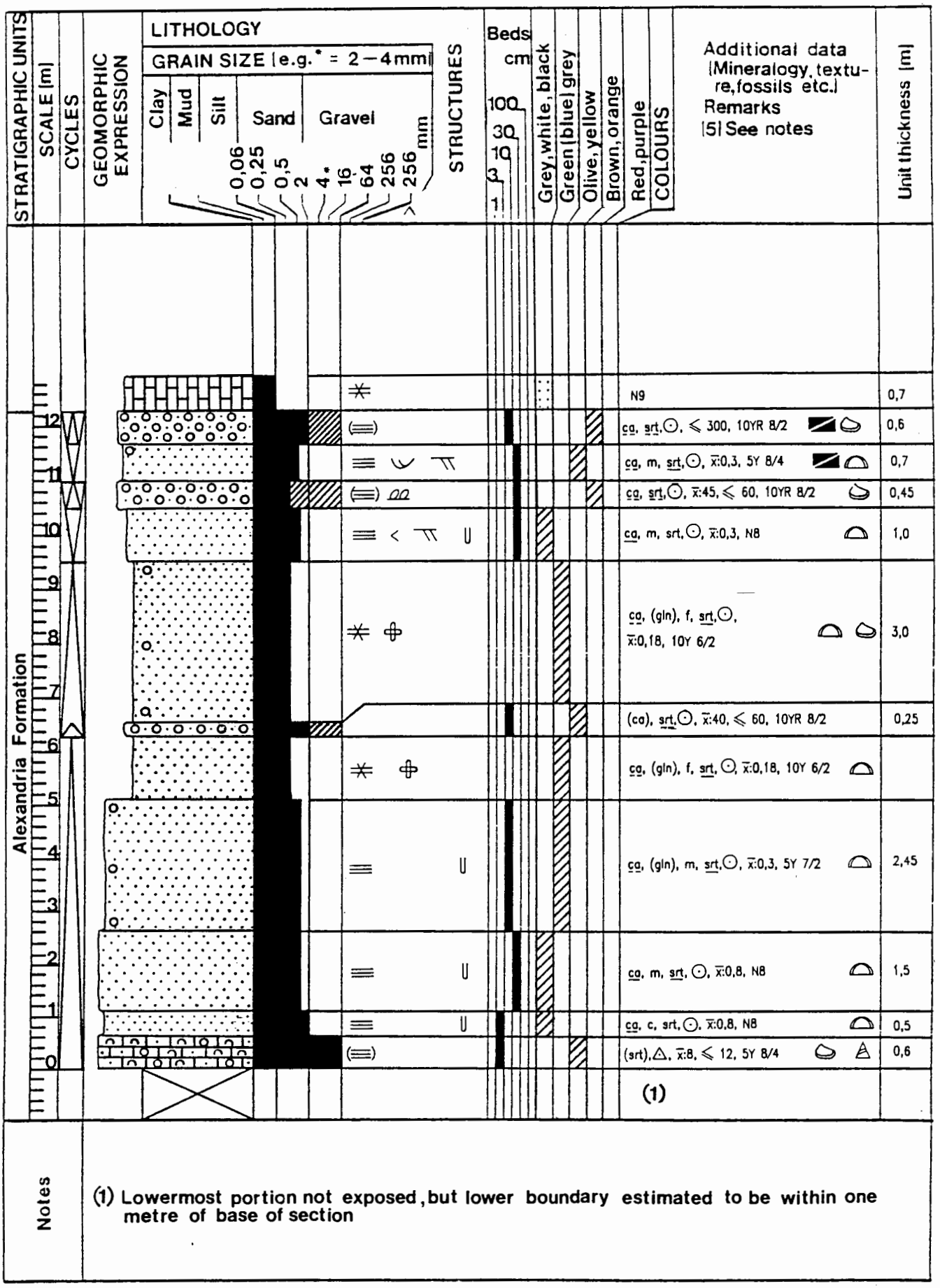

Fig. 3.5 - Stratotype B (Spring Valley) of the Alexandria Formation.

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Structure: No regional structure visible.

Reasons for inclusion: Stratotype included mainly on account of the presence of two structureless, poorly consolidated sandstones, probably representing an estuarine/ lagoonal deposit.

Adjacent units: See columnar section (Fig. 3.5).

Boundaries and contact relationships: Upper boundary defined as top of third conglomerate, below the calcrete. Lower boundary obscured by talus deposits but exposed in an outcrop on the opposite side of the valley where it occurs at the base of a conglomerate, in the same stratigraphic position as the basal coquinite, overlying greyish mudstone of the Sundays River Formation.

C. COLCHESTER STRATOTYPE

Kind and rank: Unit parastratotype.

Nature of section: Southward-facing cliff exposing the full thickness of the formation over a lateral distance of about two kilometres.

Location: See Figure 3.3.

Accessibility: Good; exposures are within 200 m of railway service road; approach to cliff restricted by thick thorny vegetation.

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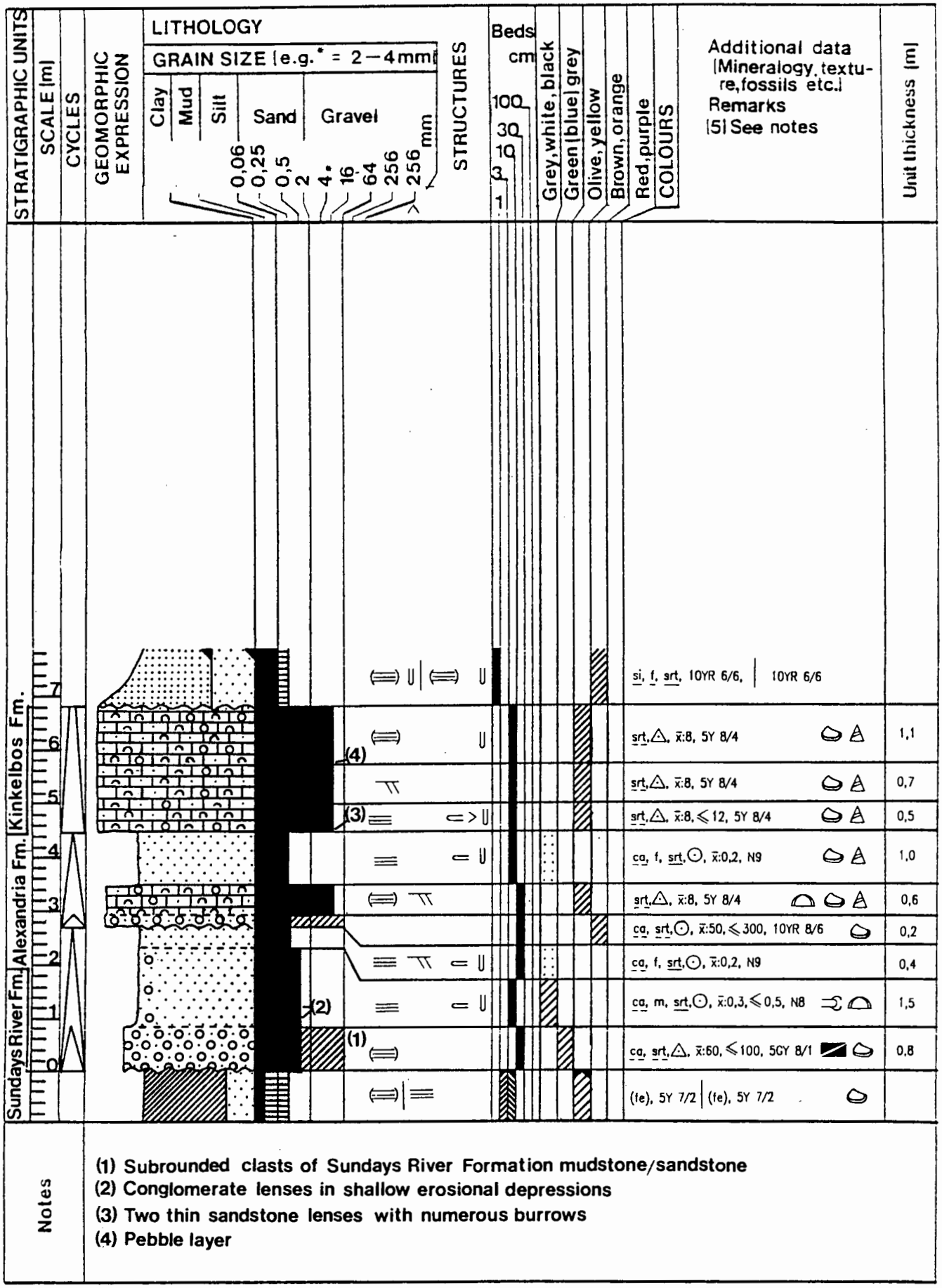

Notes

(1) Subrounded clasts of Sundays River Formation mudstone/sandstone
(2) Conglomerate lenses in shallow erosional depressions
(3) Two thin sandstone lenses with numerous burrows
(4) Pebble layer

Fig. 3.6 - Stratotype C (Colchester) of the Alexandria Formation.

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Lithology: Sandstone (43%), coquinite (42%) and conglomerate (15%) - see columnar section (Fig. 3.6). Upper coquinite unit divisible into three parts, with pebbles and shell debris relatively abundant in middle. Pebbles in upper part become smaller and less abundant towards top, while shell remains and sand matrix become more abundant.

Palaeontology: In situ Echinodiscus fossils occur in lower sandstone. Numerous burrows (Ophiomorpha) characterise upper sandstone unit, in some cases resembling possible hatching chambers.

Structure: No regional structure visible.

Reason for inclusion: Relative abundance of coquinite.

Adjacent units: See columnar section (Fig. 3.6).

Boundaries and contact relationships: Upper boundary defined as eroded top of coquinite below the reddish sands and silts of the Kinkelbos Formation. Lower boundary taken at base of basal conglomerate overlying greyish mudstones of the Sundays River Formation.

D. **TANKATARA STRATOTYPE**

Kind and rank: Unit reference stratotype.

Nature of section: Railway cutting which exposes the full

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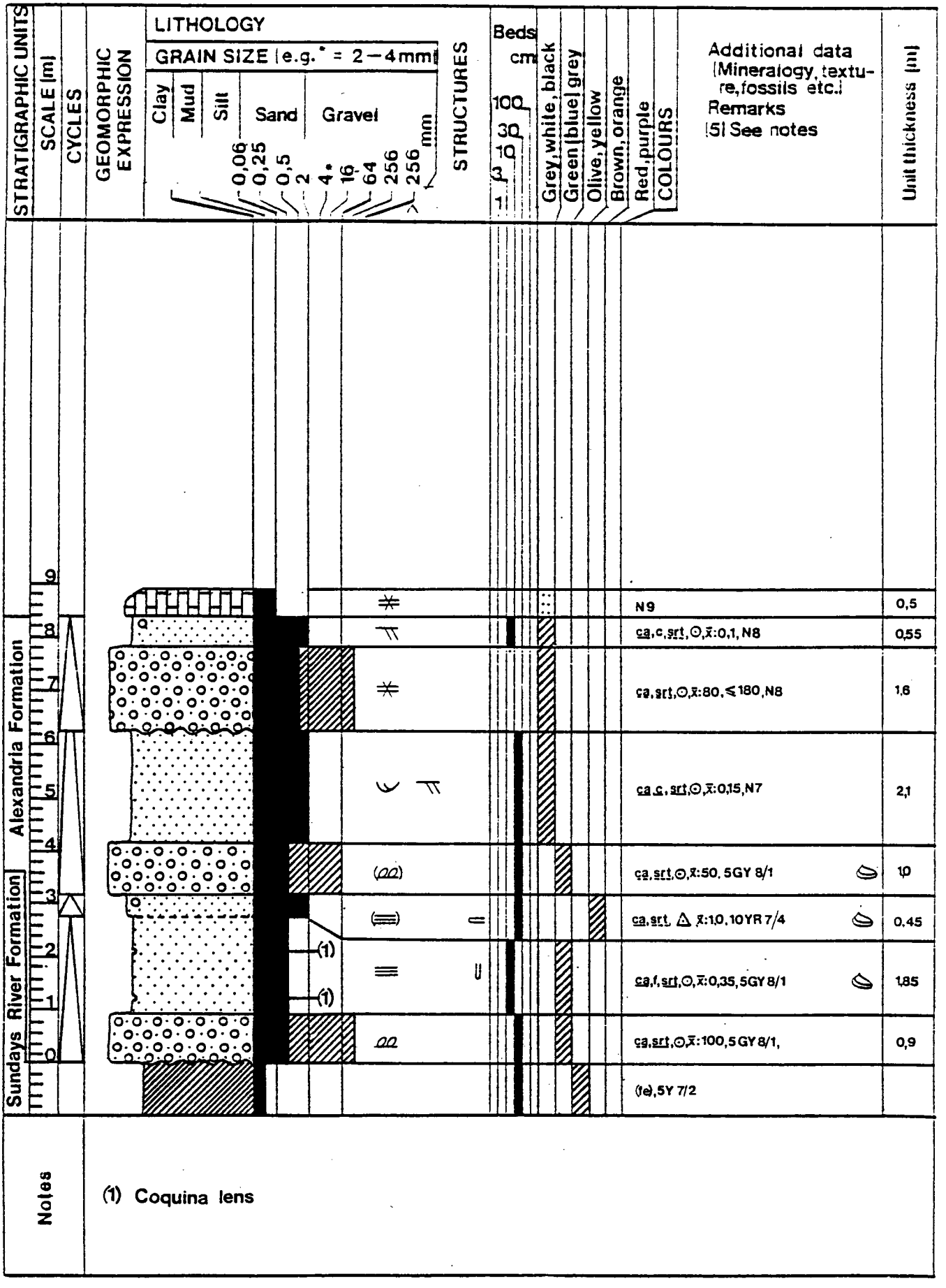

Fig. 3.7 - Stratotype D (Tankatara) of the Alexandria Formation.

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thickness of the formation over a lateral distance of about 300 m (Pl. 3-7).

Location: See Figure 3.3.

Accessibility: Good; exposures are next to railway service road.

Lithology: Sandstone (59%) (Pl. 3-8), conglomerate (41%) - see columnar section (Fig. 3.7).

Structure: A slight southerly dip (1 - 2°) is discernible.

Reason for inclusion: Stratotype included because of absence of coquinite.

Adjacent units: See columnar section (Fig. 3.7).

Boundaries and contact relationships: Upper boundary taken at top of pebbly sandstone below surficial calcrete. Lower boundary defined as base of basal conglomerate overlying greyish mudstones of the Sundays River Formation.

E. COEGA STRATOTYPE

Kind and rank: Unit reference stratotype.

Nature of section: Lower part of section is exposed by a road cutting, while upper part is exposed in a quarry immediately on top, and continuing with the cutting.

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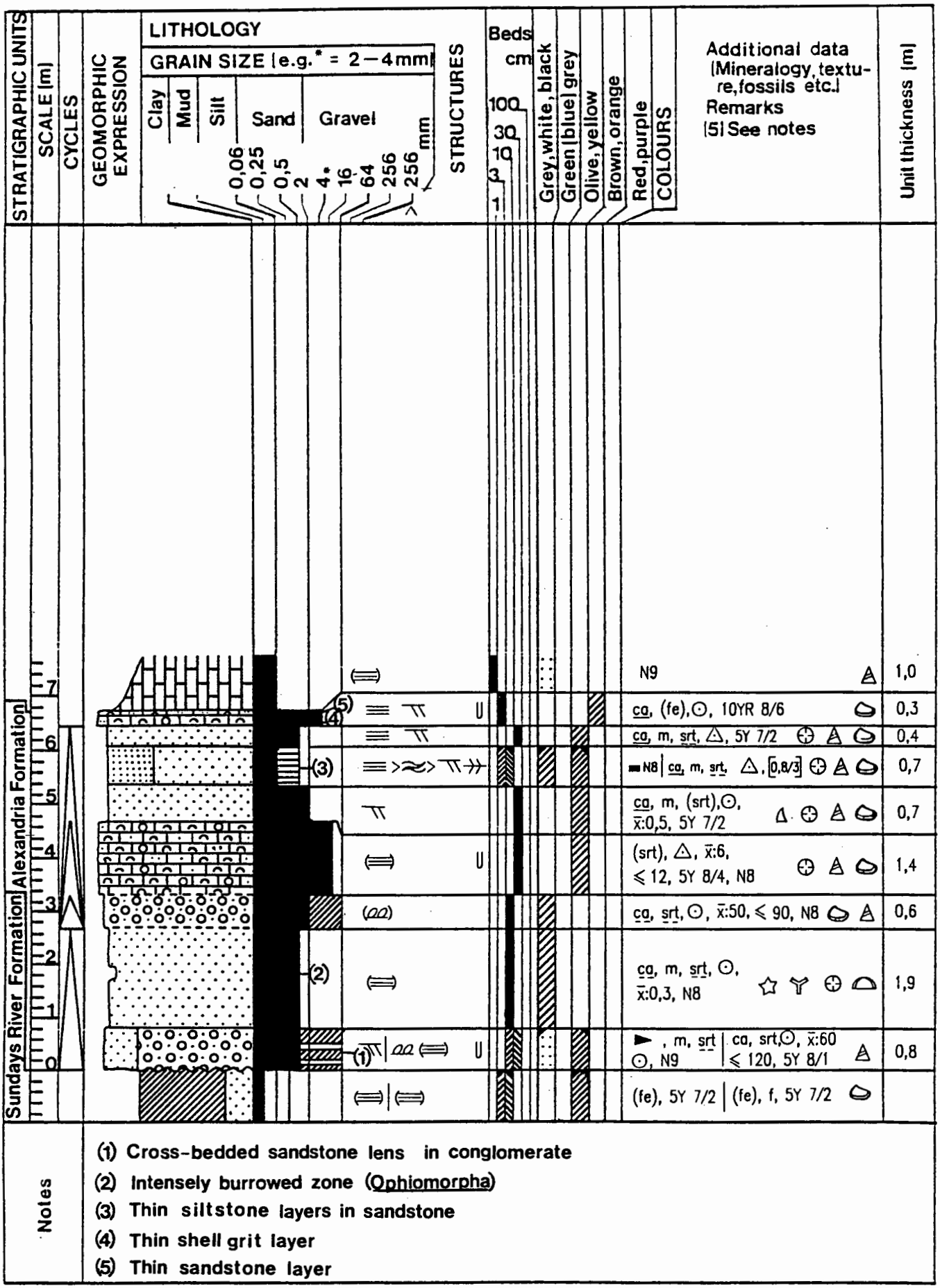

Fig. 3.8 - Stratotype E (Coega) of the Alexandria Formation.

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Location: See Figure 3.3.

Accessibility: Excellent; exposures adjoin tarred road.

Lithology: Sandstone (54%), coquinite (27%), conglomerate (17%) and siltstone (2%) - see columnar section (Fig. 3.8). Herringbone cross-bedding and wavy bedding present in places in sandstone. Alternating thicker sandstone and thinner siltstone layers occur in upper sandstone unit, while cross-bedded sandstone lenses are present in basal conglomerate. Clasts in the basal conglomerate also comprise some reworked Alexandria Formation coquinite. The siltstone has a mean grain size of 0,03 - 0,06 mm, being vaguely horizontally laminated and very light grey (N8).

Palaeontology: Occasional in situ Echinodiscus fossils found in lower sandstone together with urchin (echinoid) spines. Intensely burrowed (Ophiomorpha) zone present in middle of lower sandstone.

Structure: A general dip of 2° to 3° to the southwest could be ascertained.

Reason for inclusion: Stratotype included mainly on account of presence of sandstone/siltstone alternations in upper sandstone unit.

Adjacent units: See columnar section (Fig. 3.8).

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Boundaries and contact relationships: Upper boundary taken at top of limestone with interbedded sandstone/shell grit below surficial calcrete containing shells of Achatina zebra, a terrestrial snail. Lower boundary defined as base of basal conglomerate above the unconformity on greyish mudstone and sandstone of the Sundays River Formation.

F. SWARTKOPS RAILWAY CUTTING STRATOTYPE

Kind and rank: Unit reference stratotype.

Nature of section: Railway cutting which exposes the full thickness of the formation.

Location: See Figure 3.3.

Accessibility: Good; exposures within 200 m of railway service road.

Lithology: Sandstone (84%) and conglomerate (16%) - see columnar section (Fig. 3.9). Inclined bedding in some sandstone units. Clasts in basal conglomerate exclusively oyster shells.

Palaeontology: Crabs' claws found in third sandstone from base. Intensely burrowed (Ophiomorpha) zone occurs near top of lower sandstone. Upper conglomerate contains good specimens of Barbatia sp., Melapium sp. and Calyptraea sp.

Structure: Strata dip to the southeast at 1 - 2°.

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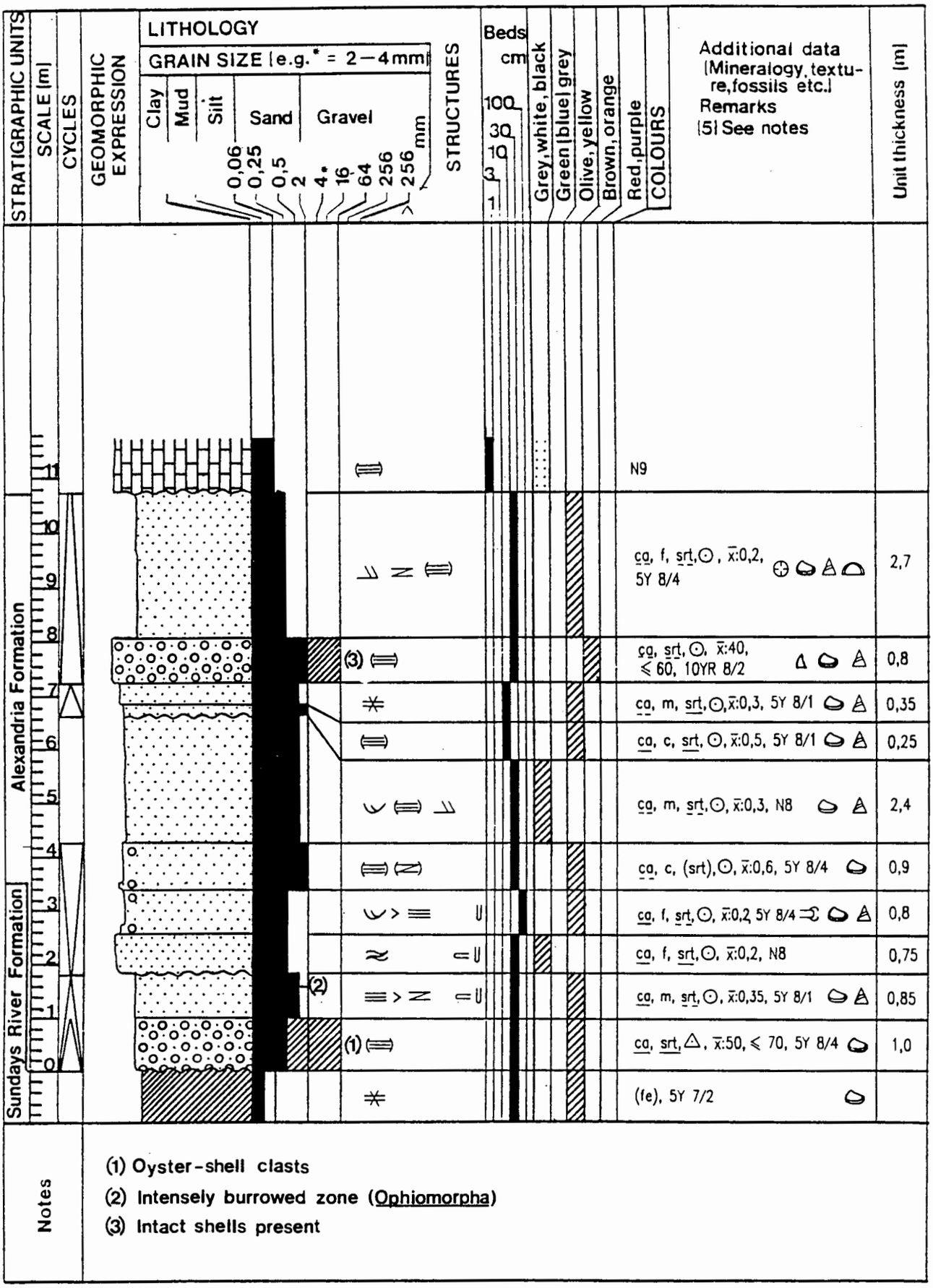

Fig. 3.9 - Stratotype F (Swartkops railway cutting) of the Alexandria Formation.

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Reasons for inclusion: Stratotype included on account of presence of basal oyster shell conglomerate, the relative abundance of sandstone and the absence of coquinite.

Adjacent units: See columnar section (Fig. 3.9).

Boundaries and contact relationships: Upper boundary taken at top of sandstone below calcrete containing shells of Achatina zebra, a terrestrial snail. Lower boundary taken at base of oyster-shell conglomerate overlying greyish mudstone of the Sundays River Formation.

G. SWARTKOPS PILLAR STRATOTYPE

Kind and rank: Unit reference stratotype.

Nature of section: Remaining pillar of Alexandria Formation sediments supporting a telephone post, resting on Sundays River Formation in Brickworks quarry.

Location: See Figure 3.3.

Accessibility: Good; exposure adjoins quarry road.

Lithology: Sandstone (64%), with load casts in upper units, and coquina (36%), unconsolidated with shells and shell fragments varying in size between 4 and 50 mm. See columnar section (Fig. 3.10).

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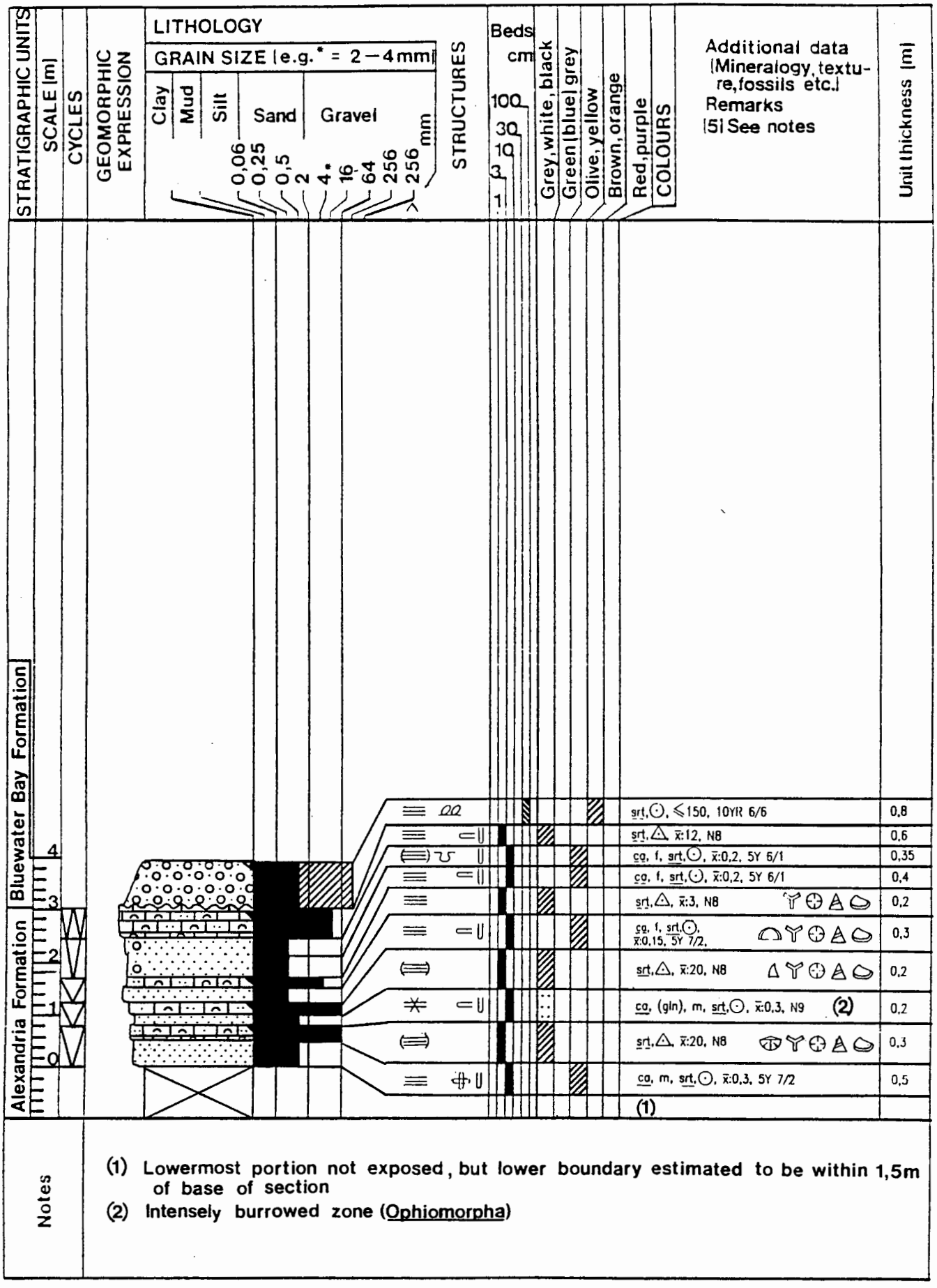

Notes

(1) Lowermost portion not exposed, but lower boundary estimated to be within 1,5m of base of section

(2) Intensely burrowed zone (Ophiomorpha)

Fig. 3.10 - Stratotype G (Swartkops pillar) of the Alexandria Formation.

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Palaeontology: Second sandstone from base is intensely burrowed (Ophiomorpha - Pl. 3-5), while basal sandstone is characterised by abnormally thick (6 cm diameter) burrows (Pl. 3-9).

Structure: No regional structure visible.

Reasons for inclusion: Presence of intensely burrowed (Ophiomorpha) sandstone as well as the occurrence of coquina.

Adjacent units: See columnar section (Fig. 3.10).

Boundaries and contact relationships: Upper boundary taken at eroded top of pebbly coquina below calcrete and reddish fluvial conglomerate of Bluewater Bay Formation. Lower boundary, though not exposed in the section, can be inferred from other parts of the quarry and is taken at the base of the very resistant calcareous sandstone above the greyish mudstone of the Sundays River Formation.

H. DASSIEKRANS (REDHOUSE) STRATOTYPE

Kind and rank: Unit reference stratotype.

Nature of section: Cliff on bank of river exposing the full thickness of the formation.

Location: See Figure 3.3.

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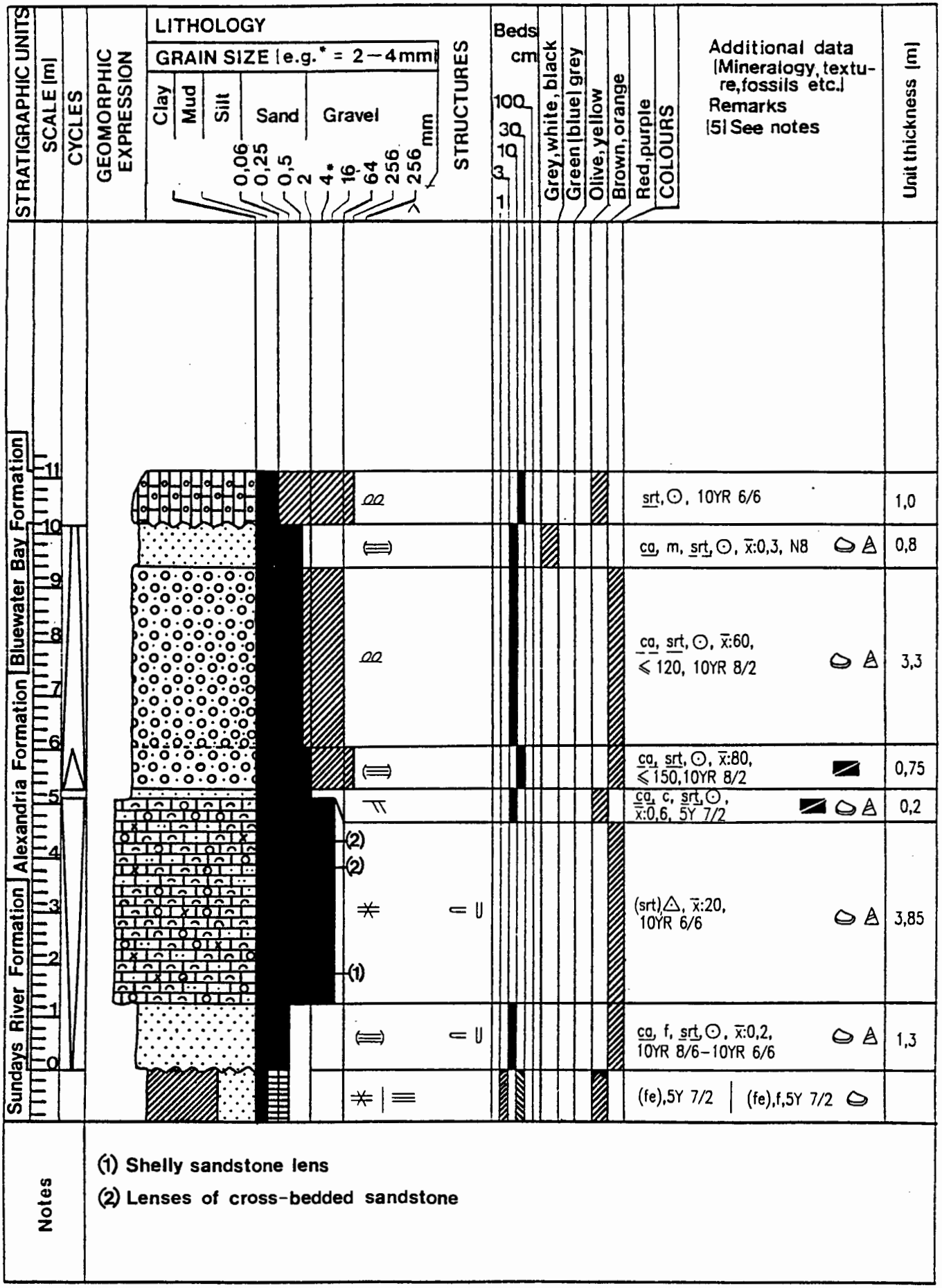

Fig. 3.11 - Stratotype H (Dassiekrans/Redhouse) of the Alexandria Formation.

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Accessibility: Reasonable. Jeep track, usually in fair condition, leads to trigonometrical beacon at top of cliff and can be negotiated by any vehicle with adequate ground clearance. Direct approach from below is practically impossible because of dense vegetation.

Lithology: Conglomerate (40%), coquinite (38%) and sandstone (22%) - see columnar section (Fig. 3.11). Coquinite pebbly to cobbly; lenses of cross-bedded sandstone present.

Palaeontology: In coquinite many shells of Glycymeris sp., Scissodesma sp., Cardium sp., Tivela sp. and others are present; also casts of gastropods (Pl. 3-10).

Structure: No regional structure visible.

Reason for inclusion: Relative abundance of conglomerate and coquinite.

Adjacent units: See columnar section (Fig. 3.11).

Boundaries and contact relationships: Upper boundary placed at top of sandstone below reddish fluvial conglomerate (Bluewater Bay Formation), in this case cemented by calcrete. Lower boundary taken at base of calcareous sandstone overlying greyish mudstones of the Sundays River Formation.

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I. SUURKOP (ADDO PARK) STRATOTYPE

Kind and rank: Unit reference stratotype.

Nature of section: Borehole core, of which recovery was complete.

Location: See Figure 3.3. Borehole core can be viewed at the Geological Survey, Port Elizabeth.

Accessibility: Good.

Lithology: Sandstone (97%), conglomerate (2%) and coquinite (1%) - see columnar section (Fig. 3.12). Herringbone cross-bedding locally present in sandstone.

Palaeontology: Sharks' teeth of the Charcharodon-type are present in the coquinite.

Structure: Not descernible.

Reasons for inclusion: Above-average thickness of formation, as well as abundance of sandstone. This stratotype also represents the Alexandria Formation situated above the 120 m contour (290 m) which is probably Miocene in age (see Chapter 12).

Adjacent units: See columnar section (Fig. 3.12).

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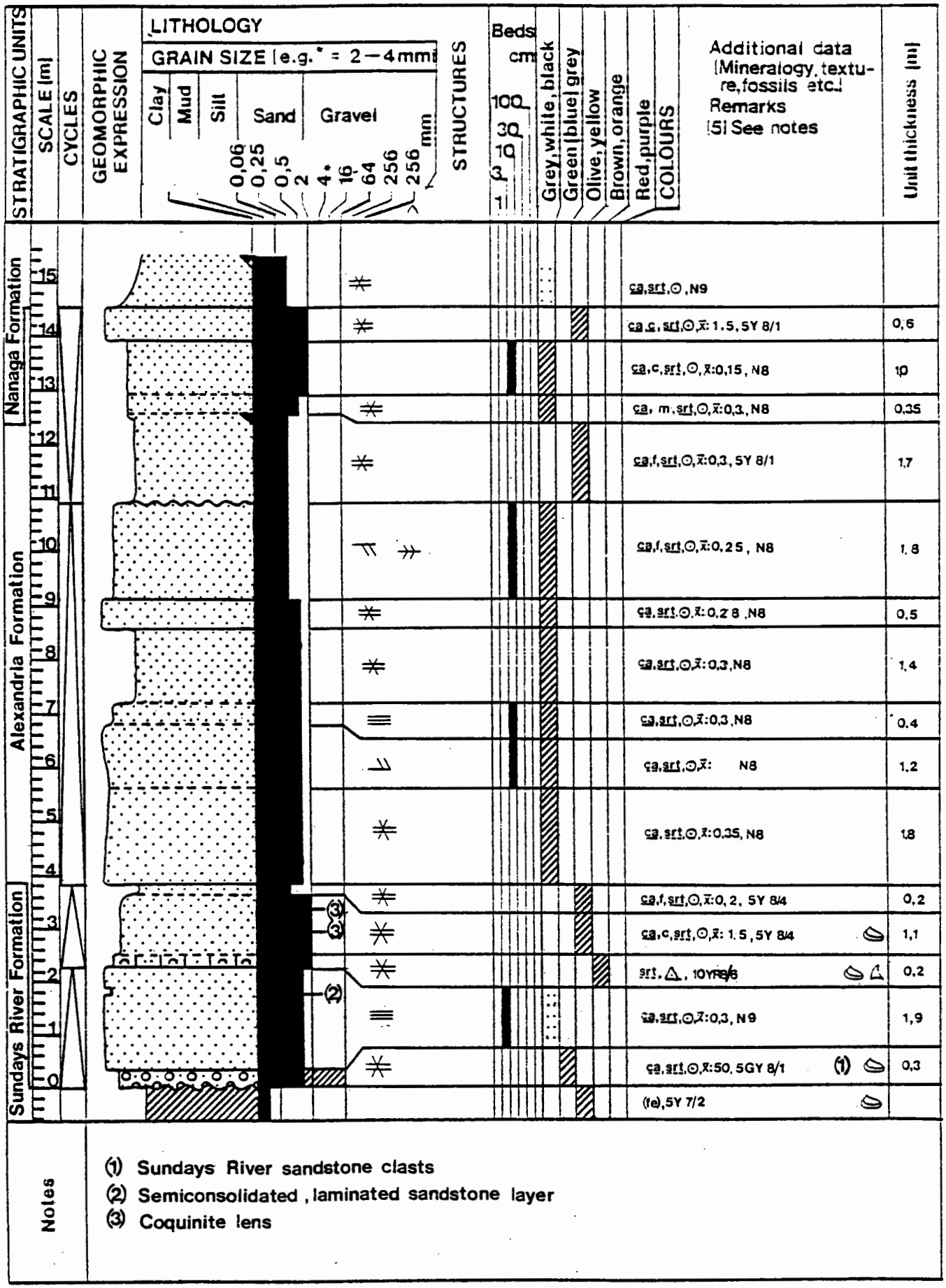

Fig. 3.12 - Stratotype I (Suurkop/Addo Park) of the Alexandria Formation.

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Boundaries and contact relationships: Upper boundary taken at top of upper sandstone below aeolian sandstone of Nanaga Formation. Lower boundary taken at base of basal conglomerate above the unconformity on greyish mudstone and sandstone of the Sundays River Formation.

J. BLAAWBAADJIESVLEI STRATOTYPE

Kind and rank: Unit reference stratotype.

Nature of section: Borehole core, of which recovery was about 80 per cent.

Location: See Figure 3.3. Borehole core can be viewed at the Geological Survey, Port Elizabeth.

Accessibility: Good.

Lithology: Sandstone (57%), conglomerate (40%) and coquinite (3%) - see columnar section (Fig. 3.13). Clasts in some conglomerates exclusively Bokkeveld shale.

Palaeontology: Fish tooth found in upper coquinite.

Structure: Not discernible.

Reasons for inclusion: Above-average thickness of formation, as well as relative scarcity of coquinite. This stratotype also represents the Alexandria Formation situated

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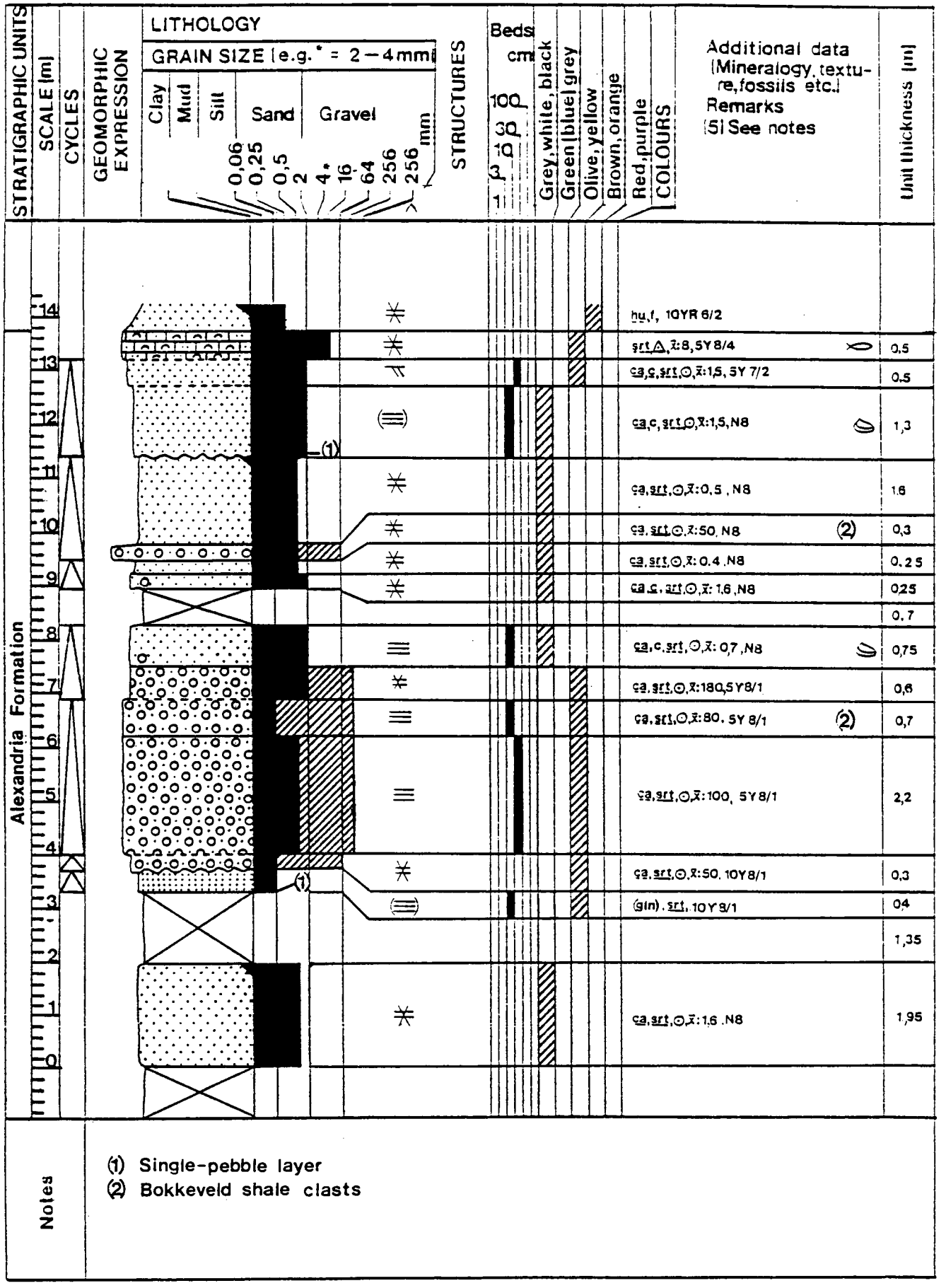

Fig. 3.13 - Stratotype J (Blaawbaadjiesvlei) of the Alexandria Formation.

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above the 120 m contour (240 m) which is probably of Miocene age (see Chapter 12).

Adjacent units: See columnar section (Fig. 3.13).

Boundaries and contact relationships: Upper boundary taken at top of coquinite below humic soil. Lower boundary obscured because of core loss.

K. ALUINKRANTZ STRATOTYPE

Kind and rank: Unit reference stratotype.

Nature of section: Cliff on western side of incised river valley, which exposes the full thickness of the formation over a lateral distance of more than 400 m.

Location: See Figure 3.3.

Accessibility: Good; exposures are within 200 m of secondary road.

Lithology: Sandstone (98%) and conglomerate (2%) - see columnar section (Fig. 3.14). Herringbone cross-bedding (Pl. 3-11) is present in basal sandstone unit.

Palaeontology: Basal conglomerate is laterally (towards north) replaced by an oyster shell conglomerate (Pl. 3-12) (max. c. 0,8 m thick) where it also occurs near top of succession.

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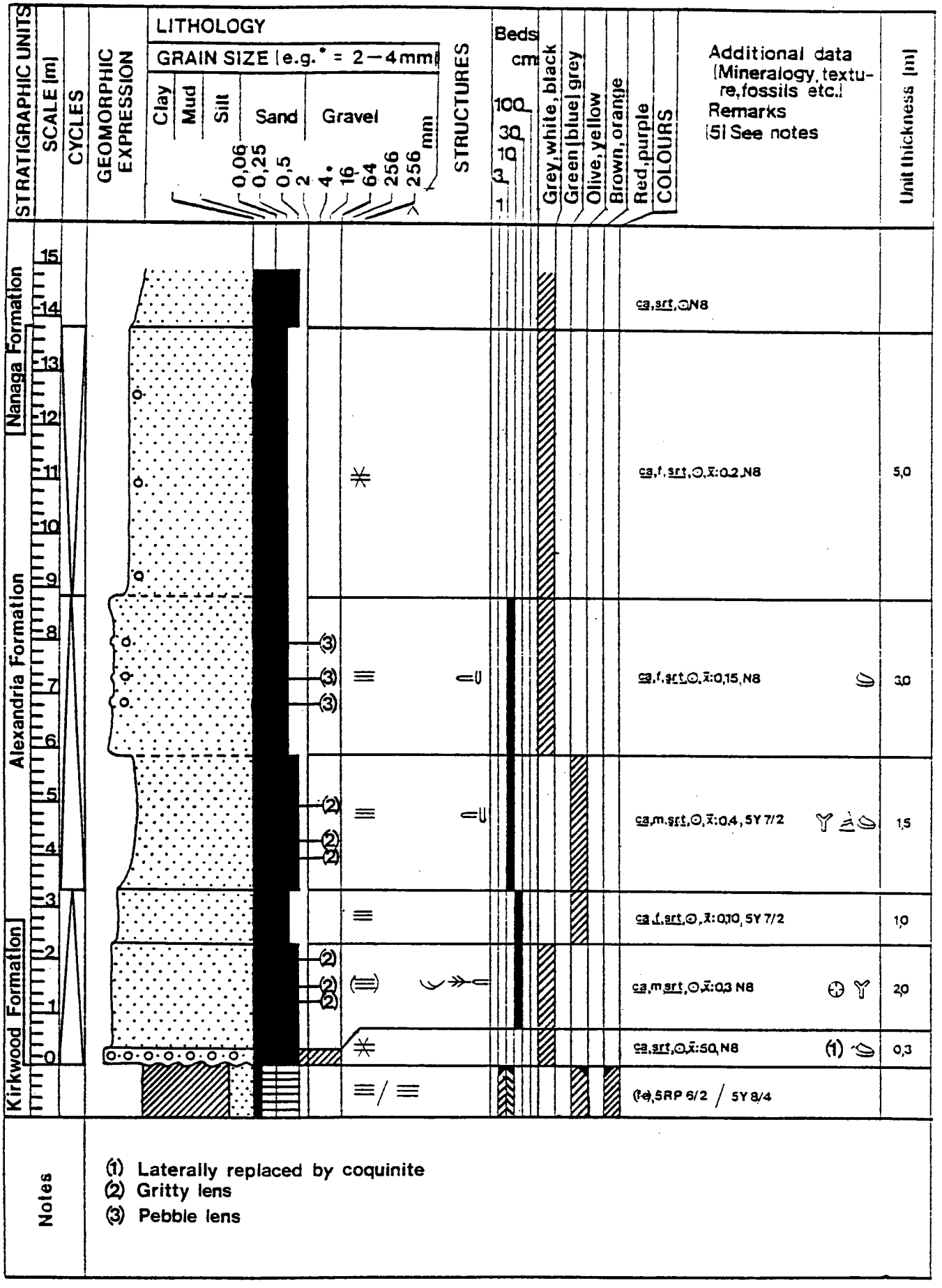

Fig. 3.14 - Stratotype K (Aluinkrantz) of the Alexandria Formation.

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Structure: No regional structure visible.

Reasons for inclusion: Stratotype is included mainly on account of dominance of sandstone. This stratotype also represents the Alexandria Formation situated above the 120 m contour (220 m) which is probably of Miocene age (see Chapter 12).

Adjacent units: See columnar section (Fig. 3.14).

Boundaries and contact relationships: Upper boundary defined as top of pebbly sandstone below aeolian sandstone of Nanaga Formation. Lower boundary taken at base of basal conglomerate above mudstone and sandstone of Kirkwood Formation.

L. GAMTOOS RIVER STRATOTYPE

Kind and rank: Unit reference stratotype.

Nature of section: Cliff on bank of river exposing the full thickness of the formation over a lateral distance of about 400 m.

Location: See Figure 3.3.

Accessiblility: Good; exposures are within 150 m of a secondary (dirt) road. Approach to top of cliff is somewhat restricted by thick thorny vegetation.

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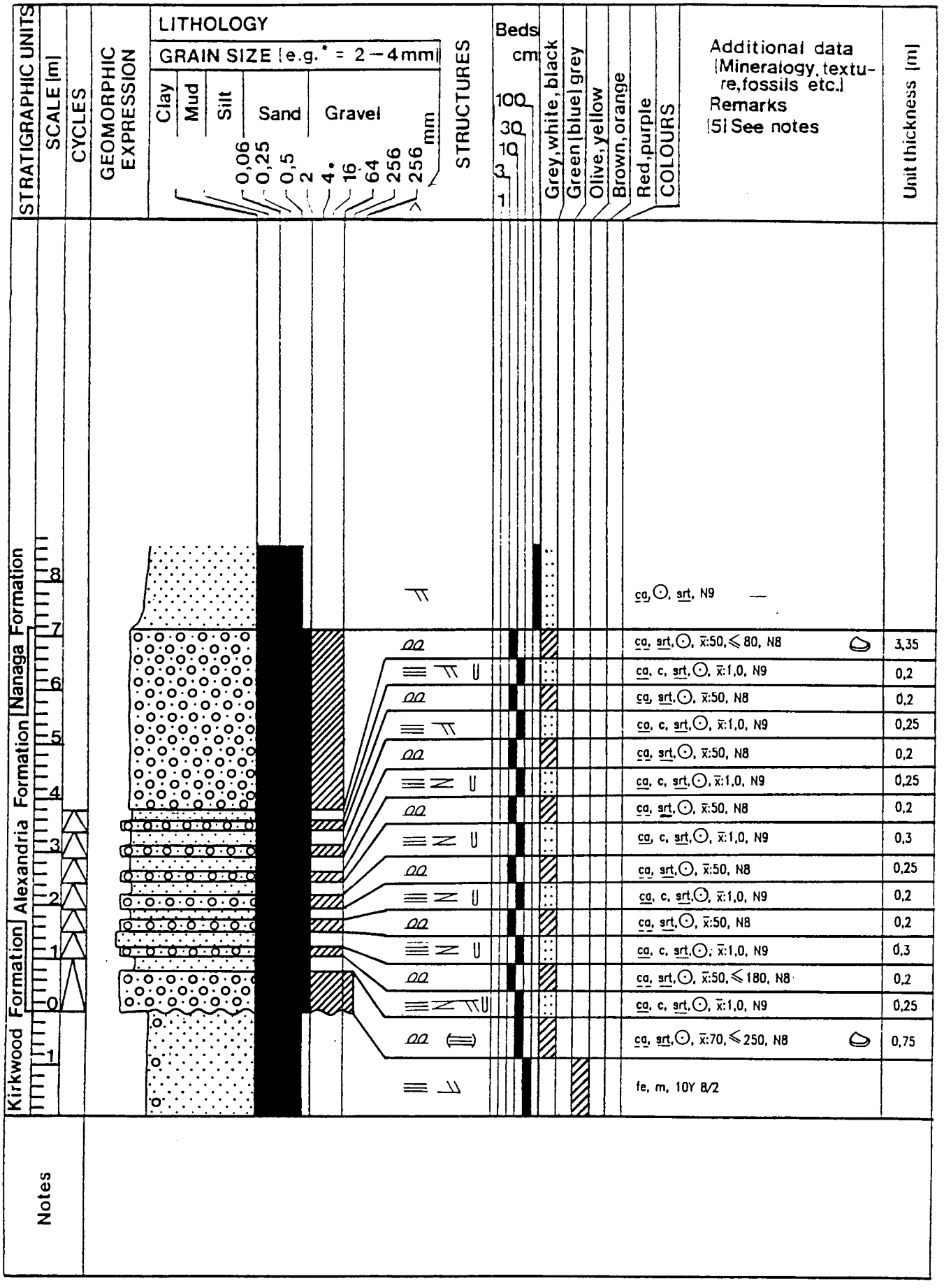

Fig. 3.15 - Stratotype L (Gamtoos River) of the Alexandria Formation.

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Lithology: Conglomerate (78%), with clasts exclusively Table Mountain Group quartzite and sandstone (22%) showing inclined bedding (beach stratification). See columnar section (Fig. 3.15).

Palaeontology: Sandstone lens in the basal conglomerate, which is directly in contact with the underlying sandstone of the Kirkwood Formation, shows burrows transgressing into the older sandstone, probably caused by bivalves of the family Pholadidae, such as Barnea alfredensis or Pholas dactylus.

Structure: No regional structure visible.

Reasons for inclusion: Stratotype included because of the total absence of coquinite, and the relative abundance of conglomerate with interlayered sandstone, representing a beach environment.

Adjacent units: See columnar section (Fig. 3.15).

Boundaries and contact relationships: Upper boundary taken at top of upper conglomerate below aeolian cross-bedded sandstone of the Nanaga Formation (see Pl. 5-4). Lower boundary taken at base of basal conglomerate which unconformably overlies greenish sandstone of the Kirkwood Formation.

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PLATE 3

3-1: Horizontally laminated Alexandria sandstone at Spring Valley.

3-2: Pebbly to cobbly Alexandria coquinite at Dassiekrans (Redhouse).

3-3: Oyster shells in Alexandria conglomerate at Gamtoos River. Note sharp erosional contact (indicated by arrow) between oyster-bearing conglomerate and overlying calcareous sandstone lens. Erosion through oyster shells is indicative of the conglomerate already being lithified before deposition of sandstone lens.

3-4: Basal oyster shell conglomerate (clasts exclusively shells of Crassostrea margaritacea) of Alexandria Formation above mudstone of Sundays River Formation (Swartkops railway cutting).

3-5: Intensely burrowed (Ophiomorpha) Alexandria sandstone between coquina layers at Swartkops pillar stratotype.

3-6: Thalassinoides on Alexandria sandstone bedding plane at Swartkops brickworks. Note cross-section of burrow (Ophiomorpha) above scale.

3-7: Railway cutting at Tankatara stratotype exposing the

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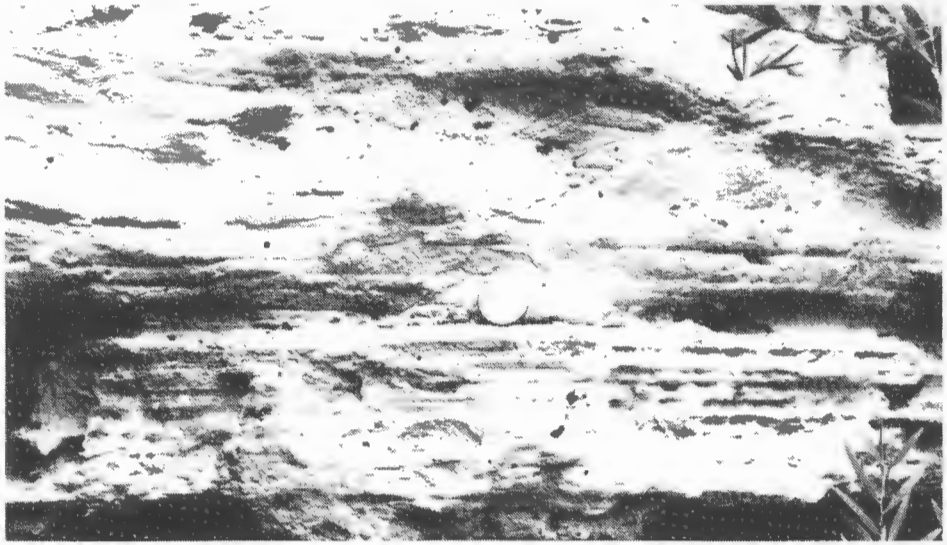
PLATE 3

1



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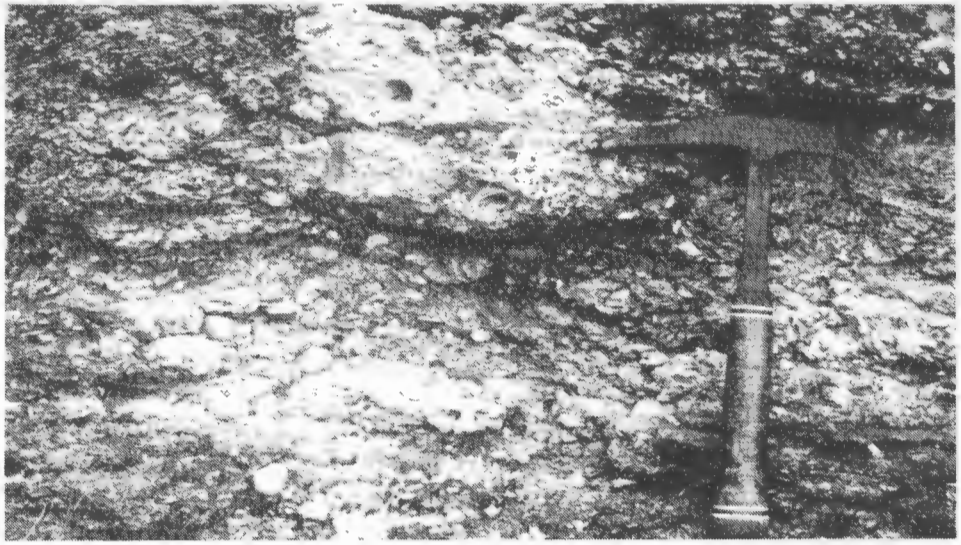

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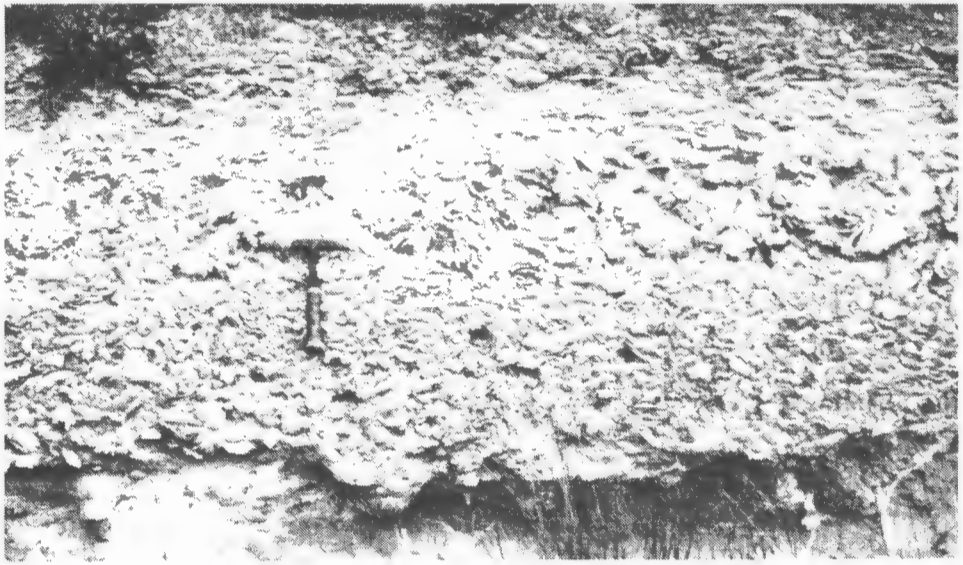

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PLATE 3

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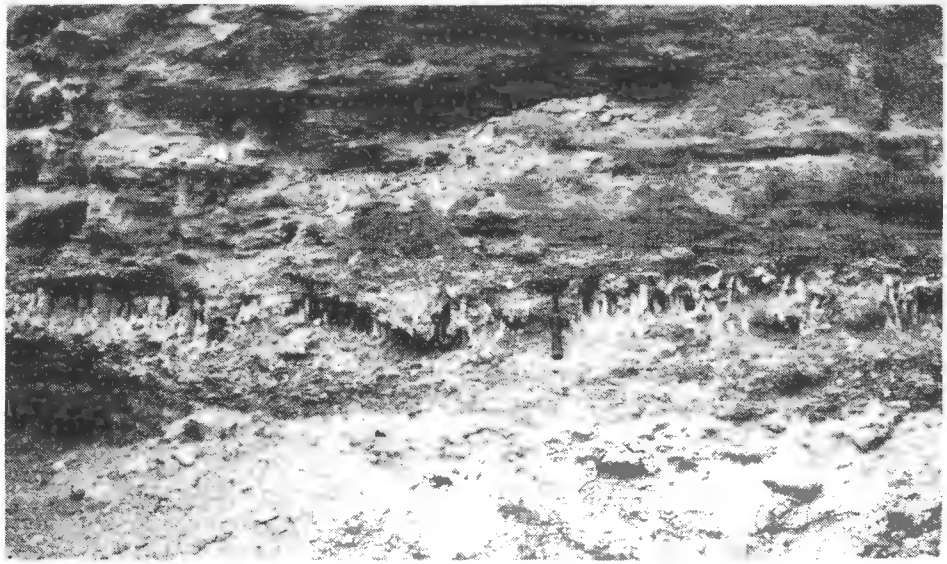

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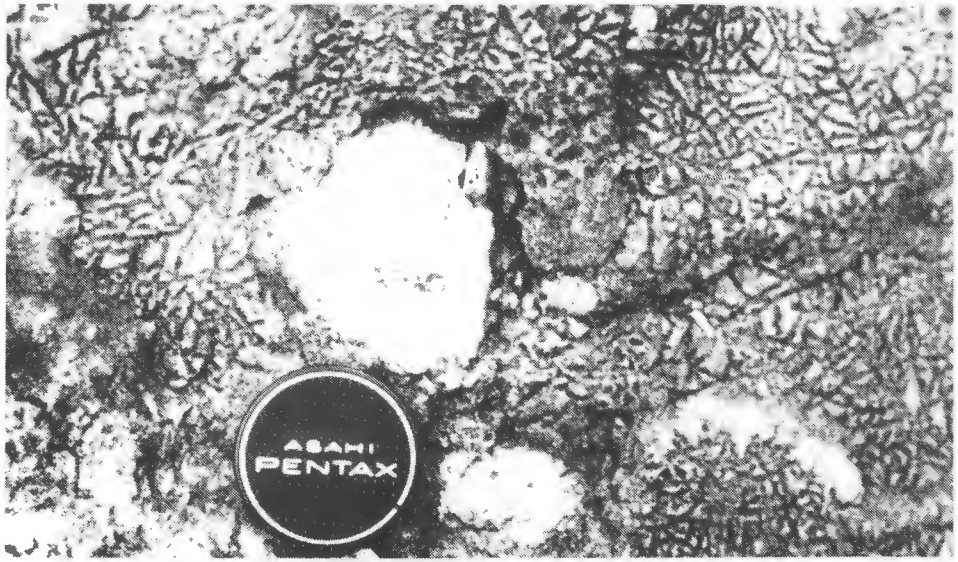

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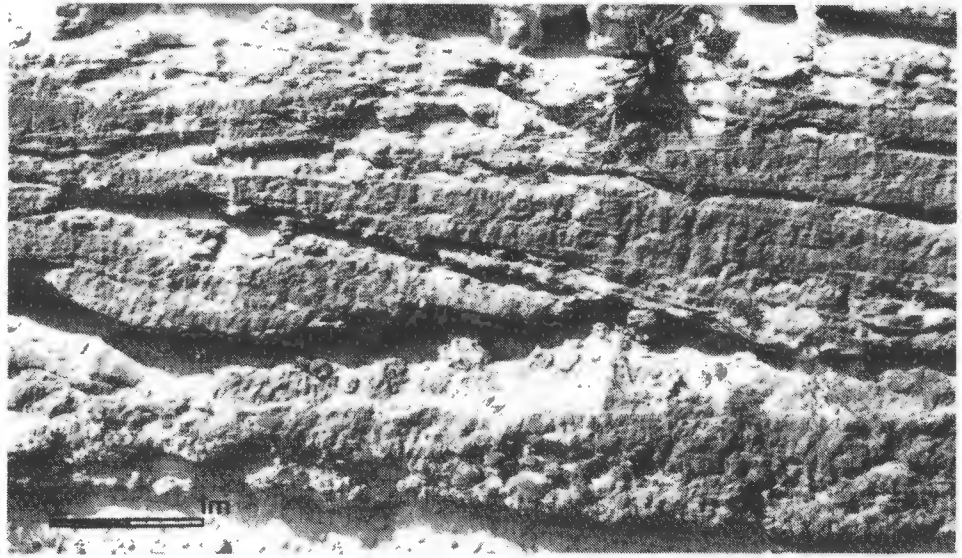

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PLATE 3 (continued)

full thickness of the Alexandria Formation over a lateral distance of about 300 m. Sundays River Formation exposed at base.

3-8: Cross-bedded Alexandria sandstone at Tankatara stratotype.

3-9: Abnormally thick Ophiomorpha burrows in Alexandria sandstone at Swartkops pillar (not stratotype locality).

3-10: Gastropod cast in Alexandria coquinite at Dassiekrans (Redhouse).

3-11: Herringbone cross-bedding in basal Alexandria sandstone at Aluinkrantz stratotype.

3-12: Basal oyster shell conglomerate (clasts exclusively oyster shells) of Alexandria Formation at Aluinkrantz (not stratotype locality).

PLATE 3

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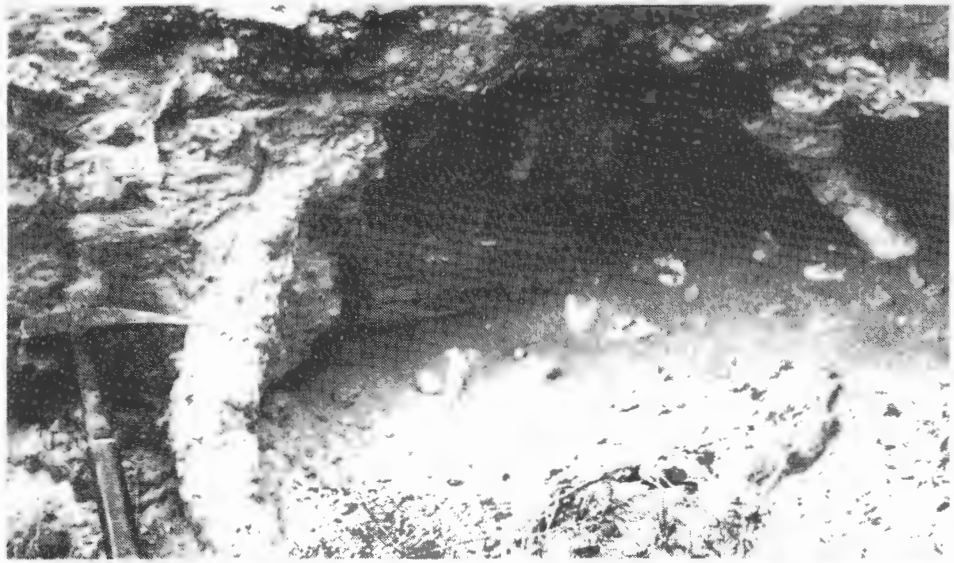

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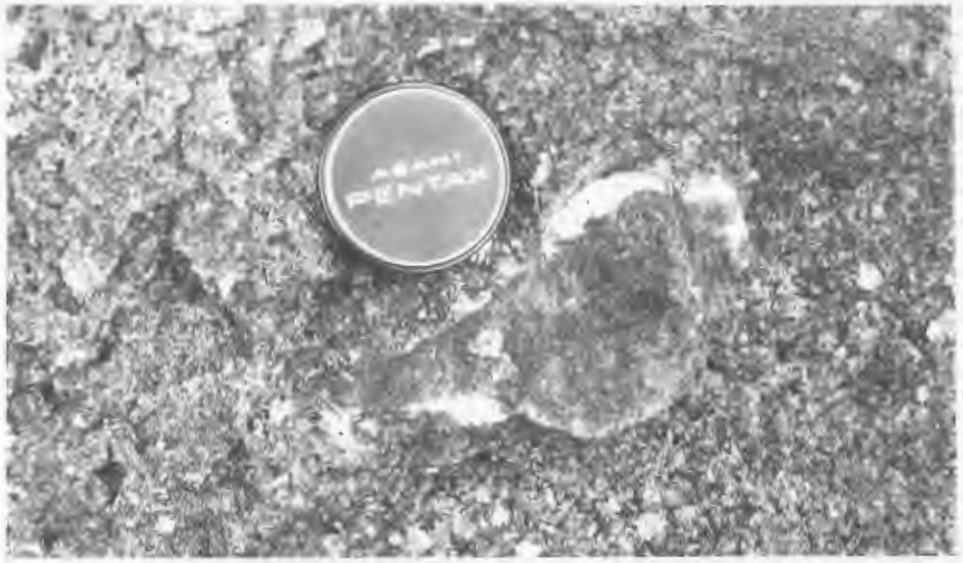

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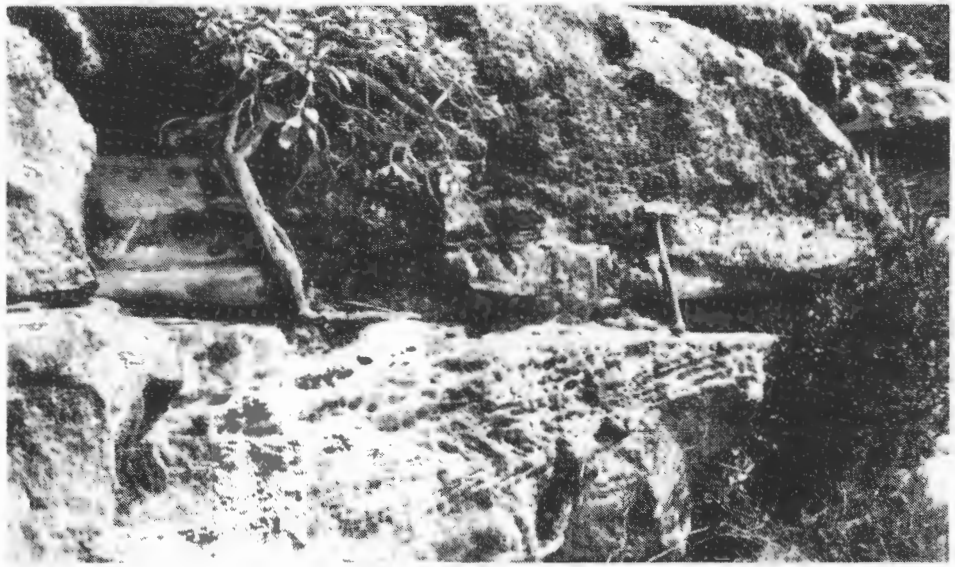

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CHAPTER 4 - SALNOVA FORMATION

The Salnova Formation represents marine and paralic deposits of Quaternary age.

4.1 LITERATURE REVIEW

W.B. Clark (1841 - cited by Newton, 1913) was probably one of the first observers in Southern Africa to recognise the presence of elevated beaches containing marine shells of existing species. Bain (1856) also referred to raised-beach deposits at, amongst others, the Great Fish, Kowie and Van Stadens Rivers. However, it was Stow (1871) who first differentiated the Cenozoic marine beds along the Eastern Cape coast. He distinguished between "Pliocene or Postpliocene Strata of the Interior" (considered to be the present-day Alexandria Formation) and "Pliocene or Postpliocene strata (Raised Beaches) on the Coast and Inland" (probably the present-day Salnova Formation). Stow's "Inland" unit is considered to represent mainly the estuarine deposits of the Salnova Formation, whilst his "Coast" unit, together with his "Latest Shell Beds", appear to be the open coast (beach) type of deposits of the same formation.

Rogers and Schwarz (1901) mentioned beach deposits along the Port Elizabeth coast, with "numbers of fragmentary shells belonging to species still living in Algoa Bay". Johnson (1903) gave some information on sections near the

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present-day Humewood, and also provided a list of fossils found at that locality.

Marine deposits "a few feet (on the shores of Algoa Bay) above sea level" which obviously belonged to the present-day Salnova Formation, were mentioned by Rogers (1906). Schwarz (1907, 1909) listed fossils found near East London and Port Elizabeth respectively and used the ratio of living to extinct species as an indication of the possible age of the deposits. Newton (1913) referred to these deposits as the "newer series", containing molluscs belonging mainly to modern species, as opposed to the "older series" (i.e. the Alexandria Formation) containing some extinct species. Krige (1927), Haughton (1925, 1928) and Mountain (1946, 1962) briefly described some raised beach deposits in the area, but it was Engelbrecht et al. (1962) who first mapped the Quaternary marine deposits of the area separately and also provided lists of fossils from them.

Although Davies (1971a, 1971b, 1971c) provided a useful description of what he regarded as Quaternary deposits along the coast between the Natal Border and Cape Town, together with lists of fossils from various localities, it is evident now that no distinction was made between Quaternary and Tertiary deposits. He briefly described estuarine deposits at Salnova (near the Coega River mouth) which led to the establishment of the name "Salnova Formation" for them (SACS, 1980).

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Ruddock (as accepted by SACS, 1980) recommended that the Quaternary raised-beach deposits of Engelbrecht et al. (1962) be included with the Neogene Alexandria Formation to form one Alexandria Formation. Le Roux (in press - a), however, proposed a reversion to the distinction made by Engelbrecht et al. (1962), since distinct lithological, palaeontological and age differences exist (see Table 4.1). Furthermore, the two units are nowhere in direct contact with one another, which can be explained by the fact that the Alexandria Formation was undercut by transgression(s) which bevelled the surface on which the Salnova Formation rests. SACS, in 1987, accepted this proposal and also a proposal that the Salnova Formation should include, in addition to paralic deposits, related marine deposits of Quaternary age.

4.2 LITHOSTRATIGRAPHY

4.2.1 Full Name

Salnova Formation.

4.2.2 Proposer of Name

The name "Salnova Formation" was first used by SACS (1980) for Late Pleistocene estuarine deposits mentioned by Davies (1971b).

4.2.3 Stratigraphic Position and Age

The Salnova Formation is situated on a wave-cut surface which truncates rocks of the Uitenhage Group north of latitude 33°57'S, and quartzite of the Table Mountain Group

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south of this latitude. Where the Salnova Formation is underlain by the Uitenhage Group, it is mostly overlain by recent windblown sand (the Schelm Hoek Formation), but also by Middle to Late Pleistocene aeolianite (the Nahoon Formation), soil layers and calcrete. Where the formation rests on Table Mountain rocks, it is often overlain by scree deposits consisting of angular quartzite fragments. The formation is thought to represent high stands of sea-level during one or more Quaternary interglacials.

4.2.4 Type Area and Derivation of Name

The type area comprises the lower course of the Swartkops River and the surrounding area (Fig. 4.1). The unit is named after the Salnova Salt Works located on the Coega estuary (SACS, 1980) where deposits of this formation have been briefly described by Davies (1971b, p. 254). The original scope of this formation has been broadened to include related marine deposits in addition to estuarine deposits. Preference is given to retaining an established name, rather than coining a new one.

4.2.5 Geological Description

Basic concept and unifying features: The formation consists essentially of fine- to coarse-grained calcareous sand/sandstone, gravel/conglomerate, shelly limestone and coquina as well as coquinite, all of marine or estuarine origin.

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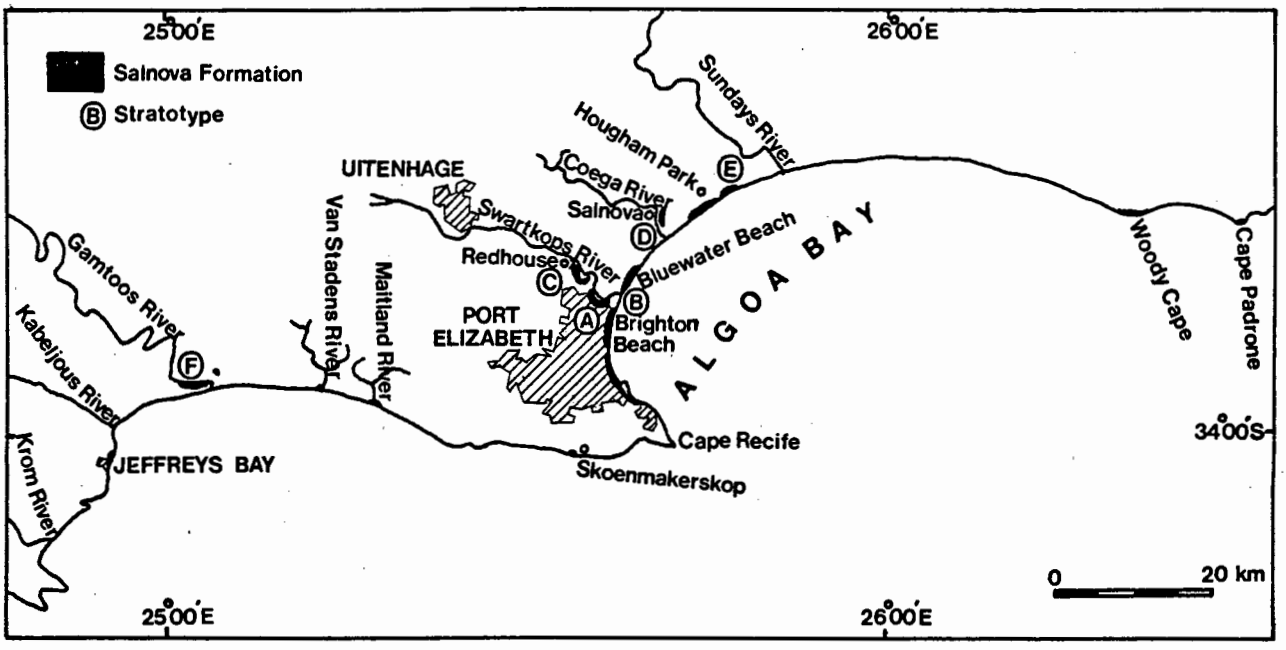

Fig. 4.1 - Distribution of Salnova Formation and location of stratotypes.

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Criteria for distinguishing between this formation and the other marine formations in the Algoa Group, namely the Neogene marine Alexandria Formation and Palaeogene Bathurst Formation, are presented in Table 4.1.

The formation is distinguished from the underlying Uitenhage Group by its highly calcareous nature, and from overlying units by the absence of terrestrial deposits such as calcrete, soil layers, scree and aeolian sand and sandstone.

Thickness: 1,5 - 6,5 m (average 3,5 m).

Lithology: **Sand and sandstone** (20 - 95%): Mean litho-unit thickness 1,0 m, max. 1,2 m (units tabular to lenticular); fine- to coarse-grained, pebbly in places; structureless to (vaguely) horizontally laminated (Pl. 4-1), inclined/wavy bedded, planar/trough cross-bedded (Pl. 4-2), and (less commonly) herringbone cross-bedded; laminated to thick-bedded; light grey (N7 - N8) to light olive grey (5Y 5/2 - 5Y 6/2) to yellowish grey (5Y 7/2 - 5Y 8/1), also greenish grey (5Y 6/1 - 5GY 8/1); calcareous; shelly; moderately to well sorted; subangular to well rounded.

Conglomerate (0 - 80%): Mean litho-unit thickness 1,1 m, max. 2,15 m (units tabular to lenticular); very large pebbles to large cobbles in coarse-grained sandstone matrix (Pl. 4-3); structureless to horizontally bedded, imbricated; thin- to medium-bedded (beds tabular); very light grey (N8) to yellowish grey (5Y 7/2) to pale yellowish orange (10YR 8/6); max. clast size 360 mm; clasts comprise

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TABLE 4.1 - CRITERIA DISTINGUISHING MARINE FORMATIONS IN THE ALGOA GROUP

	Bathurst Formation*	Alexandria Formation	Salnova Formation
1.	Hard crystalline limestone generally abundant	Hard crystalline limestone scarce	Hard crystalline limestone absent
2.	Silcrete clasts present in some conglomerates	Silcrete clasts absent	Silcrete clasts absent
3.	Generally well consolidated	Consolidated	Consolidated to partially consolidated
4.	Occurs at altitudes above 30 m above M.S.L.	Occurs at altitudes above 30 m above M.S.L.	Occurs at altitudes below 30 m above M.S.L.
5.	Palaeogene in age (microfossils)	Neogene in age (macrofossils)	Pleistocene in age (^{14}C dating)
6.	Characterised by species such as Aturia sp., Terabratulina sp., Panopea gurgitis, Entolium corneum, Pecten bathurstensis, Aequipecten sp., as well as an unidentified echinoid	Characterised by species such as Glycymeris borgesi, Cardium edgari, Notocallista schwarzi, Pirenella stowi, Cypraea zietsmani, Tivela baini, Melapium patersonae, Calyptraea kilburni and Ostrea redhousiensis (all extinct)	Characterised by species of the so-called "Swartkops fauna" such as Cerithium scabridum rufonodulosum, Cantharidus suarezensis fultoni and Monilea obscura ponsonbyi, also extinct species such as Duplicaria otiosa, Pupa daviesi and Gastrana fibrosa
7.	Silicified bone fragments (Lock 1973, p. 2) present	Silicified bone fragments absent	Silicified bone fragments absent
8.	Shark's teeth (various species) abundant	Sharks' teeth scarce	Sharks' teeth absent
9.	Biogenic structures (trace fossils) scarce	Biogenic structures abundant	Biogenic structures abundant

* Not yet approved by SACS

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quartzite (Table Mountain Group), sandstone (Uitenhage Group) and (scarce) cannibalised calcareous sandstone, also pumice at one locality; clasts discoidal to roller-shaped (Zingg classification).

Coquina/coquinite (10 - 60%): Mean litho-unit thickness 0,4 m, max. 0,6 m (units moderately tabular to lenticular); shells and shell fragments vary in size between 5 and 60 mm; pebbly in places; structureless to (vaguely) horizontally laminated; very thin- to thin-bedded; very light grey (N8) to pale greenish yellow (10Y 8/2) to pale yellowish orange (10YR 8/6); moderately to well sorted; subangular to subrounded.

Palaeontology: Comminuted shell fragments constitute between 10 and 60 per cent of the sand/sandstone grains. Fossils comprise a rich assemblage of broken and intact gastropods and pelecypods, as well as mainly broken echinoid (urchin) and crustacean (crabs and prawns) remains in coquina and sandstone.

Although more than 300 species of molluscs have been identified in this formation and its correlative along the southern Cape coast (the Klein Brak Formation), only a few are diagnostic (i.e. not found in the Alexandria Formation). The diagnostic faunal assemblage includes species of the so-called "Swartkops fauna" such as Cerithium scabridum rufonodulosum, Cantharidus suarezensis fultoni and Monilea obscura ponsonbyi, as well as extinct species such as Duplicaria otiosa, Pupa daviesi and Gastrana fibrosa (the

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latter previously only known from the Saldanha Bay area). Exotic species such as the West-African Panopaea glycymeris, Loripes liratula, Tellina madagascariensis, Venerupis dura, Nuculana bicuspidata, Felania diaphana and Leporimetis hanleyi, and the Indo-Pacific Anodontia edentula, Pseudostomatella orbiculata, Polinices tumidus, Tapes sulcarius, Pitar madecassina and Mactrotoma ovalina are also found in the Salnova Formation. It would appear that there were considerable fluctuations in marine-biogeographical provinces during the Quaternary (cf. Le Roux, 1987b).

Trace fossils in the Salnova Formation are fairly abundant and include the domichnion type - i.e. branching subvertical burrows, often with "brood chambers" with minute rootlike branches radiating from it; sometimes also shell-filled chambers - and the fodonichnion type - i.e. sub-horizontal traces which never interpenetrate. Ophiomorpha nodosa, belonging to the first-mentioned type, could be identified.

Genesis: Combined evidence from sedimentary structures, biogenic structures and fossil assemblages point to the Salnova being an intertidal deposit, ranging from the sandy beach environment (as in the case of the outcrops at Gamtoos River mouth) to a rocky shore environment (e.g. at Humewood). Estuarine and/or lagoonal elements are often present (as in the case of the outcrop at Brighton Beach), while purely estuarine and/or lagoonal sediments (finer-grained lithologies with estuarine faunal

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assemblages) may occur at other localities (e.g. at Salnova and Redhouse). The formation reflects higher stands of sea-level during Quaternary eustatic movements.

Other aspects: Where finer-grained lithologies (estuarine environments) dominate, the formation tends to weather negatively. The presence of indurated conglomerate, sandstone and coquinite (generally representing a beach environment) cause the formation to weather positively.

4.2.6 **Boundaries**

Upper boundary: Unconformable, sharp. The boundary is defined as the base of overlying terrestrial deposits, including calcrete, scree, soil and consolidated as well as unconsolidated aeolian sands (the Nahoon and Schelm Hoek Formations respectively).

Lower boundary: Unconformable, sharp. The boundary is defined as the unconformity between the formation and the Uitenhage Group (Pl. 4-4), Cape Supergroup or pre-Cape Gamtoos Group rocks. Compared with these units there is a marked increase in $CaCO_3$ content due to the presence of marine shell material in the Salnova Formation.

Lateral boundary: The inland limit of the formation roughly coincides with the 20 m contour. A prominent scarp may occur on the landward side. The eastern and western terminations (at Woody Cape and Jeffreys Bay respectively) present arbitrary vertical cut-offs. Possible offshore

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equivalents of the Salnova Formation are described by Glass and Du Plessis (1980).

4.2.7 **Subdivision**

No subdivision into members has been deemed necessary.

4.2.8 **Regional Aspects**

Geographic distribution: Discontinuous outcrops of the formation occupy a narrow strip adjacent to both the present coastline and the lower courses of some rivers, roughly between Cape Padrone and Cape St. Francis (Fig. 4.1). Small isolated outcrops occur east of Cape Padrone, e.g. at Port Alfred and Kleinemonde.

Lateral variation: As could be expected from a littoral sandy beach/rocky shore/estuarine deposit, the thickness and lithology vary considerably within short distances. No lateral trends could, however, be established.

Criteria for lateral extension: See below.

Correlation: West of Cape St. Francis, along the rocky coast towards Mossel Bay, outcrops of marine material are known at elevations below +20 m at a number of localities; the more important ones being Keurbooms, Knysna, Sedgefield, Klein Brak and Hartenbos. These deposits have been briefly investigated by the author at Sedgefield, and were found to include both littoral sandy beach and estuarine sediments. Faunal and other similarities of the Sedgefield deposit with

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that of the type area, suggest a correlation of these deposits. This correlation has subsequently been confirmed by Malan (in press - b) after detailed investigations in the area between Knysna and Gansbaai. The name "Klein Brak Formation" has been proposed by Malan (1987b) for deposits west of Knysna that are equivalent to the Salnova Formation. SACS (1980, p. 607) considers the Sedgefield and similar deposits to be equivalent to the Salnova Formation in its originally defined sense, being essentially an estuarine deposit with fine-grained lithologies. It is suggested that the above-mentioned deposits along the southern Cape coast be correlated with the Salnova Formation as defined herein. Similar deposits below +20 m along the West coast, as well as east of Cape Padrone will probably in future be positively correlated with this formation.

4.2 9 **Stratotypes**

Stratotypes have been selected at the following localities (Fig. 4.1):

A. Brighton Beach (neostratotype).
B. Bluewater Beach (parastratotype).
C. Redhouse (parastratotype).
D. Salnova (reference stratotype).
E. Hougham Park (reference stratotype).
F. Gamtoos River Mouth (reference stratotype).

A. **BRIGHTON BEACH STRATOTYPE**

Kind and rank: Unit neostratotype.

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Nature of section: Low coastal cliff, produced by undercutting during spring tides, exposing the formation over a lateral distance of about 350 m. Outcrops are continuously being modified by marine erosion.

Location: See Figure 4.2.

Accessibility: Excellent; exposures near main road.

Lithology: Sand (70%) and coquina (30%) - see columnar section (Fig. 4.3). Sediments at this locality are unconsolidated (Pl. 4-5).

Palaeontology: Shells mainly intact, many pelecypods in situ with articulated valves (e.g. Solen capensis, Tellina madagascariensis, Lutraria lutraria, Tapes sulcarius and Panopea glycymeris). Echinodiscus fossils in situ. Fossils of the so-called "Swartkops fauna" present, e.g. Cerithium scabridum rufonodulosum and Cantharidus suarezensis fultoni. Ophiomorpha-type burrows and tubes, with intervening delicate root-like tubes, are present (Plates 4-6 and 4-7).

Structure: A primary southward dip of about 2° is observable.

Reasons for selection: The original stratotype mentioned by Davies (1971b) has since been destroyed by operations to divert part of the Coega River. Although another stratotype exists at Salnova, the neostratotype has been

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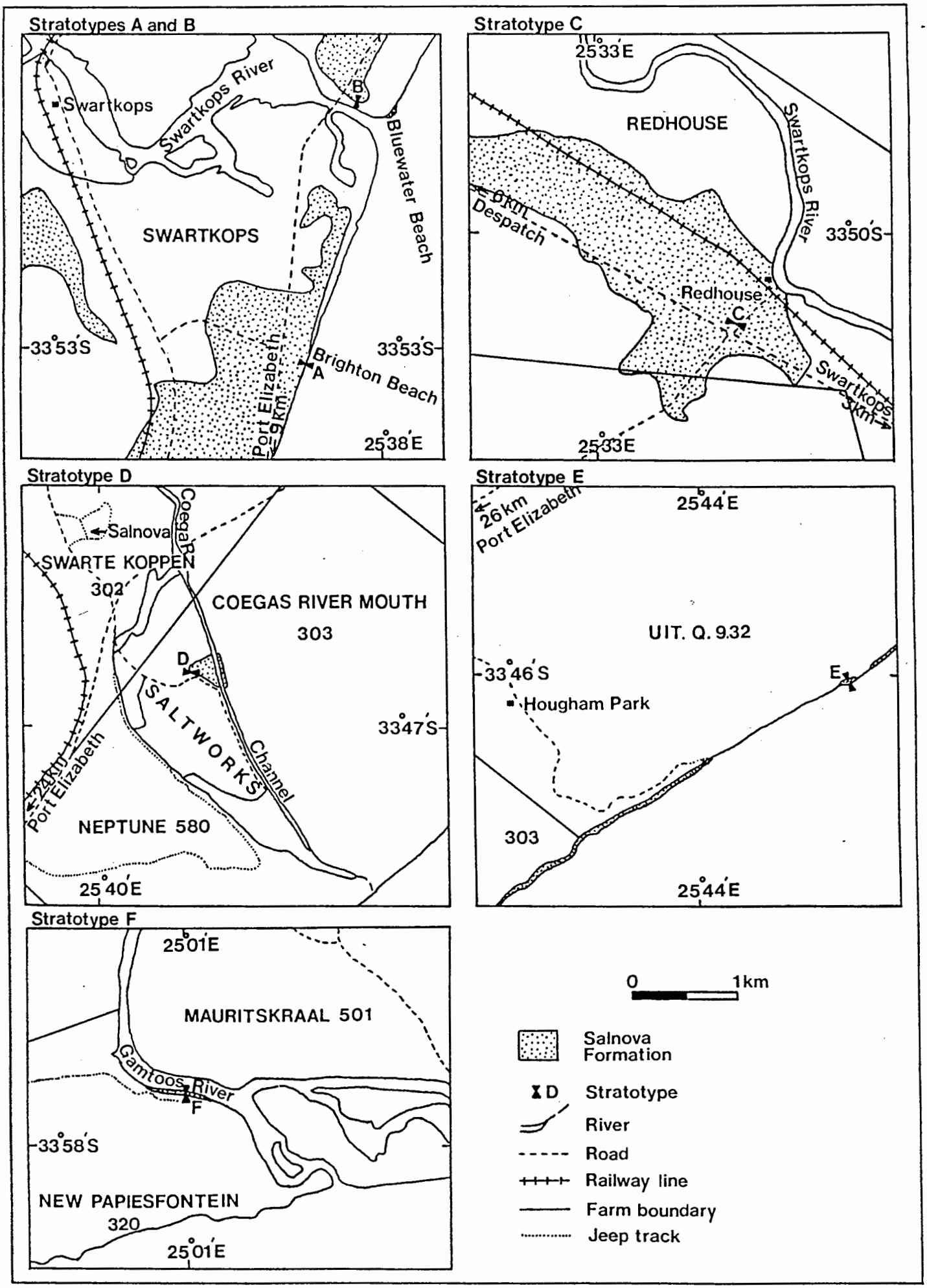

Fig. 4.2 - Location of stratotypes A (Brighton Beach), B (Bluewater Beach), C (Redhouse), D (Salnova), E (Hougham Park) and F (Gamtoos River).

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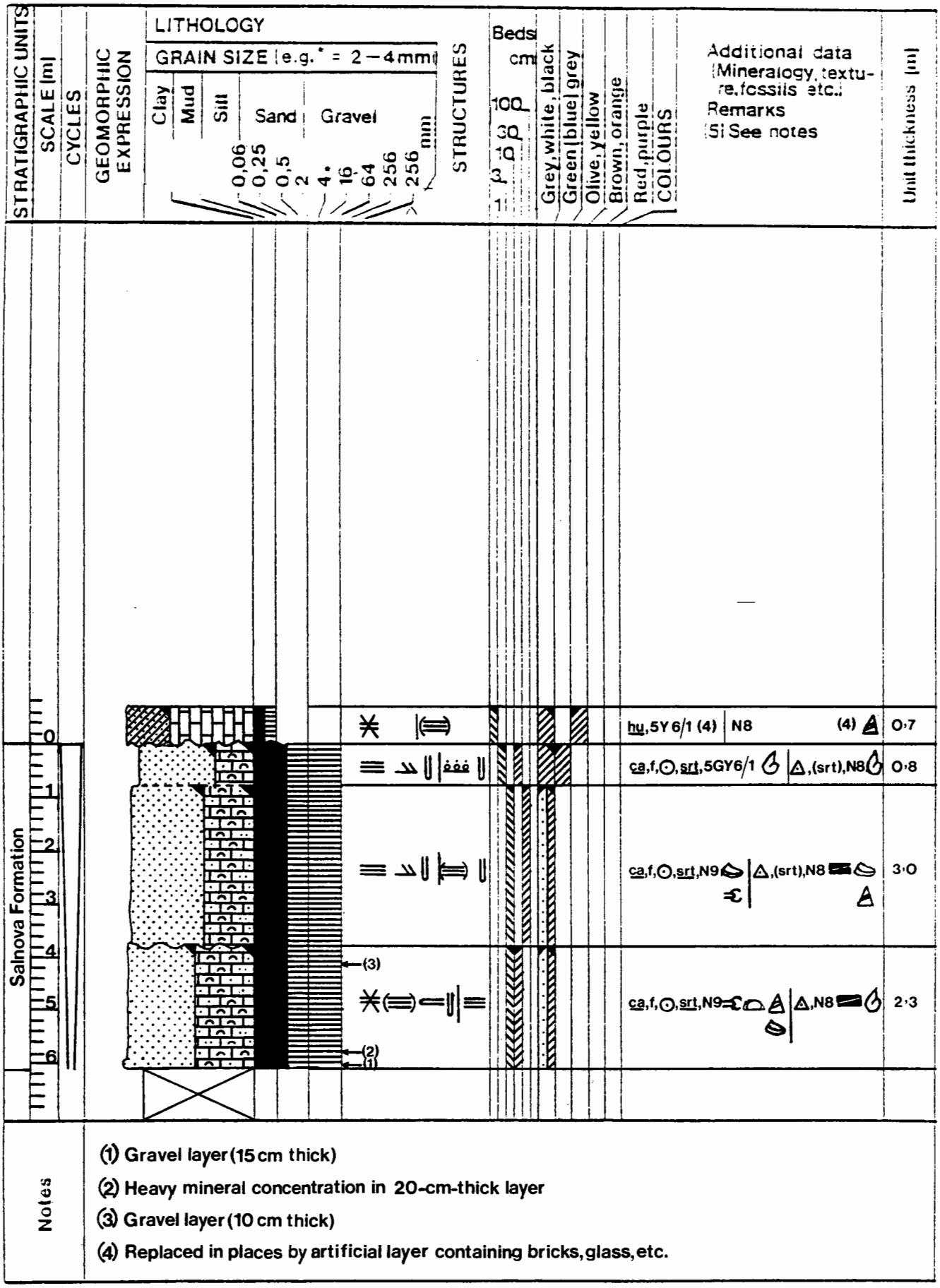

Fig. 4.3 - Stratotype A (Brighton Beach) of the Salnova Formation.

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selected at Brighton Beach, not only because it is considered to be more representative of this particular stratigraphic unit, but also because it is situated in a type area where it is supplemented by a number of parastratotypes.

Adjacent units: Formation overlain by calcrete and soil. Underlying unit not exposed.

Boundaries and contact relationships: Upper boundary taken at base of soil horizon and/or calcrete, both containing shells of terrestrial snails such as Achatina zebra and Tropidophora ligata. In some parts of the outcrop the upper boundary is taken at the base of an artificial layer containing bricks, glass etc. Lower boundary not exposed.

B. **BLUEWATER BEACH STRATOTYPE**

Kind and rank: Unit parastratotype.

Nature of section: Small cliff exposing about 1,5 m of the formation over a lateral distance of about 25 m.

Location: Above east bank of Swartkops River, near mouth. (The boundary wall of a river-front property has been erected on top of the cliff). See Figure 4.2.

Accessibility: Excellent; exposures near main road.

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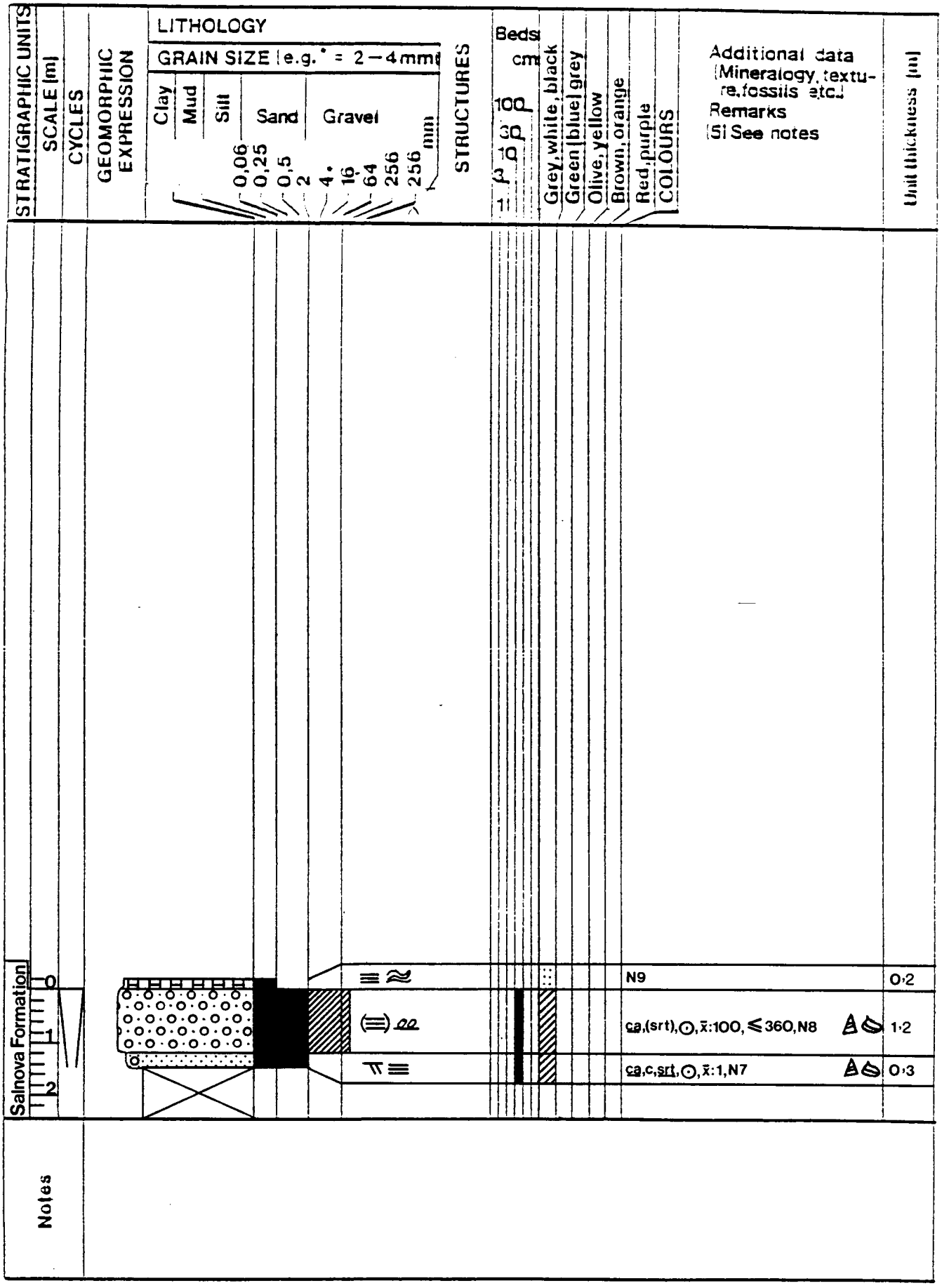

Fig. 4.4 - Stratotype B (Bluewater Beach) of the Salnova Formation.

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Lithology: Conglomerate (80%) and sandstone (20%) - see columnar section (Fig. 4.4) and Pl. 4-8. Sandstone is coarse-grained, also in conglomerate matrix. A few boulders occur in conglomerate. Broken and whole shells present.

Structure: A primary seaward dip of about 2° is present.

Reason for inclusion: Stratotype included on account of permanence of outcrop and presence of beach conglomerate with unusually big clasts, as well as absence of coquina/coquinite.

Adjacent units: Formation overlain by calcrete and underlain by Sundays River Formation (not exposed).

Boundaries and contact relationships: Upper boundary taken at base of surficial calcrete. Lower boundary not exposed, but encountered at a depth of 2 m in a borehole situated about 10 m from the cliff edge. Boundary in borehole section taken at base of conglomerate overlying greyish mudstones.

C. **REDHOUSE STRATOTYPE**

Kind and rank: Unit parastratotype.

Nature of section: Eastern wall of excavation, previously used as a refuse dump, exposing about 2,6 m of the formation.

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Location: See Figure 4.2.

Accessibility: Excellent; exposures adjoin main road.

Lithology: Coquina (57%) and sandstone (43%) - see columnar section (Fig. 4.5) and Pl. 4-9. Sandstone (semi-consolidated) contains whole and broken shells. Coquina consists mainly of intact shells (mainly pelecypods) in a sparse matrix of fine-grained sandstone. Second coquina layer from base has an erosional contact with the underlying sandstone (Pl. 4-9). Upper coquina (shown as calcrete in columnar section) encrusted in calcrete.

Palaeontology: Shells in coquina mainly intact, many pelecypods in situ with articulated valves (e.g. Lutraria lutraria, Venerupis corrugata, Tapes sulcarius and Loripes liratula). Fossils of the so-called "Swartkops fauna" e.g. Cerithium scabridum rufonodulosum and Monilea obscura ponsonbyi are abundant.

Structure: No regional structure visible.

Reason for inclusion: Stratotype included mainly on account of the presence of purely estuarine/lagoonal sediments as well as the occurrence of "Swartkops fauna" fossils.

Adjacent units: Formation overlain by soil. Underlying unit not exposed.

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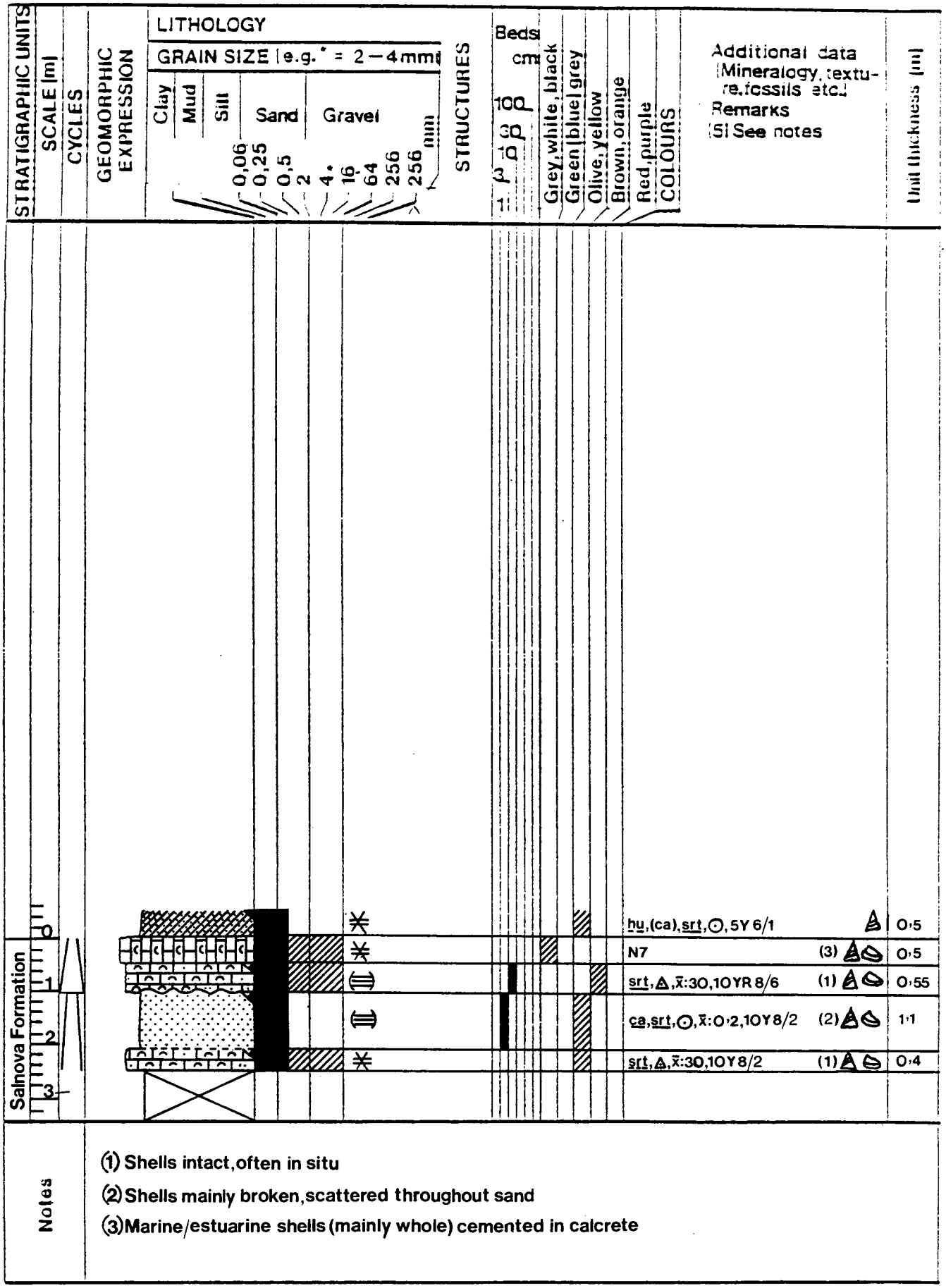

Fig. 4.5 - Stratotype C (Redhouse) of the Salnova Formation.

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Boundaries and contact relationships: Upper boundary taken at the top of the coquina (calcretised) below the humic soil. Lower boundary not exposed.

D. **SALNOVA STRATOTYPE**

Kind and rank: Unit reference stratotype.

Nature of section: Artificial cutting exposing about 3,6 m of the formation over a lateral distance of some 15 m.

Location: Parking-area below offices of salt factory - see Figure 4.2.

Accessibility: Good; exposures adjoin private road.

Lithology: Sandstone (92%) and coquina (8%) - see columnar section (Fig. 4.6). Sandstone fairly well consolidated, shelly, bioturbated in places and locally glauconitic. Upper sandstone hard, somewhat calcretised. Coquina contains some small quartzite cobbles.

Palaeontology: Intact and broken shells are present in coquina (marine species) and scattered through sandstone units (mainly estuarine species); some in situ bivalves e.g. Solen capensis, Panopaea glycymeris, Anodontia edentula and Venerupis corrugata; gastropods such as Cerithium scabridum rufonodulosum (member of "Swartkops fauna") and other estuarine species such as Natica tecta and Nassarius

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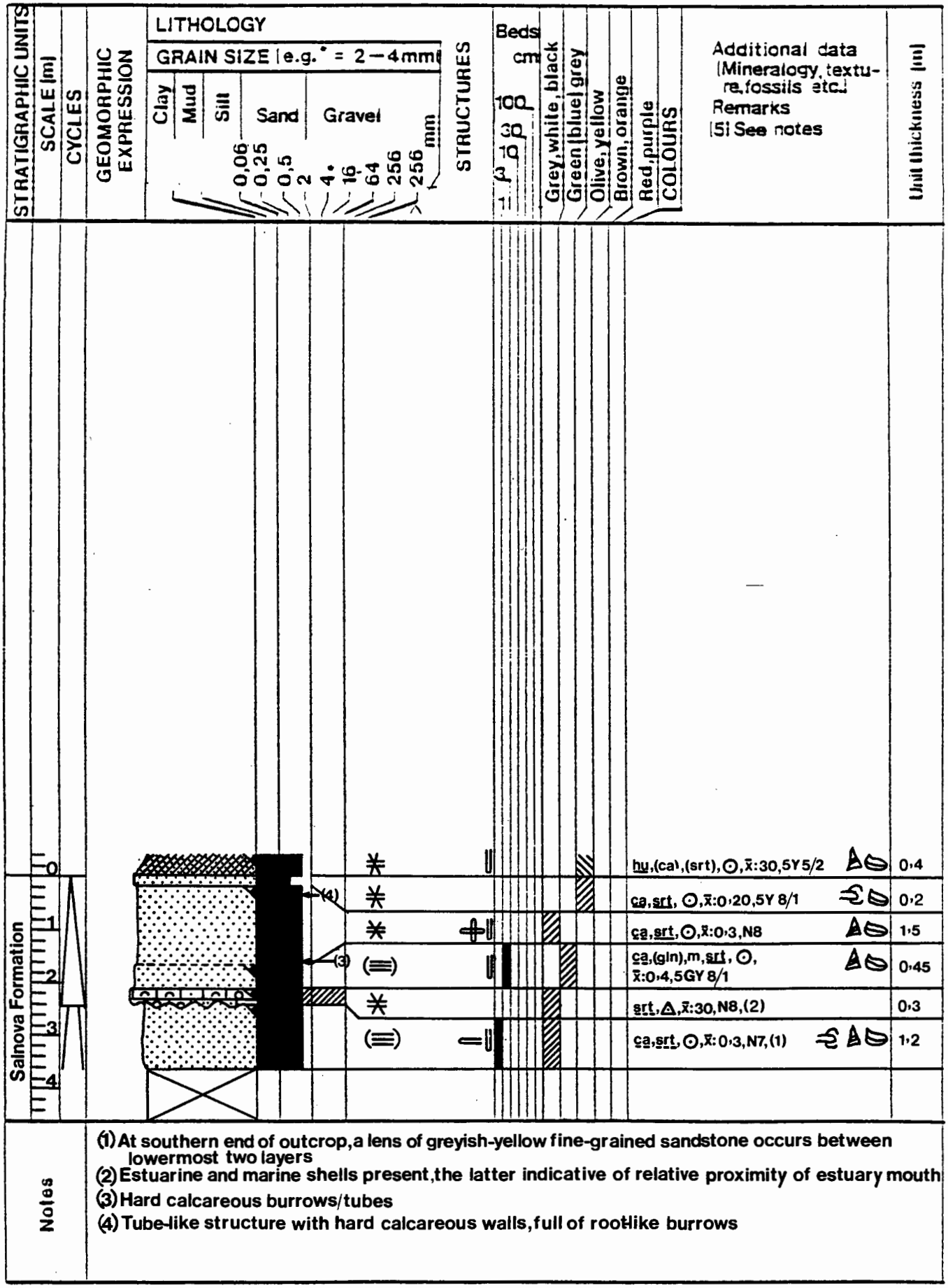

Fig. 4.6 - Stratotype D (Salnova) of the Salnova Formation.

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kraussianus. Ophiomorpha-type as well as bivalve burrows (Pl. 4-10) abundant in sandstone.

Structure: No regional structure visible.

Reasons for inclusion: Relative abundance of sandstone as well as presence of bivalve burrows with bivalves still in situ.

Adjacent units: Formation overlain by soil. Underlying unit not exposed.

Boundaries and contact relationships: Upper boundary taken at top of sandstone (superficially resembling calcrete) below humic soil. Lower boundary not exposed in this section.

E. HOUGHAM PARK STRATOTYPE

Kind and rank: Unit reference stratotype.

Nature of section: Coastal cliff produced by undercutting during storm tides, exposing the formation over a lateral distance of about 50 m.

Location: See Figure 4.2.

Accessibility: Fair. The 2 km stretch of beach between the road and the section can be negotiated with a four-wheel-drive or beach vehicle.

Lithology: Sandstone (66%) and conglomerate (34%) - see columnar section (Fig. 4.7). Sediments are indurated; sandstone pebbly in places. Exceptionally large clasts locally present (Plates 4-11, 4-12).

Structure: An eastward dip of between 1° and 3° is apparent.

Reasons for inclusion: Stratotype included mainly on account of exposure of lower boundary (eroded top of Sundays River Formation, Pl. 4-4), and absence of coquina/coquinite.

Adjacent units: Formation overlain by calcrete and aeolian sand (Schelm Hoek Formation) and underlain by Sundays River Formation.

Boundaries and contact relationships: Upper boundary located at eroded top of sandstone below calcrete and/or unconsolidated aeolian sand (Schelm Hoek Formation). Lower boundary taken at base of conglomerate above eroded top of mudstone and sandstone (Sundays River Formation).

F. GAMTOOS RIVER MOUTH STRATOTYPE

Kind and rank: Unit reference stratotype.

Nature of section: Cliff produced by undercutting of river bank during floods, exposing some 6 m of the formation over a lateral distance of about 400 m.

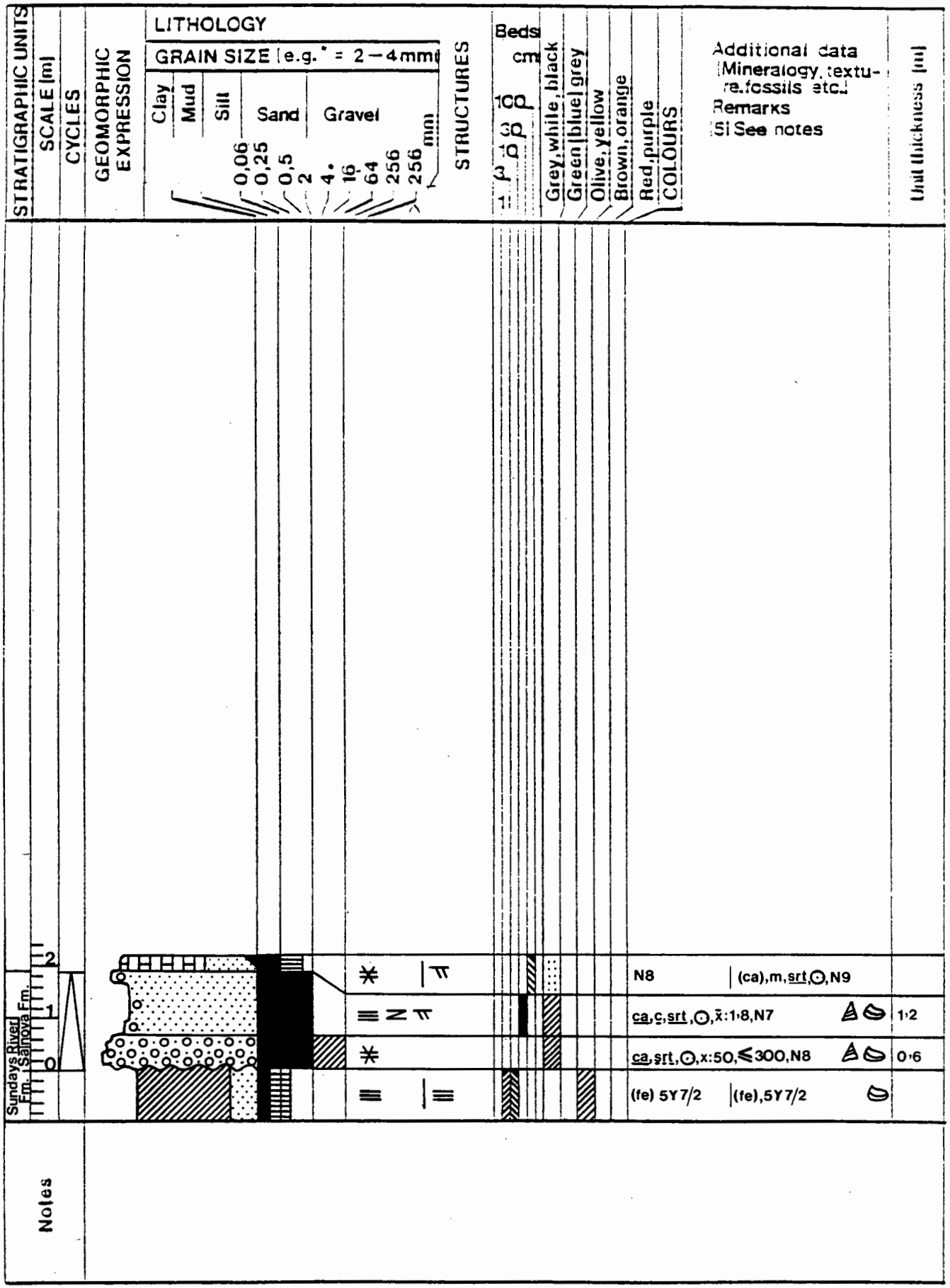


Fig. 4.7 - Stratotype E (Hougham Park) of the Salnova Formation.

Location: See Figure 4.2.

Accessibility: Fair. Jeep track leads from homestead to within 20 m of outcrop. However, since the section is situated in a private game reserve with no-one residing on the farm, locked gates may prevent entrance. The outcrop is clearly visible from the Gamtoos River and can easily be approached by boat.

Lithology: Conglomerate (54%) and sandstone (46%) - see columnar section (Fig. 4.8). Sediments are indurated. Basal conglomerate clast-supported (Pl. 4-13), with well-developed imbrication in middle conglomerate (Pl. 4-14). Second conglomerate from base is upward-coarsening (Pl. 4-15). Sandstone shelly (Pl. 4-16) and cross-bedded.

Palaeontology: Shells mainly broken; identifiable shells belong mainly to extant species, e.g. bivalves such as Venus verrucosa, Scissodesma spengleri, Donax serra and Solen capensis; a single valve of the West African Tellina madagascariensis was found; gastropods such as Charonia lampas pustulata, Turbo sarmaticus and Tonna variegata are abundant. Ophiomorpha-type as well as bivalve burrows present in sandstone.

Structure: No regional structure visible.

Reasons for inclusion: Stratotype included mainly on account of above-average thickness of succession, as well as

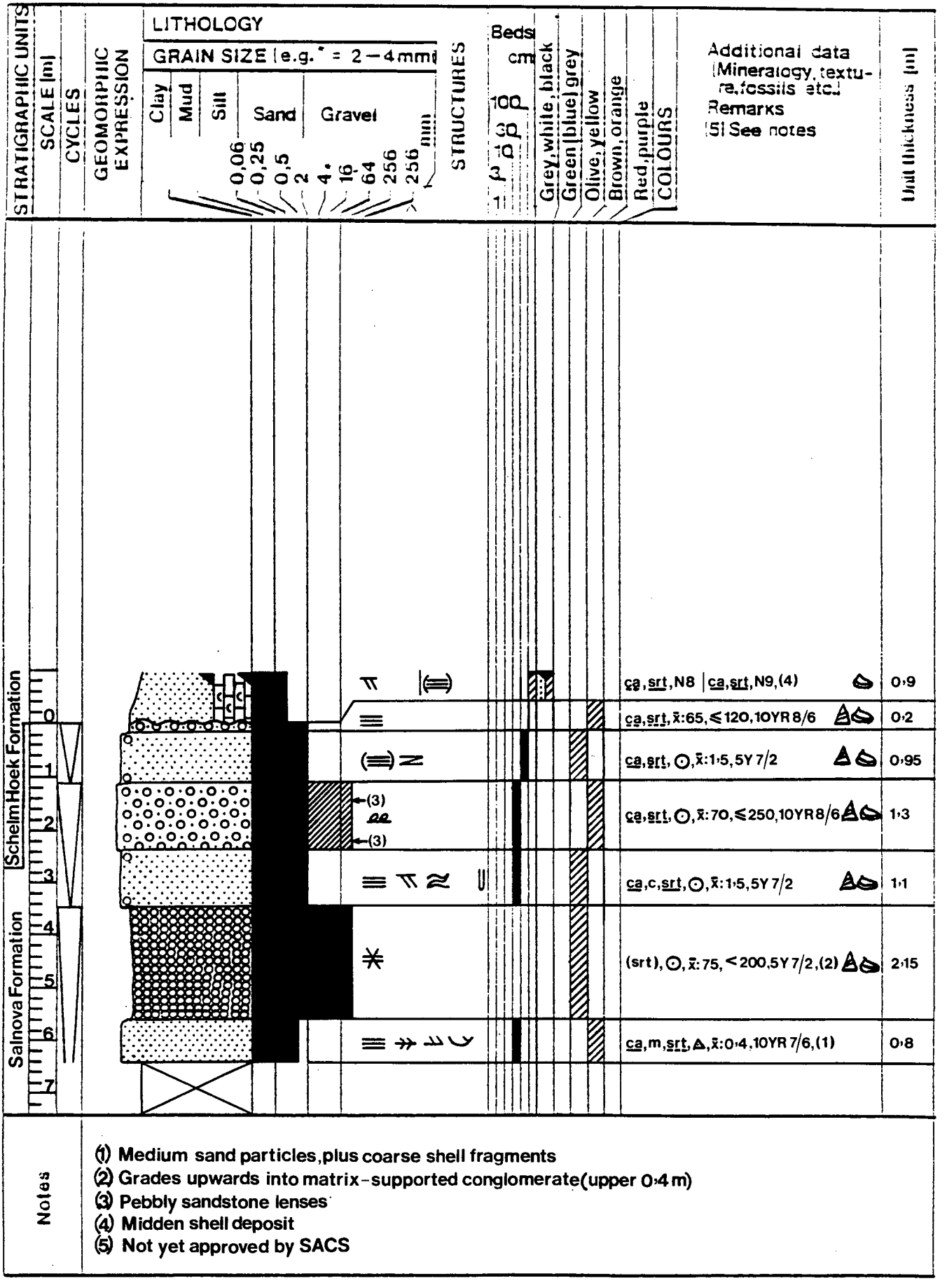


Fig. 4.8 - Stratotype F (Gamtoos River) of the Salnova Formation.

the presence of sedimentary structures typical of a beach-environment.

Adjacent units: Formation overlain by calcrete and aeolian sand. Underlying unit not exposed.

Boundaries and contact relationships: Upper boundary taken at top of eroded conglomerate below calcrete or unconsolidated aeolian sand. Towards the east of the outcrop, shell middens of the Schelm Hoek Formation overlie the formation. Lower boundary not exposed.

PLATE 4

4-1: Horizontally laminated pebbly sandstone of Salnova Formation on beach at Hougham Park (not stratotype locality). Note shell layers.

4-2: Cross-bedding in Salnova Formation sand (above coquina layer) at Brighton Beach stratotype. Note structureless sand at base.

4-3: Matrix-supported Salnova conglomerate at Bluewater Beach.

4-4: Salnova Formation at Hougham Park, here represented by a single conglomerate layer, unconformably overlying the Sundays River Formation.

4-5: Exposure of Salnova Formation (unconsolidated) at Brighton Beach.

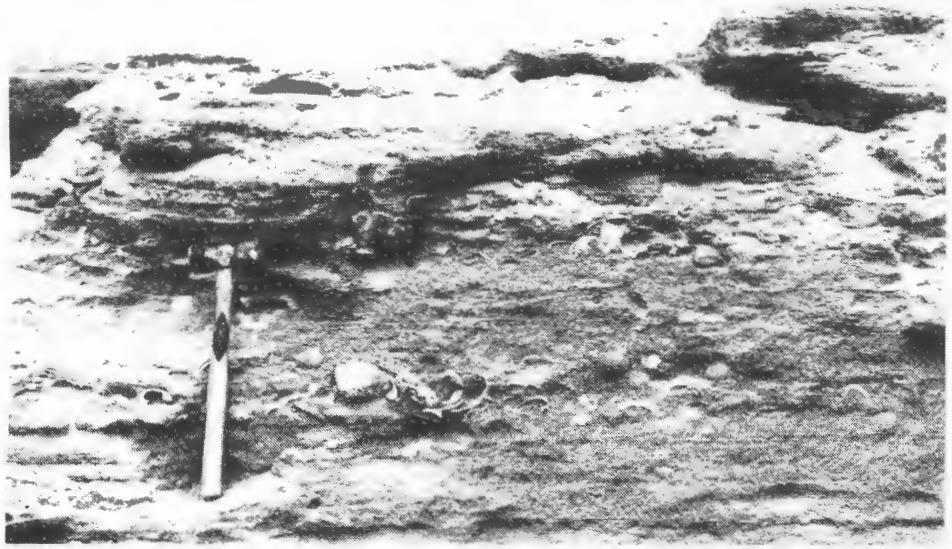
4-6: Ophiomorpha-type burrows and tubes in Salnova Formation with intervening delicate root-like tubes (Brighton Beach).

4-7: Delicate root-like tubes in Salnova sand at Brighton Beach.

4-8: Cross-bedded Salnova sandstone overlain by conglomerate of the same formation at the Bluewater Beach stratotype.

PLATE 4

1



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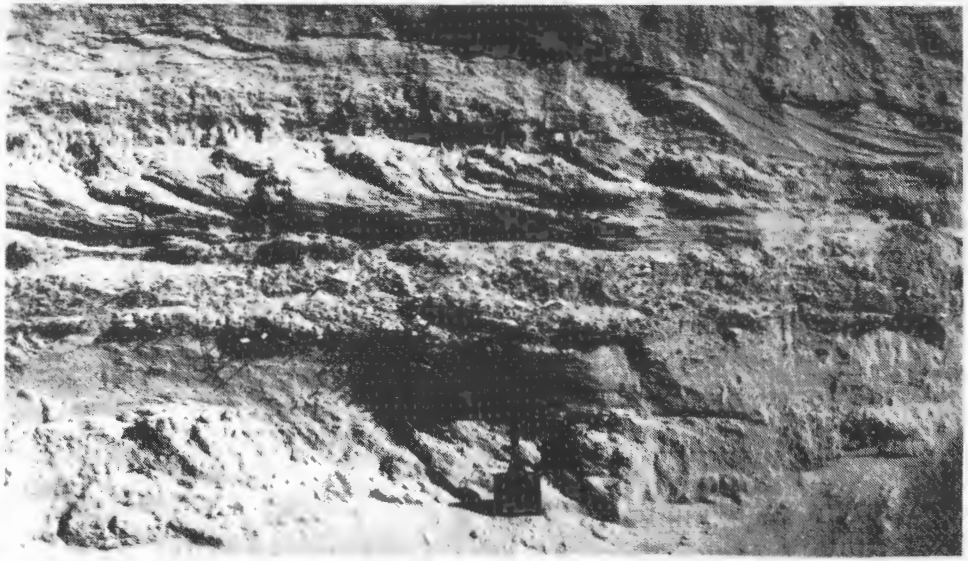

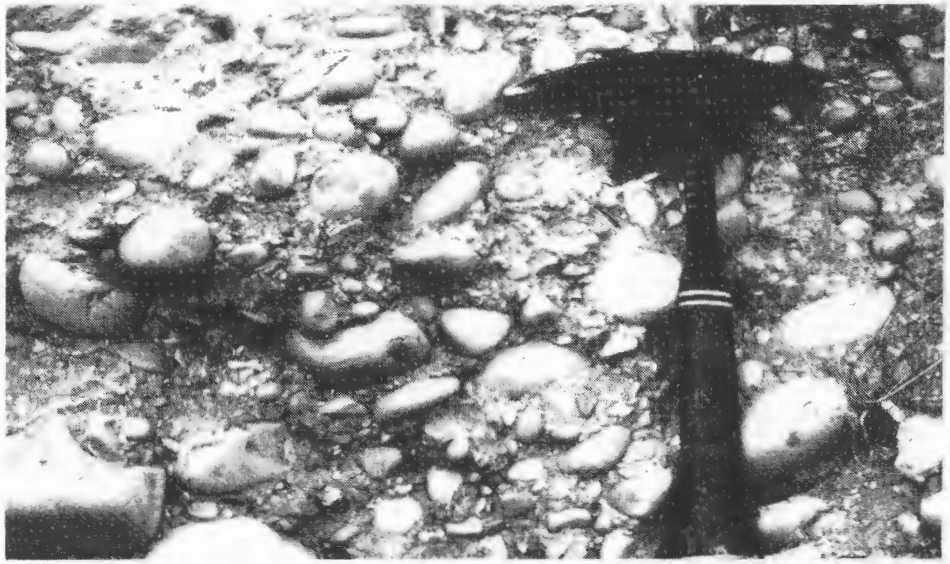

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PLATE 4

5

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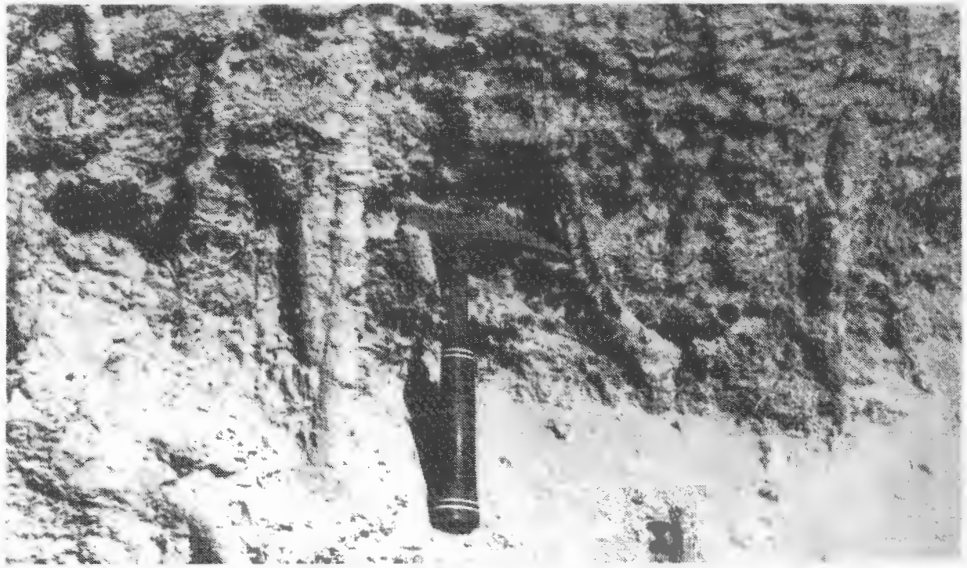

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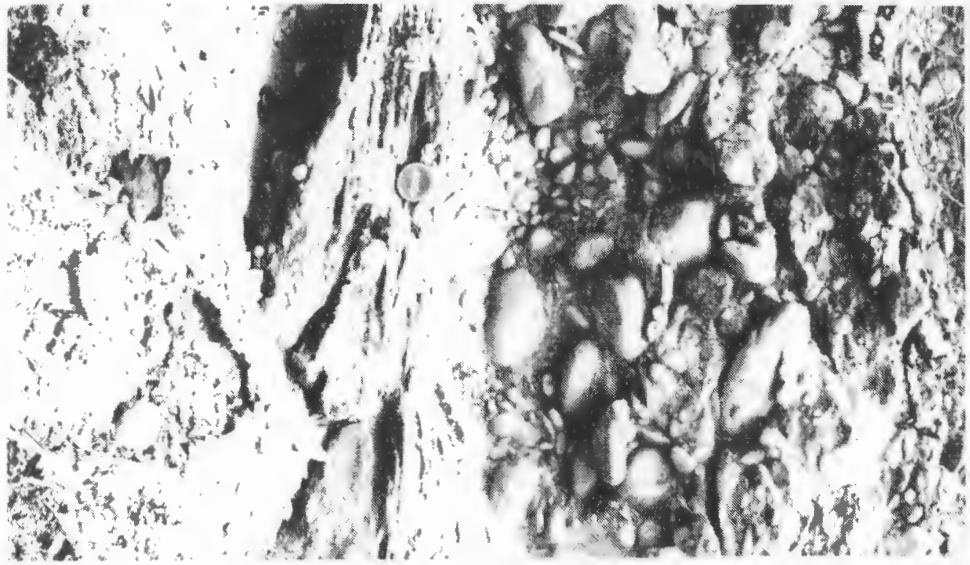


PLATE 4 (continued)

4-9: Erosional contact between sand and coquina, Salnova Formation at Redhouse stratotype.

4-10: Bivalve burrows with Barnea manilensis still in situ in Salnova sandstone at Salnova stratotype.

4-11: Slab of Sundays River Formation sandstone in cobbly Salnova sandstone at Hougham Park.

4-12: Salnova conglomerate (note boulder) overlain by sandstone of the same formation at Hougham Park stratotype. Upper boundary is taken at base of calcrete overlying horizontally laminated sandstone.

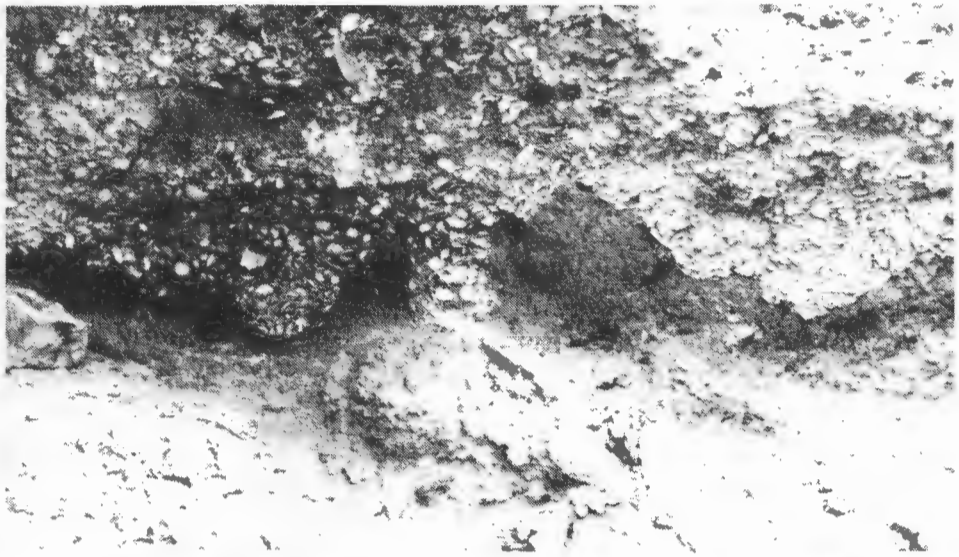
4-13: Basal Salnova conglomerate (clast-supported) overlain by pebbly sandstone at Gamtoos River mouth stratotype.

4-14: Part of Salnova succession at Gamtoos River mouth stratotype. Basal clast-supported conglomerate overlain successively by low-amplitude wavy-bedded sandstone (note burrow indicated by arrow), matrix-supported conglomerate (note imbrication at base), and pebbly to cobbly sandstone at top.

4-15: Matrix-supported Salnova conglomerate (upward-coarsening) overlain by cross-bedded sandstone at Gamtoos River mouth stratotype.

PLATE 4

9



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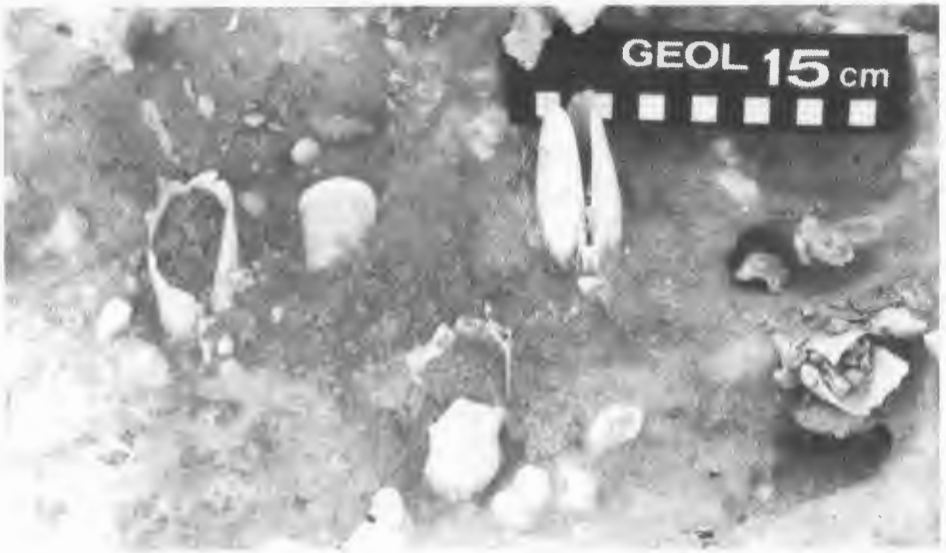

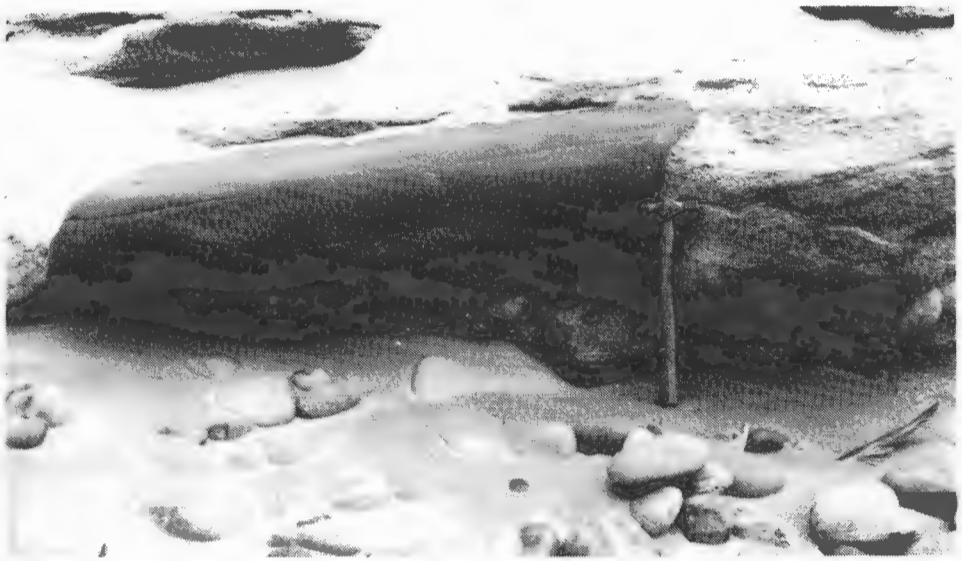

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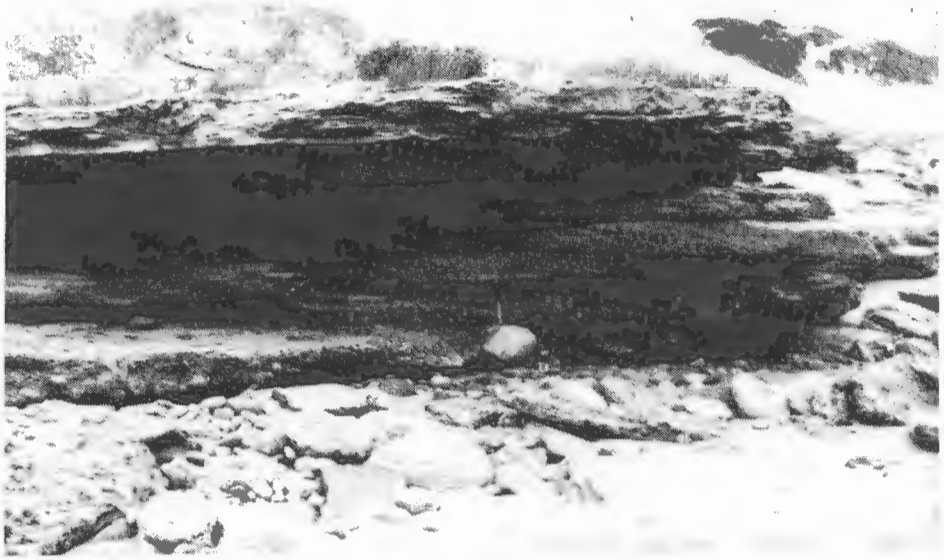

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PLATE 4

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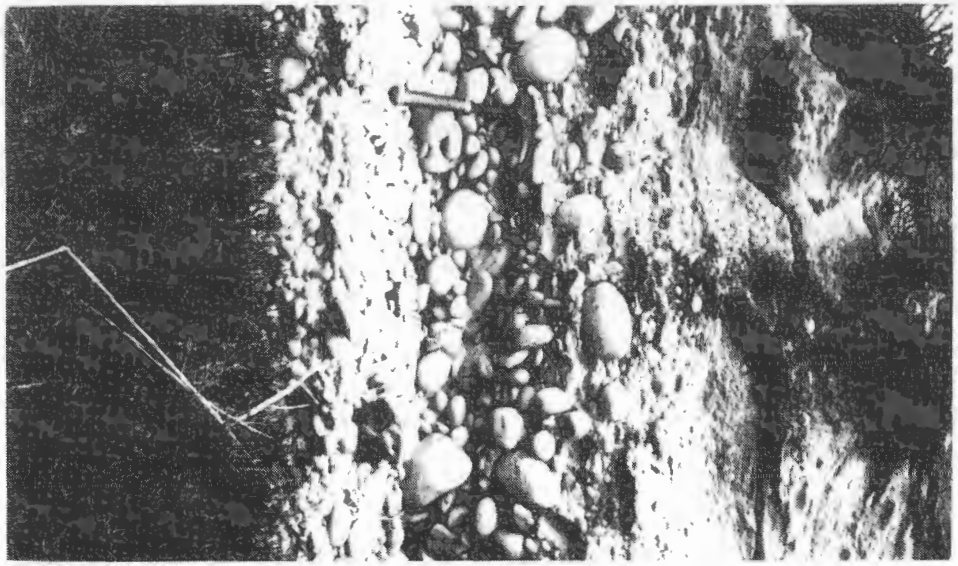

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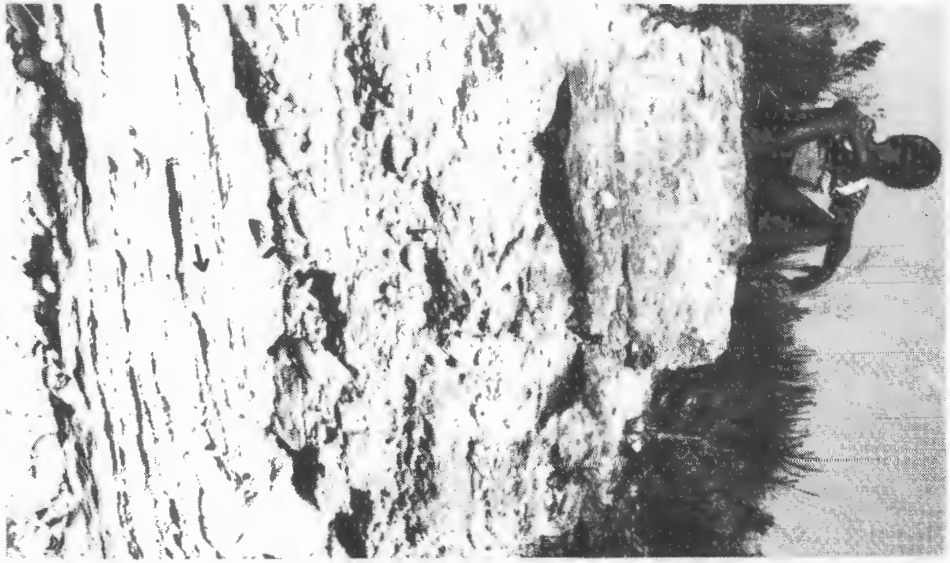

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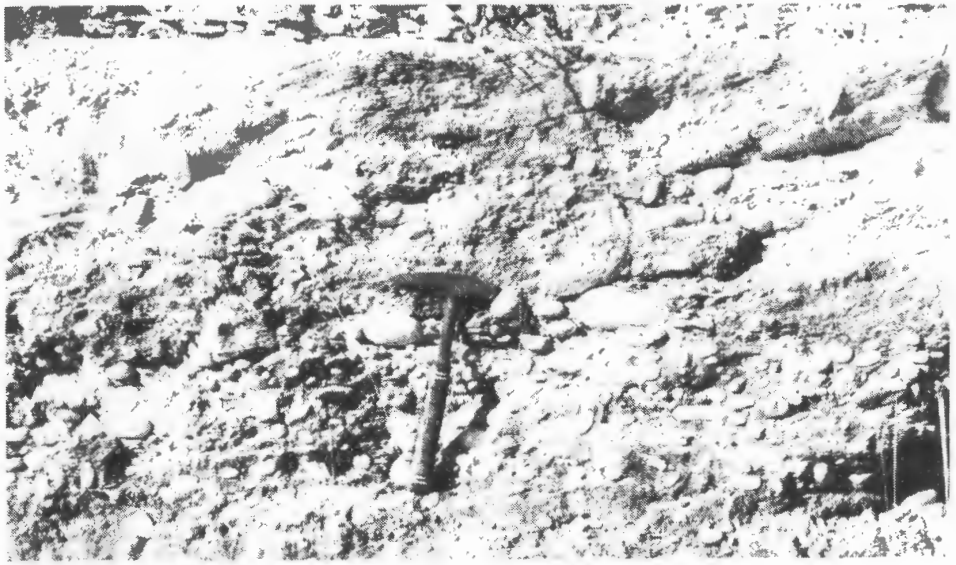

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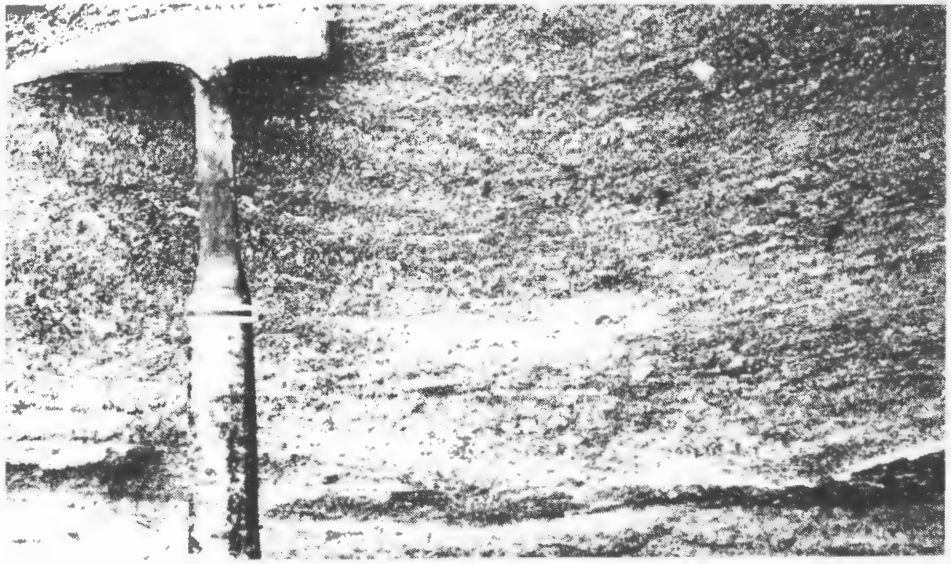


PLATE 4 (continued)

4-16: Shelly, coarse-grained, cross-bedded basal Salnova sandstone at Gamtoos River mouth stratotype.

MARINE-RELATED (AEOLIAN) DEPOSITS

Cenozoic aeolian deposits along the S.E. coast, formerly known as the **Nanaga Formation**, presently consist of three separate formations. They are related to transgressive/regressive seas and can be subdivided into the **Nanaga**, **Nahoon** and **Schelm Hoek Formations**, based on lithological and age differences.

CHAPTER 5 - NANAGA FORMATION

The Nanaga Formation represents Pliocene to Early Pleistocene aeolian deposits occurring up to 40 kilometres inland from the coast.

5.1 **LITERATURE REVIEW**

Atherstone (1850 - quoted by Schwarz, 1908) used the name "Pecke limestone" for what are considered by Dingle et al. (1983) to be wind-blown deposits forming part of the present Nanaga Formation. Haughton (1928) grouped similar aeolian calcareous sandstone with the "Alexandria beds" and also referred to a "limestone formation ..... at least 450 ft thick" (op. cit., p. 30), the bulk of which probably belongs to the present-day Nanaga Formation.

Engelbrecht et al. (1962) distinguished between "consolidated and partly consolidated dune sand" and "moving dune sand". From their map it is clear that the presently known Nahoon Formation (see Chapter 6) was included in the "consolidated dune sand", while the "partly consolidated dune sand" would correspond mainly to the present-day Nanaga Formation.

Acting on a proposal by Ruddock in 1979, SACS (1980) defined the Nanaga Formation to embrace Late Tertiary to Recent semi-consolidated dune-sand including the "windblown sand", "fixed dunes" and "dune-rock" of Mountain (1946) (shown on

Geological Survey Sheet 136 Grahamstown), i.e. all Cenozoic aeolian deposits along the south-eastern Cape coast. However, Le Roux (1988) proposed that the name "Nanaga Formation" be reserved for aeolian deposits formed during regression of the "Alexandria sea", i.e. the Neogene regression(s) during which the Alexandria Formation was deposited. SACS, in 1988, accepted the proposal by Le Roux (in press - b) that both the well consolidated "dune-rock" and unconsolidated "windblown sand" (Mountain 1946)/"moving dune-sand" (Engelbrecht et al., 1962) be excluded from this formation, since these deposits differ lithologically from, and are younger than the Nanaga Formation. These can be regarded as separate formations (respectively named the Nahoon and Schelm Hoek Formations - see Chapters 6 and 7).

Stear (1987a) described a road-cutting near Nanaga and determined palaeo-wind directions (mainly easterlies and westerlies). He also illustrated the relationships between dune cordons and regressive Cenozoic shorelines.

5.2 LITHOSTRATIGRAPHY

5.2.1 Full Name

Nanaga Formation.

5.2.2 Proposer of Name

A. Ruddock to SACS Working Group for the Tertiary and Quaternary Periods in 1973 (SACS, 1980, p. 606).

5.2.3 Stratigraphic Position and Age

The Nanaga Formation normally overlies the Neogene Alexandria Formation paraconformably, but in places unconformably overlies the Palaeozoic Cape Supergroup or Mesozoic Uitenhage Group. It is locally (near Ingleside - Fig. 5.1) overlain by the Kinkelbos Formation and in places by the Schelm Hoek Formation; elsewhere it is the uppermost unit present. The age of the Nanaga Formation is probably Pliocene to Early Pleistocene (SACS, 1980).

5.2.4 Type Area and Derivation of Name

The type area is situated east of the Sundays River (Fig. 5.1) in the vicinity of the farms Nanaga Hoogte 299, Nanaga 166, Landsdown 168, and Buffels Hoek 165. The unit is named after the farm Nanaga (Nanaga 166) where it is well exposed in road cuttings.

5.2.5 Geological Description

Basic concept and unifying features: The formation consists of semi- to well-consolidated calcareous sandstone and sandy limestones, displaying typical large-scale aeolian cross-bedding (Pl. 5-1). It is distinguished from the underlying Cape Supergroup and Uitenhage Group by its calcareous nature and poorer consolidation, and from the Alexandria Formation by its aeolian cross-bedding and lack of pebbles and/or coarse fragments of marine shells exceeding about 0,5 cm in diameter. It is distinguished from the (locally) overlying Kinkelbos Formation by its aeolian cross-bedding,

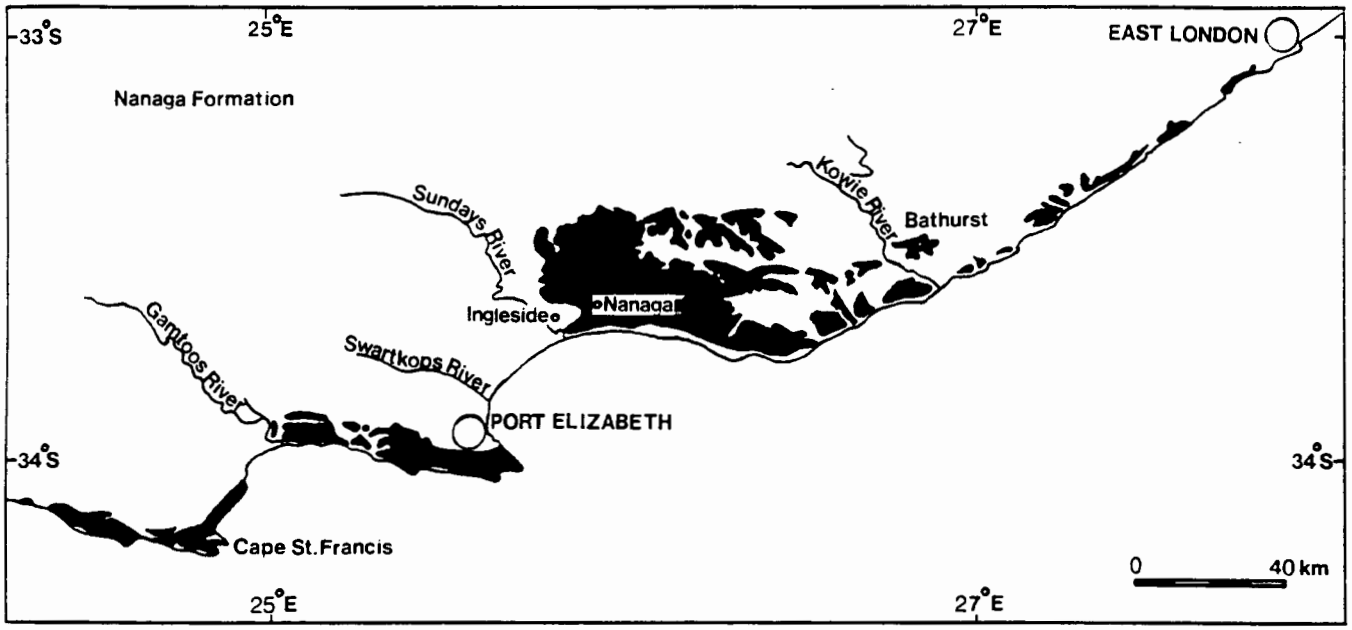


Fig. 5.1 - Distribution of Nanaga Formation.

coarser-grained lithologies, lack of clasts and whitish colour (as opposed to the reddish-brown colour of the Kinkelbos Formation). The generally semi-consolidated nature of the Nanaga Formation distinguishes it from the Nahoon Formation (well-consolidated) and Schelm Hoek Formation (unconsolidated).

Thickness: Variable - governed by surface reliëf; often attains 150 m, and exceptionally 250 m.

Lithology: Calcareous sandstone/sandy limestone (100%): Medium- to coarse-grained; cross-bedded (large scale), structureless in places; very thick-bedded; white (N9) to very light grey (N8) to greyish yellow (5Y 8/1) and yellowish grey (5Y 8/4); well sorted; grains rounded to well rounded.

Palaeontology: Minute fragments of marine macro-organisms (mainly shells), foraminifera (sometimes constituting up to 80 per cent of the rock), and occasional land gastropods such as Achatina, Tropidophora, Trigonephris and Natalina are present.

Genesis: The distinctive high-angle, large-scale cross-bedding, as well as the characteristic undulating geomorphic expression indicate an aeolian environment of deposition (most probably coastal dunefields). It normally consists of composite, overlapping parts separated by unconformities, each deposited in relation to a specific

Late Cenozoic shoreline, and generally diminishing in age seawards.

Mountain (1962, p. 9) and Ruddock (in a formal proposal to SACS in 1979) mention marine sediments overlying aeolian sediments near the trigonometric beacon at Bathurst. No evidence for this could be found by Siesser (1972b) or the present author. It is believed that the apparent low-angle cross-bedding in the penultimate cutting (from the top of the section) appeared to the first-mentioned authors to be beach stratification. On close examination, however, it was found that there is a steep (aeolian) northerly dip of cross-bed foresets into the face of the cutting.

Other aspects: Geomorphologically the formation occurs as smooth rounded hills within undulating ridges trending sub-parallel to the present shoreline.

5.2.6 **Boundaries**

Upper boundary: Ruddock (in a formal proposal to SACS in 1979) mentions that "the present surface may be locally transgressed by a tongue of the Alexandria Formation (Bathurst?)". Investigation by the present author could not substantiate this suggestion. Near Ingleside 215 the upper boundary is taken at the base of reddish-brown silts and/or fine-grained sand of the Kinkelbos Formation; the boundary is sharp and presumably conformable. Elsewhere the upper boundary is marked by the base of unconsolidated

windblown sand (Schelm Hoek Formation), or localised surficial calcrete/red soil.

Lower boundary: The formation locally overlies Uitenhage Group or Cape Supergroup rocks unconformably. More commonly a sharp paraconformable lower contact with the Alexandria Formation exists. The boundary is then taken at the top of the uppermost horizontally stratified unit (without aeolian cross-bedding) containing pebbles and/or coarse fragments (> 0,5 cm diameter) of marine shells.

Lateral boundary: The formation is terminated by a depositional boundary in the east, north and west. Where the formation is overlain by the Kinkelbos Formation (east of Ingleside 215), its distribution is obscured.

5.2.7 **Subdivision**

No subdivision into members has been made.

5.2.8 **Regional Aspects**

Geographic distribution: The formation is present between East London and west of Cape St. Francis, and extends up to 40 km inland from the coast (Fig. 5.1).

Lateral variation: Lenses of greenish to yellowish very fine-grained sand are present in the cross-bedded sandstone at some localities, while lenses of fine powdery $CaCO_3$ occur locally, e.g. at Bathurst. However, no lateral trends could be established.

Criteria for lateral extension: Undulating topography over semi-consolidated calcareous sand is a characteristic feature in the coastal hinterland (e.g. Grassridge Plateau).

Correlation: The formation is correlated with the Wankoe Formation of the Bredasdorp Group in the south-western Cape (Malan, in press - c). Similar sand and dune ridges also occur in Zululand.

5.2.9 **Stratotypes**

Stratotypes have been selected at the following localities (Fig. 5.2):

A. Nanaga (holostratotype).
B. Bathurst (reference stratotype).
C. Gamtoos River (reference stratotype).

A number of possible stratotypes occur in road cuttings near Nanaga. Any of these could have served as parastratotypes. However, because of the similarity of these sections, only the holostratotype has been measured.

A. **NANAGA STRATOTYPE**

Kind and rank: Unit holostratotype.

Nature of section: Road cutting which exposes about 16 m of the formation (Pl. 5-2).

Location: See Figure 5.2.

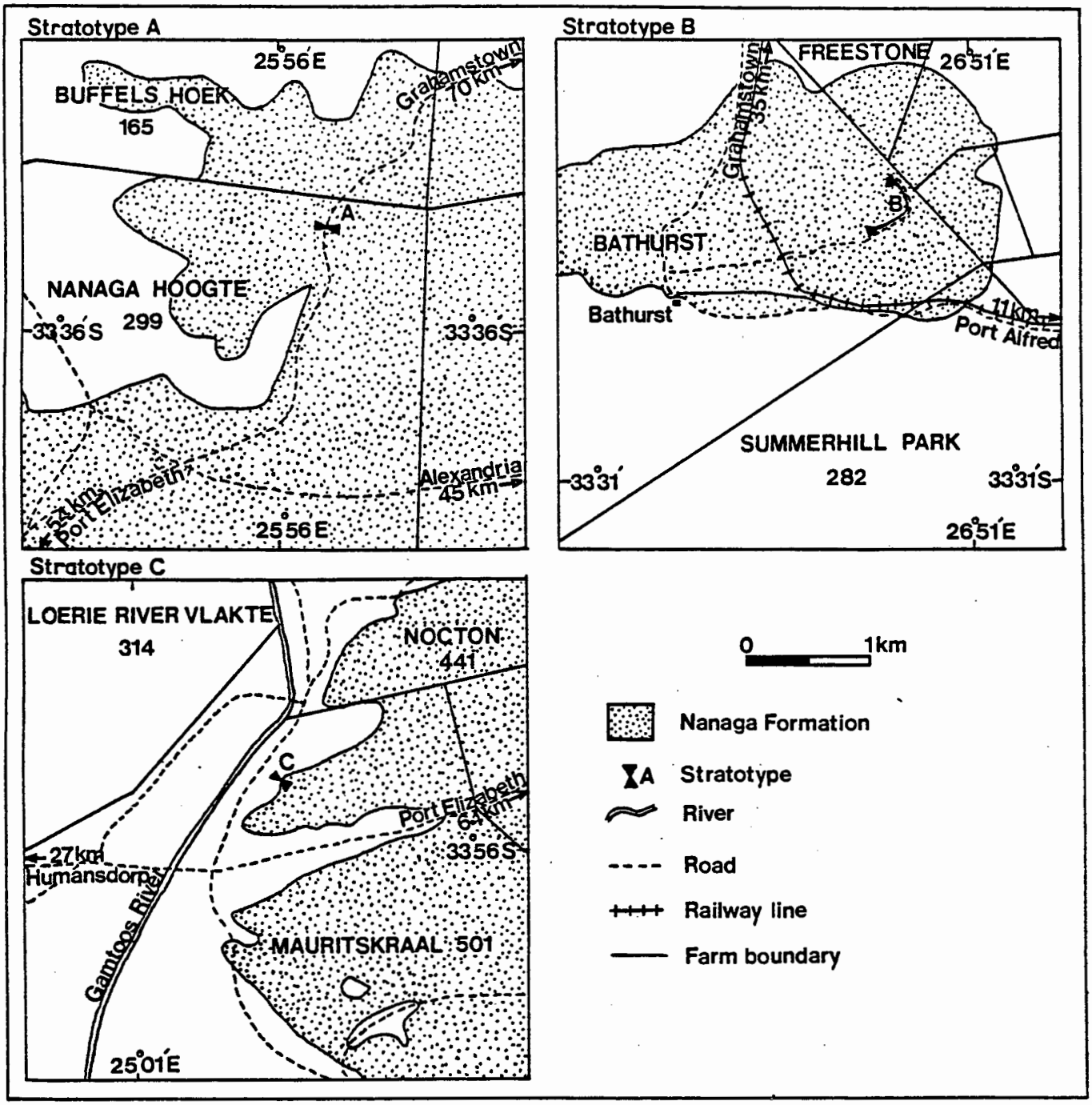


Fig. 5.2 - Location of stratotypes A (Nanaga), B (Bathurst) and C (Gamtoos River).

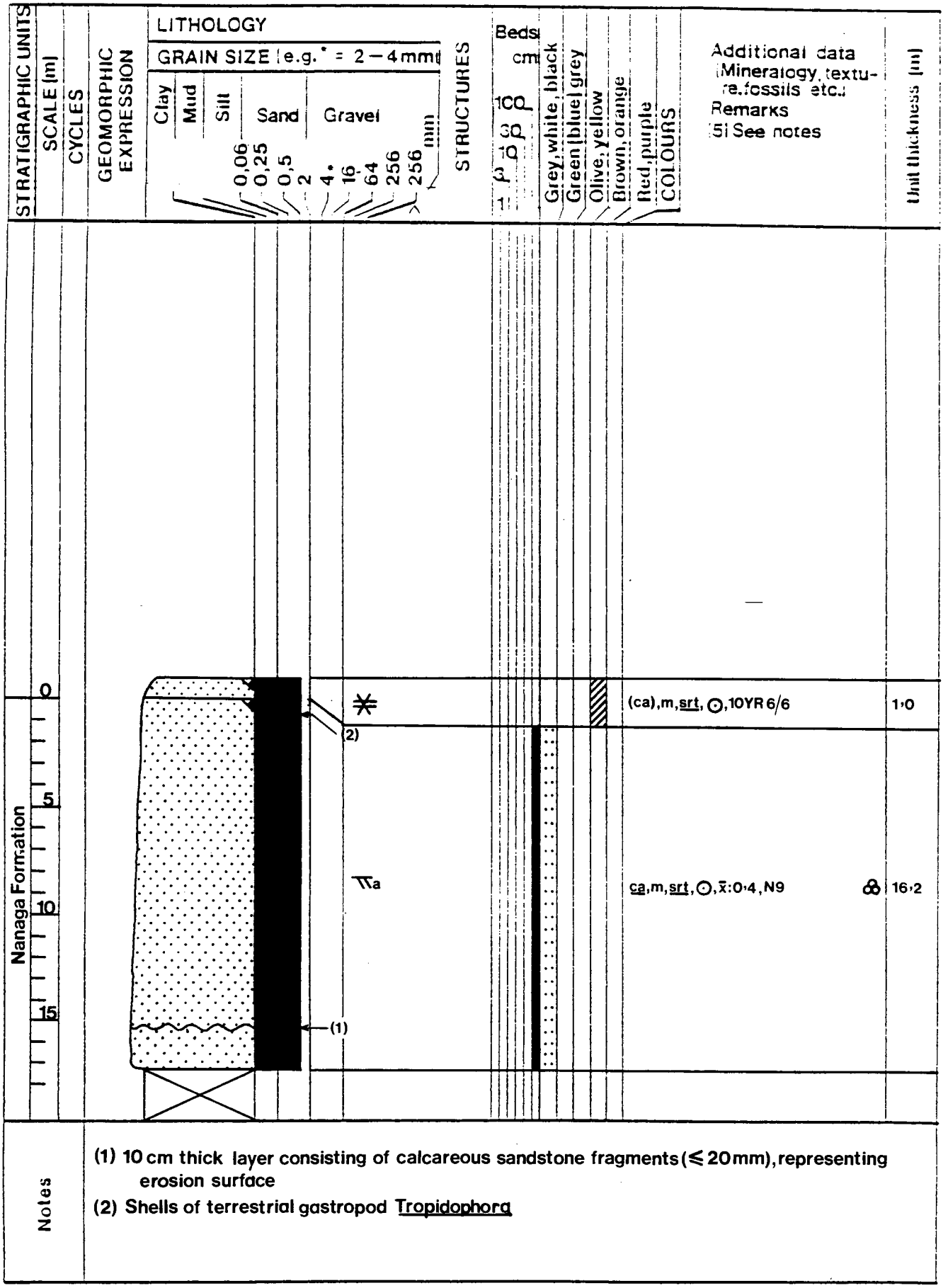


Fig. 5.3 - Stratotype A (Nanaga) of the Nanaga Formation.

Accessibility: Excellent; exposures adjoin main road.

Lithology: Medium-grained calcareous sandstone (100%) - see columnar section (Fig. 5.3). An erosional layer occurs near the base of the section (Pl. 5-1).

Palaeontology: Shells of the terrestrial gastropod Tropidophora occur near top of section.

Structure: No regional structure visible. An interdune filling (fine-grained soil) occurs in northern part of cutting.

Adjacent units: See columnar section (Fig. 5.3).

Boundaries and contact relationships: Upper boundary taken at base of red soil. Lower boundary not exposed (estimated to be c. 120 m below base of section).

B. **BATHURST STRATOTYPE**

Kind and rank: Unit reference stratotype.

Nature of section: Road cutting exposing approximately 40 m of the formation over a lateral distance of about 600 m.

Location: See Figure 5.2.

Accessibility: Excellent; exposures adjoin tarred road.

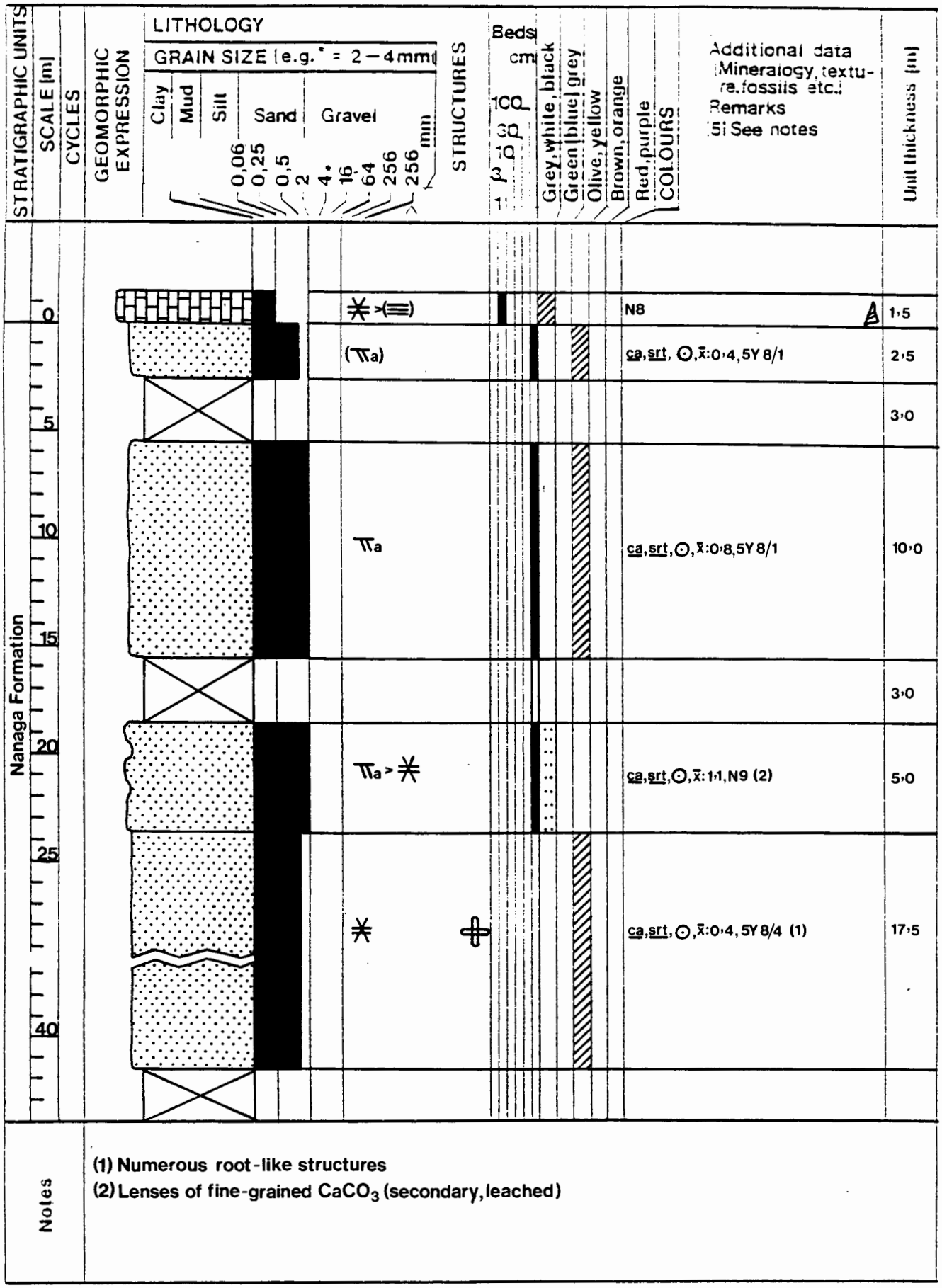


Fig. 5.4 - Stratotype B (Bathurst) of the Nanaga Formation.

Lithology: Calcareous sandstone (99%), fine-grained limestone (1%) - see columnar section (Fig. 5.4).

Palaeontology: Broken shells of the terrestrial gastropod Trigonephris occur in upper few metres of section.

Structure: Strata are flat-lying.

Reason for inclusion: Stratotype included because of the presence of white powdery $CaCO_3$.

Adjacent units: See columnar section (Fig. 5.4).

Boundaries and contact relationships: Upper boundary taken at base of calcrete (on which beacon was built). Lower boundary not exposed (estimated to be c. 50 m below base of section).

C. **GAMTOOS RIVER STRATOTYPE**

Kind and rank: Unit reference stratotype.

Nature of section: Westward-facing cliff exposing about 18 m of the formation over a lateral distance of about 600 m.

Location: See Figure 5.2.

Accessibility: Fair; exposures are within 150 m of a secondary (dirt) road, but approach to top of cliff is somewhat restricted by thorny vegetation.

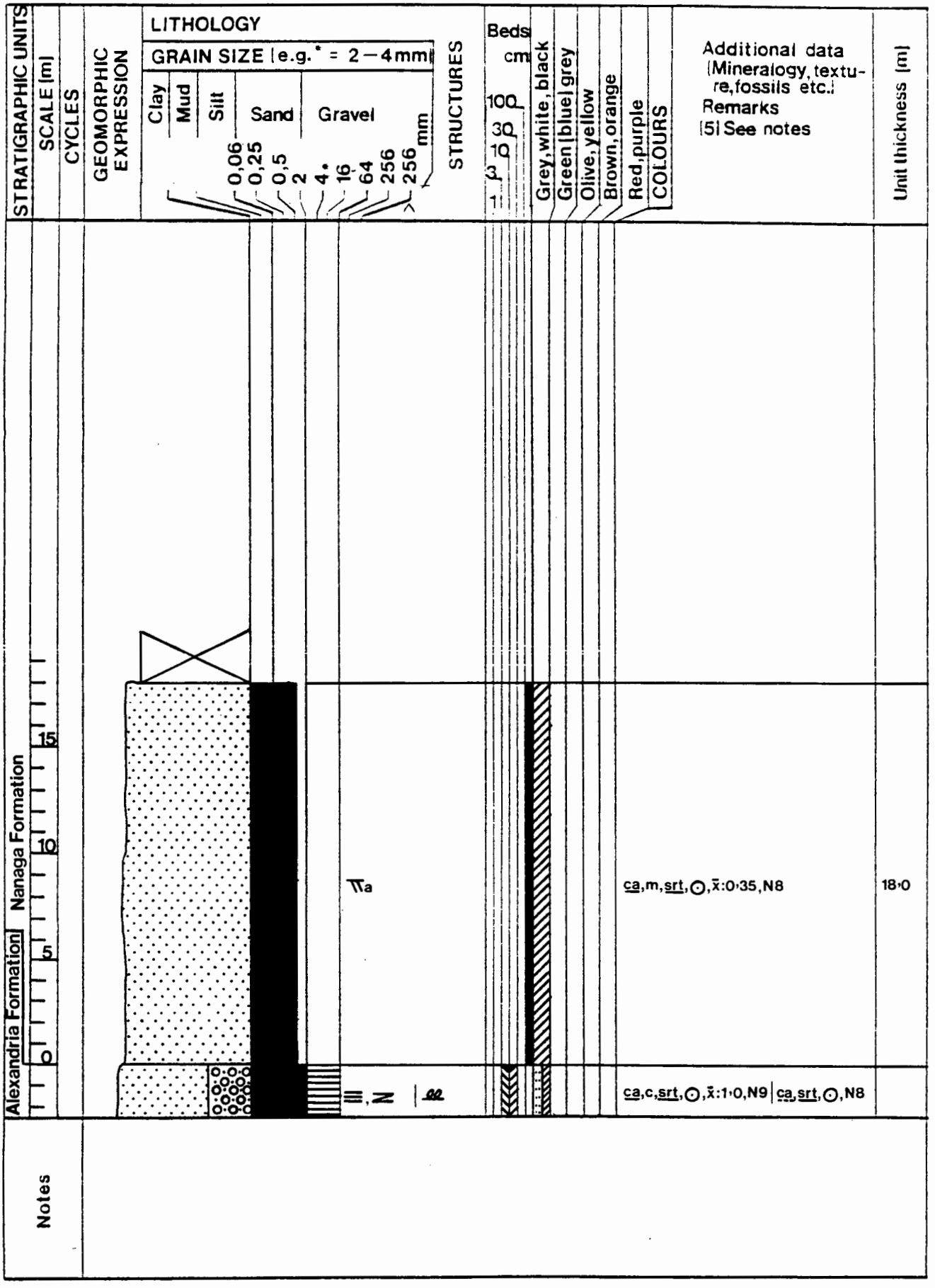


Fig. 5.5 - Stratotype C (Gamtoos River) of the Nanaga Formation.

Lithology: Calcareous sandstone (100%) - see columnar section (Fig. 5.5) and Plates 5-3, 5-4.

Palaeontology: Comminuted marine shell fragments constitute about 50% of the sandstone.

Structure: No regional structure visible.

Reason for inclusion: Stratotype included because of exposed lower contact with Alexandria Formation.

Adjacent units: See columnar section (Fig. 5.5).

Boundaries and contact relationships: Upper boundary not exposed in this outcrop. Lower boundary placed at top of conglomerate/sandstone of underlying Alexandria Formation (Pl. 5-4).

PLATE 5

5-1: Aeolian cross-bedding in calcareous sandstone of Nanaga Formation on the farm Nanaga Hoogte 299 (holostratotype). Length of staff 1,4 m. Note erosion surface (arrows).

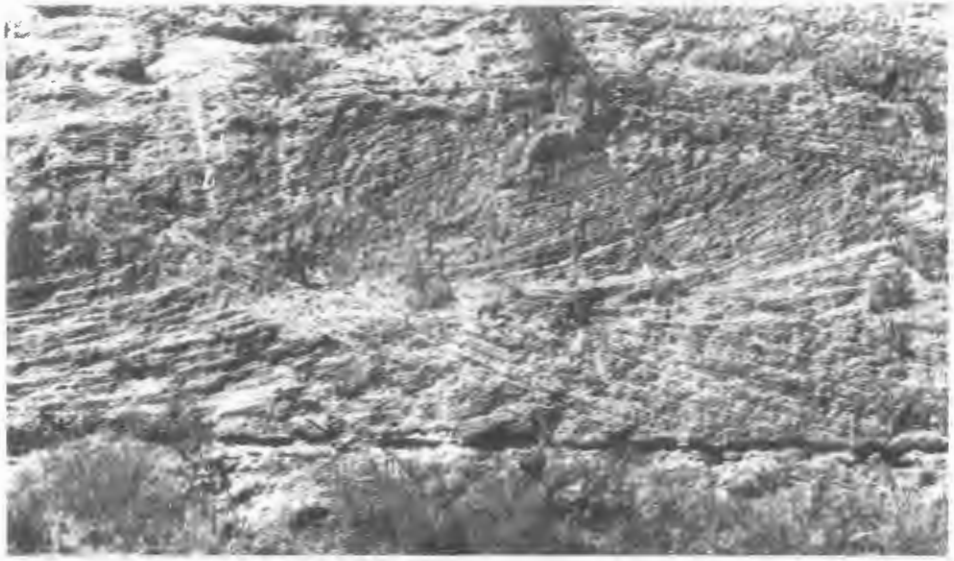
5-2: Unit holostratotype of Nanaga Formation on Nanaga Hoogte 299.

5-3: Cross-bed foresets in Nanaga Formation at Gamtoos River stratotype.

5-4: Cross-bedded aeolian sandstone of Nanaga Formation overlying conglomerate of Alexandria Formation at Gamtoos River stratotype.

PLATE 5

1



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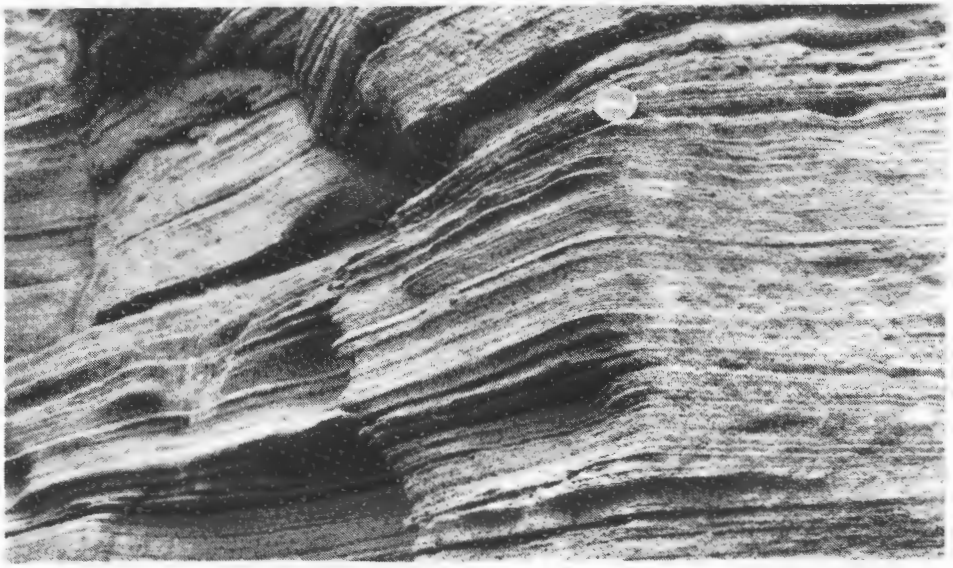

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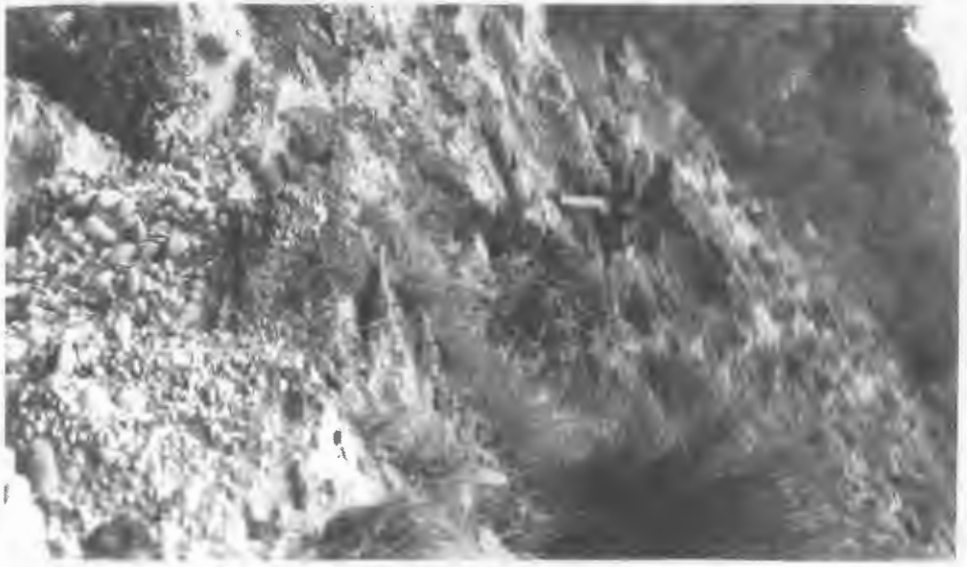

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CHAPTER 6 - NAHOON FORMATION

The Nahoon Formation represents Middle to Late Pleistocene aeolianites fringing the coastline.

6.1 **LITERATURE REVIEW**

Atherstone (1858) referred to a "post tertiary (sic) sand rock" near the mouth of the Kasouga River which, according to him, was still better developed between the Kariega and Bushmans Rivers. He remarked on certain features which he regarded as proof of the wind-borne origin of the formation. As far as is known this was the first attempt to relate some coastal formations in this region to the agency of wind. Haughton (1925) mentioned "crossbedded consolidated dunesand overlain by layers of loam and sand" at Woody Cape and also referred to similar deposits at the Riet River on Tharfield Park (Fig. 6.2) as well as at Three Sisters (Black Rock - Fig. 6.1), the latter containing "Phortion capense and Tropidophora sp.".

Mountain (1946) distinguished between "dune-rock" and other aeolian deposits, stating that the former had "a very limited distribution, usually along the shore". He briefly described the dunerock at Bats Cave (Great Fish River mouth) and commented on some root and stalactitic structures. Other outcrops of dune-rock between East London and Kwaaihoek were also mentioned.

SACS (1980) accepted a proposal made by Ruddock in 1979 that "dune-rock" along the coast should also be included with the other aeolian deposits in one Nanaga Formation. However, Le Roux (in press - c) maintained that the "dune-rock" exposed along the coast differs lithologically and in certain other aspects from the Nanaga and Schelm Hoek Formations, and that it should be distinguished as a separate formation. This was accepted by SACS in 1988.

Further useful information on coastal aeolianites of Southern Africa were contributed by McCarthy (1967), Coetzee (1975a, 1975b), Flemming et al. (1983) and Martin and Flemming (1986), amongst others.

6.2 LITHOSTRATIGRAPHY

6.2.1 Full Name

Nahoon Formation.

6.2.2 Proposer of Name

F.G. le Roux (in press - c).

6.2.3 Stratigraphic Position and Age

The Nahoon Formation generally overlies a wave-cut surface which truncates Palaeozoic and Mesozoic rocks. Occasionally it overlies Pleistocene marine/estuarine deposits of the Salnova Formation disconformably. It is overlain either by recent unconsolidated wind-blown sand of the Schelm Hoek Formation or by soil horizons and calcrete.

The formation was most probably deposited during the regressions associated with the WÜrm and Riss glacials. Le Roux (1989) deduced a late Middle to Late Pleistocene age. Radiocarbon dating of calcareous material in the sandstone at Nahoon Point yielded an age of 29090 $^{+410}_{-390}$ years B.P. (Deacon, 1966), which is in agreement with deposition during the Würm.

6.2.4 Type Area and Derivation of Name

The type area is situated along the coastline at East London between Eastern Beach and Nahoon Point (Fig. 6.2). The unit is named after Nahoon Point which consists of this formation.

6.2.5 Geological Description

Basic concept and unifying features: The formation consists essentially of calcareous sandstone with interbedded palaeosols and occasional very thin calcrete layers. It is distinguished from the underlying marine Salnova Formation by the presence of large-scale aeolian cross-bedding and terrestrial fossil fragments as well as the absence of clasts and (intact) marine shells, while the calcareous nature of the formation distinguishes it from the underlying pre-Cenozoic rocks. Criteria distinguishing the Nahoon Formation from the other aeolian formations are presented in Table 6.1.

Thickness: 6 - 50 m (average 15 m).

TABLE 6.1 - CRITERIA DISTINGUISHING MARINE-RELATED (AEOLIAN) FORMATIONS IN THE ALGOA GROUP

	Nanaga Formation	Nahoon Formation	Schelm Hoek Formation
1.	Semi-consolidated	Well consolidated	Unconsolidated
2.	Paleosols scarce	Often with paleosols	Paleosols absent
3.	Peat horizons absent	Peat horizons sometimes present	Peat horizons absent
4.	Midden shell deposits absent	Midden shell deposits absent	Midden shell deposits abundant
5.	Maximum thickness c. 250 m	Maximum thickness c. 50 m	Maximum thickness c. 140 m
6.	Overlies Alexandria Fm, never Salnova Fm	Overlies Salnova Fm, never Alexandria Fm	Overlies Salnova Fm and/or recent beach sediments
7.	Late Pliocene to Early Pleistocene in age	Middle to Late Pleistocene in age	Holocene in age
8.	Occurs up to 40 km's inland from coast, probably absent on continental shelf	Occurs within first few hundred metres from highwater mark, extensively developed on continental shelf	Fringes coastline, up to a few kilometres inland. Absent on continental shelf

Lithology: **Calcareous sandstone** (20 - 100%): Fine- to coarse-grained; aeolian cross-bedded (Pl. 6-1), structureless in places; ripple marked; disturbed bedding (Pl. 6-2) and slumping (Pl. 6-3) present locally; very thick-bedded; yellowish grey (5Y 8/1) to greyish yellow 5Y 8/4), also light olive grey (5Y 5/2) to pale yellowish brown (10YR 6/2); moderately to well sorted; grains subrounded to well rounded; glauconitic; heavy minerals such as rutile, zircon and ilmenite present in small quantities.

Palaeosols (0 - 80%): Fine- to medium-grained; structureless; thick- to very thick-bedded; yellowish grey (5Y 7/2) to light olive grey (5Y 5/2); well sorted; humic; semi-consolidated.

Palaeontology: Minute fragments of (allogenic) marine macro-organisms (mainly shells) are common, while foraminifera also occur. Occasional land gastropods such as Achatina, Tropidophora, Trigonephrus and Phortion are present, especially in the palaeosol horizons. Fragments of fossil bone have been observed in the aeolianite at Black Rock and Ship Rock (Kasouga), and have also been reported from Brenton-on-Sea outside the study area near Knysna (R.D.F. Oosthuizen - pers. comm., 1985). These were probably introduced by carnivores, in a similar way to those from Swartklip in the western Cape (Klein, 1975). Human as well as bird and probably hyena footprints have been found at Nahoon Point, East London (Mountain, 1966). Middle Stone Age artifacts are present at Bats Cave, East London (Mountain, 1945b), Cove Rock (Mountain, 1962) and Woody Cape

(W.K. Illenberger - pers. comm, 1986). Root-like structures (Pl. 6-4) are present, e.g. at Bats Cave (Great Fish River) while peat horizons are present at Woody Cape.

Genesis: The characteristic high-angle cross-bedding with sets up to 20 m thick (e.g. at Eersterivierstrand), as well as textural features such as absence of matrix, good sorting and well-rounded quartz grains indicate an aeolian origin for this formation. Increased aeolian deposition as coastal dune fields on land during regressions associated with at least the last two Pleistocene glacials (Riss and Würm) can be attributed to the fact that vast quantities of calcareous sand were available on the exposed sea floor. The presence of glauconite (exclusively marine) is indicative of reworked platform sediments. Prevailing winds were from the south-west and south-east, as deduced from cross-bed orientation (unpubl. data). Percolation of meteoric water probably caused lithification by solution and redeposition of $CaCO_3$.

Other aspects: These coastal aeolianites typically protrude as headlands into the sea, e.g. at Dias Cross, Kwaaihoek, Bushmans River mouth (Pl. 6-5) and Bats Cave (Great Fish River). There is also a tendency to form islands or peninsulas. Nahoon Formation aeolianites often underlie vegetated backshore dunes which are aligned slightly oblique to the present coastline. Other geomorphological features of coastal aeolianites such as sea cliffs (e.g. Woody Cape, Kwaaihoek, Ship Rock), emergent platforms (Pl. 6-6), intertidal platforms, raised rims, sea-level notches, potholes

(Pl. 6-7), solution pipes etc. are abundant; similar features are described in detail by Coetzee (1975a) in Natal. Names such as "Mushroom Rock" indicate the peculiar form of some aeolianites, caused by undercutting due to wave action (Pl. 6-8). Honeycomb weathering (Pl. 6-9) is abundant, especially in the splash zone.

6.2.6 **Boundaries**

Upper boundary: Disconformable, sharp. The boundary is defined as the base of overlying unconsolidated (commonly vegetated) aeolian sand of the Schelm Hoek Formation (e.g. Pl. 6-5), soil or surficial calcrete.

Lower boundary: A disconformable lower contact is present where the Nahoon overlies the Salnova Formation. More commonly it overlies pre-Cenozoic rocks with a marked unconformity.

Lateral boundary: A western cut-off point for the Nahoon Formation is proposed at the Groot River (Fig. 6.1) in view of the apparent absence of aeolian sediments in the Groot River - Plettenberg Bay area. Bredasdorp Group sediments occur west of Plettenberg Bay. In the east a cut-off is proposed at the Gonubie River (Fig. 6.1), beyond which aeolianite outcrops are scarce. Because the formation is confined to the coastline, the landward boundary is generally located within a few hundred metres from the high-tide mark. Although largely covered by younger dunes, remnants of the formation are however present a few

kilometres inland at Cape St. Francis as well as in the Congoskraal - Lake Eric area east of the Sundays River. Seaward the formation continues onto the continental shelf, as is the case with correlative units in other areas as described by McCarthy (1967) and Martin and Flemming (1986), amongst others.

6.2.7 **Subdivision**

The formation does not lend itself to further subdivision.

6.2.8 **Regional Aspects**

Geographic distribution: The formation is found along the coastline between the Groot River in the west and the Gonubie River in the east and in places occurs up to 4 km inland from the coastline. However, recent dune cover (Schelm Hoek Formation) causes outcrops to be relatively few and far between, being mainly confined to the vicinity of river mouths (Fig. 6.1).

Lateral variation: No lateral trends could be established in the Nahoon Formation, which internally shows little significant petrographic or mineralogical variation.

Criteria for lateral extension: In some areas such as the first few kilometres immediately west of Black Rock, as well as at Bonza Bay (Fig. 6.1), bench-like outcrops occur in the intertidal zone. Although no aeolian cross-bedding is discernable due to encrustation and covering by marine growth, the calcareous nature of these rocks is revealed by

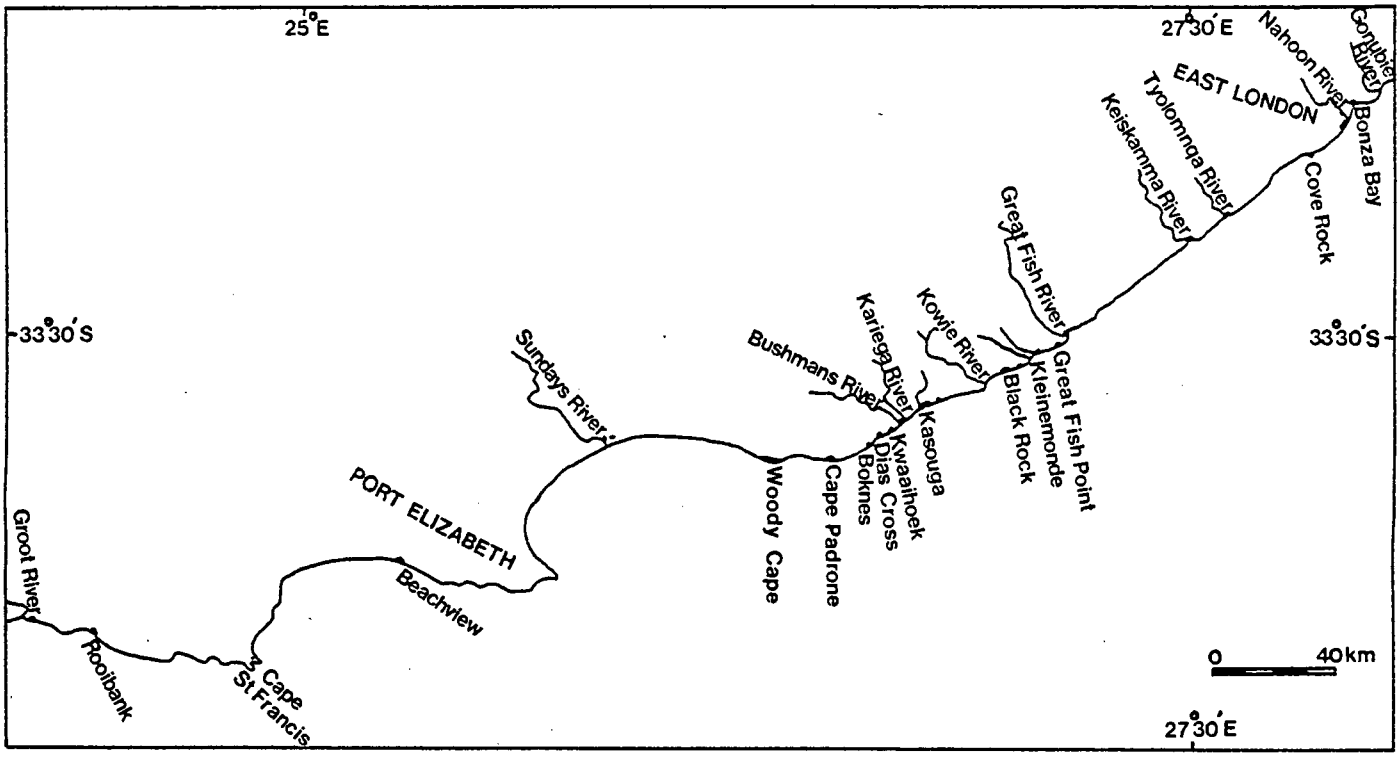

Fig. 6.1 - Distribution of Nahoon Formation.

the presence of typical "potholes" or "tufa-lined basins" (Mountain, 1937) - and even some cylindrical solution pipes similar to those described by Coetzee (1975a). These outcrops are therefore included in the Nahoon Formation.

Correlation: Since the Nahoon Formation represents global lower stands of sea-level, similar deposits occur along most of the Southern African coastline. The formation is correlated with the Langebaan Limestone Member (Visser and Schoch, 1973) in the Saldanha Bay area, and also with the Waenhuiskrans Formation (Malan, in press - d) along the Cape south coast west of Plettenberg Bay. Similar deposits occur along the Natal, Zululand and Mozambique coasts, e.g. at Durban (Bluff Sandstone Formation - SACS, 1980), Umhloti, Cape Vidal, Black Rock and Pomene, the latter two occurrences being described by Coetzee (1975b). Small scattered outcrops may also be present east of the Gonubie River along the Transkei coast.

6.2.9 **Stratotypes**

Stratotypes were selected at the following localities (Fig. 6.1):

A. Nahoon Point (holostratotype).

B. Bats Cave (parastratotype).

C. Cove Rock (reference stratotype).

D. Black Rock (reference stratotype).

E. Woody Cape (reference stratotype).

F. Eersterivierstrand (reference stratotype).

A. NAHOON POINT STRATOTYPE

Kind and rank: Unit holostratotype.

Nature of section: Sea cliff exposing formation over a lateral distance of about 200 m.

Location: See Fig. 6.2 and Pl. 6-10.

Accessibility: Good; about three minutes walk from the parking area at Nahoon Point.

Lithology: See columnar section (Fig. 6.3).

Palaeontology: Human and other footprints were found in this formation in the immediate vicinity of the stratotype locality (Mountain, 1966). Foraminifera of the Rotalia type were also reported by Mountain.

Structure: No regional dip visible.

Reason for selection: Stratotype is easily accessible, while a fairly detailed description (sedimentological, petrographical and structural) is provided by Mountain (1966).

Adjacent units: Formation overlain by Schelm Hoek Formation. Underlying strata not exposed (below low-tide mark), but presence of dolerite boulders in intertidal zone

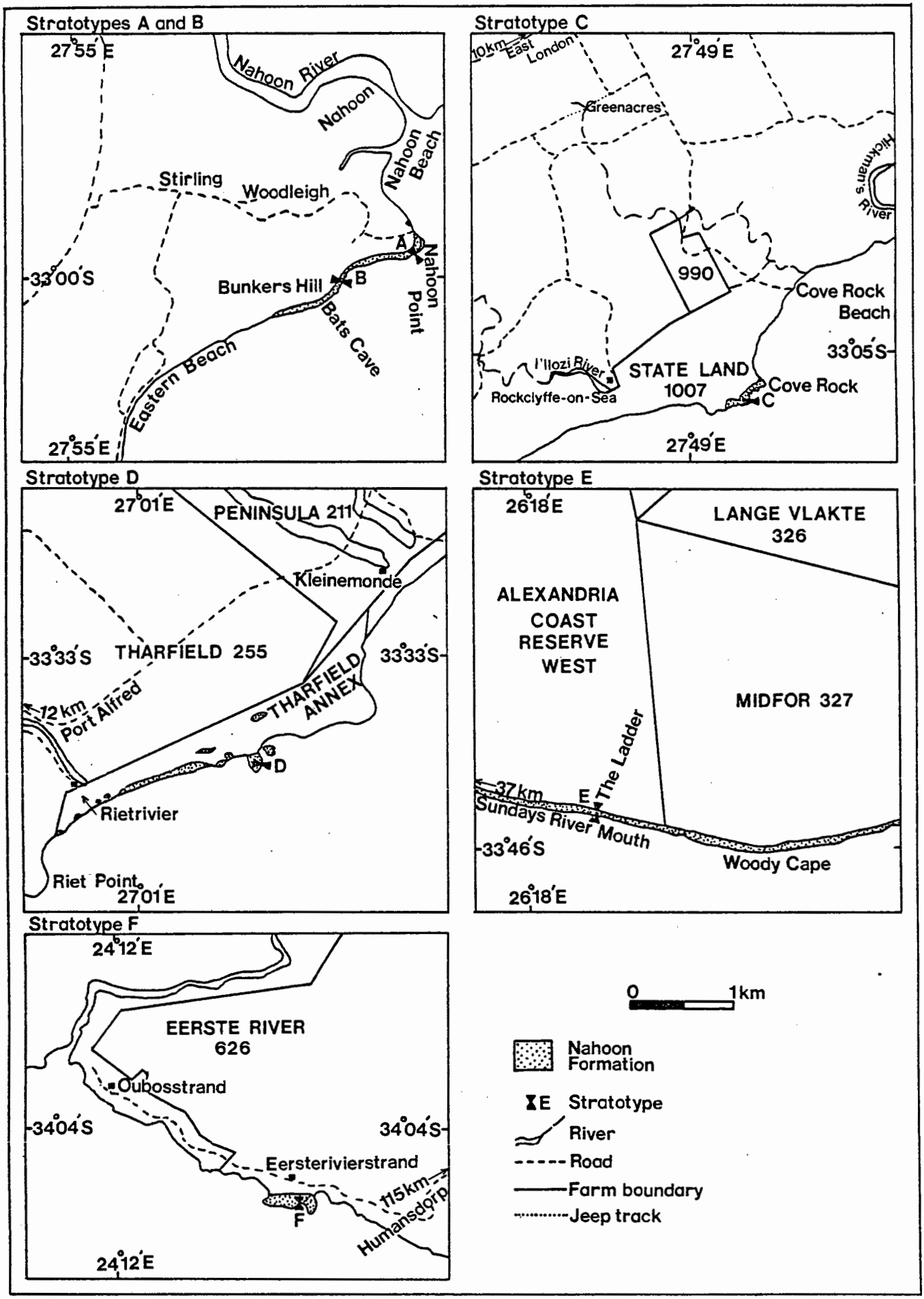

Fig. 6.2 - Location of stratotypes A (Nahoon Point), B (Bats Cave), C (Cove Rock), D (Black Rock), E (Woody Cape) and F (Eersterivierstrand).

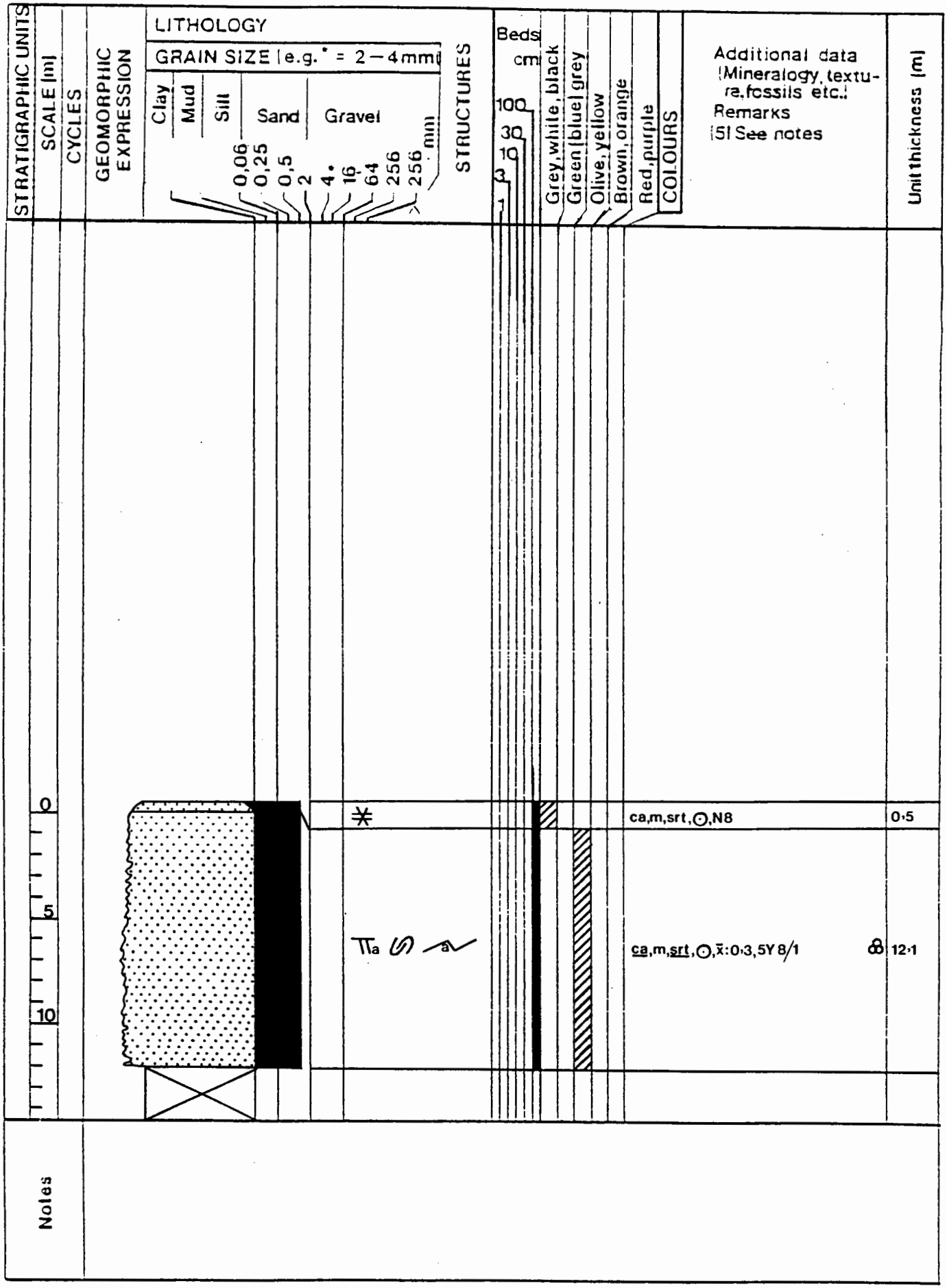

Fig. 6.3 - Stratotype A (Nahoon Point) of Nahoon Formation.

indicates presence of dolerite sill underneath Nahoon Formation.

Boundaries and contact relationships: Upper boundary defined as base of overlying unconsolidated sand. Lower boundary not exposed.

B. BATS CAVE STRATOTYPE

Kind and rank: Unit parastratotype.

Nature of section: Promontory exposing formation over a lateral distance of about 600 m.

Location: See Fig. 6.2.

Accessibility: Fair; about 15 minutes walk from the parking area at Nahoon Point. Basal exposures are covered during high tides.

Lithology: See columnar section (Fig. 6.4).

Palaeontology: About 200 m from the stratotype locality, towards Eastern Beach, Middle Stone Age artifacts were found in the basal part of the outcrop (Mountain, 1966).

Structure: No regional dip visible.

Reason for inclusion: Above-average thickness of formation.

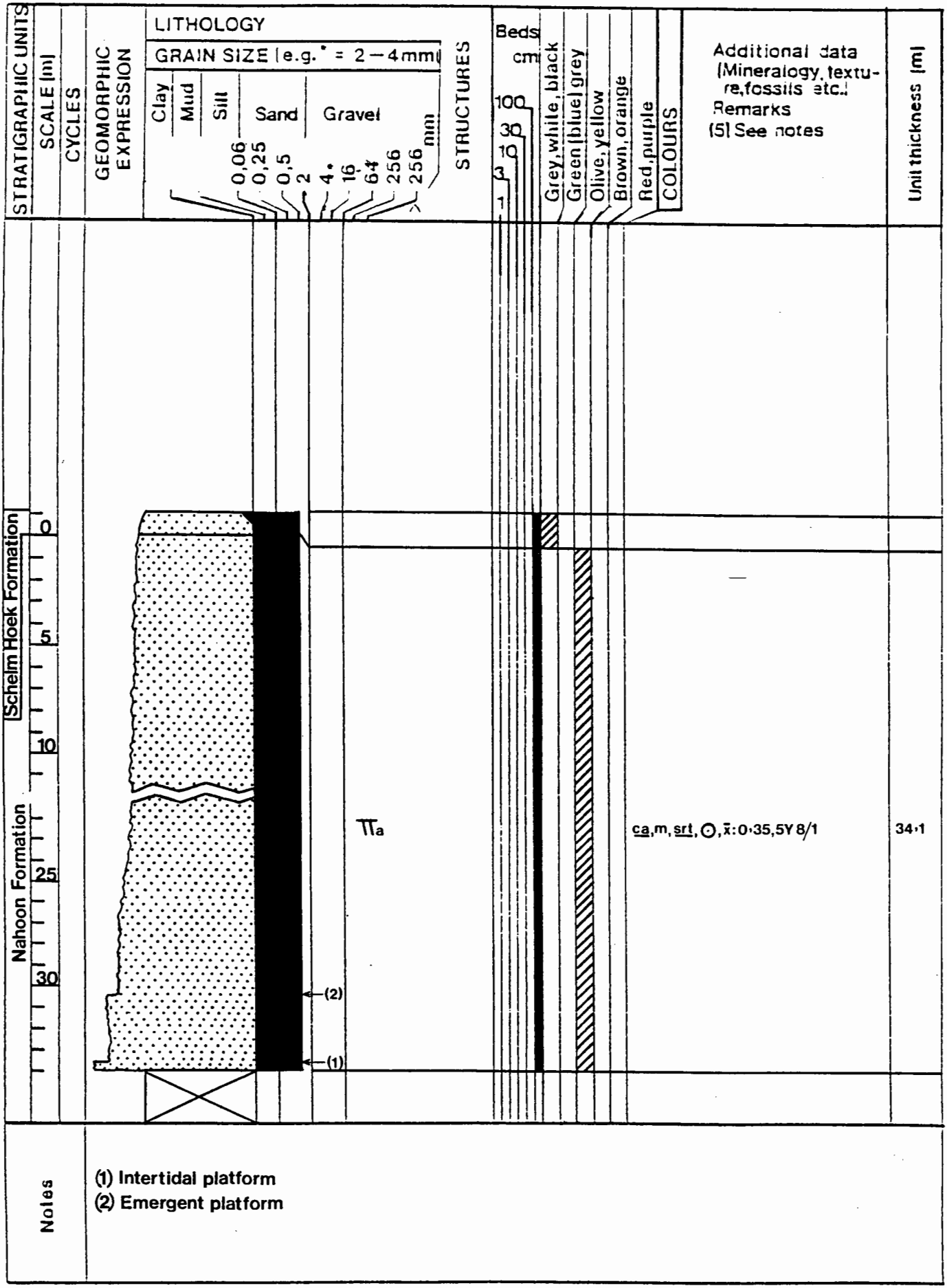

Fig. 6.4 - Stratotype B (Bats Cave) of Nahoon Formation.

Adjacent units: Formation overlain by Schelm Hoek Formation. Underlying strata not exposed (below low-tide mark) but outcrops near Nahoon Point indicate presence of dolerite sill underneath the Nahoon Formation.

Boundaries and contact relationships: Upper boundary taken at base of overlying unconsolidated sand (vegetated) at top of cliff. Lower boundary not exposed (below low-tide mark).

C. **COVE ROCK STRATOTYPE**

Kind and rank: Unit reference stratotype.

Nature of section: Vertical cliff on eastern side of headland, exposing a thickness of about 22 m (Pl. 6-11).

Location: See Fig. 6.2.

Accessibility: Fair; can be reached by four-wheel-drive or beach vehicle or on foot from the Cove Rock Beach side, a distance of about one kilometre.

Lithology: See columnar section (Fig. 6.5).

Palaeontology: Root-like structures are common.

Structure: No regional dip discernible.

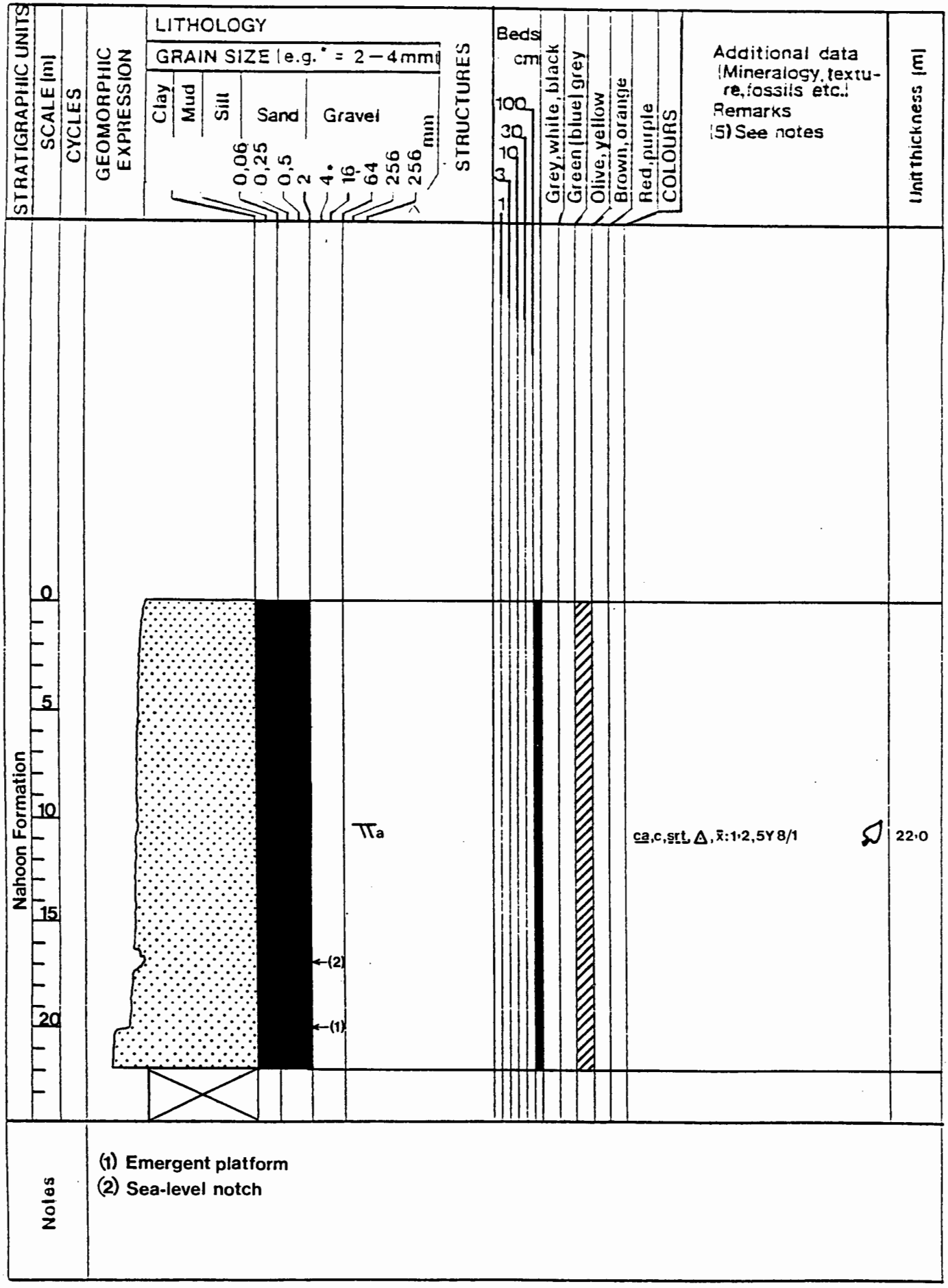

Fig. 6.5 - Stratotype C (Cove Rock) of Nahoon Formation.

Reasons for inclusion: Coarser-grained character as well as presence of emergent platform and sea-level notch.

Adjacent units: None exposed.

Boundaries and contact relationships: No overlying strata present. Lower boundary not exposed.

D. **BLACK ROCK STRATOTYPE**

Kind and rank: Unit reference stratotype.

Nature of section: Vertical cliff on eastern side of headland, exposing a thickness of about 18 m.

Location: See Fig. 6.2.

Accessibility: Fair; can be reached by four-wheel-drive or beach vehicle from either the Kleinemonde or Riet River side, distances of about four and two kilometres respectively. Cliff is best negotiated from the top downwards.

Lithology: See columnar section (Fig. 6.6).

Palaeontology: A fossil bone fragment was found near top of section.

Structure: No regional dip discernible.

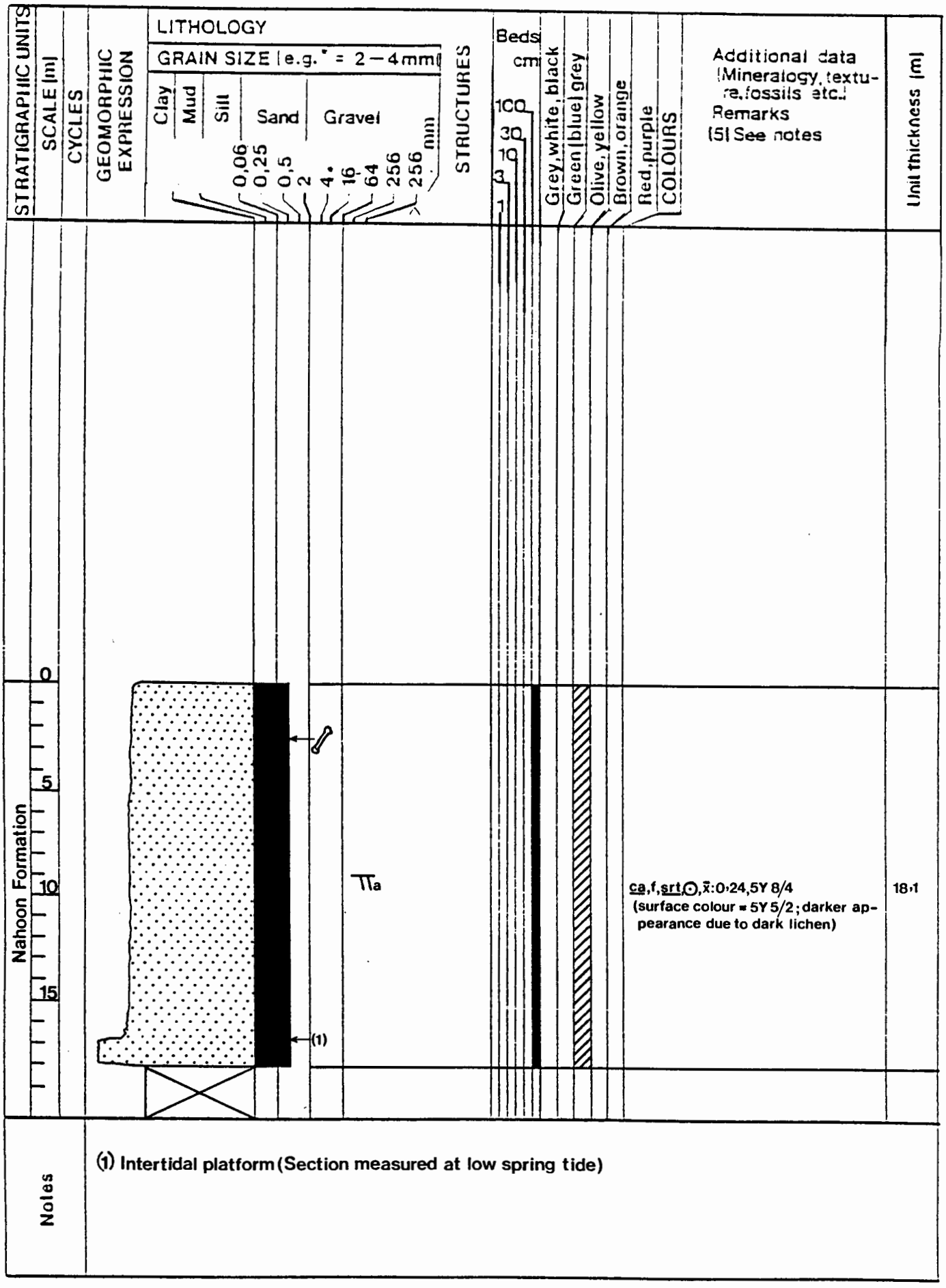

Fig. 6.6 - Stratotype D (Black Rock) of Nahoon Formation.

Reasons for inclusion: Presence of fossil bone fragment as well as finer-grained character.

Adjacent units: None exposed.

Boundaries and contact relationships: No overlying strata present. Lower boundary not exposed.

E. **WOODY CAPE STRATOTYPE**

Kind and rank: Unit reference stratotype.

Nature of section: Sea cliff exposing the formation over a lateral distance of about 10 km.

Location: Adjacent to ladder attached to cliff face. (See Fig. 6.2 and Pl. 6-12).

Accessibility: Poor. A beach or four-wheel-drive vehicle is necessary. Can be reached by driving from Sundays River Mouth along the beach to the western edge of the cliff at low tide, followed by about an hour's walk to the stratotype locality. A fixed ladder allows a close examination of the cliff face.

Lithology: Sandstone (66%), palaeosols (34%) - see columnar section (Fig. 6.7). Palaeosols may comprise up to 80 per cent of sections at some adjacent localities (Pl. 6-13); up to 14 palaeosol units have been observed (Pl. 6-14).

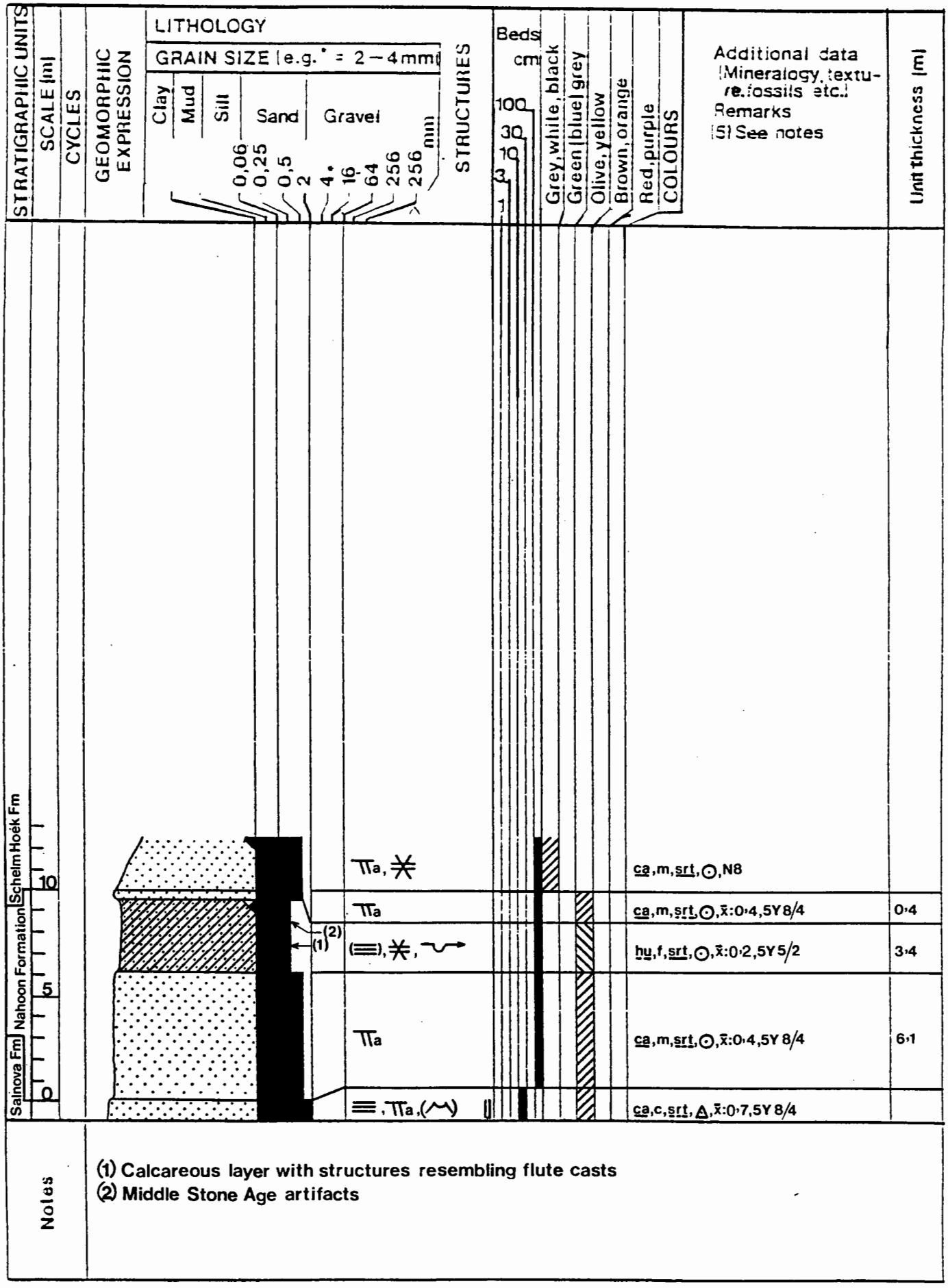

Fig. 6.7 - Stratotype E (Woody Cape) of Nahoon Formation.

Palaeontology: Land gastropod shells, especially Achatina zebra (Pl. 6-15) are abundant in palaeosols. Up to four peat horizons (Pl. 6-16) are present about two kilometres west of the stratotype locality. Middle Stone Age artifacts were found near the top at the stratotype locality (W.K. Illenberger, pers. comm., 1986).

Structure: No regional dip visible.

Reasons for inclusion: Presence of palaeosols and exposure of lower boundary with Salnova Formation.

Adjacent units: Formation overlain by Schelm Hoek Formation and underlain by Salnova Formation.

Boundaries and contact relationships: Upper boundary taken at base of overlying unconsolidated sand. Lower boundary taken at top of coarse-grained beach-stratified sandstone (Pl. 6-11).

F. **EERSTERIVIERSTRAND STRATOTYPE**

Kind and rank: Unit reference stratotype.

Nature of section: Sea cliff exposing thickness of about 18 m of the formation.

Location: See Figure 6.2.

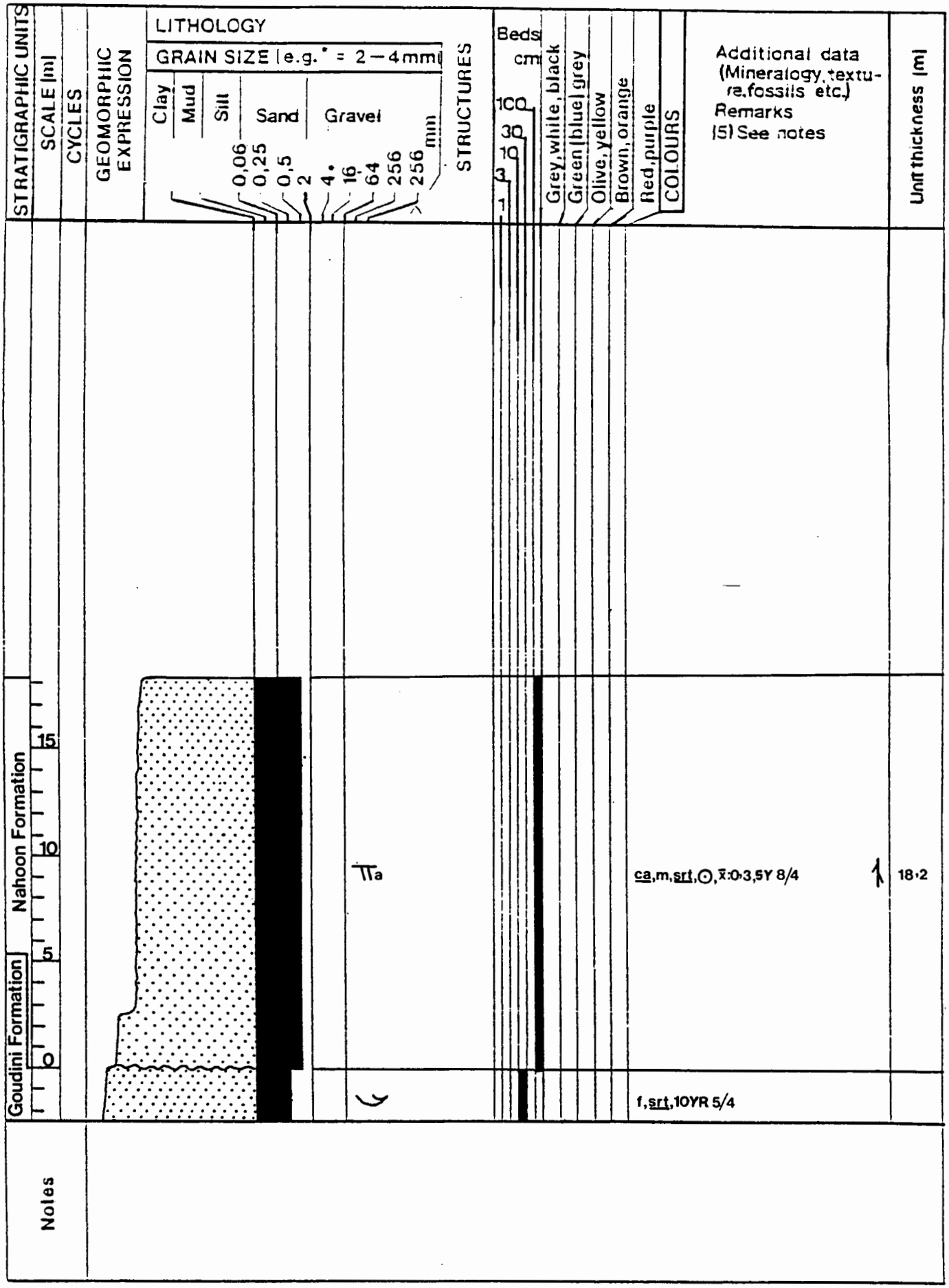

Fig. 6.8 - Stratotype F (Eersterivierstrand) of Nahoon Formation.

Accessibility: Good. Exposures are within 400 m of tarred road.

Lithology: See columnar section (Fig. 6.8).

Palaeontology: Some root-like structures present near top of section.

Structure: Strata dip seaward at about two degrees.

Reason for inclusion: Lower boundary with Goudini Formation (Table Mountain Group) is exposed at this locality.

Adjacent units: No overlying strata present. Formation underlain by Goudini Formation (Table Mountain Group).

Boundaries and contact relationships: Upper boundary taken at base of overlying unconsolidated sand (Schelm Hoek Formation) (only about 0,2 m thick). Lower boundary taken at basal unconformity.

PLATE 6

6-1: Aeolian cross-bedding in Nahoon sandstone at Cove Rock. Scale in decimetres.

6-2: Disturbed bedding in calcareous sandstone of the Nahoon Formation at Nahoon Point.

6-3: Slump structures in calcareous sandstone of the Nahoon Formation at Eersterivierstrand.

6-4: Rootlike structures in aeolianite of the Nahoon Formation at Bats Cave (Great Fish River).

6-5: Promontories caused by resistant aeolianite of the Nahoon Formation. Photo taken eastward from Dias Cross (foreground) with Kwaaihoek in middle distance and Kenton on Sea (Bushmans River mouth) in background.

6-6: Emergent platform (c. 2,5 m above m.s.l.) on aeolianite at Eersterivierstrand. Scale in decimetres.

6-7: Pothole (diameter c. 0,8 m) in aeolianite on emergent platform at Eersterivierstrand.

6-8: Landform, c. 5 m high, resulting from undercutting by wave action at Mushroom Rock, Kasouga. Note typical rugged upper surface, as well as potholes (foreground) in intertidal platform.

PLATE 6

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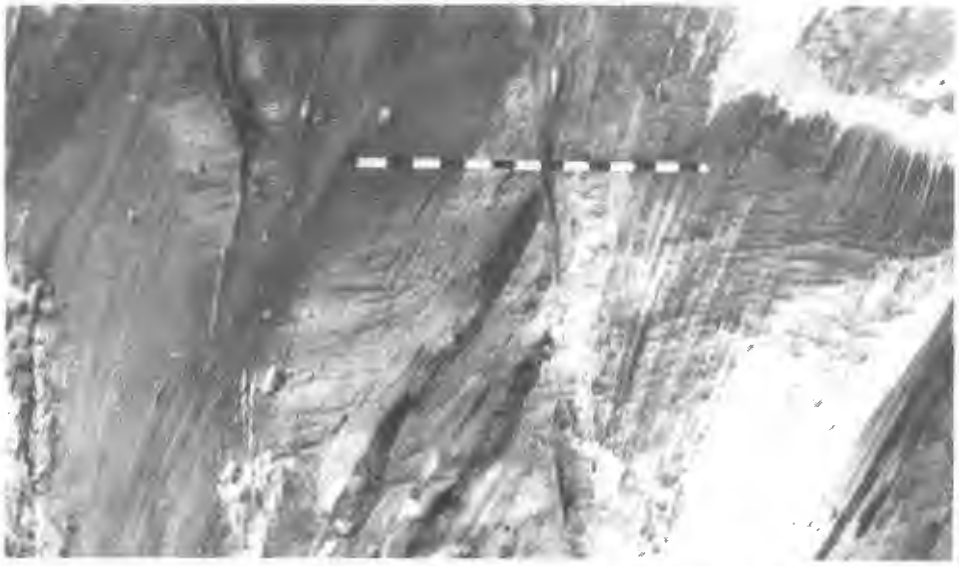

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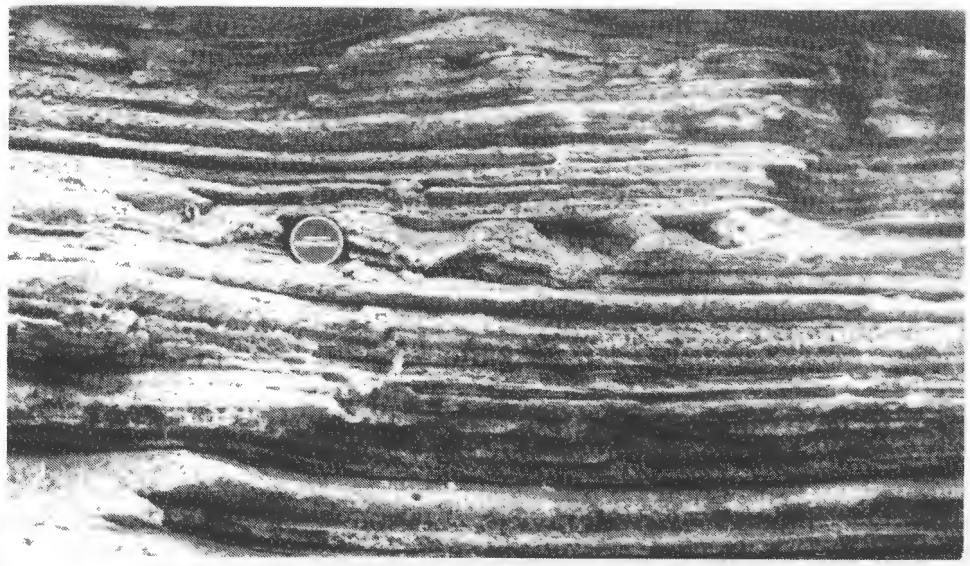

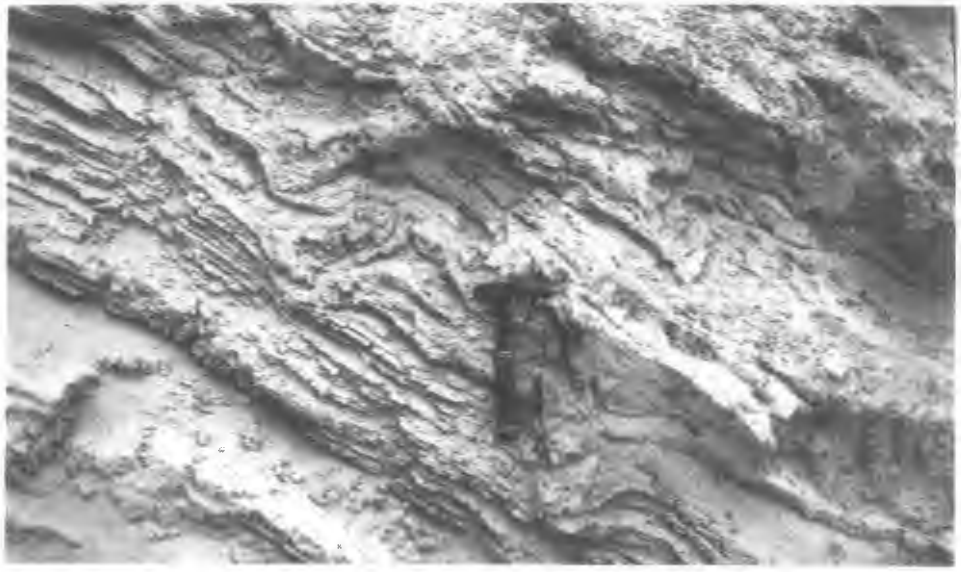

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PLATE 6

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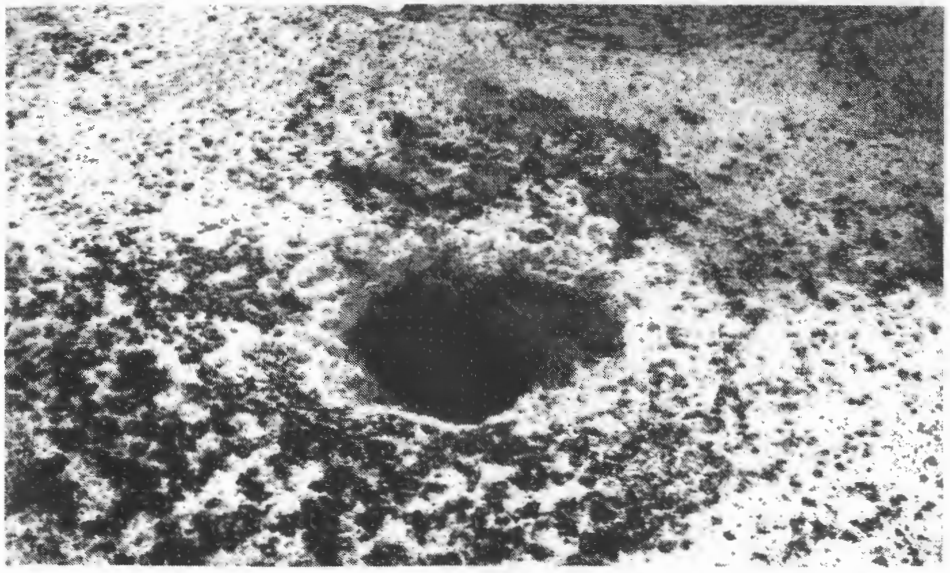

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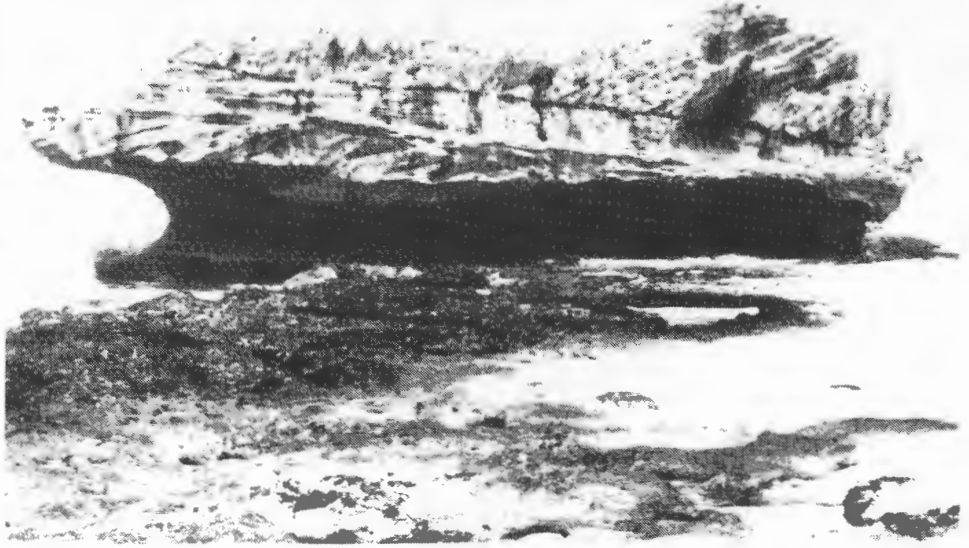

PLATE 6 (continued)

6-9: Honeycomb weathering in aeolianite at Cove Rock. Scale in decimetres.

6-10: Location of Stratotype A, Nahoon Point; note prominent aeolian cross-bedding. Scale in decimetres.

6-11: Nature of section (Stratotype C) at Cove Rock. Note intertidal platform at base of cliff. Vertical height of exposure c. 22 m.

6-12: Location of Stratotype E, Woody Cape. Note beach-stratified sandstone of Salnova Formation at base (from top of staff downwards). Scale in decimetres.

6-13: Part of cliff, Woody Cape. Palaeosol comprises up to 80 per cent of section (extreme right of photograph). Cliff height (to base of vegetated sand of Schelm Hoek Formation) 15 m.

6-14: Alternating aeolianite and soil horizons at Woody Cape. Cliff height c. 19 m.

6-15: Fossil shell of land gastropod Achatina zebra in palaeosol, Woody Cape.

6-16: Peat horizons within palaeosol at Woody Cape. Scale in decimetres.

PLATE 6

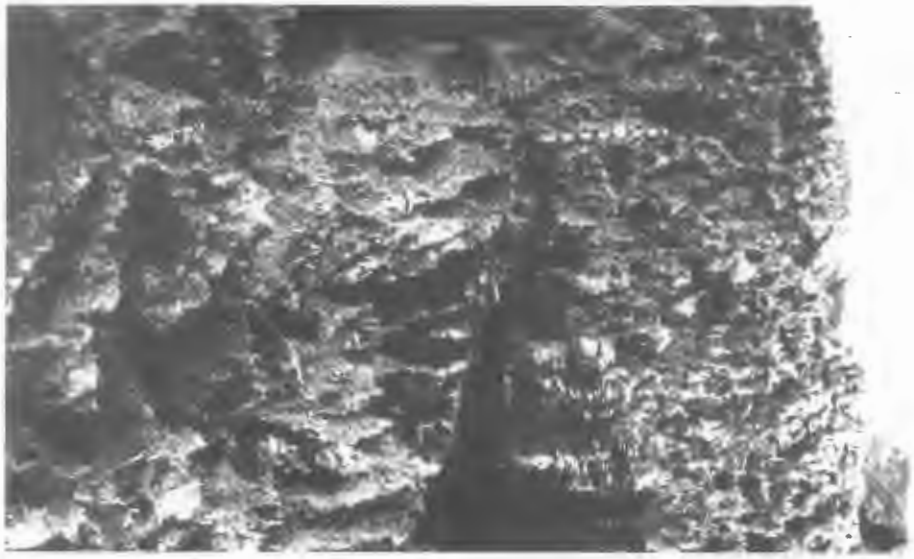

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PLATE 6

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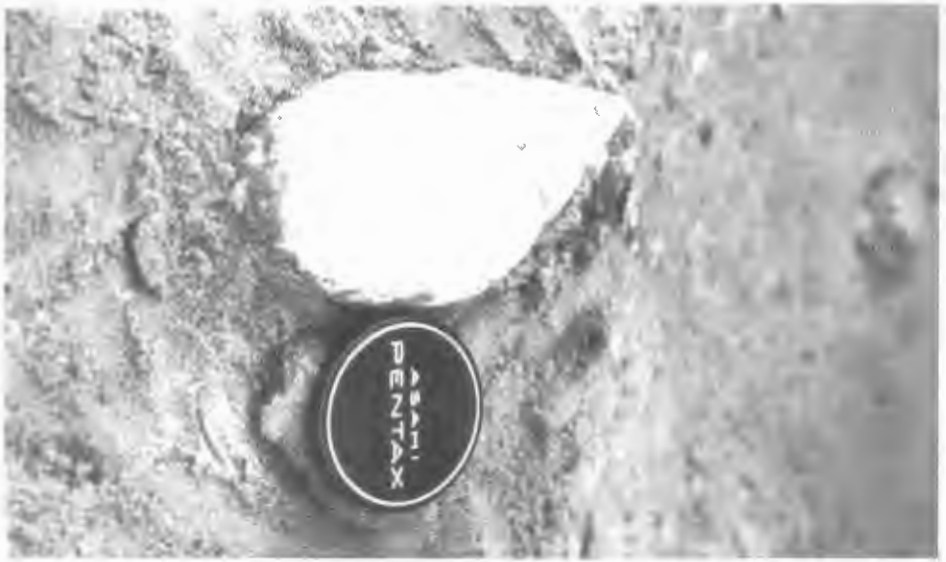

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CHAPTER 7 - SCHELM HOEK FORMATION

The Schelm Hoek Formation comprises unconsolidated windblown sand of Holocene age occurring op to six kilometres inland from the coast.

7.1 HISTORICAL BACKGROUND

(See also sections 3.1, 5.1 and 6.1).

Haughton (1928), Mountain (1946) and Engelbrecht et al. (1962) mapped this formation as "sand dunes and blown sand", "windblown sand" and "moving dune-sand" respectively. Ruddock, in a proposal to SACS in 1979, included these unconsolidated deposits in his Nanaga Formation, which comprised all Cenozoic aeolian deposits along the south-east coast and its hinterland. However, Le Roux (in press - b) proposed that it be excluded from the redefined Nanaga Formation since it differs lithologically from, and is younger than this formation (see Table 6.1). This was accepted by SACS in 1988.

7.2 LITHOSTRATIGRAPHY

7.2.1 Full Name

Schelm Hoek Formation.

7.2.2 Proposer of Name

F.G. le Roux (1986b).

7.2.3 Stratigraphic Position and Age

The Schelm Hoek Formation represents the youngest (uppermost) formation in the Algoa Group (see Chapter 8). It overlies the Nanaga, Nahoon and Salnova Formations disconformably. It also overlies pre-Cenozoic formations unconformably in places. The age of the Schelm Hoek Formation is inferred to be Holocene (Illenberger and Rust, 1988; Illenberger, in press). Deposition was probably initiated at the beginning of the regression from the transgressive maximum (c. 3m above present m.s.l.) of the Flandrian transgression. It is still being deposited at present.

7.2.4 Type Area and Derivation of Name

The type area is situated on the farm Schelm Hoek 311, on the inside of the last "elbow" of the Sundays River (Fig. 7.2). The unit is named after this farm.

7.2.5 Geological Description

Basic concept and unifying features: The formation consists essentially of unconsolidated calcareous sand of aeolian origin, with intercalated lenses of strandloper middens and occasional extremely poorly developed soil horizons. It is distinguished from the underlying Nahoon and Nanaga Formations (both also aeolian), and also from pre-Cenozoic formations by its unconsolidated nature. The absence of clasts distinguishes it from the beach deposited sands.

Thickness: Up to 140 m, depending on dune height.

Lithology: **Sand** (97%): Mean thickness c. 15 m (units lenticular); fine- to medium-grained; planar aeolian cross-bedding, wind ripples; thick- to very thick-bedded; very pale orange (10YR 8/2) to very light grey (N8); calcareous, heavy minerals (mainly ilminite) present in small quantities (< 1%); well sorted, grains rounded to subrounded.

Soil horizons (2%): Mean thickness 0,8 m (units lenticular); fine- to medium-grained; structureless; thick-bedded; yellowish grey (5Y 7/2) to light olive grey (5Y 5/2); humic; well sorted.

Shell middens (1%): Mean thickness 0,2 m (units lenticular); coarse-grained; structureless; medium-bedded; white (N9).

Palaeontology: Minute fragments of (allogenic) marine macro-organisms (mainly shells and skeletal algae); also foraminifera and echinoid spines. Occasional land gastropods such as Achatina zebra and Trigonephrus sp. Root casts (scarce), mainly in soil horizons. In shell middens Donax serra (sand-mussel) predominates along sandy shores, while gastropods such as Patella sp. (limpets) and Turbo sp. prevail along rocky shores; also artifacts, pottery fragments (both very scarce) and vertebrate skeletal remains (Pl. 7-1).

Genesis: The characteristic high-angle (up to 35 degrees) cross-bedding with sets up to 30 m thick, as well as

textural features such as absence of matrix, good sorting and well rounded quartz grains indicate an aeolian origin for this formation. The sediments were mainly derived from the adjacent sandy shoreline.

Other aspects: The formation comprises a number of active coastal dunefields such as the Alexandria and Schelm Hoek dunefields (separated only by the Sundays River - see Pl. 7-2) and the Gamtoos dunefield, respectively on the shores of Algoa Bay and St. Francis Bay. The Buffelsbos dunefield inland of Cape St. Francis and the dunefield inland of Cape Recife (the latter largely vegetated) both originated from south-westerly winds "short cutting" these capes (Fig. 7.1). The formation is often vegetated, especially along the inland rims of the dunefields.

7.2.6 **Boundaries**

Upper boundary: No upper boundary exists.

Lower boundary: A disconformable lower contact is present where the Schelm Hoek overlies the Salnova, Nahoon and Nanaga formations. More commonly it overlies pre-Cenozoic rocks with a marked unconformity.

Lateral boundary: A western cut-off point for the Schelm Hoek Formation is proposed at the Groot River (Fig. 7.1) in view of the apparent absence of unconsolidated aeolian sediments in the Groot River - Plettenberg Bay area. Bredasdorp Group sediments occur west of Plettenberg Bay.

In the east a cut-off is proposed at the Gonubie River beyond which only small scattered deposits occur. Although the formation is mainly confined to the coastline, the landward boundary may be located up to six kilometres inland from the coast, e.g. the Buffelsbos dunefield (Fig. 7.1). The seaward boundary is taken at the high tide mark.

7.2.7 **Subdivision**

The formation does not lend itself to further subdivision.

7.2.8 **Regional Aspects**

Geographic distribution: The formation is found along the coastline between the Groot River in the west and the Gonubie River in the east (see Figure 7.1). In places it occurs up to six kilometres inland from the coastline.

Lateral variation: The formation attains its maximum width and thickness along the northern shores of Algoa and - to a lesser extent - St. Francis Bay where it manifests itself in the Alexandria and Schelm Hoek, as well as the Gamtoos dunefields respectively. Elsewhere, especially along straight stretches of the coastline, the formation may consist of a narrow (20 - 100 m) singular shore-parallel dune. Isolated patches of the formation are also common, particularly along rocky shores or more commonly where rocky headlands (consisting mainly of the Nahoon Formation) are connected to the mainland by tombolos, e.g. at Cove Rock, Black Rock, Dias Cross and Eersterivierstrand (see Fig. 6.1).

Criteria for lateral extension: In certain areas thick vegetation obscures the aeolian features of this formation. In such cases the typical undulating topography over unconsolidated sand facilitates recognition and mapping of the formation.

Correlation: Since the Schelm Hoek Formation represents a global sea-level regression, similar deposits occur along most of the Southern African coastline. The formation is correlated with the Witzand Formation* of the Sandveld Group* in the Cape west coast area, and also with the Strandveld Formation* (Malan, in press - e) of the Bredasdorp Group along the Cape south coast west of Plettenberg Bay. Similar deposits are present along the Natal and Zululand coasts.

7.2.9 Stratotypes

Because of the shifting nature of the sand dunes, no fixed stratotype section has been selected. The unconsolidated nature of the formation also eliminates the possibility of a borehole core being stored as a stratotype section, since all primary and secondary sedimentary structures are destroyed/disturbed during drilling/vibracoring. Storage of a resin reliëf peel as a stratotype section would also be impractical. The reader is therefore referred to the stratotype sections of the Nahoon Formation, since they display the very same sedimentary structures, mineralogy, texture etc. one would expect in the Schelm Hoek Formation.

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* Not yet approved by SACS.

The presence of shell middens in, and the unconsolidated nature of the Schelm Hoek Formation as opposed to the absence of shell middens and the well consolidated nature of the Nahoon Formation are the only features differentiating the two formations.

Stratotypes were, however, selected in the following areas (Fig. 7.1):

A. Schelm Hoek dunefield (holostratotype).
B. Alexandria dunefield (reference stratotype).
C. Gamtoos dunefield (reference stratotype).

A. SCHELM HOEK DUNEFIELD STRATOTYPE

Kind and rank: Unit holostratotype.

Nature of stratotype: Dunefield stretching from Sundays River mouth in the east to Swartkops River mouth in the west. Best developed on farm Schelm Hoek on western side of Sundays River.

Location: See Figures 7.1, 7.2 and Pl. 7-2.

Accessibility: Good; dunefield adjacent to main road. Park at western side of bridge across Sundays River and walk into dunefield. This dunefield can also be viewed from eastern bank of last stretch of Sundays River.

Lithology: See Section 7.2.5.

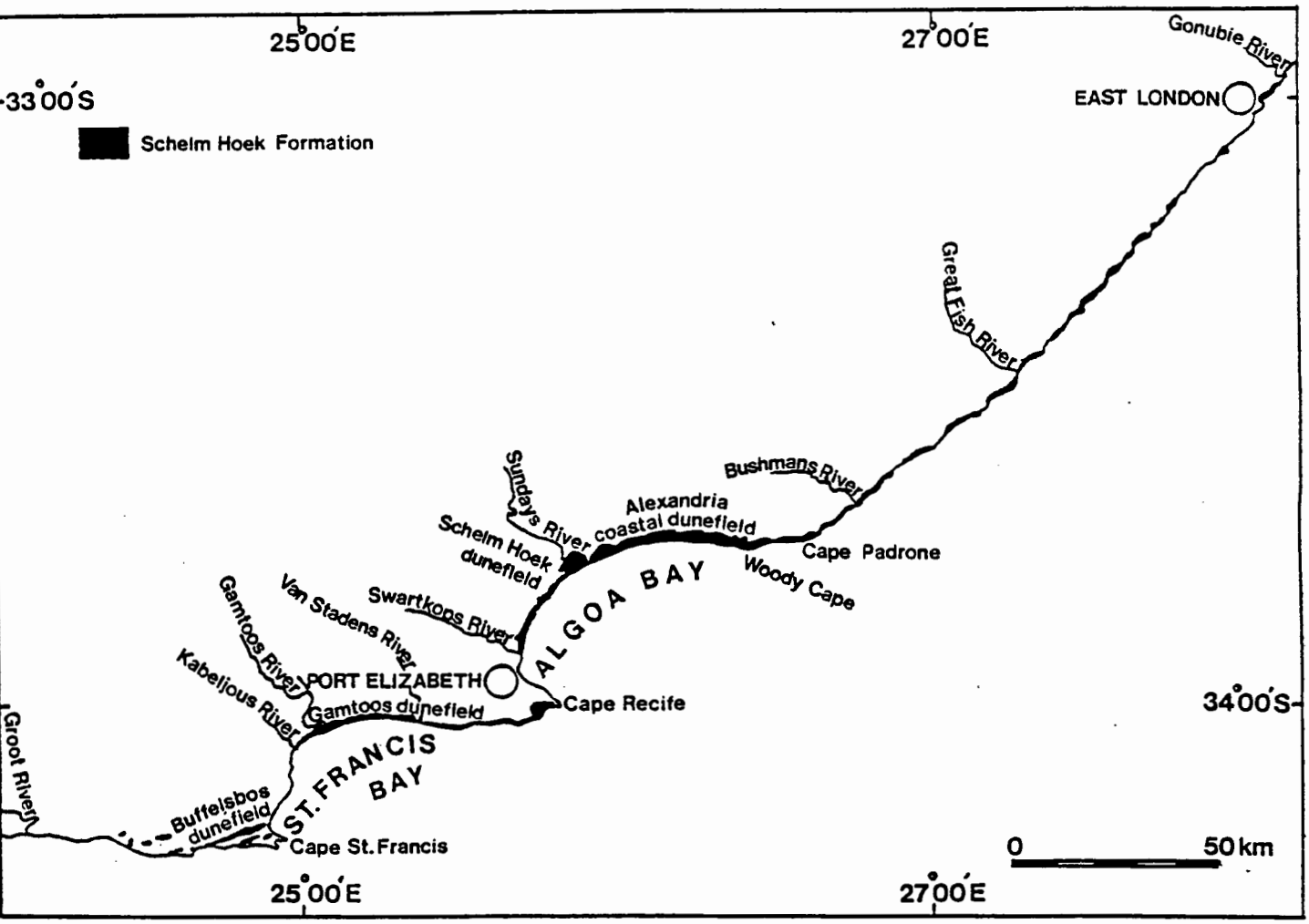


Fig. 7.1 - Distribution of Schelm Hoek Formation and location of dunefields.

(See also Pl. 7-3).

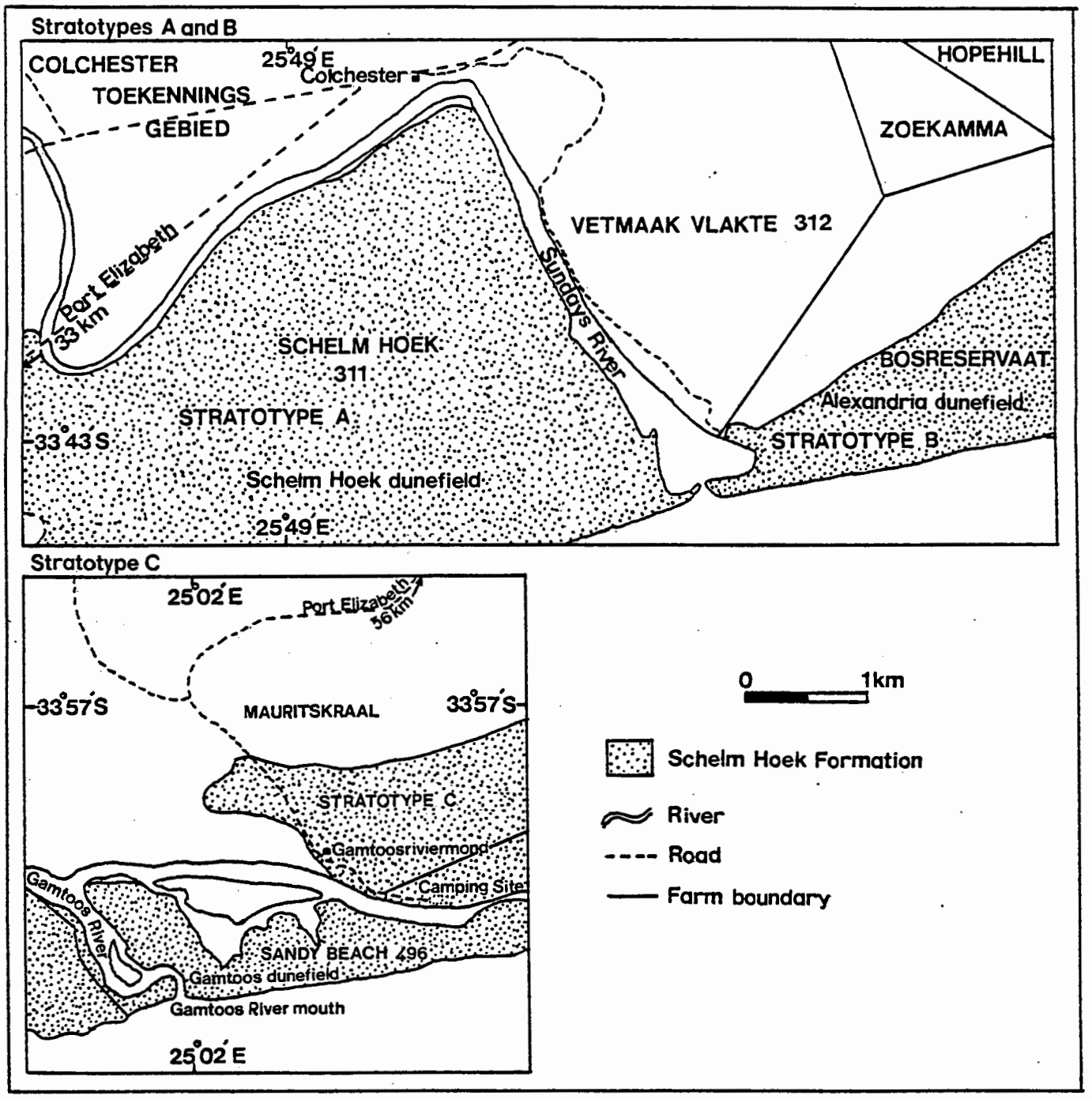


Fig. 7.2 - Location of stratotypes A (Schelm Hoek dunefield), B (Alexandria dunefield) and C (Gamtoos dunefield).

Structures: None.

Reasons for selection: Stratotype is easily accessible, and can also be viewed from main road.

Adjacent units: No overlying sediments present. Underlying strata (mainly Sundays River Formation) largely unexposed. Nahoon or Salnova Formations periodically exposed by wind/wave action in places.

Boundaries and contact relationships: No upper boundary exists. Lower boundary defined as base of unconsolidated calcareous sand.

B. **ALEXANDRIA COASTAL DUNEFIELD STRATOTYPE**

Kind and rank: Unit reference stratotype.

Nature of stratotype: Dunefield of c. 300 km² stretching from Sundays River mouth to Bushmans River mouth (Fig. 7.1).

Location: See Figures 7.1, 7.2 and Pl. 7-2.

Accessibility: Fair; western edge of dunefield is about 15 minutes walk from Sundays River mouth.

Lithology: See Section 7.2.5.

Palaeontology: Strandloper shell middens are particularly abundant in this dunefield.

Structure: None.

Reasons for inclusion: Largest coastal dunefield along Southern African coastline; also a fairly detailed description (bedforms, sand budget etc.) provided by Illenberger (1986).

Adjacent units: No overlying sediments present. Underlying strata largely unexposed, except in the Woody Cape - Cape Padrone area where the Nahoon Formation underlies the Schelm Hoek Formation in a coastal cliff over a distance of about 14 km. East of Cape Padrone the Schelm Hoek Formation is underlain in places by Bokkeveld Group rocks.

Boundaries and contact relationships: No upper boundary exists. Lower boundary defined as base of unconsolidated calcareous sand.

C. **GAMTOOS DUNEFIELD STRATOTYPE**

Kind and rank: Unit reference stratotype.

Nature of stratotype: Coastal dunefield on both sides of Gamtoos River mouth stretching from Kabeljous River mouth to Van Stadens River mouth (Fig. 7.1).

Location: See Figures 7.1 and 7.2.

Accessibility: Good; parking area at Gamtoosriviermond camping site is situated on inland edge of dunefield. Eastern and western edges of dunefield accessible (on foot or with beach vehicle) from Van Stadens and Kabeljous River mouths respectively.

Lithology: See Section 7.2.5.

Structure: None.

Reasons for inclusion: Fairly easily accessible; also second largest coastal dunefield along south-east coast.

Adjacent units: No overlying sediments present. Underlying strata largely unexposed. Salnova Formation exposed on southern bank of last stretch of Gamtoos River. Nanaga Formation (vegetated) exposed along inland edge of dunefield. Pre-Cape sediments (Kleinrivier Formation of Gamtoos Group) periodically exposed on eastern bank at Van Stadens River mouth.

Boundaries and contact relationships: No upper boundary exists. Lower boundary defined as base of unconsolidated calcareous sand.

PLATE 7

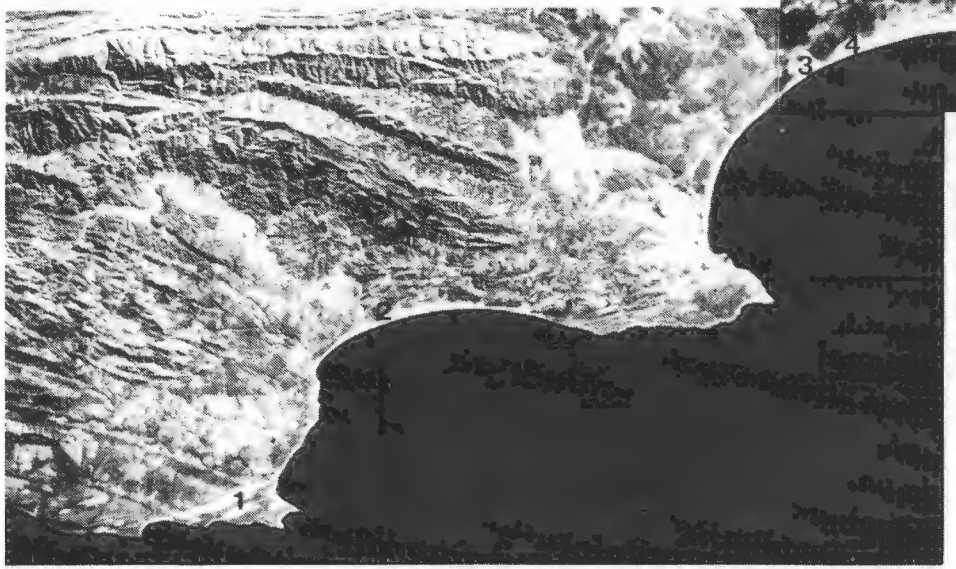
7-1: Vertebrate skeletal remains, in this case lower jaw with tusks of *Hippopotamus amphibius*, in shell midden of Schelm Hoek Formation, Tyolomnqa River mouth (see Fig. 6.1). Note shells of *Patella* sp. (indicated by arrow 1) and *Oxystele sinensis* (indicated by arrow 2).

7-2: Part of Alexandria and Schelm Hoek dunefields (respectively in upper and lower parts of photo), separated only by the Sundays River.

7-3: Photo of satellite image of south-east coast area. Note conspicuous (white) dunefields of Schelm Hoek Formation. Numbers on photo indicate the following: 1) Buffelsbos dunefield; 2) Gamtoos dunefield; 3) Schelm Hoek dunefield; 4) Alexandria coastal dunefield.

PLATE 7

1



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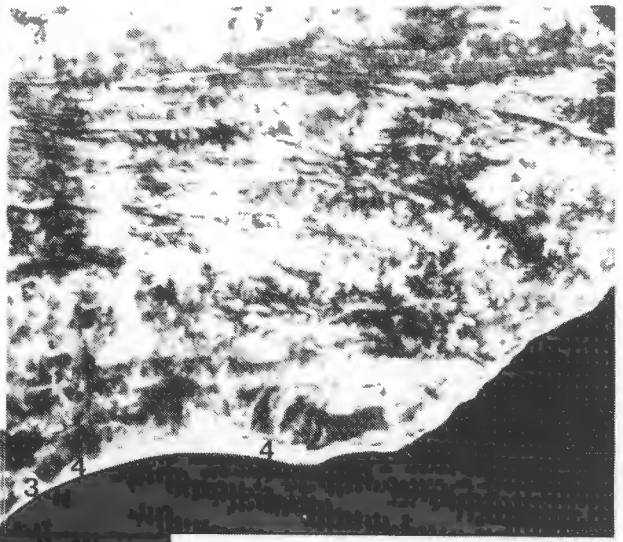

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CHAPTER 8 - ALGOA GROUP

All the Cenozoic marine and marine-related (aeolian) formations along the south-eastern Cape coast, which are characterised by calcareous clastics, have been grouped together in a newly defined Algoa Group.

8.1 LITHOSTRATIGRAPHY

8.1.1 Full Name

Algoa Group.

8.1.2 Proposer of Name

F.G. le Roux (1988; in press - d).

8.1.3 Derivation of Name

The unit is named after Algoa Bay - since most of the group's formations are present in the circum-bay area (Fig. 8.1).

8.1.4 Type Area

A type area has not been designated for the group as a whole.

8.1.5 Stratigraphic Position and Age

The Algoa Group unconformably overlies pre-Cape Gamtoos Group, Palaeozoic - Mesozoic Cape Supergroup, Karoo Sequence or Uitenhage Group strata along the south-eastern Cape coast

and embraces the youngest sediments present here. It is overlain in places by non-marine/marine-related Cenozoic sediments. It comprises Cenozoic formations ranging from Eocene to Holocene in age (Table 8.1).

8.1.6 Geological Description

Basic concept and unifying features: The Algoa Group consists essentially of calcareous sandstone, limestone (generally sandy), conglomerate and coquinite. It is distinguished from underlying rock units by its predominantly calcareous nature, which can be attributed to comminuted or recrystallised marine shell material.

Thickness: Variable - governed by surface relief; often attains 160 m, exceptionally 250 m.

Lithology: A generalised lithological column is depicted in Fig. 8.2. Comprehensive lithological data are provided in the lithostratigraphic descriptions of the individual formations in the group, which have been described previously (Chapters 2 - 7).

Palaeontology: The Bathurst Formation is characterised by specific microfossil assemblages as well as certain macrofossils. The Alexandria and Salnova Formations are typified by characteristic marine macrofossil (mainly mollusc) assemblages. The aeolian deposits (Nanaga, Nahoon and Schelm Hoek Formations) contain occasional land

TABLE 8.1 - AGE RANGES OF THE ALGOA GROUP AND ITS CONSTITUENT FORMATIONS

	TERTIARY					QUATERNARY			
	Palaeocene	Eocene	Oligocene	Miocene	Pliocene	Pleistocene Early	Pleistocene Middle	Pleistocene Late	Holocene
SACS(1980)						Alexandria Fm			
						Nanaga Fm			
						Salnova Fm			
THIS PUBLICATION						ALGOA GROUP			
									Schelm Hoek Fm
								Nahoon Fm	
							Salnova Fm		
					Nanaga Fm				
					Alexandria Fm				
			Bathurst Fm						

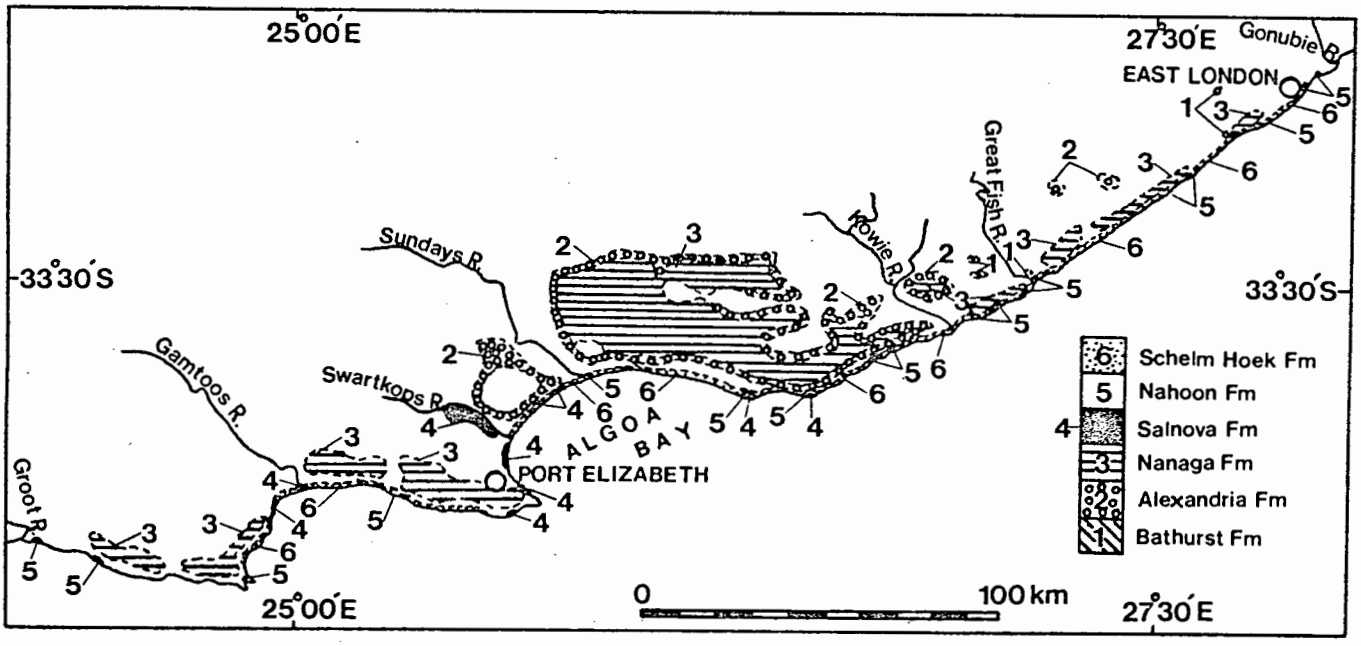

Fig. 8.1 - Distribution of the Algoa Group and its constituent formations.

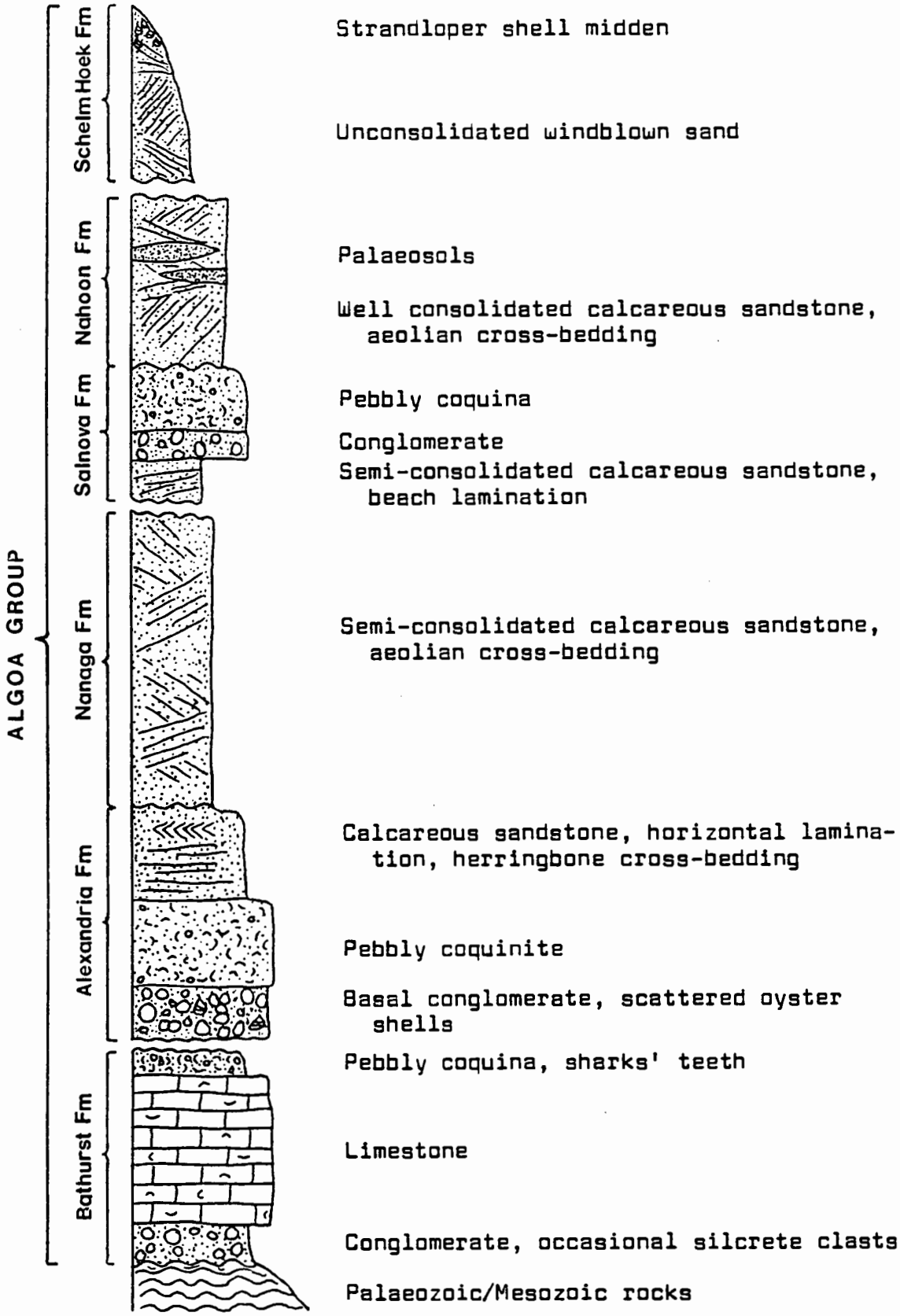

Fig. 8.2 - Idealised composite section of Algoa Group (schematic) showing relative stratigraphic positions and lithology of formations (not to scale).

gastropods. Further palaeontological data are provided in the lithostratigraphic descriptions of the individual formations in the group.

Genesis: The Algoa Group consists of marine and marine-related deposits. The Bathurst, Alexandria and Salnova Formations are beach/nearshore/estuarine deposits associated with regressive shore-lines. The Nanaga, Nahoon and Schelm Hoek Formations, though aeolian in origin, are also related to transgressive/regressive events.

8.1.7 **Boundaries**

Upper boundary: Unconformable, sharp. The boundary is defined as the base of terrestrial non-aeolian Cenozoic deposits or recent calcrete/soil. Note that where the Schelm Hoek Formation is present, the group in effect has no upper boundary.

Lower boundary: Unconformable, sharp. The boundary is defined as the unconformity between the Cenozoic marine deposits and the older pre-Cenozoic strata. The boundary is normally characterised by a sharp upward increase in $CaCO_3$-content.

Lateral boundary: Cut-off points for the Algoa Group have been located at the Groot River in the west and the Gonubie River in the east, beyond which calcareous Cenozoic sediments are generally absent for some distance. The

northern limit of the group roughly coincides with the 350 m contour which generally follows the southernmost mountain ranges. Seaward it may pass onto the continental shelf.

8.1.8 Historical Background

A.G. Bain's map, published in 1856, labelled the Cenozoic marine and marine-related deposits as "Tertiary". Siesser (1972a, 1972b) and Ruddock (1973) used the terms "Cainozoic coastal limestones" and "Tertiary limestones" respectively as collective names for the marine plus aeolian deposits of Cenozoic age.

8.1.9 Subdivision

The group comprises six formations. In order of decreasing age these are the Bathurst, Alexandria, Nanaga, Salnova, Nahoon and Schelm Hoek Formations (Fig. 8.2).

8.1.10 Regional Aspects

Geographic distribution: The distribution of the Algoa Group and its formations is indicated on Figure 8.1.

Criteria for lateral extension: The calcareous nature of the sediments and the diagnostic faunas of the Bathurst, Alexandria and Salnova Formations, as well as the undulating topography of the aeolian deposits, are used to extend the group laterally.

Correlation: The Algoa Group is correlatable with the Bredasdorp Group (Malan, in press - f) in the south-western

Cape, with the Alexandria, Nanaga, Salnova, Nahoon and Schelm Hoek Formations being the equivalents of the De Hoopvlei, Wankoe, Klein Brak, Waenhuiskrans and Strandveld Formations respectively.

FLUVIAL DEPOSITS

Fluvial deposits in the S.E. Cape are divided into the **Martindale, Kinkelbos, Bluewater Bay, Kudus Kloof** and **Sunland Formations.**

CHAPTER 9 - KINKELBOS FORMATION

The Kinkelbos Formation consists of calcareous silt and fine-grained sand of fluvial origin (Le Roux, in press - e). It is presumably of Late Pliocene to Middle Pleistocene age and seems to be restricted to a relatively small area east of the Sundays River (Fig. 9.1).

9.1 HISTORICAL BACKGROUND

Ruddock (1968) was the first to distinguish these silts as a separate entity, referring to them as "The Silts of the Kinkelbos Plateau". Although he did not mention any lithological criterion for distinguishing between these silts and other alluvial silts, it was in all probability the relatively high $CaCO_3$ in the former that provided this distinction. Engelbrecht et al. (1962) considered these deposits, which were developed on their "terrace no. 5" or "Kinkelbos terrace" to be fluvial silts of the palaeo-Sundays River. SACS (1980) assigned formation status to these deposits.

9.2 LITHOSTRATIGRAPHY

9.2.1 Full Name

Kinkelbos Formation.

9.2.2 Proposer of Name

Name proposed in 1979 by the SACS Working Group for the Tertiary and Quaternary Periods (SACS, 1980).

9.2.3 Stratigraphic Position and Age

The Kinkelbos Formation unconformably overlies the Alexandria Formation in the southern part of its distribution area (Pl. 9-1). In the northern part of the area it is separated from the Alexandria Formation by a wedge of partly consolidated aeolian sand belonging to the Nanaga Formation. The age of the Kinkelbos Formation is regarded to be Pliocene to Middle Pleistocene (SACS, 1980).

9.2.4 Type Area and Derivation of Name

The type area is situated north of Colchester (Fig. 9.1). The unit is named after Kinkelbos railway siding since some of the best accessible exposures are situated nearby.

9.2.5 Geological Description

Basic concept and unifying features: The formation consists essentially of silt and fine-grained sand with beds and lenses of silty/sandy calc-tufa (Pl. 9-2) and tufaceous silt/sand. Gravel layers and lenses (Fig. 9-3) as well as isolated clasts are subordinate. It is distinguished from the underlying units by its typical reddish-brown colour (as opposed to the generally whitish to light greyish colour of the former), its poor consolidation, finer-grained lithologies, horizontal bedding (cross-bedding scarce) and lack of shell fossils.

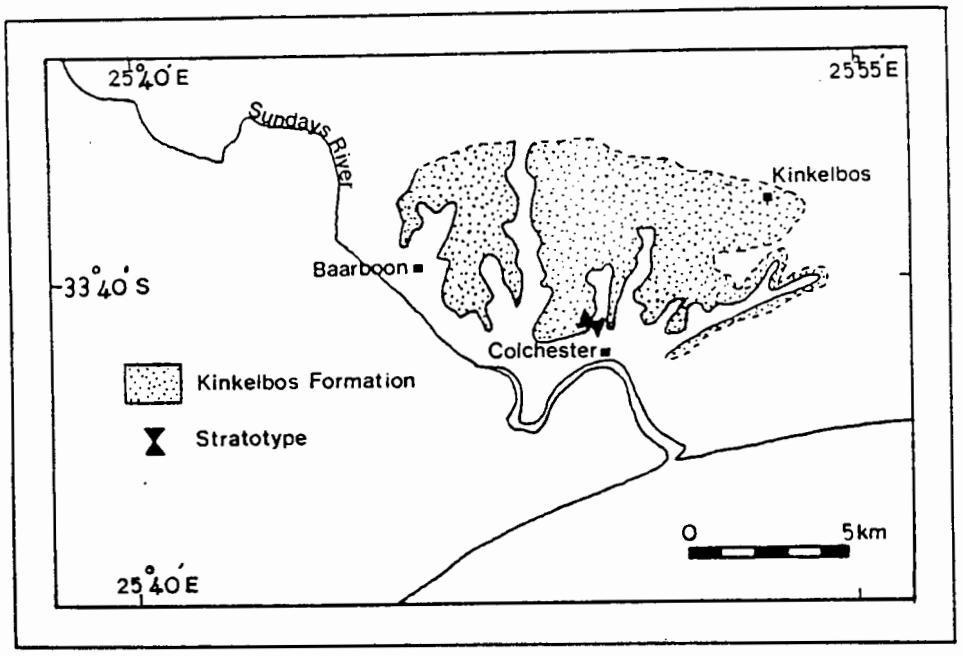

Fig. 9.1 - Distribution of the Kinkelbos Formation and stratotype location.

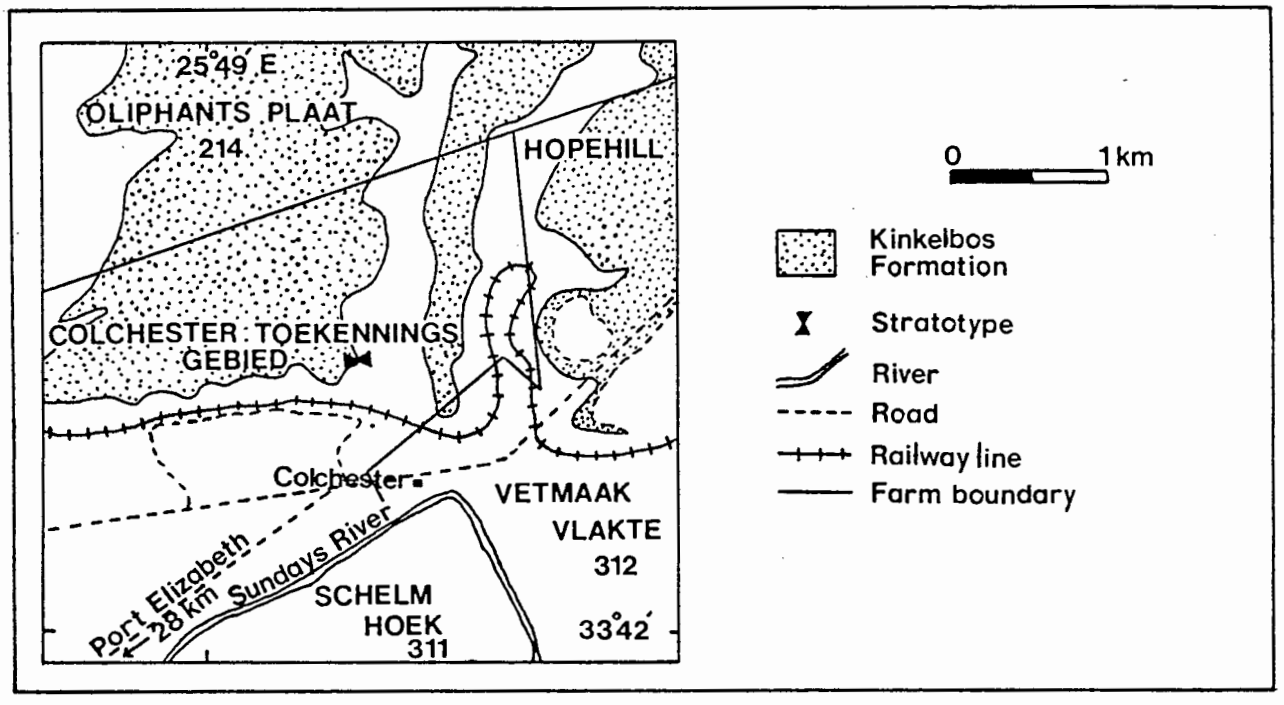

Fig. 9.2 - Location of holostratotype, Kinkelbos Formation.

Thickness: 6 - 37 m.

Lithology: **Silt** (45%): Mean litho-unit thickness 2,0 m (units tabular); structureless (Pl. 9-4) to horizontally laminated; ripple cross-laminated; thin-bedded; light brown (5YR 5/6) to pale olive (10Y 6/2); calcareous; well sorted, but with a bimodal grain-size distribution.

Sand (15%): Mean litho-unit thickness 2,5 m (units moderately tabular to lenticular); fine-grained; structureless to horizontally laminated; thin-bedded; moderate brown (5YR 4/4) to light olive grey (5Y 5/2); calcareous; well sorted.

Silty/sandy calc-tufa (35%): Mean litho-unit thickness 1,1 m (units lenticular); structureless; very light grey (N8) to white (N9).

Gravel (5%): Mean litho-unit thickness 0,3 m (max. 6 m), units moderately tabular to lenticular; small pebbles to small cobbles in a matrix of silt/sand, tufaceous silt/sand or silty/sandy calc-tufa; structureless to vaguely horizontally bedded, with indications of graded bedding; thin- to medium-bedded (beds moderately tabular); dark yellowish orange (10YR 6/6) to light brown (5YR 5/6); max. clast size 120 mm; clasts comprise mainly quartzitic sandstone (Table Mountain Group, some of them probably derived from Alexandria Formation conglomerates), calcrete (scarce), and Alexandria Formation coquinite (rare); clasts

discoidal, blade-shaped and roller-shaped (Zingg classification); moderately to well sorted; well rounded.

Palaeontology: Fossils are absent, except for one locality where some comminuted shell fragments were found in a pebble layer. Vague structures resembling burrows are abundant, especially in the tufaceous silt layers. Carbon flecks locally abundant.

Genesis: The horizontal lamination of some of the sediments near Colchester points to deposition in a sheltered water body. Ruddock (1968, p. 221 - 222) gives a more detailed discussion of their morphological and sedimentological characteristics. A partly marine/lagoonal environment is envisaged by him for the silts beneath the "Colchester plateau" in the south (p. 219 - 220). However, fossils and trace fossils, which are typical of such a sheltered paralic environment are lacking, casting some doubt on this interpretation. A fluvial overbank depositional environment, which could also account for the horizontal lamination, appears more likely. The presence of calcareous material (which probably gave rise to Ruddock's idea of marine influence) could quite possibly be attributed to aeolian influx during interflood periods, especially if it is borne in mind that the neighbouring Nanaga Formation at that stage was probably still unconsolidated or semi-consolidated. During relatively dry periods $CaCO_3$ could have been leached from these sediments to give rise to the typical interlayered calcareous lenses.

Other aspects: Compared to the underlying Alexandria Formation, the formation tends to weather negatively.

9.2.6 Boundaries

Upper boundary: No upper boundary exists, except for the base of localised surficial calcrete or dark greyish humic soil at some localities.

Lower boundary: Unconformable, sharp. The boundary is characterised by a sudden colour change from reddish brown (Kinkelbos Formation) to greyish white (Alexandria and Nanaga Formations). In the north-western part of the outcrop area, where it is underlain by aeolian sand of the Nanaga Formation, the lower boundary is taken at the horizon below which aeolian cross-bedding occurs.

Lateral boundary: In the north, east and south-east (broken line in Fig. 9.1), the wedge-out of the formation against the Nanaga Formation represents a depositional termination.

9.2.7 Subdivision

No further subdivision into members has as yet been made, although Ruddock (1968, p. 219) mentions that "a prominent band of tufa at a level varying from about 18 to 60 feet above the base of the silts occurs north and south of the beacon on Fascadale (ground level 476 feet) and may be the boundary between two distinct groups of strata that display a superficial resemblance to one another". The present author found no evidence of this.

9.2.8 Regional Aspects

Geographic distribution: The formation occupies an area of about 65 square kilometres on a dissected plateau situated west and south-west of Kinkelbos Siding on the north-eastern side of the lower Sundays Valley. A north-south valley divides the outcrop area into two (see Figure 9.1).

Lateral variation: The total thickness of these silty deposits varies from 37 m at its inland margin to 6 m at the seaward extremity of the plateau (Ruddock, 1968, p. 219). Horizontal bedding is well developed in the southern part of the outcrop area, but becomes virtually unrecognisable towards the north. Sediment ratios vary conspicuously over relatively short distances.

Criteria for lateral extension: In the Baarboon area (Fig. 9.1), thick, thorny impenetrable vegetation covers the outcrops. However, the abrupt change from the greyish white colour of the Nanaga and Alexandria formations to the typical reddish brown colour of the Kinkelbos Formation, facilitates recognition of the lower boundary of the unit from a distance.

Correlation: No correlates are known although the fluvial deposits of the Bluewater Bay Formation may be an age-equivalent.

9.2.9 Stratotypes

Of all the accessible outcrops, only the cliff north of the store at Colchester is suitable as a stratotype.

COLCHESTER STRATOTYPE

Kind and Rank: Unit holostratotype.

Nature of section: Steep hill slope above cliff (Alexandria Formation) which exposes about 18 m of the formation (see Pl. 9-1).

Location: Western side of valley inlet north of Colchester - see Fig. 9.2.

Accessibility: Good; exposures are within 300 m of railway service road, although approach to cliff and slope above is somewhat restricted by thick, thorny vegetation.

Lithology: Silt (c. 62%), calc-tufa (c. 29%), sand (c. 6%), and gravel (c. 3%) - see columnar section (Fig. 9.3). Thin (60 - 150 mm) reddish gravel lenses as well as scattered clasts occur in some sands, silts and calc-tufa. A few coquinite clasts derived from the Alexandria Formation are present. Some of the silt layers, especially the uppermost one, contain some clay material. Lowermost gravel layer is fining upward.

Structure: No regional structure visible.

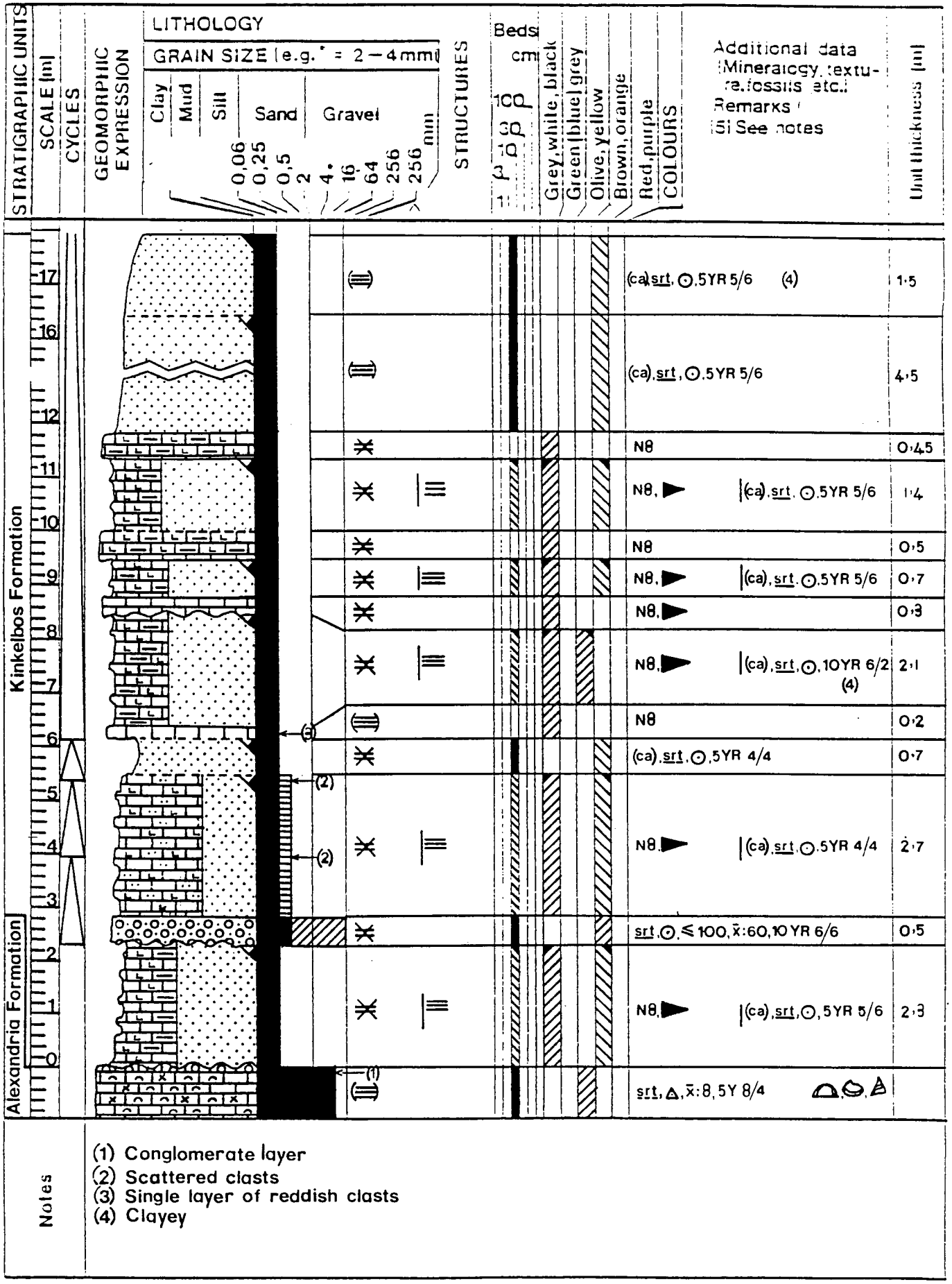

Fig. 9.3 - Holostratotype (Colchester) of Kinkelbos Formation.

Adjacent units: No overlying deposits present. The formation is underlain by the Alexandria Formation.

Boundaries and contact relationships: The formation does not have an upper boundary at this locality. Lower boundary somewhat obscured, but taken at eroded top of uppermost whitish cobble layer in the succession.

PLATE 9

9-1: Holostratotype of Kinkelbos Formation (steep hill slope above cliff of Alexandria Formation). Resistant beds in Kinkelbos represent calc-tufa.

9-2: Lenticules of calc-tufa in clayey silt of Kinkelbos Formation near Colchester (not stratotype locality).

9-3: Pebble/cobble layer in tufaceous sand of Kinkelbos Formation at holostratotype locality.

9-4: Structureless silt layer of Kinkelbos Formation in jeep track cutting on Ingleside 215 (near Baarboon Siding).

PLATE 9

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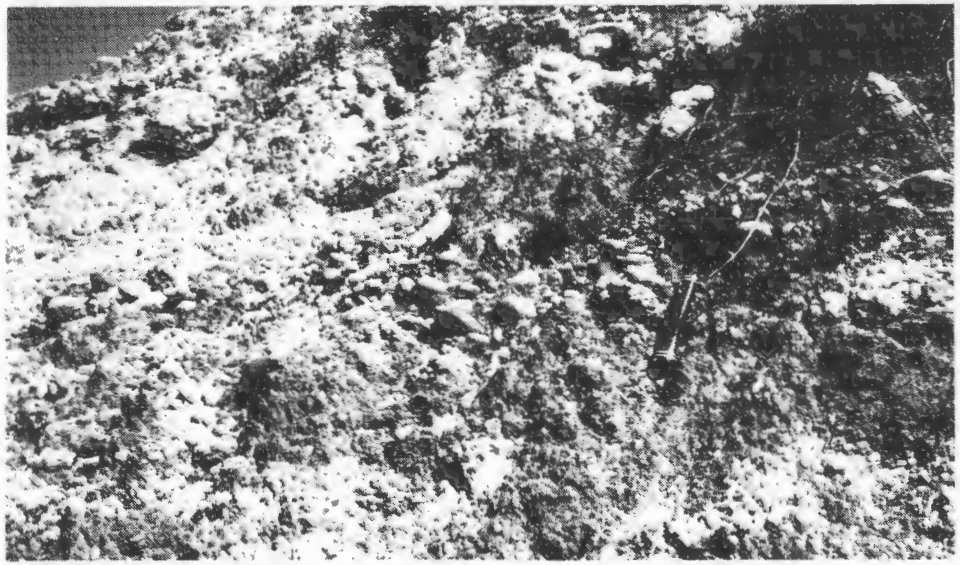

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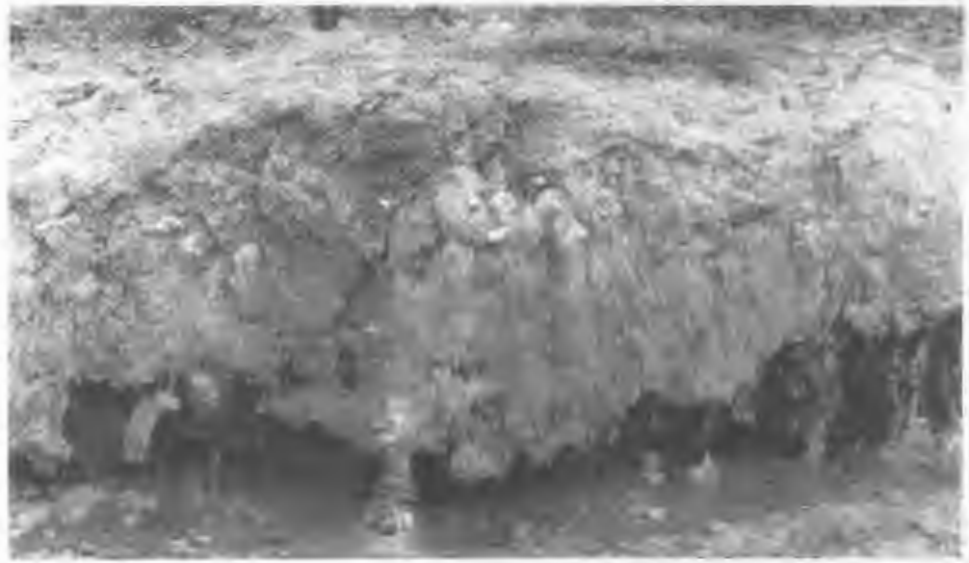

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CHAPTER 10 - BLUEWATER BAY FORMATION

The Bluewater Bay Formation represents alluvial gravel, silt and fine-grained sand of presumably Late Pliocene to Early Pleistocene age (Le Roux, 1987e; in press - f), and is best developed between the lowermost reaches of the Swartkops and Sundays Rivers (Fig. 10.1).

10.1 HISTORICAL BACKGROUND

Engelbrecht et al. (1962, p. 35) first noted the occurrence of red gravels on a plain underlain by Neogene marine sediments of the Alexandria Formation. However, they regarded the reddish pebble layer blanketing most of the Alexandria Formation in the area between the lower Swartkops and Sundays Rivers, to be in situ weathered Alexandria conglomerate. The wider extent of these deposits, their fluvial character and the two distinct generations of gravel were first recorded by Le Roux (1987e), who suggested the name "Bluewater Bay Formation" for these previously unmapped deposits.

10.2 LITHOSTRATIGRAPHY

10.2.1 Full Name

Bluewater Bay Formation.

10.2.2 Proposer of Name

Le Roux (1987e).

10.2.3 Stratigraphic Position and Age

The Bluewater Bay Formation disconformably overlies the Neogene Alexandria Formation. At a number of localities channels have been scoured through the Alexandria Formation, causing the Bluewater Bay Formation to be in direct contact with the Cretaceous Sundays River Formation. The age of the Bluewater Bay Formation is probably Late Pliocene to Early Pleistocene (Le Roux, 1987e).

10.2.4 Type Area and Derivation of Name

The type area is situated east of the Swartkops River in the vicinity of Amsterdamhoek (Fig. 10.1). The unit is named after the suburb of Bluewater Bay, since the best of the very few representative natural exposures are situated nearby.

10.2.5 Geological Description

Basic concept and unifying features: The formation consists essentially of two generations of alluvial gravel, silt and fine-grained sand. A coarse-grained sand, often calcretised, is sometimes present as matrix. The two generations are often separated by a calcrete layer, indicating a hiatus of appreciable magnitude. These alluvial sediments are distinguished from younger river-terrace sediments of existing drainage systems such as those of the Sundays, Coega and Swartkops Rivers by their reddish-brown colour, the presence of Alexandria Formation clasts, and their form (steep-sided channel-fill deposits). They are distinguished from the underlying Alexandria

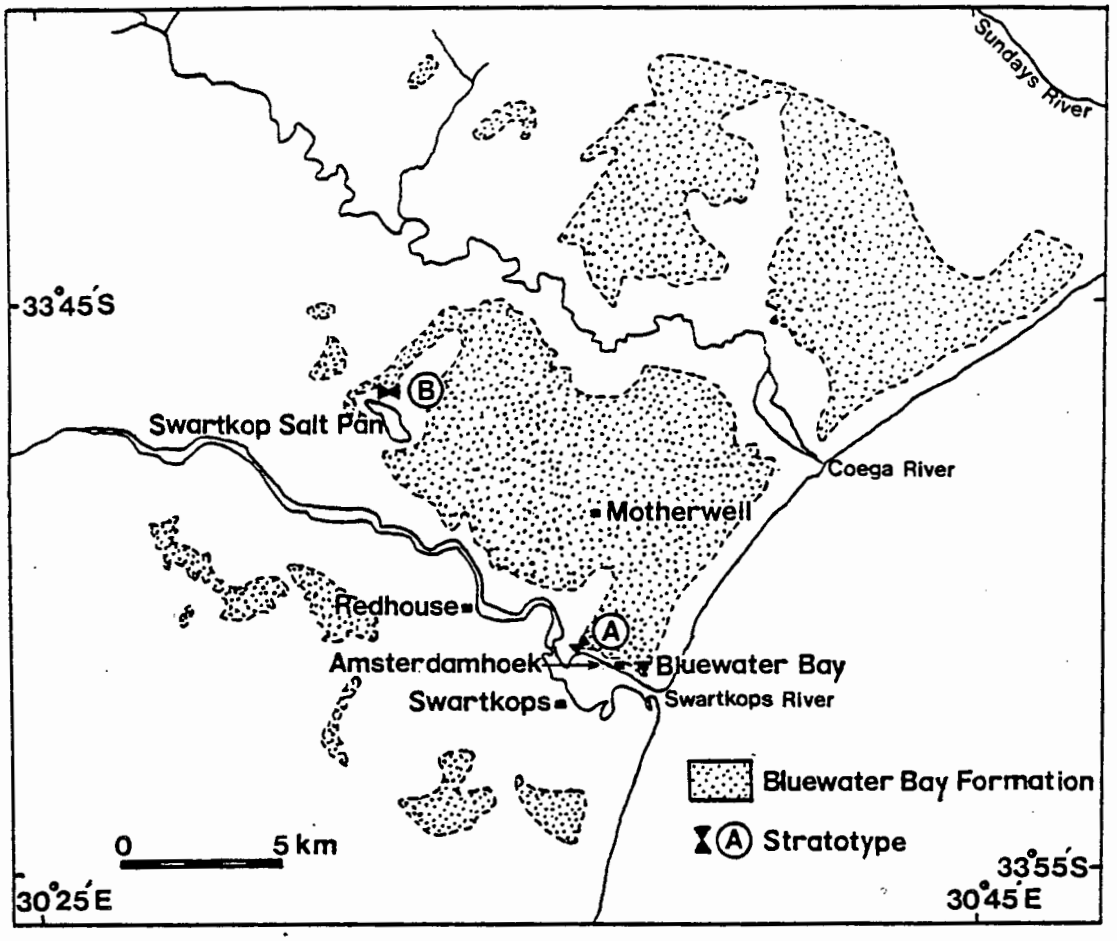


Fig. 10.1 - Distribution of Bluewater Bay Formation and location of stratotypes.

Formation by their non-calcareous character (except for the calcrete), poor consolidation, lack of marine shell fossils, bimodal clast size distribution, rather poorly sorted sand matrix, the presence of argillaceous material (usually as matrix), and the rather typical reddish-brown colour (as opposed to the generally whitish to light greyish colour of the Alexandria Formation).

Thickness: 0,2 - 7 m (average c. 1,2 m).

Lithology: **Gravel/conglomerate** (10 - 100%): Litho-unit thickness varies between 1,0 and 6,0 m (units tabular to sheet-like); very large pebbles to large cobbles set in a matrix varying from clay and silt to poorly sorted medium- to coarse-grained sand, as well as calcrete; matrix often absent; structureless to vaguely horizontally bedded, trough cross-bedded; imbricated; thin- to medium-bedded (beds moderately tabular); light brown (5YR 5/6) to moderate reddish brown (10YR 4/6) to dark yellowish orange (10 YR 6/6), but very light grey (N 8) to light grey (N 7) in the case of the older generation gravels; max. clast size 400 mm; clasts exclusively quartzitic sandstone (Table Mountain Group), some of which were derived from the Alexandria Formation conglomerates; clasts spheroidal to blade-shaped or roller-shaped (Zingg classification); moderately to well sorted; well rounded.

Silt/sand (0 - 90%): Mean thickness c. 1,2 m (max. c. 3 m) (units moderately tabular to lenticular); sand fine-grained; structureless; greyish orange (10YR 7/4) to

light brown (5YR 5/6) to yellowish orange (10YR 6/6); well sorted; well rounded.

Palaeontology: Occasional freshwater shells (Unio sp. and other species) and fragments of terrestrial shells occur.

Genesis: The older generation gravels were probably deposited as flash-flood and sheet-flow deposits in channels scoured into earlier deposits on the emerged post-Alexandria coastal plain. This was followed by a hiatus during which surface calcretisation took place. The later gravels occur in channels eroded into the calcrete and underlying older successions. Channel orientation indicates a —provenance towards the W.N.W., probably the Great Winterhoek Mountains. A diagnostic feature of this younger generation is the existence of smaller, steep-sided channels (Pl. 10-1) at the base of more extensive channels. This feature was probably caused by solution along irregularities in the floors of the more extensive channels. Stear (1987a) also favours a "solution pipe" model. The often vertical orientation of blade and roller-shaped clasts in these solution channels is probably the result of gradual settling of clasts originally deposited on the channel floors into the solution channels. Some channel fills consist of a thin gravel layer along the floor and sides of the channel, while the remainder is filled up with silt or fine-grained sand (Fig. 10.3; Pl. 10-2). The Bluewater Bay sediments were probably deposited as flash floods and sheet flows on the emerged post-Alexandria coastal plain. Most likely this took place in the distributive network; typical of the old stage of a

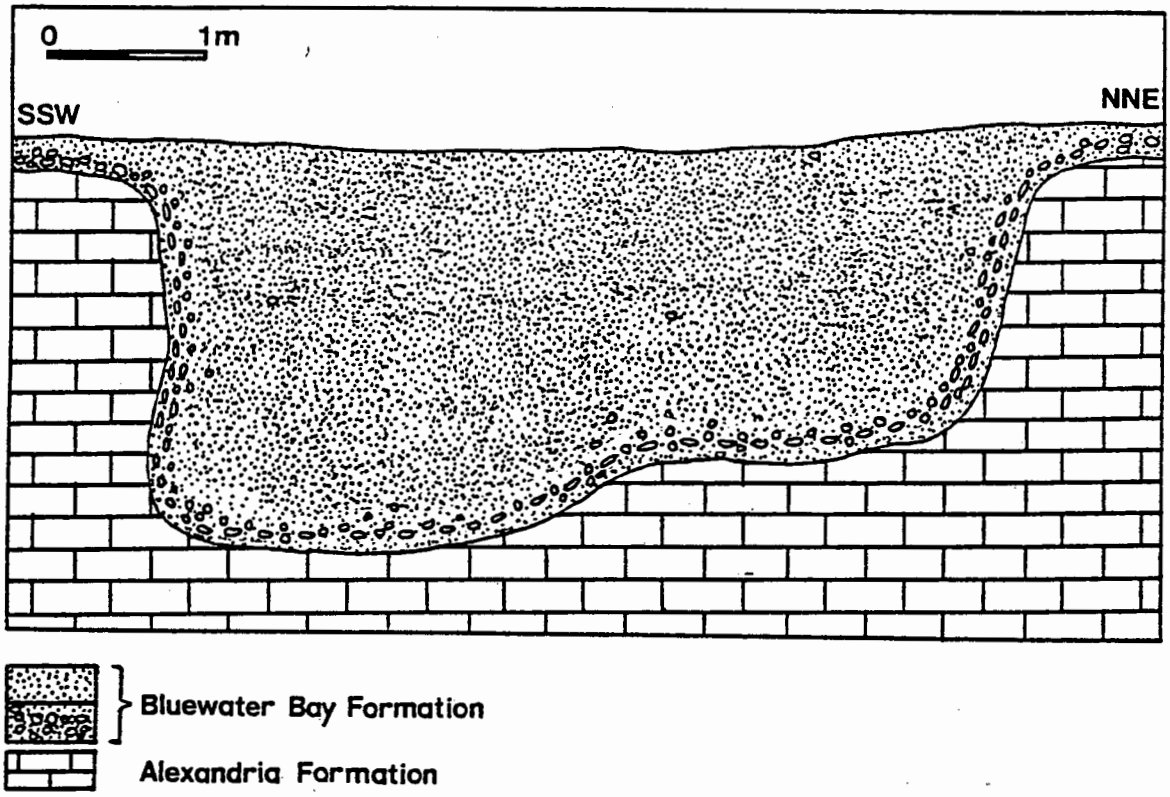


Fig. 10.3 - Cross-section showing unusual arrangement of clasts along floor and sides of silt and fine-grained sand-filled channel. Southern part of Motherwell township. Vertical scale = horizontal scale.

river system where several floodplains of different river systems would coalesce.

Other aspects: Often only the younger gravels are present. They occur mainly as a thin veneer (usually less than one metre thick) covering a somewhat irregular surface cut into the Alexandria Formation and/or calcrete of post-Alexandria age. Where cemented by calcrete, the formation tends to weather positively.

10.2.6 **Boundaries**

Upper boundary: Very rarely the Bluewater Bay Formation is overlain by gravel of the Kudus Kloof Formation. The upper boundary is then taken at the base of horizontally layered light greyish gravel of the latter formation. In other instances the upper boundary is taken at the base of surficial calcrete or dark greyish humic soil.

Lower boundary: Disconformable, erosional. The boundary is often marked by a sharp increase in $CaCO_3$-content just below it due to the presence of abundant marine shell material in the underlying Alexandria Formation. In many cases the boundary is typified by a sudden colour change from reddish brown (Bluewater Bay Formation) to greyish white (Alexandria Formation). Conspicuous differences in vegetation, which tends to be grassy on the calcareous Alexandria Formation and bushy where the fluvial gravels occur, facilitate mapping of the unit.

Lateral boundary: Thick impenetrable vegetation prevented the establishment of the exact position of the northern boundary. In the south-west and north-east, the formation is terminated by an erosional cut-off (mainly caused by the palaeo-drainage systems of the Sundays and Swartkops Rivers respectively). In the south-east it is terminated by an erosional boundary caused by undercutting during an (Early?) Pleistocene transgression (see Chapter 12).

10.2.7 Subdivision

Although two distinct generations of gravels exist over large portions of the outcrop area, natural exposures are scarce and mapping these two generations as separate members would be impracticable.

10.2.8 Regional Aspects

Geographic distribution: The formation occupies an area of about 130 km², mainly situated between the Sundays and Swartkops Rivers. A few outliers occur south-west of the Swartkops River. The lower Coega Valley divides the main outcrop area into two (see Fig. 10.1).

Lateral variation: The formation is rather variable as far as thickness and lithology are concerned. However, no definite trends could be established. Facies analyses of the Bluewater Bay deposits led Stear (1987b) to the conclusion that the palaeo-beach ridges and swales in the underlying Alexandria Formation played a significant role in determining their aerial distribution, i.e. that they are

more fully developed and thicker in the swales between palaeo-beach ridges.

Criteria for lateral extension: Although vertical exposures showing the fluvial characteristics are absent over large parts of the outcrop area, the residual layer of reddish clasts on the surface, together with vegetation differences (see Section 10.2.6) facilitate mapping of the unit.

Correlation: No correlates are known although the silts of the Kinkelbos Formation may be age-equivalent. Deposits of gravel seemingly similar to that of the Bluewater Bay Formation occur on remnants of the original post-Alexandria erosion surface between the lowermost Gamtoos and Kabeljous Rivers (See Figs. 1.2 and 7.1).

10.2.9 **Stratotypes**

Excavations and trenches made during 1986 between the Swartkops and Sundays Rivers resulted in excellent temporary exposures of the Bluewater Bay Formation, showing the relationship between the older and younger generations of gravels and other diagnostic features. Some of these artificial exposures are depicted by Plates 10-3 and 10-4. Natural (vertical) exposures of the Bluewater Bay Formation are extremely scarce and do not always show the diagnostic features and relationships mentioned earlier. However, since stratotype exposures must be of a more permanent nature, the following stratotypes have been selected (Fig. 10.1):

A. Amsterdamhoek (holostratotype).

B. Swartkop Salt Pan (reference stratotype).

A. AMSTERDAMHOEK STRATOTYPE

Kind and rank: Unit holostratotype.

Nature of section: Cliff exposing about 2,5 m of the Bluewater Bay Formation.

Location: See Figure 10.2.

Accessibility: Good. Exposures are within 400 m of tarred road.

Lithology: Gravel (50%) and fine-grained sand (50%) - see columnar section (Fig. 10.4). No matrix present in gravel (Pl. 10-5). Only the younger gravels are present here.

Structure: No regional structure visible.

Adjacent units: The Bluewater Bay Formation is here underlain by the Alexandria Formation. No overlying deposits are present.

Boundaries and contact relationships: The lower boundary is taken at the eroded top of the uppermost calcareous conglomerate of the underlying Alexandria Formation.

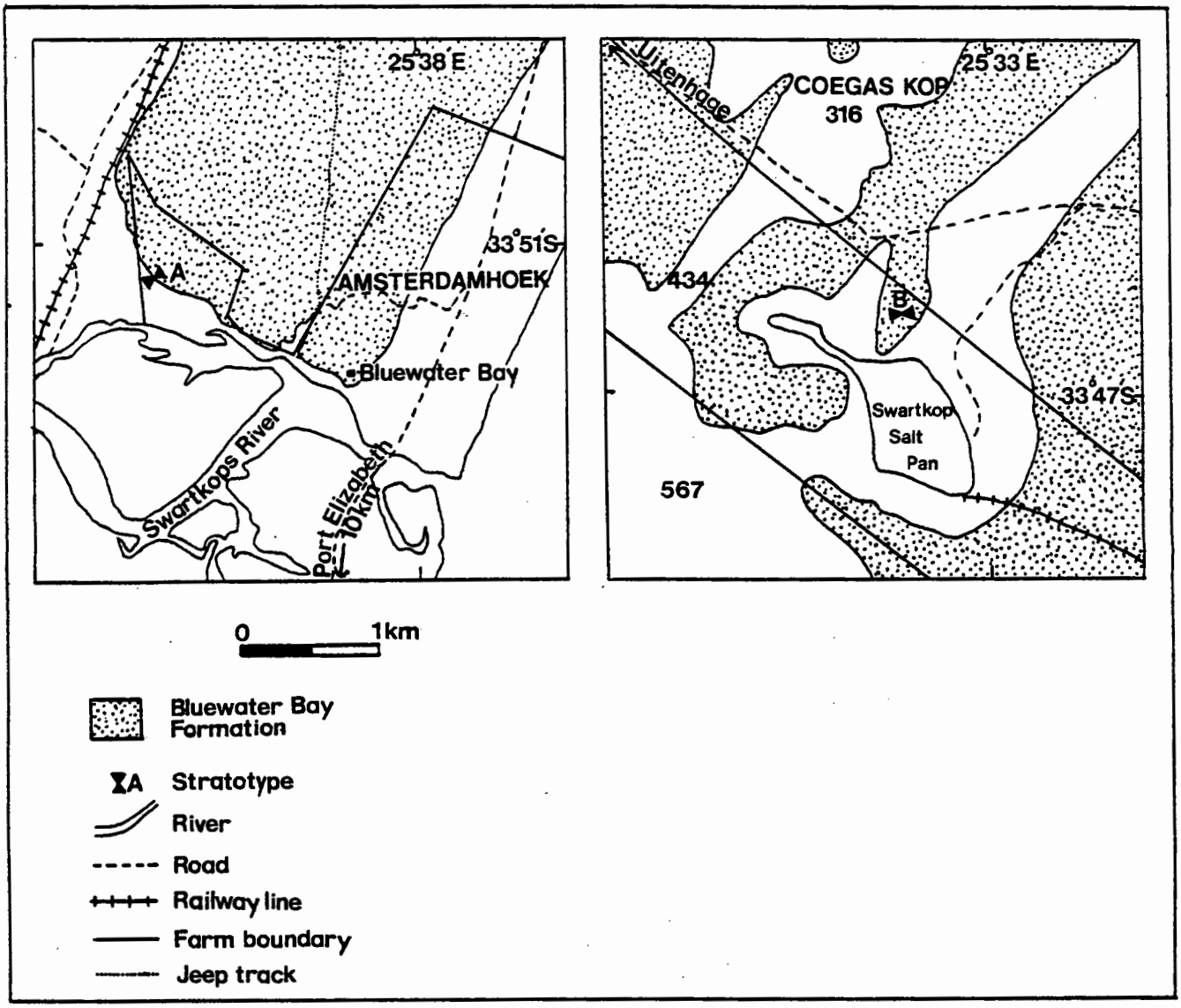


Fig. 10.2 - Location of stratotypes A (Amsterdamhoek) and B (Swartkop Salt Pan).

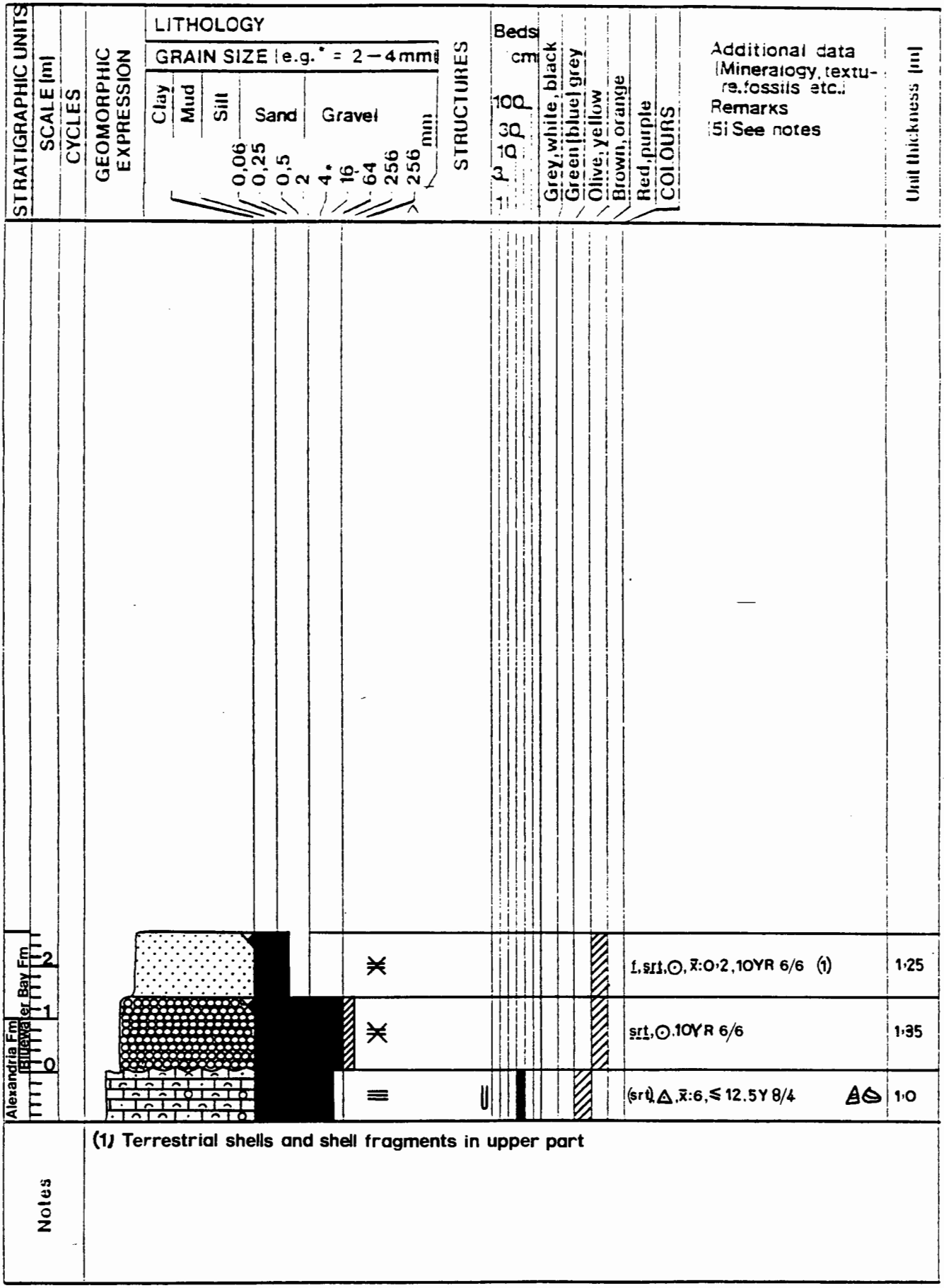


Fig. 10.4 - Stratotype A (Amsterdamhoek) of Bluewater Bay Formation.

B. SWARTKOP SALT PAN STRATOTYPE

Kind and rank: Unit reference stratotype.

Nature of section: Northern wall of quarry, which exposes about 3,5 m of the older gravels together with about 0,5 m of the younger gravels (Pl. 10-6).

Location: See Figure 10.2.

Accessibility: Good. Secondary road links quarry with main road.

Lithology: Gravel (100%) - see columnar section (Fig. 10.5). Gravel matrix in this case consists of very coarse-grained sand. During a previous visit to the quarry, about 1,5 m of the younger generation gravel was exposed (Pl. 10-7). Upper metre of older generation is calcretised.

Structure: No regional structure visible.

Reasons for inclusion: This quarry provides the only available exposure at present which shows the nature and relationship of both the younger and older gravels of the Bluewater Bay Formation. Although no quarrying is taking place at this site at present, work may be resumed at a later stage.

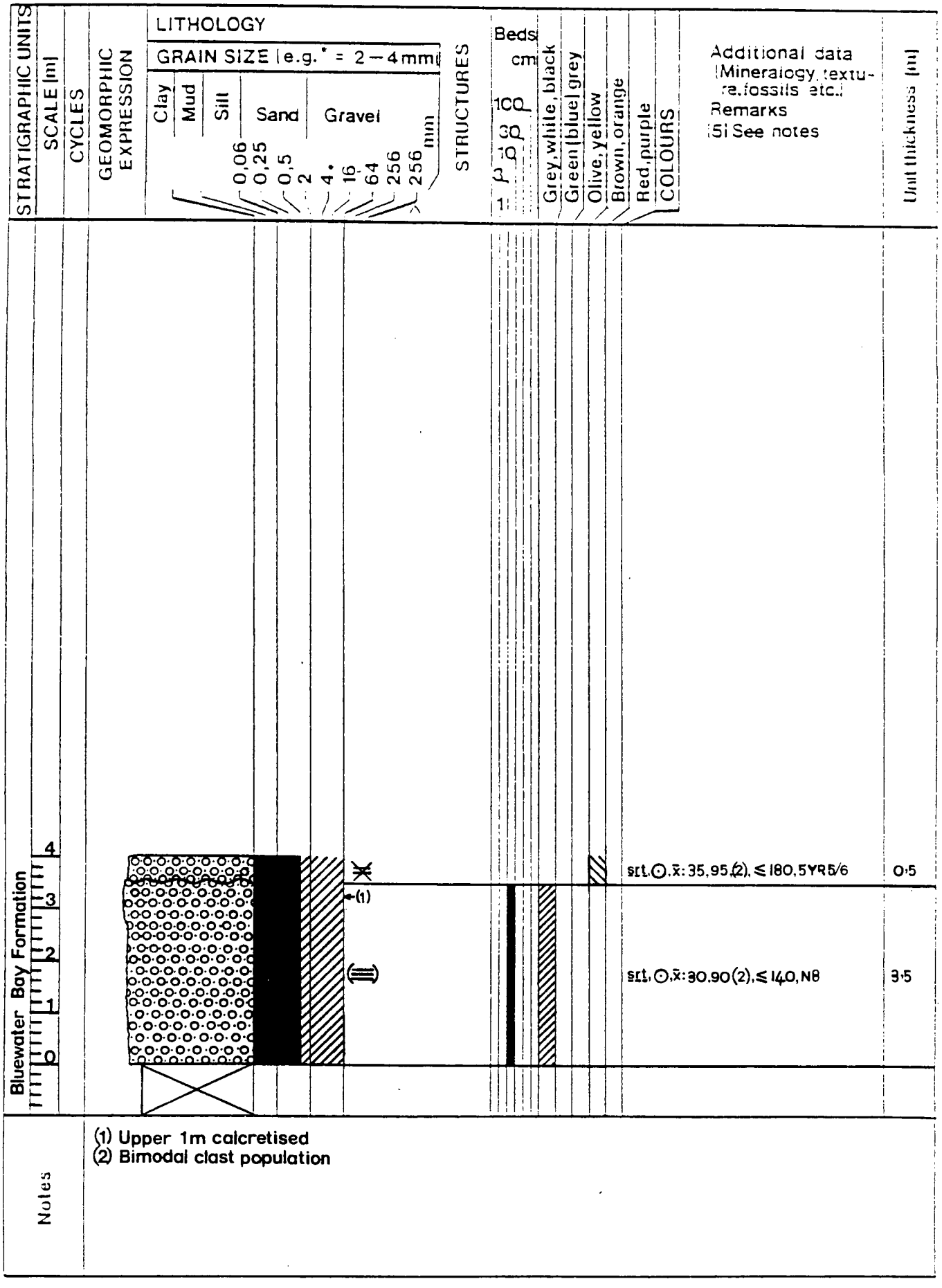


Fig. 10.5 - Stratotype B (Swartkop Salt Pan) of Bluewater Bay Formation.

Adjacent units: Underlying unit not exposed, but 200 m to the south the Bluewater Bay lies on the Sundays River Formation. The Alexandria Formation has here been removed by fluvial processes. Any overlying deposits that may have been present have been removed by quarrying.

Boundaries and contact relationships: Lower boundary not exposed at this locality, but can be seen about 200 m to the south near the north-western inlet of the salt pan (Pl. 10-8) where it is taken at the base of the gravel overlying greenish grey mudstone and sandstone.

PLATE 10

10-1: Artificial exposure in trench near Motherwell showing reddish-brown Bluewater Bay gravel (matrix-supported in this case) filling steep-sided channel cut into lighter-coloured Alexandria Formation. Length of staff 1,4 m.

10-2: Bluewater Bay Formation (dark) near Motherwell, with thin gravel layer near floor and along sides of channel. Remainder of channel is filled with silt and fine-grained sand. Apparent width of channel about 10 m (see Fig. 10.3).

10-3: Artificial exposure of Bluewater Bay Formation in trench near Motherwell showing younger alluvial gravel (clast-supported in this case) in steep-sided channels cut into the Alexandria Formation.

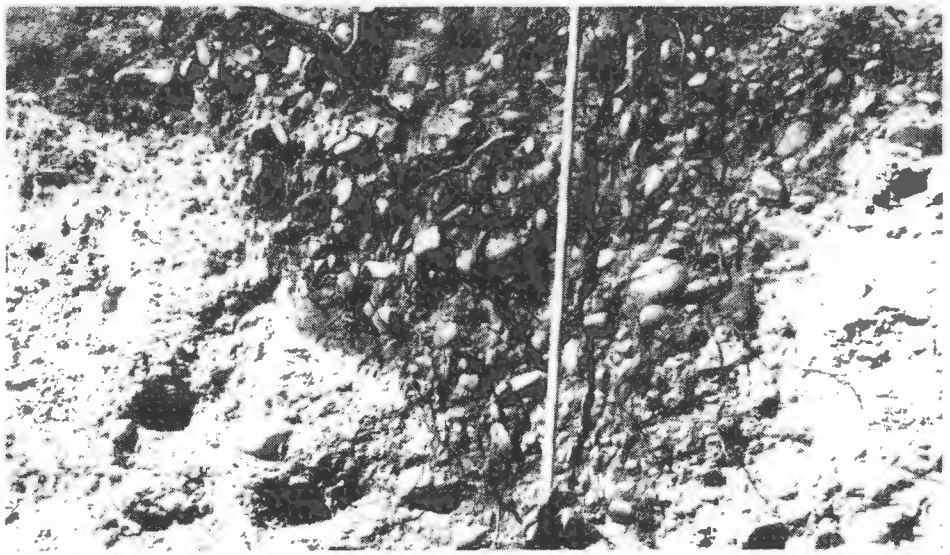
10-4: Artificial exposure in trench near Motherwell, showing Bluewater Bay alluvial gravel (dark) in channel cut into the Alexandria Formation (light). Depth of trench 3 m.

10-5: Bluewater Bay gravel (clast-supported) in distinct channel cut into Alexandria Formation (Ta) at holostratotype locality. Scale in decimetres.

10-6: Northern wall of quarry near Swartkop Salt Pan, exposing about 3,5 m of light-coloured, older Blue-

PLATE 10

1



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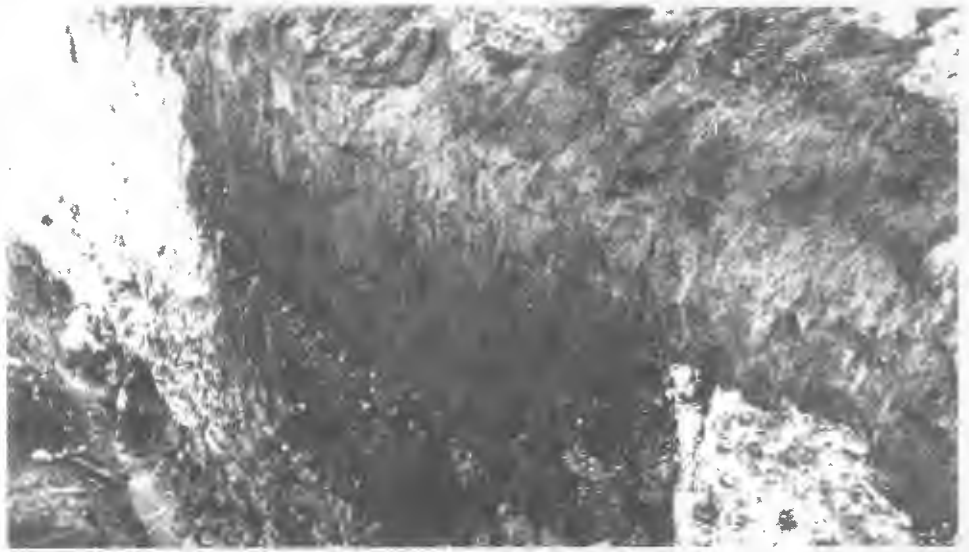

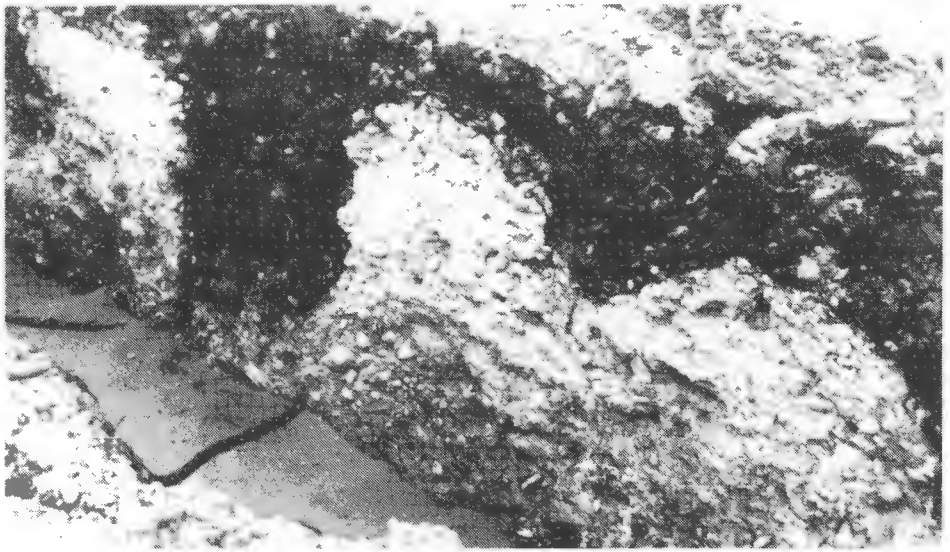

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PLATE 10 (continued)

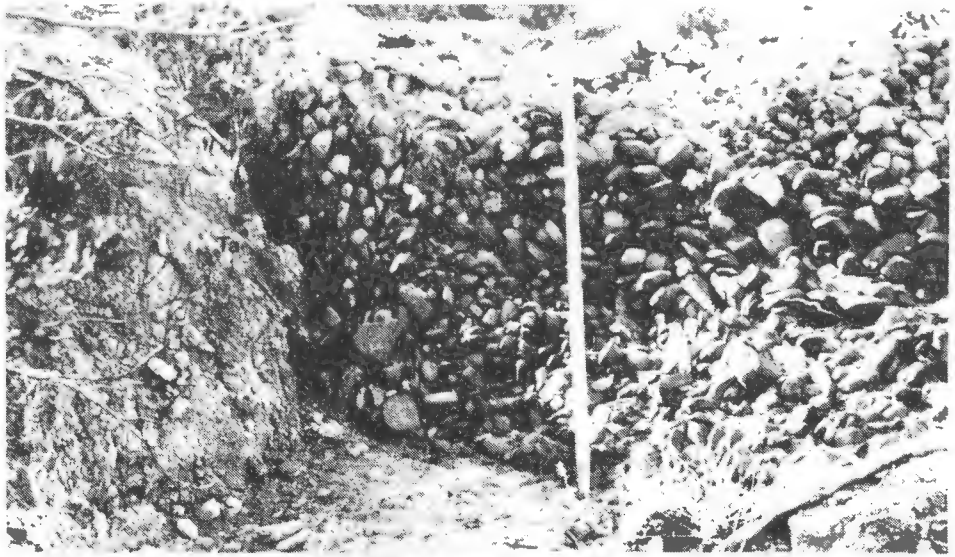
water Bay gravel together with about 0,5 m of younger darker-coloured gravel of the same formation.

10-7: Northern wall of quarry near Swartkop Salt Pan exposing about 1,5 m of younger Bluewater Bay gravel overlying older gravel of the same formation with an erosional contact. Note calcretised nature of the older gravel.

10-8: Older Bluewater Bay gravel which fills a channel cut into sandstone and mudstone of the Sundays River Formation. Near north-western inlet of Swartkop Salt Pan.

PLATE 10

5



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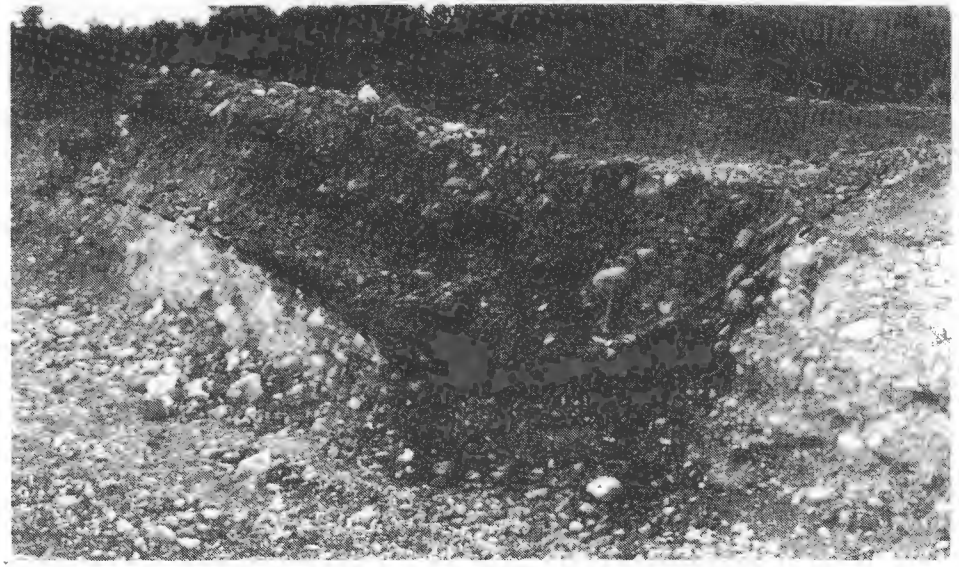

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CHAPTER 11 - OTHER FLUVIAL DEPOSITS

No formal lithostratigraphic descriptions for the Martindale Sandstone Formation, the Kudus Kloof or Sunland Formations are provided in this study. In the former case, no additional information to that supplied by Mountain (1946) could be gathered, mainly because of the extreme scarcity of useful outcrops. In the case of the Kudus Kloof and Sunland Formations, only a general description is provided, mainly because of the complexities involved in the classification and labelling of these deposits which will require a great deal of time and effort to unravel.

Since the deposits occur on discrete terraces which also represent separate time intervals, they are spatially and temporally separated. Individual names for all these therefore seem tenable at first. Similar river terrace deposits occur in the other river valleys in the study area. Specific terraces of one river may probably be correlated with those of other rivers in the area on the grounds of their corresponding heights, since they are related to specific (global) sea-levels. If another set of names for these are coined, correlation with those of the other rivers would be possible, but would result in a chaotic proliferation of names!

Ideally, these deposits should be named after the river valleys in which they occur, e.g. Sundays River Formation,

Swartkops River Formation and Gamtoos River Formation. Terraces could then be numbered from highest to lowest, which would ease correlation. However, these names have been sterilised by previous use.

It is thus clear that a great effort will be needed to:

(i) clarify the stratigraphy of these river valley deposits;

(ii) correlate specific terraces of different river valleys by means of lithology, depositional cycles, corresponding heights etc;

(iii) relate them to specific sea-levels and

(iv) to name/number/classify them logically to be acceptable in accordance with lithostratigraphic principles.

11.1 MARTINDALE SANDSTONE FORMATION

This formation, which is restricted to the area north of Port Alfred (see Fig. 1.2), was first described by Mountain (1946). It was only briefly visited by the present author. According to Mountain (1946) the formation consists essentially of ferruginous sandstones which were sub-aqueously transported and deposited. In places these sandstones show well defined stratification, while in other places they contain layers of well rounded clasts. The clasts grade in size from pebbles to boulders, and consist of sandstone, quartzite, vein-quartz, silcrete and agate (rare). The formation overlies an irregular surface of highly-tilted beds of Witteberg quartzite.

SACS (1980) assigned formation status to these deposits which were originally named "Martindale beds" by Mountain (1946).

11.2 THE SUNLAND AND KUDUS KLOOF FORMATIONS

These two formations are represented by fluvial deposits, probably of Late Pliocene to Pleistocene age, on various terraces in the lower reaches of the Sundays River (see Fig. 1.2).

11.2.1 Previous Work

Ruddock (1947) distinguished between "Higher Terraces" and "Lower Terraces" which were graded, respectively, to sea-levels from 52 metres upwards, and those below about 32 metres (Fig. 11.1). The two sets of terraces are clearly separated in the field by a steep and prominent scarp, varying from about 20 m in height to as much as 65 m farther inland at Sunland. The lower terraces occupy that part of the valley mapped as "alluvium" on Geological Sheet no. 9 (Haughton, 1928), and those labelled as Terraces no's 5, 6 and 7 on the map of Engelbrecht et al. (1962).

A distinction is made between "unpaired terraces" - formed during periods of simultaneous lateral and vertical erosion - and those whose upper surface formerly constituted a flood-plain of more or less stable form, graded to a sea-level that remained stationary for an appreciable length of time. Terraces of the latter type have been called

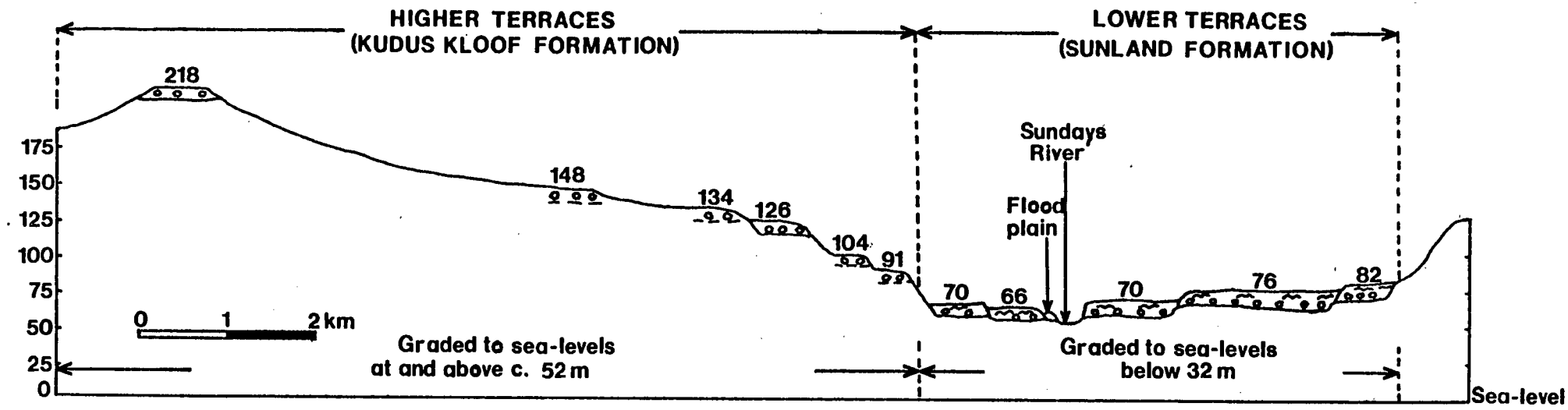


Fig. 11.1 - Generalised section across Sundays River Valley in the vicinity of Klein Gras Rug 88 showing the relationship between the Kudus Kloof and Sunland Formations as defined by Ruddock (1975 - in SACS, 1980).
Figures m.a.s.l.

"principal terraces" (Steers, 1937) and can be recognised by its corresponding heights above river level along the valley.

Four principal terraces were determined by Ruddock (1947) in his set of "Lower Terraces" and he named them, from highest to lowest, the Kirkwood, Harveyton, Addo and Colchester terraces. The maximum elevation difference between the highest of these and the low-water level of the present-day river amounts to about 40 m.

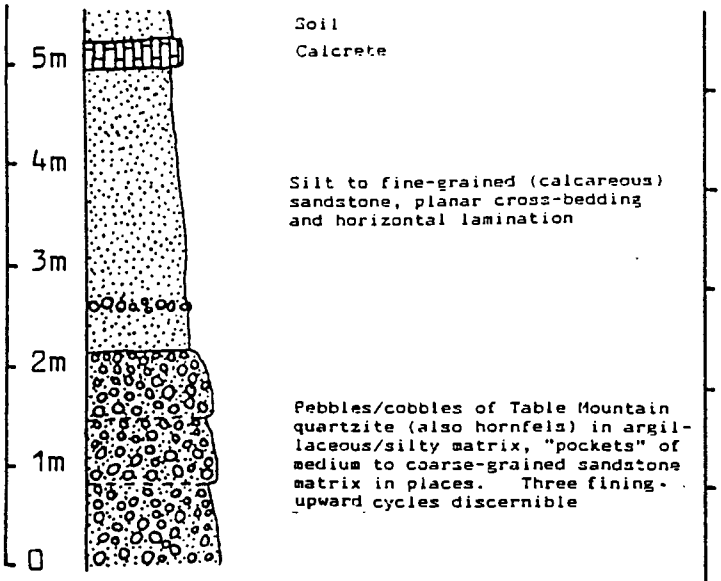
These "Lower Terraces" are composed of alluvium, resting on a relatively thin gravel/boulder bed, generally not thicker than one metre. Cretaceous rocks form the base in every case.

Ruddock (1957) assigned a Middle Pleistocene age to the "Higher terraces" based on the presence of stone implements. The reliability of this dating is doubtful (see Chapter 12.2.3).

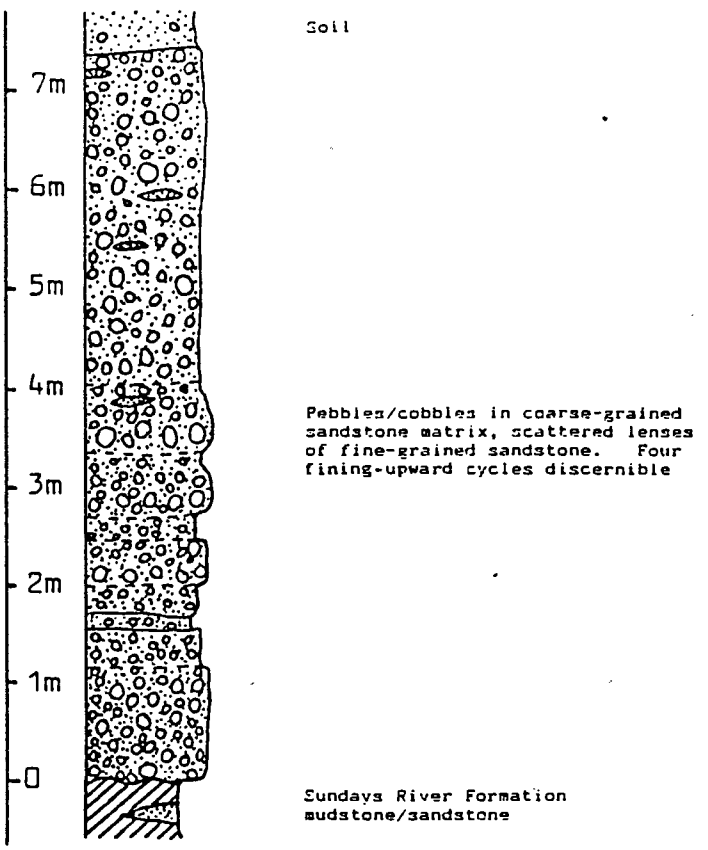
In a submission during 1975 to the Working Group for the Tertiary and Quaternary, Ruddock proposed the names Sunland and Kudus Kloof Formations for his "Lower" and "Higher" terraces respectively. This was accepted by SACS (1980).

11.2.2 Recent Work

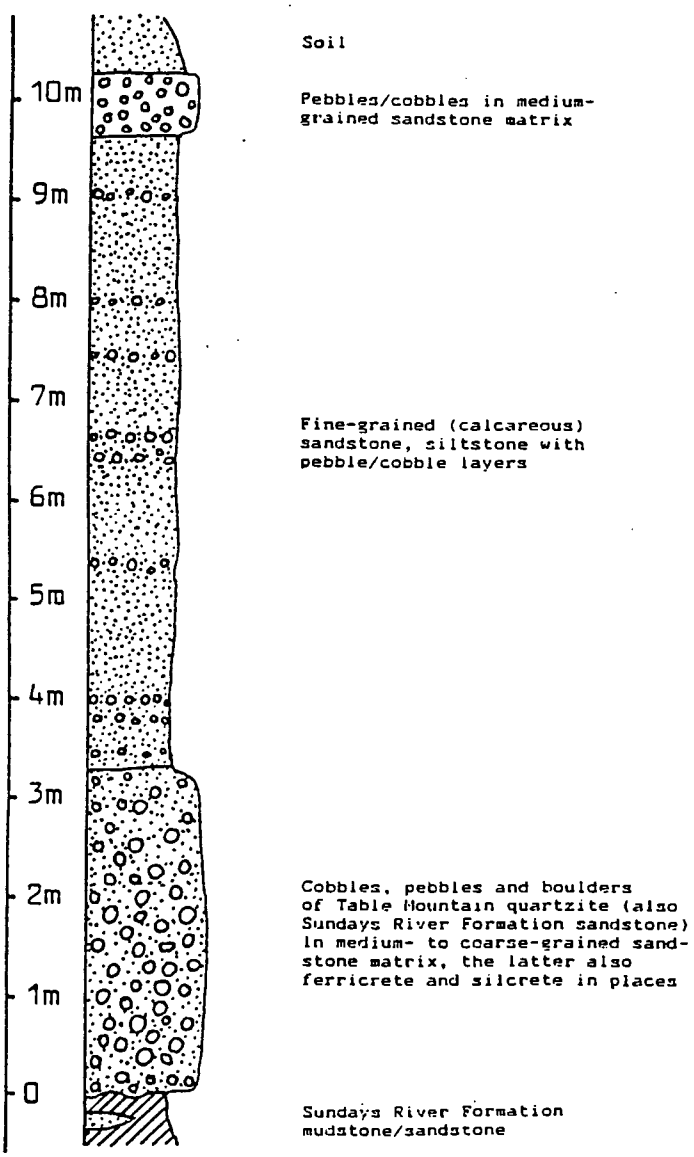
Four sections of the Kudus Kloof Formation ("Higher Terraces") were measured by the present author (Fig. 11.2



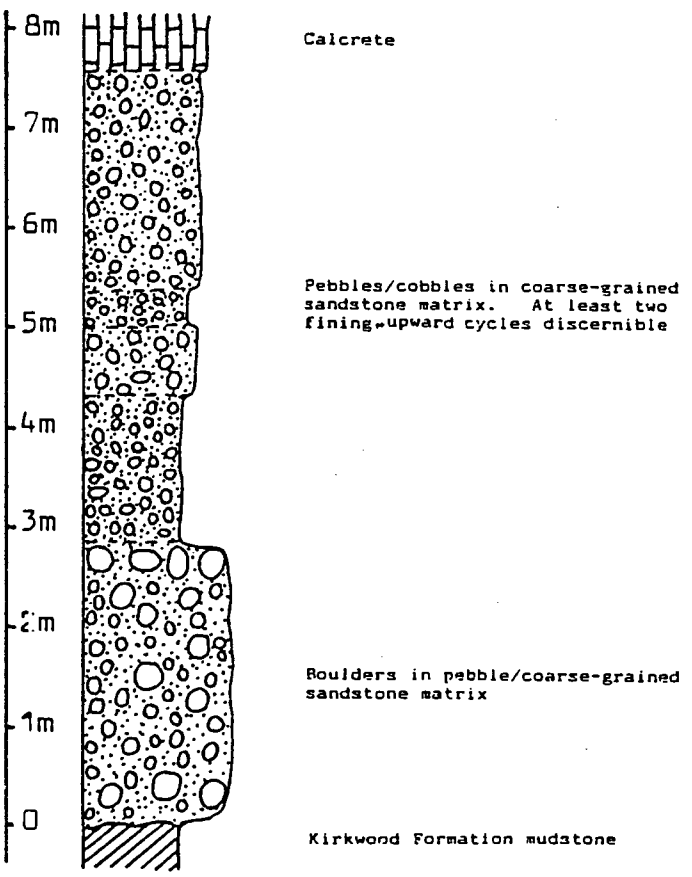
a) Section of Kudus Kloof Formation at Kudus Kloof 117



b) Section of Kudus Kloof Formation at Tankatara 217 (railway cutting)



c) Section of Kudus Kloof Formation at Coega Kammas Kloof 191 (Kentvale)



d) Section of Kudus Kloof Formation at Kirkwood (South bank, Sundays River)

Fig. 11.2 a - d: Sections of Kudus Kloof Formation.

a-d; see also Plates 11-1 to 11-4). Compared to the deposits of the Sunland Formation, those of the older Kudus Kloof Formation are better consolidated; ferricretisation, calcretisation and silcretisation being common.

PLATE 11

11-1: Kudus Kloof Formation resting on sandstone and mudstone of the Sundays River Formation at Tankatara 217.

11-2: Pebbles and boulders in Kudus Kloof Formation at Kudus Kloof 117. Note calcretised lens in middle of photo.

11-3: Gravel of Kudus Kloof Formation overlying Kirkwood Formation in cliff overlooking Sundays River valley near Kirkwood.

11-4: Kudus Kloof Formation on terrace in mudstone and sandstone of Kirkwood Formation (south bank, Sundays River near Kirkwood).

PLATE 11

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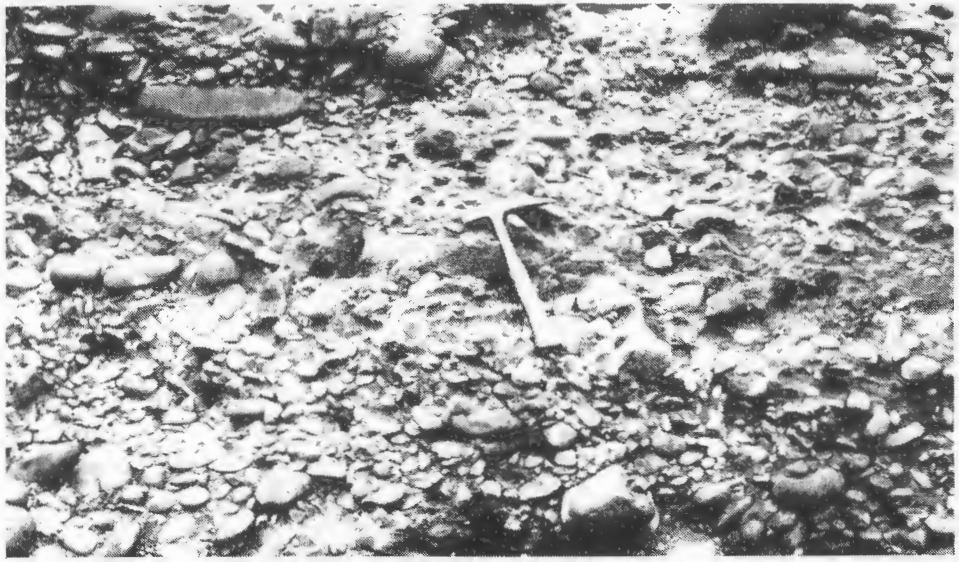

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CENOZOIC SEA-LEVELS AND ASSOCIATED AGES

CHAPTER 12 - CENOZOIC SEA-LEVELS AND ASSOCIATED AGES

Several attempts to determine sea-levels (global and Southern African) during the Cenozoic have been made over the last decades, e.g. Fairbridge (1961), Guilcher (1969), Tankard (1975), Hendey (1981, 1983), Siesser and Dingle (1981), Jacobs (1986) and Haq et al. (1987), amongst many others. Initially, evidence was mainly gathered from geomorphological features of continental shelves, coastal plains and river terraces, but more lately offshore drilling has provided a wealth of data. Micropalaeontological and, to a lesser extent, archaeological evidence (for the Quaternary Period) have also contributed to the dating of different sea-level stands.

12.1 DISCUSSION

Comparison of various authors' shoreline elevations for South Africa is provided by Table 12.1, while a sea-level curve for the south-east coast, based mainly on local onshore evidence, is presented in Fig. 12.1.

According to Siesser and Dingle (1981) the earliest Cenozoic transgression followed upon a sea-level low in Late Cretaceous times. This Early Palaeocene transgression reached the highest recorded altitude for the era and accords with the dating of the Bathurst Formation at Needs Camp (330 m), Birbury (200 m) and Pato's Kop (140 m). The marine-cut

TABLE 12.1 - COMPARISON OF VARIOUS AUTHORS' SHORELINE ELEVATIONS (m) FOR SOUTH AFRICA, WITH A SIMPLIFIED SCHEME FOR THE SOUTH-EAST COAST

Maud (1968)	Rudcock (1968)	Carrington & Kensley (1969)	Davies (1970)	Davies (1971 a,b)	Butzer & Helgren (1972)	Tankard (1975)	Marker (1984)	Marker (1987)	Stear (1987a)	Others	Simplified Scheme for South-east coast	
Natal	Algoa Basin	West Coast	Natal	S.A. Coast	Knysna - Cape St. Francis	Cape Town - Gans Bay	Kei Mouth - Cape St. Francis	George - Knysna	Algoa Basin		Cape St. Francis - Kei Mouth	
							-1/-2				-1/-2	QUATERNARY
1,0												
1,5			1,5	1,5		0 - 1,5					0 - 1,5	
		2					2				2 - 3	
2,4						2,3 - 3.1		2 - 3		2 - 3 m. Emerged platforms in Nahoon Fm. (own observation)		
			3,5	3,5								
4,5	4					4,0 - 4,7				4,9 m. (Engelbrecht et al., 1962)	4 - 5	
		5										
	6		6	6		5,8 - 6,9	5 - 8	6 - 8		6 m. (Krige 1927); 6 - 8 m. Beach terrace south of Kleinemonde (own observation)	6 - 8	
8		7 - 8	9		5 - 12	8 - 11			10	11 m. } Benches in Nahoon Fm. at Bonza Bay &	8 - 11	
12							15	15	15	14 m. } Kwaaihoek (Mountain, 1937); (Le Roux, 1989)	15	
18	18	17 - 21	18	18	15 - 20	15 - 20				18 m. (Krige, 1927)	15 - 20	
									20 - 30	22 m. Inland limit (escarpment) of Salnova	20 - 30	
33	24-30	29 - 34	30	30	30	29 - 32	30	30	30	Fm. in Amsterdamhoek - St. Georges Strand area (own observation). Caves in sea-cliff east of Groot River estuary (own observation).	30	TERTIARY
			38									
45		45 - 50	48	48								
	52										52	
	58		61	60	60		60	60	60		60	
	64											
70			73									
	84	75 - 90	82	73 - 85							84	
	91						90 - 100	90		99-102 m. Algoa Basin (Engelbrecht et al., 1962)	90 - 100	
	106										106	
115			110		120.				115	120 m. { Bench near Kei Mouth (Mountain, 1945a) "Humansdorp terrace" (Toerien, 1976)	115 - 120	
								120-140		137 m. Algoa Basin (Haughton, 1925)	120 - 140	
170												
				155 - 200	170-200							
							200				200	
								200-240	200-215			
	207-300			269			240 - 300		245	260-275 m. Algoa Basin (Haughton, 1925)	240 - 300	
								340-400		Up to 400 m. Ciskei (Maud et al., 1987)		

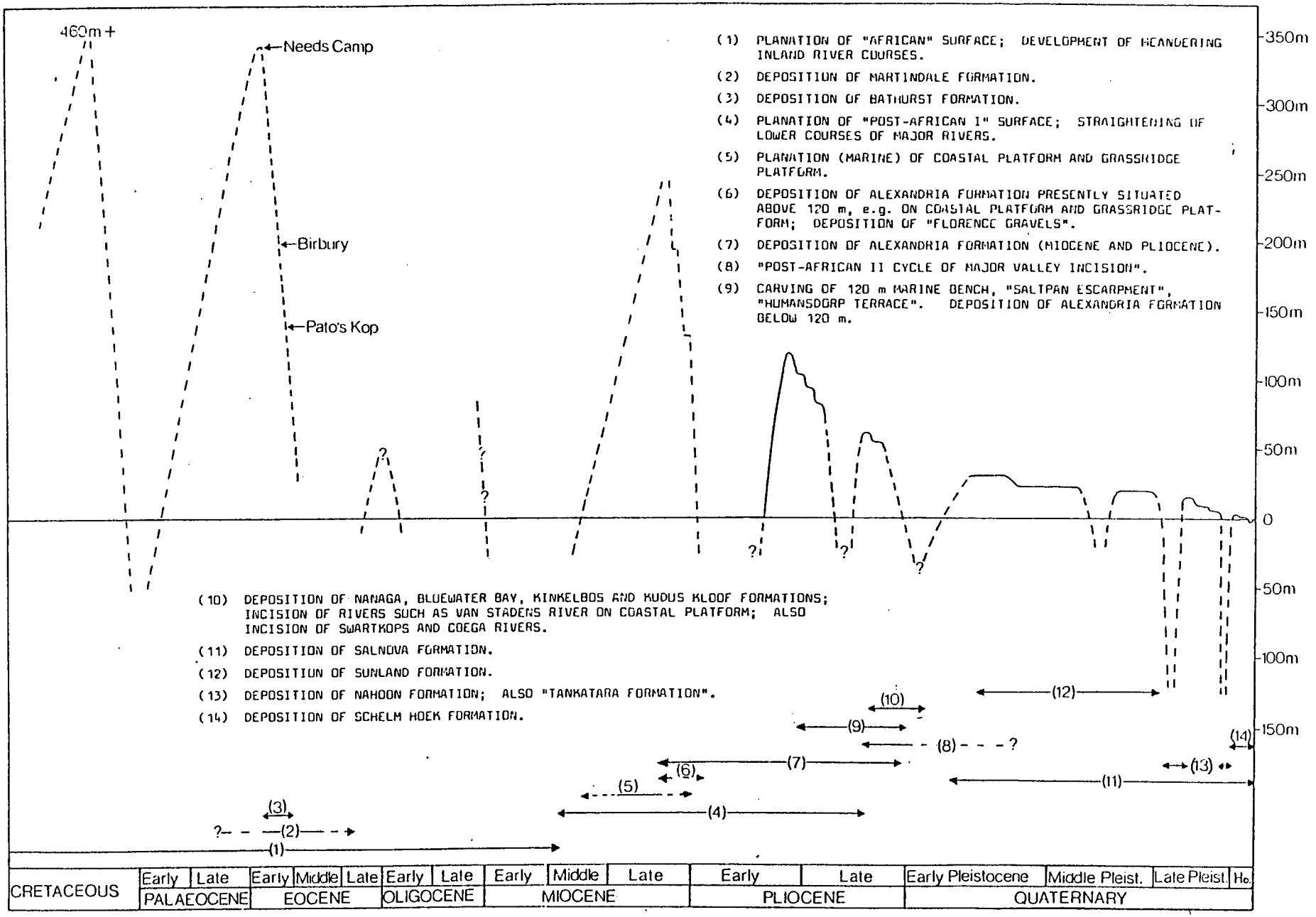

Fig. 12.1 - Sea-level curve for south-east coast.

platform upon which these deposits were laid down is considered by Partridge and Maud (1987) to have followed the breakup of Gondwanaland in the Late Jurassic to Early Cretaceous. It was terminated by uplift and marginal tilting of the subcontinent in the early Mid-Miocene.

Inland this marine platform passes into the sub-aerially planed "African" surface, which is characterised by a deeply weathered profile. In the area around Grahamstown, this surface carries silcrete remnants overlying kaolin (Pl. 12-1). Immediately west of the Pato's Kop (Great Fish River) outcrop, another remnant of this type is present (Maud et al., 1987). The occurrence of silcrete pebbles in the Bathurst Formation indicates that silcrete had already formed on kaolinised profiles during the Cretaceous, prior to the deposition of most of the Bathurst Formation in the Early Eocene. Partridge and Maud (1987) show that all occurrences of silcrete without associated kaolinisation are related to younger shorter-lived cycles of erosion. The name "Grahamstown Silcrete Formation" should thus be confined to Late Cretaceous silcretes where kaolinisation is present. This deviates from SACS (1980) who incorporated all silcrete occurrences in the study area into the Grahamstown Silcrete Formation, considering them to be "Early Tertiary" in age. Younger silcretes such as the "coastal plain silcretes" and "Fishriver silcretes" (Mountain, 1946), the silcretes associated with "high-level gravels" (Haughton et al., 1937) and the Fort Grey silcretes (Adamson, 1934) need further investigation to ascertain

their stratigraphic position within the Tertiary. A clue as to their age (especially for those of the coastal plateau) could be provided by the possibility that their formation relates to poor drainage (Mountain, 1945a), thus indicating an age preceding the incision of drainage systems into the coastal plain following the early Miocene uplift.

The Martindale Sandstone Formation, which occurs near the inland margin of the earliest coastal plain at an elevation of about 360 m, consists of ferruginous sandstone with pebble inclusions of various rock types, including silcrete (Grahamstown Formation?). SACS (1980) ascribes an Eocene age to these deposits but they could conceivably be even somewhat older.

A second lesser transgression/regression cycle occurred in Late Eocene to Early Oligocene times (Siesser and Dingle, 1981). As far as is presently known, no deposit in the outcrop area of the Algoa Group can be definitely related to this cycle.

The Early Miocene uplift, whilst terminating the "African" cycle of erosion, also initiated the Post-African I erosion cycle which lasted till Late Pliocene times (Partridge and Maud, 1987). A conspicuous feature of many of the rivers in the area is that the lowermost 4 to 10 km of their courses are straight, contrasting with their meandering incised valleys in the hinterland, the latter courses being inherited from the "African" erosion cycle. The straight

segments represent the extension of the rivers across former areas of continental shelf which were exposed as a result of the Miocene uplift. Partridge and Maud (1987) consider the coastal platform (Pl. 12-2) of the southern Cape (which can be followed to the eastern Cape) to belong to the Post African I erosion cycle. Earlier suggestions of an Eocene age (Helgren and Butzer, 1977; Hendey, 1983; Marker, 1984), or a Pliocene age (King, 1972b) are clearly incompatible with the evidence presented by Partridge and Maud (1987). Consequently, the Eocene age assigned to the overlying Knysna lignites (Thwaites and Jacobs, 1987), mainly on the grounds of geomorphological evidence by the earlier authors mentioned, seems untenable.

Marker (1987) recognised a 120 - 140 m bench in the George - Knysna area, while Butzer and Helgren (1972) recorded one at 120 m in the Knysna - Cape St. Francis area. This probably corresponds with the 120 m bench Toerien (1976) recognised at Natures Valley (Pl. 12-2), as well as with the inland limit of his "Humansdorp Terrace", which is traceable from west of Humansdorp eastwards to the Gamtoos River. In the area between the Gamtoos River and Port Elizabeth, this terrace is obscured by the overlying Nanaga Formation. In the Algoa Basin a wave-eroded cliff, the "Saltpan escarpment"* of Ruddock (1968) and Stear (1987b) also corresponds (altitudewise) to the inland limit of the "Humansdorp Terrace". A well-developed bench at a similar

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* Originally named the "Saltpan Terrace" by Engelbrecht *et al.* (1962).

altitude south of the Kei Mouth has been recorded by Mountain (1945a).

The "Humansdorp Terrace" is overlain by fluvial gravels probably coeval with the Bluewater Bay Formation, which is developed on the "Middle" and "Lower" terraces of Engelbrecht et al. (1962) in the area between the Swartkops and Sundays Rivers. The 120-m bench thus pre-dates the Bluewater Bay Formation, which is considered to be Late Pliocene in age (see under Section 12.2).

The overall Middle Miocene to Early Pliocene transgressive stage was interrupted by a strong regressive pulse near the Miocene/Pliocene boundary (Siesser and Dingle, 1981, amongst others). On the coastal platform in the area between Port Elizabeth and the Gamtoos River, alluvial gravels of up to 3 m thick (Pl. 12-3) overlie the Alexandria Formation at a number of localities. These gravels, here provisionally named the "Florence gravels" after the farm Florence 444 in the Hankey district, are considered to represent alluvial gravel which accumulated (probably as alluvial fans) on the emerged near-horizontal coastal plain of the Miocene/ Pliocene regression. The proximity of coastal mountain ranges (in this case the Van Stadens and Elands Mountains) probably inhibited the establishment of extensive drainage systems. Elsewhere (east of the Coega River) where major drainage systems had already existed, the lower courses of major rivers were extended over the former continental shelf, as mentioned before.

During the ensuing Early Pliocene transgression, which is considered to have reached a maximum present-day elevation of 120 m, the "Florence gravels" below this elevation were eroded. At levels above 120 m they often separate the Nanaga Formation in this area from the Alexandria Formation. It is suggested that the Nanaga Formation accumulated since the Late Pliocene regression. Also the bulk of the Alexandria Formation in the Algoa Basin is thought to have been deposited during this regression. Elsewhere, remnants of Alexandria sediments occur on isolated spurs in the valleys of major rivers, below the level of the Miocene coastal platform, e.g. the Sundays River near Fascadale (Engelbrecht et al., 1962), Bushmans River and Great Fish River near Jagers Drift and Kaffir Drift respectively (Mountain, 1945a). These occurrences probably originated from the same Late Pliocene regression and their location at an altitude of between 90 and 110 metres indicate the existence of these valleys prior to deposition of the marine sediments.

The Alexandria deposits on the Grassridge Platform - the "Highest terrace" of Engelbrecht et al. (1962), or "Unit I" of Stear (1987a) - are thus, in accordance with the foregoing reasoning, considered to be Late Miocene to Early Pliocene in age. In a contribution to the work of Stear (1987a), McMillan recognised five successive shorelines of a regressing sea in "Unit I". No indications as to their respective heights are mentioned, however. Subsequent erosion of older Alexandria deposits by the next transgres-

sive/regressive cycle is indicated by cannibalised clasts in the Alexandria below 120 m, on both the Coega Plateau and the "Humansdorp terrace".

The Late Pliocene regression (from a transgressive maximum of c. 120 m) experienced several relatively long still-stands which probably account for the 106 m, 90 to 100 m and 84 m benches (see Table 12.1). Even the 60-m and 52-m shorelines could have been formed during this regression. However, preliminary palaeontological evidence suggests that the 60-m shoreline represents a transgressive maximum of a subsequent cycle followed by a regression with at least one significant stillstand at 52 m. The palaeo-beach ridges encountered on the Coèga Plateau (often expressed in the form of dolinas due to karstic processes) are also ascribed to this Late Pliocene regressive phase. Furthermore, sub-aerial solution and reprecipitation of shell material promoted the lithification of both the Alexandria and Nanaga Formations during this time.

As the Late Pliocene regression continued to well below the present sea-level, large areas of the newly-exposed coastal plain in the Algoa and Gamtoos Basins were inundated by alluvial sheetflood deposits of the Bluewater Bay Formation, blanketing most of the underlying Alexandria Formation (Le Roux, 1987e, also see Chapter 10). The coeval Kinkelbos Formation (see Chapter 9) is considered to be overbank deposits of the palaeo-Sundays River. The Bluewater Bay

Formation antedates the incision of the Swartkops and Coega Rivers.

The last-mentioned, as well as the Van Stadens River on the coastal platform is considered to have been incised as a result of the Late Pliocene uplift and warping of the sub-continent. This event introduced the "Post-African II cycle of major valley incision" of Partridge and Maud (1987), and also marks the termination of the Tertiary Period. Higher alluvial terraces along major rivers is a result of this incision. The Kudus Kloof Formation fits into this category.

The 30-m shoreline is considered by Tankard (1975) to be of Early Pleistocene age, whereas the 20 to 30-m shoreline possibly dates from the late Early to early Middle Pleistocene. Both shorelines have been recognised in the area under discussion (see Table 12.1) and have their fluvial counterparts in some of the Sundays River's "Lower terraces" which Ruddock (1947) relates to the "Major Emergence" of Krige (1927). The 15 to 20-m shoreline is probably also compatible with Krige's "Major Emergence" (18 m). According to Ruddock (1968) the 18-m shoreline was preceded by a sea-level close to that of the present, implying that the 18-m shoreline represents a transgressive maximum, and not merely a standstill in a regression from higher levels. Uncertainty surrounding the age of this strandline, as well as those at 15 m, 8 to 11 m and 6 to 8 m could be resolved in part by a more definite age for the Nahoon Formation.

Marker (1984, 1987) recorded wave-cut benches in the aeolianites of the Nahoon Formation at elevations of 2 m, 5 to 8 m and 13 to 16 m. At Bonza Bay, Mountain (1946) also recorded distinct marine-cut platforms in these aeolianites at about 14 m and 11 m while corresponding heights were recently observed at Kwaaihoek (Pl. 12-4) and elsewhere (Le Roux, 1989). It is generally accepted that sea-levels never exceeded +3 m during the Flandrian transgression, nor during any of the interstadials of the WÜrm (Fairbridge, 1961; Guilcher, 1969; Barwis and Tankard, 1983). During some of the pre-WÜrm glacials (probably during the pre-ceding Riss) sea-levels also receded to less than -100 m (Donn et al., 1962) during which the Nahoon Formation could have been deposited. Subsequent transgressions (e.g. the Eemian, specifically the 12 to 18 m Lower Normannian, according to Guilcher, 1969) could account for these marine benches.

The deepening of the lower reaches of many river valleys following the fall in oceanic base-level during both the last (WÜrm) and the preceding (Riss) regressions, when sea-level dropped by approximately 100 m, resulted in gorges being filled by great thicknesses of younger estuarine sediments (tentatively named the Tankatara Formation by W.K. Illenberger - pers. comm., 1987) during subsequent Eemian and Flandrian transgressions (Maud, 1968). If, for arguments sake, it is accepted that the Nahoon Formation was deposited during the Riss glacial, one would expect the ensuing Eemian transgression to have left some deposits on at least some of the benches in the aeolianites. Nothing

of this kind is known along the S.E. coast. However, occurrences of aeolianite similar to that of the Nahoon Formation have been described in the Durban (Bluff) and offshore (Aliwal Shoal) areas (McCarthy, 1967). He, however, on the grounds of not very convincing evidence, related these deposits to a Late Pliocene regression. If this age is ruled out and a Pleistocene age accepted (as indicated by King and Maud, 1965), the outcrop at the Bluff where raised beach deposits are overlying aeolianites, could be used as evidence for Pleistocene marine deposits overlying Pleistocene aeolianites. SACS (1980), also considers these deposits to be of Quaternary age and gives it formal status (Bluff Sandstone Formation). An erosion surface cut into it with elevation up to 8,1 m above m.s.l., overlain by a pebble layer with Eemian artifacts, is mentioned. Similar successions occur along the Cape south coast, e.g. at Dana Bay west of Mossel Bay (J.A. Malan, pers. comm., 1988).

It is thus tentatively suggested that the Nahoon Formation was at least partially deposited during the Riss glacial and was subsequently partially eroded during the Eemian interglacial. During the ensuing WÜrm glacial similar conditions existed and aeolianites were probably also deposited. The age of 29090 $^{+410}_{-390}$ years B.P. yielded by radiocarbon dating of calcareous material in the sandstone at Nahoon Point (Deacon, 1966) is in agreement with deposition during the latter glacial.

Shorelines at and below 16 m are tentatively considered to be of Eemian age, probably representing standstills in the regression from the 16 m level. Ruddock (1968), however, indicates that the 4-m shoreline was preceded by a sea-level as low as -34 m, thus indicating a transgressive and not a regressive standstill. The 2 to 3 m, 0 to 1,5 m and -1 to -2 m sea-levels have also originated from either a WUrm interstadial transgression or the Flandrian transgression.

Accepting that the Pleistocene glaciations, which were the main cause of sea-level fluctuations during this epoch, progressively diminished in duration and intensity (Hallam, 1981), then palaeo-shorelines at lower elevations should postdate those at higher elevations.

All marine and paralic deposits related to 30 m and lower shorelines (see Table 12.1) are included in the Salnova Formation which is considered to have been deposited during one or more Quaternary interglacials (see Chapter 4).

The Schelm Hoek Formation, which is still being deposited, originated from the transgressive maximum (c. 3 m) of the Flandrian transgression (see Chapter 7) at the start of the Holocene.

From the afore-cited evidence it is clear that Cenozoic sea-level changes were not solely eustatically controlled, but that isostatic compensating movements and local diastrophism

(see Ruddock, 1947, 1968; and King, 1972a) also played a significant role.

12.2 DISCREPANCIES IN THE AGES OF CERTAIN DEPOSITS

12.2.1 Alexandria Formation

Stear (1987a) distinguishes four chronostratigraphic units within the Cenozoic deposits of the Algoa region, based mainly on micropalaeontological work by McMillan (contribution in Stear, 1987a). They are: Unit I - deposits on the Grassridge Plateau, dated as Pliocene; Unit II - deposits below 120 m on the Coega and Colchester Plateaux, dated as Early to Middle Pleistocene; Unit III - deposits on the Amsterdamhoek Plateau, regarded to be of Late Pleistocene/Early Holocene age; Unit IV - outcrops along the Woody Cape coastline, dated as Holocene. It is clear from McMillan's thicknesses for the various units that both marine and overlying aeolian deposits were treated as one unit. Samples, apparently from the aeolian deposits, yielded a younger age for the unit as a whole.

The marine part of Stear's Unit II is considered by the present author to be of Late Pliocene age on account of evidence presented earlier (p.221), as well as macrofossil assemblages (comparison with dated west-coast assemblages). From information supplied by McMillan (Stear, 1987a) it is obvious that Unit III represents the Salnova Formation whose deposition was associated with transgressions/regressions up to about 30 m above present sea-level. The boundary

separating Stear's Units III and II seems to be very arbitrary and based on very little information. He used the "Swartkops lineament" as a convenient boundary between the two units, thereby shifting the boundary established by McMillan (Stear, 1987a) a few kilometres inland. Late Pliocene marine sediments of the seaward portion of Unit II are thus erroneously included in Unit III. With the interval postulated between Units II (Late Pliocene according to the present author) and III (Early Holocene according to Stear, 1987b), one would not expect macrofossil assemblages to be accordant. As a result of Stear's arbitrary boundary typically extinct Alexandria fossils such as Cypraea zietsmani, Glycymeris borgesi, Notocallista schwarzi and Tivela baini, which have never been recorded from the Quaternary marine deposits (the Salnova Formation), occur in those portions of his Unit III which lie above 30 m.

It is concluded that the Alexandria Formation below 120 m is Pliocene in age. Some occurrences of this formation at Nanaga and elsewhere have been erroneously assigned an early Pleistocene age by Stear (1987a), probably as a result of microfossils found in the overlying (younger) Nanaga Formation. This wrong interpretation obviously also affected the postulated ages of subsequent deposits.

12.2.2 **Bluewater Bay Formation**

East of the Swartkops River, between Bluewater Bay and St. Georges Strand (Fig. 10.1) the 30-m contour marks the top of a scarp which is the seaward edge of the Alexandria Forma-

tion as well as the Bluewater Bay gravels. Erosion, by undercutting, during Pleistocene transgression(s) probably accounts for their absence below this contour. Also, on account of their occurrence being restricted to a Tertiary surface, it would appear that the Bluewater Bay gravels antedate the post-Tertiary incision of the Swartkops River.

Stear (1987a), by implication, regards the Bluewater Bay deposits, which he named the "Motherwell" deposits, to be of Holocene age. He considers these gravels to be a singular-event overbank flash-flood deposit of the Swartkops River during a "catastrophic flood". This interpretation seems to be invalidated by the presence of two distinct generations of gravels separated by a hiatus. Also, if Stear's (1987a) age were correct, the Swartkops River must have experienced a major incision during the Holocene. The present Swartkops River Valley is thought to be more likely the result of the Late Pliocene to Early Pleistocene uplift, thus providing an upper age limit for the Bluewater Bay Formation.

12.2.3 River terrace gravels

Ruddock (1957) considered all marine deposits below 84 m to be Quaternary in age. This inference was based on the presence of artifacts in associated terrace gravels of the Sundays River. For the same reason Davies (1971a) considered shorelines to be of Tertiary age only when they occurred more than 150 m above sea-level. However, ages based on

stone implements should be treated with caution for several reasons:

(1) For artifacts to be used as zone fossils it must be known that they are older than the deposits in which they have been found and that their inclusion is the work of fluvial or marine processes. Neither Ruddock (1957) nor Davies (1971a) gives clear indications as to whether any of the artifacts were found in situ; apparently they were mainly from terrace surfaces.

(2) Artifacts illustrated by Davies (1971a) seem to be unworn, which makes it doubtful that they formed part of the original deposits.

(3) Ruddock's (1957) "very well worn" and "well worn" specimens which, according to him, suggest that they were original inclusions during fluviatile transport are mainly found on lower terraces relating to sea-levels below 18 m.

(4) It remains doubtful that, after vigorous abrasion in a river bed or cobble/boulder beach, artifacts could be sufficiently recognisable and useful for reliable age determinations.

(5) Ages of artifacts are beset with uncertainties since they span different time ranges in different localities.

12.2.4 **Nahoon Formation**

Malan (1987) considers the Waenhuiskrans Formation of the S.W. Cape - which is correlated with the Nahoon Formation - to have been deposited during the WÜrm regression. This

seems to be at variance with the evidence presented earlier (p.224-225) which indicates that the Nahoon Formation, or at least part of it, has been deposited during the pre-WÜrm regression(s).

McMillan (in Stear, 1987a) indicates a Holocene age for the Nahoon Formation at Woody Cape. This is also incompatible with the previously-mentioned evidence (p.224-225).

12.2.5 **Salnova Formation**

Marker (1984) tentatively suggests an age of 25 000 years to 29 000 years B.P. for the 5 to 8 m bench. However, sea-levels probably never reached these elevations during any of the WÜrm interstadials (Fairbridge, 1961). Also, warm-water molluscs characterise fossil assemblages from estuarine/lagoonal facies associated with the 6 to 8 m shoreline (Le Roux, 1987b). This warm period possibly coincides with the well documented period of higher temperature at c. 120 000 B.P. (Kilburn and Tankard, 1975).

PLATE 12

12-1: Deeply weathered (kaolinised) profile capped by silcrete on Gletwyn 338, Grahamstown.

12-2: Bench at 120 m (left of photo) with higher (Miocene) coastal platform (right of photo) near Natures Valley.

12-3: Alexandria Formation (Ta) overlain by "Florence" gravels on Florence 444, Hankey.

12-4: Bench in Nahoon Formation at Kwaaihoek, Alexandria.

PLATE 12

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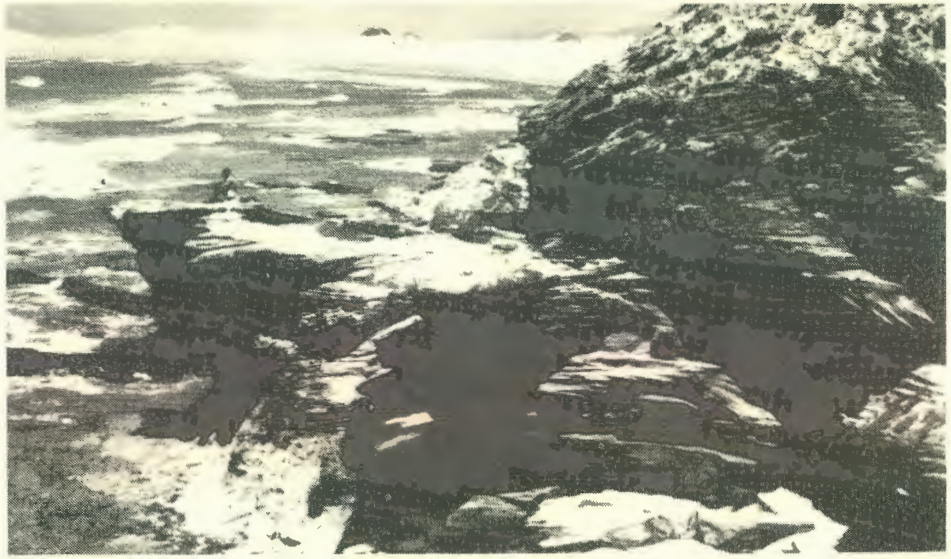

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CHAPTER 13 - CONCLUSION

The Cenozoic stratigraphy of the south-eastern Cape was consolidated along established lithostratigraphic principles. In the process some new formations were defined, whilst certain existing formations needed redefinition. Each of the units was tentatively linked to the latest findings on Southern African sea-level fluctuations during the Cenozoic period. However, age discrepancies do exist.

Since eustatic sea-level changes are of a global nature, Cenozoic marine deposits should be investigated on the largest possible scale. At the same time proper allowance should be made for local variations due to diastrophism. This aspect has received scant attention during the present study and should be pursued further. Also, certain age discrepancies could probably be resolved by more palaeontological work. The determination of zone fossils and/or index fossils in the Alexandria and De Hoopvlei Formations should provide a link with similar Cape west coast deposits. The latter have been studied more thoroughly with regard to marine transgressions/regressions (e.g. Pether, 1986), and have also been dated more definitely by means of associated vertebrate remains.

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