

LAST INTERGLACIAL SHORELINES IN THE SOUTH CAPE

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INTRODUCTION

My paper discusses the Last Interglacial shorelines of the South Cape with reference to findings from the rest of the world. I call them Eemian shorelines, and define Eem as an interglacial with three peaks of sea level separated by two stadials when the ocean dropped. I use the term Eem though it has been wrongly applied in north-west Europe (Kukla 1977). Other names have been given to this interglacial; in the deep-ocean record the stage is referred to as Stage X or Stage 5. It has been dated mostly by Uranium/Thorium as lasting from about 125 000 to 80 000 B.P. The dates and the fluctuations will be discussed below.

The Eemian was preceded by a glacial stage known in the Alps as Riss and in North Europe as Saale (Warthe), during which there were one or two interstadials perhaps of interglacial rank; dates are uncertain. The Eemian was followed by the last glaciation, Würm or Weichsel, which contained two well-defined interstadials less warm than today and several minor fluctuations, and it lasted from soon after 80 000 to 10 000 B.P. The Eemian interglacial began with very rapid warming (Shackleton 1969, Ruddiman 1977a) and ended with very rapid cooling (Lalou *et al.*, 1971, McIntyre *et al.*, 1972). I avoid the presumed equivalence of the North American Sangamon, since Cooke (1973) has suggested that the Sangamon is much older and that the period 125 000–80 000 B.P. was an interstadial of the last or Wisconsin glaciation.

I refer to the three warm peaks of Eem as Eem I, the oldest, Eem II and Eem III. Other names have been given: for example Barbados III, II and I; Stages 5 e-a for deep-ocean cores; for the pollen-record Q,R,S in Macedonia (Wijmstra 1969);

Eem, St. Germain I and II in the Vosges (Woillard 1978).

Far more confusing has been the pot-pourri of names and dates given to support varying theories of climatic sequence. It is generally agreed that the whole Eem lies beyond the range of radiocarbon, but extreme finite dates of about 68 000, 64 000 and 60 000 (Woillard 1978) have been obtained for the first Würm interstadial: three peaks existed, Amersfoort, Brörup — the warmest — and Odderade. It is also agreed that molluscs are liable to contamination, so high finite dates on them may be invalid. Most thorium dates have statistical errors of 10 000 years or more so cannot be used for assignation to any stage as short as an interstadial. Corals are used, but molluscs are chemically suspect (Kaufmann 1971). Sequences of pollen and of stable isotopes in deep-sea cores indicate four stages of decreasing warmth separated by colder stages; this pattern suits the sequence Eem I–III and Brörup. But contrary to Shotton (Shackleton 1977a), French scholars have challenged the finite dates of the Brörup complex and have moved Brörup back to what I call Eem II and/or III; so Duplessy (1976, cp. Matthews 1973) equates his Eem with my Eem I, Amersfoort with my Eem II and Brörup-Odderade with my Eem III. Möerner (1972a, b) starts the Würm at the end of my Eem II and equates my Eem III with Brörup. Confusion has reigned also in the Mediterranean nomenclature. Three stages have been named (Bonifay and Mars 1959): Tyrrhenian I or Paleotyrrhenian which is nearly always pre-Eem; Tyrrhenian II or Eutyrrhenian, probably my Eem I; Tyrrhenian III or Neotyrrhenian which is almost certainly Eem II or III but frequently defined as a Würm interstadial (e.g. De Lumley 1976: 311–25). Kéraudren

(1970–2) rejects the Paleotyrrenian, and Perthuisot (1972) jumbles up the nomenclature. A further source of confusion is the transference of names from the emerging Moroccan Atlantic coast (Angelier *et al.*, 1976) to the much less stable Mediterranean coast of Morocco and Algeria.

THE SOUTH CAPE

In estuaries of the South Cape between Coega and Mossel Bay and apparently as far west as Arniston beds occur with warm water fauna at peak altitudes of +4–+9 m. Some have probably been eroded, and all would have been laid down under water, so M.S.L. would have been over +9 m and high water (H.W.) about +10 m. In addition to many modern species of mollusc these beds have yielded several species which today live in the tropics:

Cerithium scabridum rufonodulosum (Gulf of Oman to Mascarenes)

Pitar madecassinus (Natal)

Paphia textilis (Natal)

Rhinoclavis kochi (Natal)

Anodonta edentula (Natal)

Mactra ovalina (Natal)

Tapes sulcarius (Indo-Pacific)

Pseudostomatella orbiculata (Indo-Pacific)

The beds have also yielded six species which today are found in West Africa but not in the South Cape (Tankard 1975; Kilburn and Tankard 1975) and several species now extinct:

Cantharidus suarezensis fultoni (formerly *Calliostoma mosselense*)

Monilea ponsonbyi

Diala infrasulcata

Pupa daviesi.

I have named this fauna the Swartkops fauna from several sites on the Swartkops River near Port Elizabeth.

Such beds have not been identified in all estuaries. Some such as Keurbooms River are very narrow; others, as perhaps Bietou River, have no exposures. In dredging the incised trench of the latter, none of the typical species were found (Schwarz 1899). Swartkops beds are unknown east of the Coega River where many estuaries are steep and narrow; only modern species occur in estuarine collections at +9 m from Richmond Strand and Kleinemonde and at +6 m at Port Alfred (Mountain 1962). Fauna of perhaps slightly warmer conditions than today's has been found at +9 m in the Great Fish estuary. Those species that today live north of Natal have not been found in the poorly exposed and decalcified estuarine beds at +6–+9 m in this province.

West of Mossel Bay molluscs now extinct or no longer in the area have been reported from estuarine beds at Sandvlei near Cape Town (Davies 1972: 277) and at Wortel Gat on the Klein River (Barnard 1962); but there are no typical members of the Swartkops fauna. Indurated estuarine beds

at the Breë mouth, probably Late Pleistocene, have yielded only modern species (Wybergh 1919). In the Western Cape a warm fauna occurs on open coast sites much older than Eemian; but the typical species are not the same, and their extinction is unconnected with the appearance of the Swartkops fauna. In estuaries between the Olifants River and Langebaan Lagoon at +5–+7 m there are several West African but no Indo-Pacific species. Warm water forms occur on ramparts at about +7 m at the mouth of Saldanha Bay (Tankard 1976).

On open coast sites in the South Cape where the top of the beach is traceable at about +9 m (i.e. M.S.L. about +8 m) only modern fauna is found except for single specimens from King Neptune, Ferreiratown and perhaps Frog Rock at Mossel Bay. There is confusion about the exposures at the last site and two shorelines may be mixed. I collected modern fauna and one archaic species from a beach up to +17.4 m; Goodwin (1933) claimed *Cantharidus suarezensis fultoni* from a beach up to +8.7 m. This site is not estuarine. Several other species in the South African Museum (Kilburn and Tankard 1975) may have come from somewhere in the general district and not specifically from Frog Rock.

Artefacts have been found on few of the estuarine sites with Swartkops fauna. The most significant is Mouritzkraal at the Gamtoos mouth exposed in a road cutting (fig. 1).

I interpret the beds above 4.3 m (perhaps +6 m M.S.L.) as the tidal estuarine beach of a transgressing sea on which men at low tide collected *Donax* and left their artefacts. As the exposed surface of the water-laid beds may be eroded, maximum M.S.L. may have been +8 or +9 m. The artefacts are typically Middle Stone Age (fig. 2), so this industry must have been well established before the maximum of the transgression.

At Coega Salnova I found artefacts on and just above the surface of the estuarine beds at +7.2 m in red dune sand (fig. 3). These are suggestive of a late Acheulian biface industry rather than of the Middle Stone Age; but as in Europe, there must have been a transitional period when small bifaces were current along with Middle Stone Age flake and blade tools. There are two small bifaces from a gravel at +9 m at Gibraltar Rock on the Great Fish estuary (Davies 1971: fig. 6:2).

At the mouth of the Klein Brak River a shelly indurated sand is exposed up to +2.5 m. I found only modern fauna; but Haughton (1937) reports, apparently from the same bed, one Swartkops species. The sand is probably conformable with the lagoon deposits 3 km inland which rise to +8 m and contain abundant Swartkops fauna. With the sand at the mouth I found a lightly rolled core, probably Middle Stone Age (fig. 4).

Evidence from other sites is less definite. In the caves at Die Kelders and Klasies River lower, Middle Stone Age remains overlay an 8-metre terrace, not necessarily conformably. At Redhouse I

above
flood - plain,
m.

5.1

5.0

4.9

4.8

4.7

4.6

4.5

4.4

4.3

rather gritty

very fine

sand

White dune - sand, no shells
? Erosion - surface

Harder sand

many Assiminea

2 sharp flakes, a few Donax

Many Assiminea

Fine water - laid sand, many very small
Assiminea and other mollusc fragments

Soft sand, flakes, cores, set pebbles
many Donax serra

Varved water - laid silts and sands
Scattered shells, incl. Loripes liratula
(Swartkops - fauna)

BASE NOT EXPOSED

MOURITZKRAAL, GAMTOOS MOUTH, SECTION

Flood - plain estimated 1.5 - 2 m above m.s.l.

Figure 1.

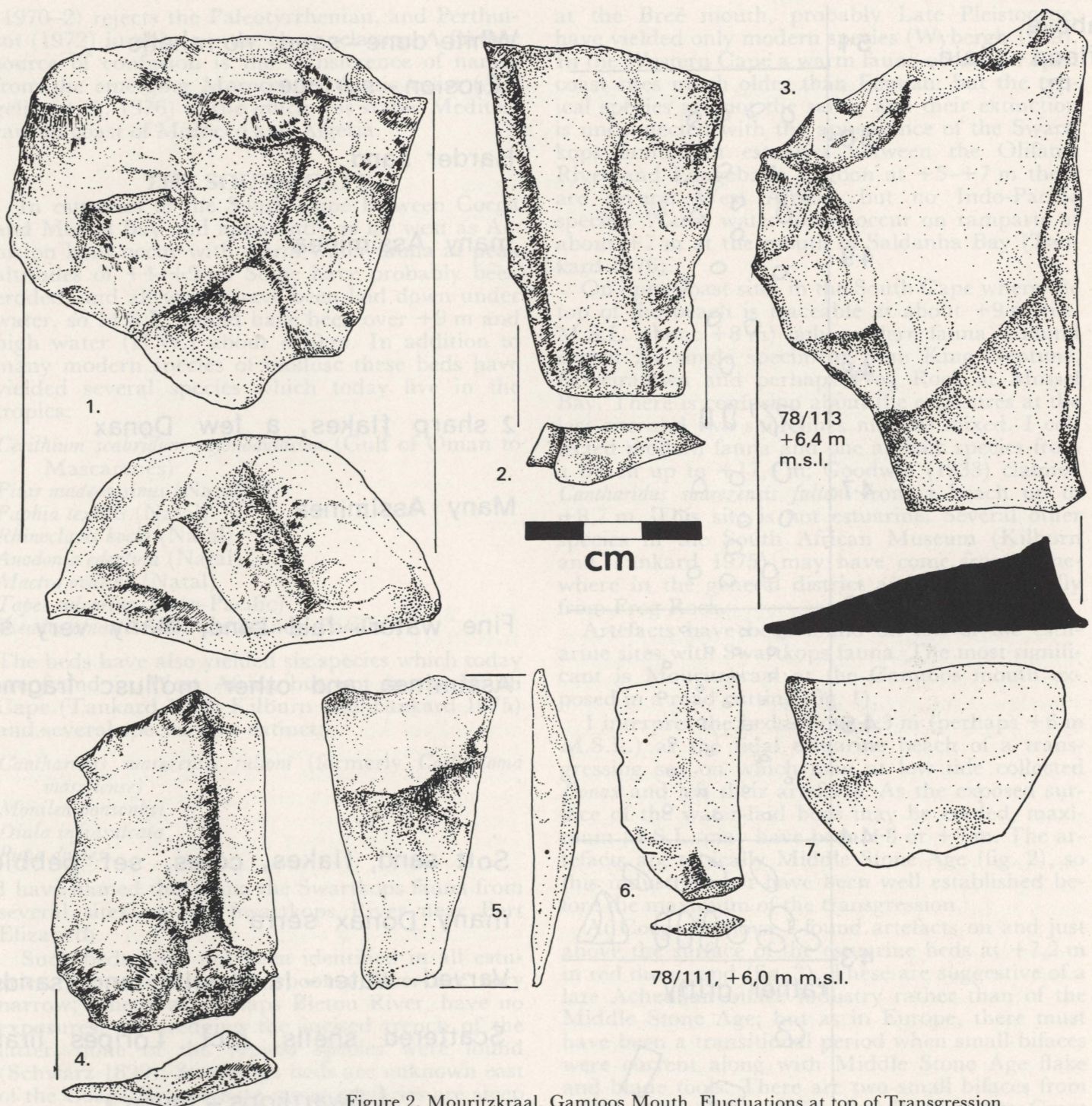


Figure 2. Mouritzkraal, Gamtoos Mouth. Fluctuations at top of Transgression.

found Middle Stone Age pieces in sand above but not on the estuarine clay. In a shingle-bar up to +9 m at the mouth of the Bietou River Macfarlane (1958) claimed to have found rolled Middle Stone Age flakes and an unrolled cleaver that should have been Acheulian; it may have been derived, and this author's reports are particularly unsystematic. Volman (1978) reports Middle Stone Age artefacts from a midden on a rock terrace at +8 m at Sea Harvest, Saldanha, but the terrace is probably Early-Middle Pleistocene (Kilburn and Tankard 1975: 214).

Numerous wave cut platforms at +8–+9 m are known on the open coasts of the South Cape; some carry pebbles, modern species of mollusc and sand. Artefacts are scarce. In general they are unrolled Middle Stone Age pieces subsequent, therefore, to the maximum transgression; for instance on storm ridges at +7,5 m at Cape Hangklip (Mabbutt 1954). Rolled Middle Stone Age flakes occur on a beach at Nahoon Point which passes beneath a Late Pleistocene dune so that its crest is concealed; perhaps also on a storm ridge about +5 m at Kidds Beach (Macfarlane 1937: 900–1).

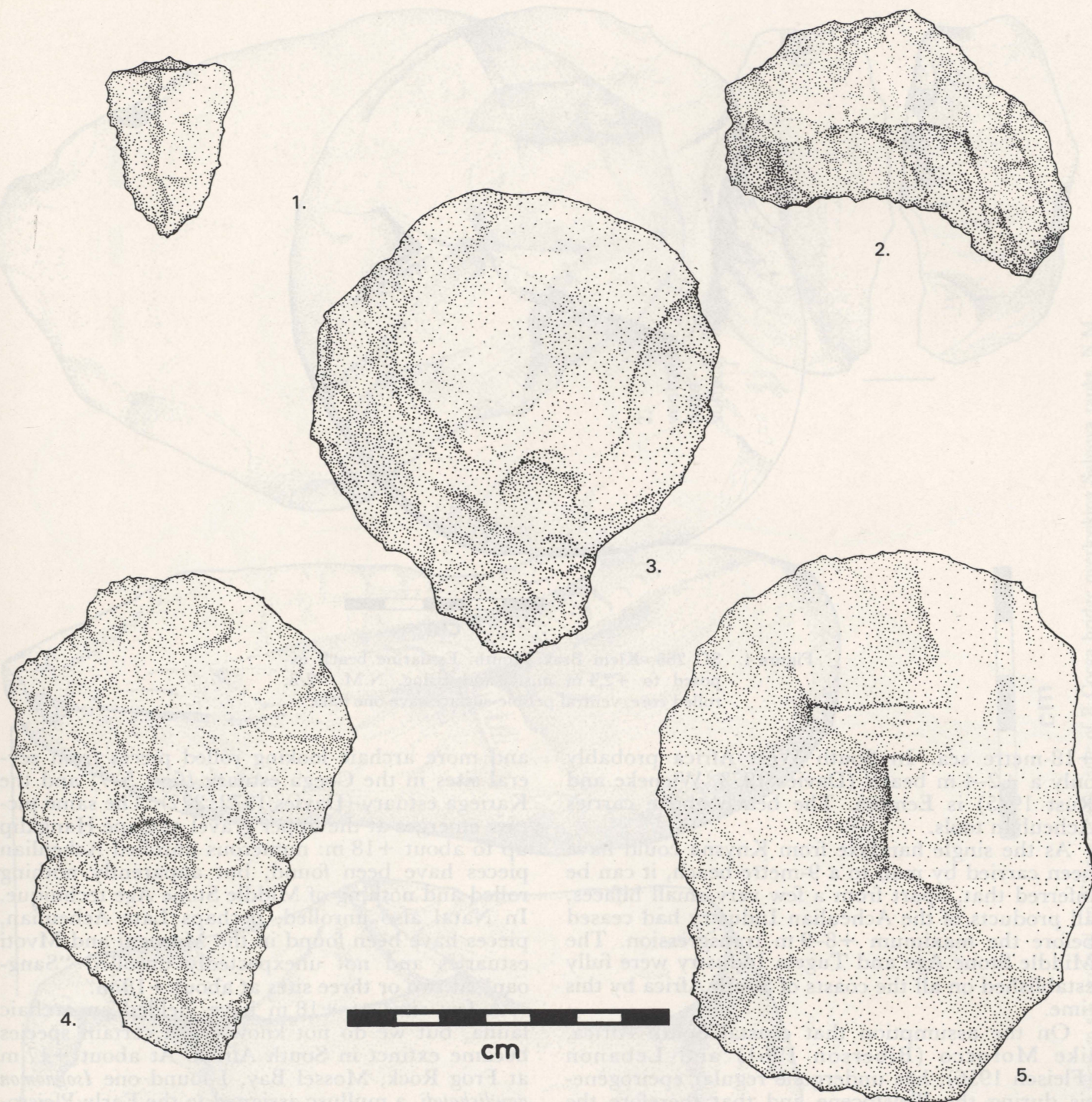


Figure 3. Coegasmond Salnova
Artefacts at base of red sand, resting at +7,17 m.
m.s.l. on top estuarine bed with Swartkops fauna.

Similarly, in Natal rolled flakes were cemented to a beach ridge up to +6 m at Tiger Rocks (Beater 1967); small rolled bifaces comparable to those from Coega Salnova were found at +5,5 m in an estuarine gravel at Ngane Mouth (Davies 1970: figs. 41–2); near Durban there were lightly rolled and unrolled picks of the Tugela industry, which I regard as an early facies of the Middle Stone Age. Rolled bifaces have been found in similar gravels in the South Cape at Kleinemonde and Pletten-

berg Bay (Davies 1972: figs. 11, 13); they are older than the marine beds and may have been derived from a continental surface. Unrolled bifaces are doubtfully reported from Plettenberg Bay and Knysna East (Mortelmans 1945), and better authenticated from a 9-metre terrace near the Hluhluwe mouth in Zululand (Davies 1970: 433). I would hesitate to date the latter assemblage as late as the Tugela Industry. Considering the altitude, it is possible that this is an estuarine gravel of the

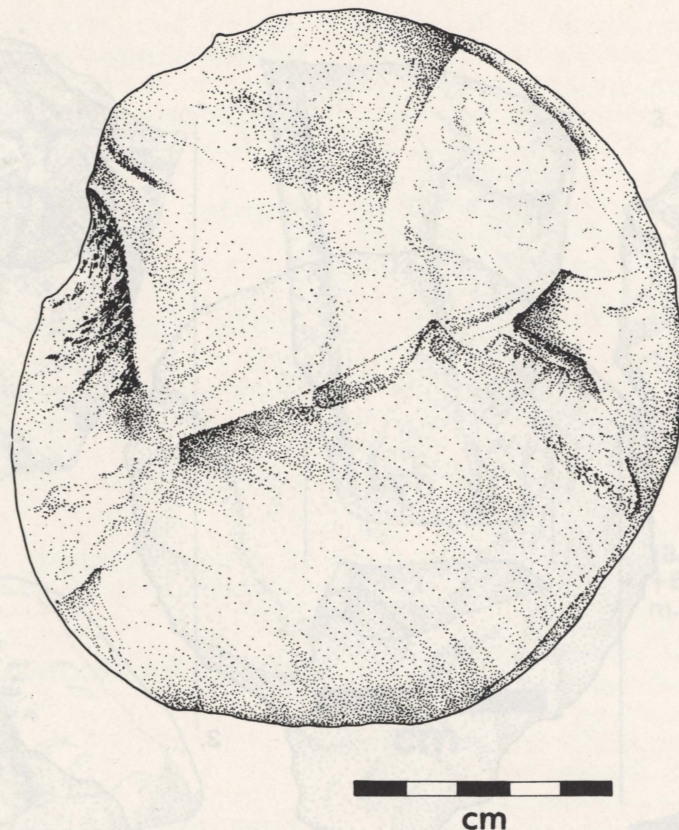


Figure 4. SC 268, Klein Brak Mouth: Estuarine beach exposed to +2,4 m m.s.l. and rising. N.M. 72/3, rolled core, ventral pebble-surface save one flake.

+18-metre sea. In South West Africa probably only a +2–4 m beach (Davies 1973, Wieneke and Rust 1975) is Eemian. The beach above carries Acheulian tools.

As the single handaxe from Knysna could have been carried by man to a 9-metre beach, it can be inferred that, apart from a few very small bifaces, all products of the Acheulian Industry had ceased before the maximum +8–9 m transgression. The Middle Stone Age and Tugela Industry were fully established on all the coasts of South Africa by this time.

On the assumption that coastal South Africa, like Morocco (Biberson 1961) and Lebanon (Fleisch 1956), has undergone regular epeirogenesis during the Pleistocene and that therefore the crest of each transgression is older than that of the one below it, I have identified both estuarine and open shore exposures at +15–21 m. There is no evidence for or against a theory by Butzer and Helgren that Nelson's Bay Cave at +18 m was opened in the Early Eem (Klein 1972). Some reports on artefacts from estuarine gravels at these levels seem to indicate that they were Acheulian, such as New Brighton (Breuil MS: 3) and the Bietou estuary (Macfarlane 1938: 239, S.A. Mus. 6833). Elsewhere undoubted Acheulian pieces have been found: probably unrolled Late Acheulian at Duineplaas (Davies 1972: 237), Gouritz Mouth, Goukamma Drift and perhaps the Harveyton Terrace on Sundays River (Ruddock 1957);

and more archaic looking rolled pieces from several sites in the Coega estuary (figs. 5–7) and the Kariega estuary (Davies 1972: 227). The same picture emerges at the upper gravel at Cape Hangklip up to about +18 m: numerous unrolled Acheulian pieces have been found, but apparently nothing rolled and nothing of Middle Stone Age technique. In Natal also unrolled, perhaps Late Acheulian, pieces have been found in the Mzeneni and Mvoti estuaries and not unexpectedly unrolled "Sangoan" at two or three sites at about +18 m.

A few sites at +18 m have yielded an archaic fauna, but we do not know when certain species became extinct in South Africa. At about +17 m at Frog Rock, Mossel Bay, I found one *Isognomon gaudichaudi*, a mollusc assigned to the Early Pleistocene and probably also to the Mio-Pliocene. I found *Pitar schwarzi* beneath and perhaps earlier than the +18-metre gravel on the National Road at Coega in a fine silt; this belongs to the early part of the Alexandria Formation, probably Late Miocene to early Middle Pleistocene. A vague and inaccurate report (Engelbrecht *et al.*, 1962) of a mollusc collection from Fishwater Flats on the Swartkops River, said to have been at +9 m, lists several extinct species. I have not identified the site; it may have been a pit exploiting Cretaceous, Miocene and Quaternary beds near the old Grahamstown road.

On the other hand, sites far up estuaries near Port Elizabeth have yielded a few specimens of

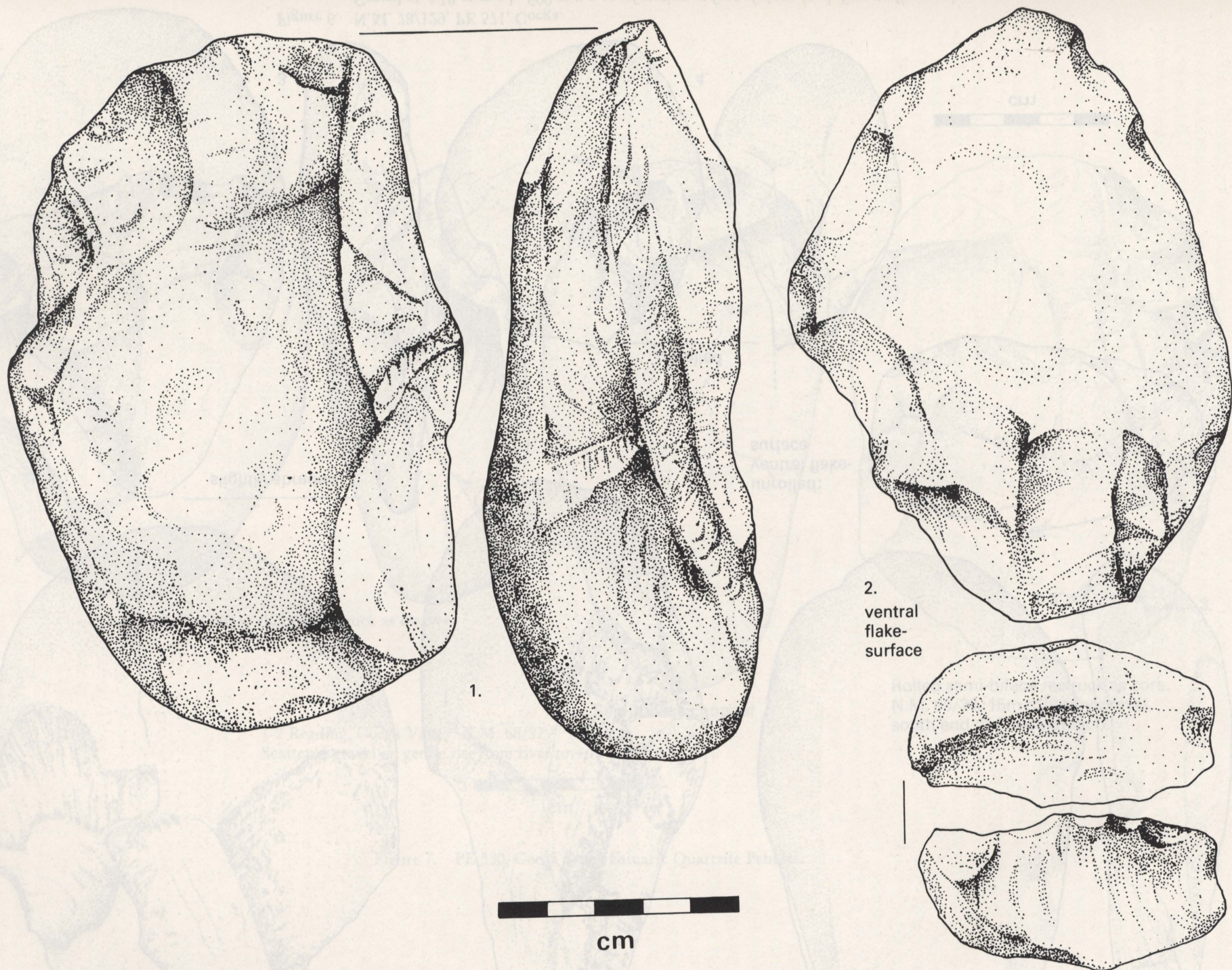


Figure 5. PE 535, Gravel at +18 m m.s.l. exposed on N2 road, west side of R Coega bridge overlooking Salnova tanks. N.M. 68/40, Rolled artefacts in gravel.

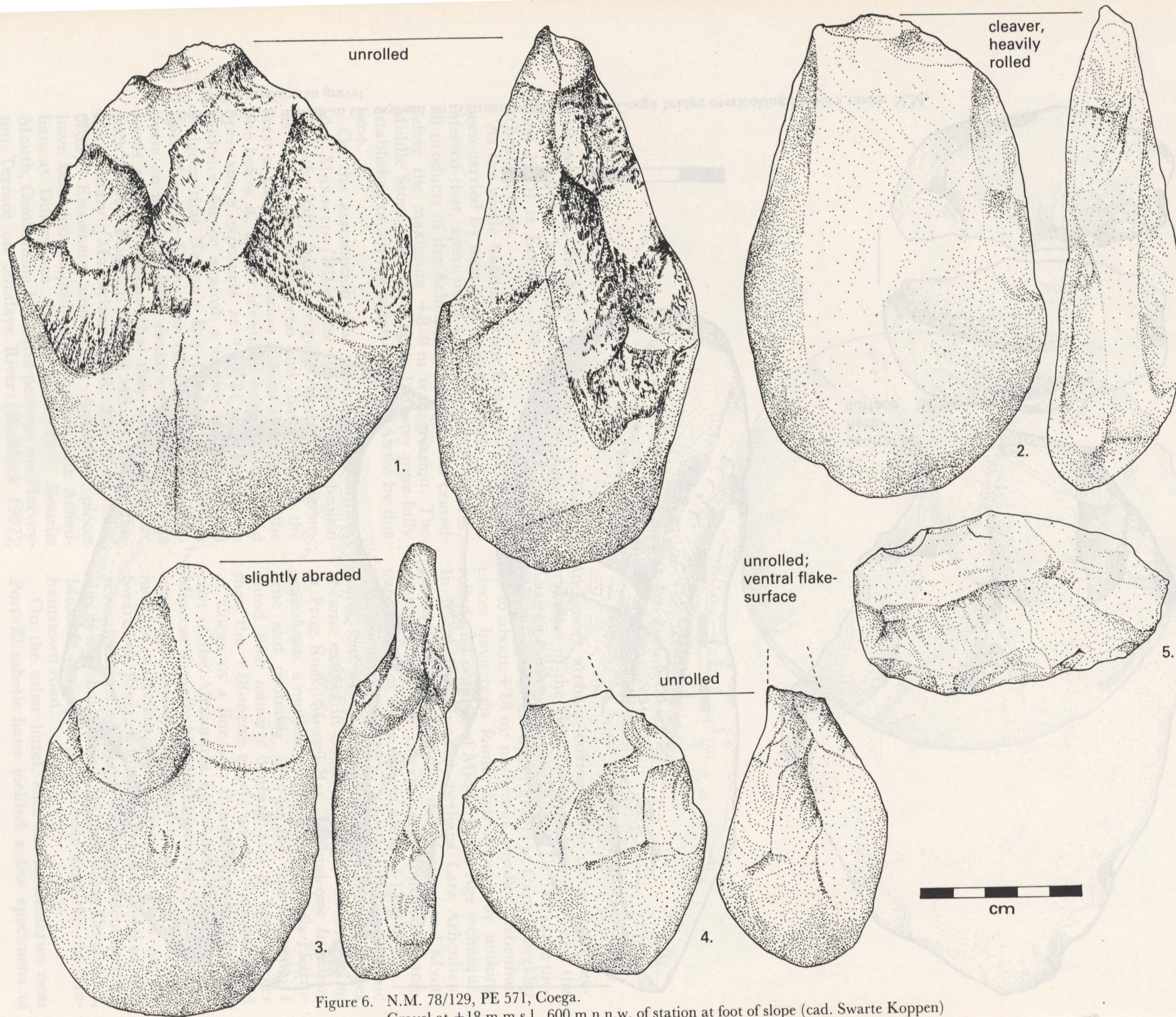
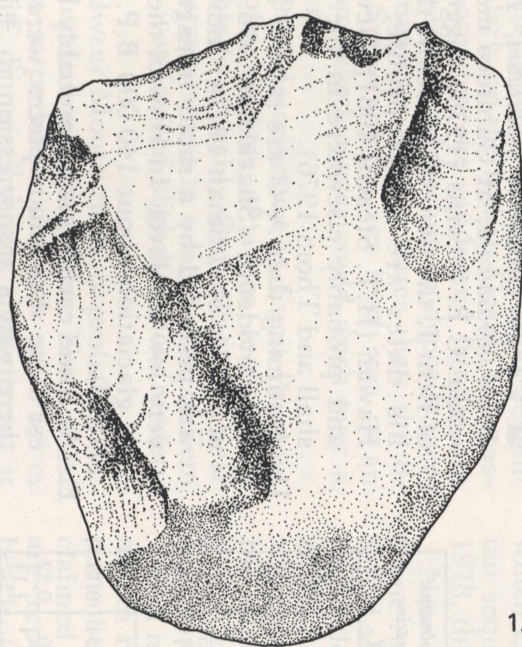
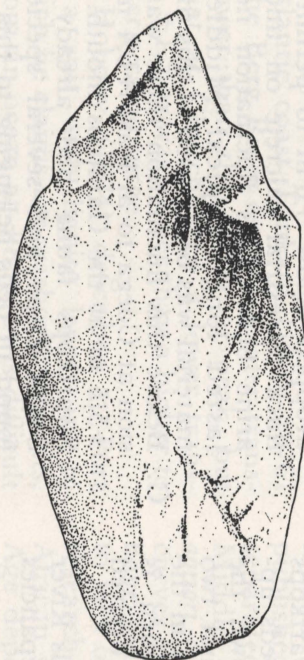


Figure 6. N.M. 78/129, PE 571, Coega.
Gravel at +18 m m.s.l., 600 m n.n.w. of station at foot of slope (cad. Swarte Koppen)



1.

Rolled biface chopper restruck as cleaver



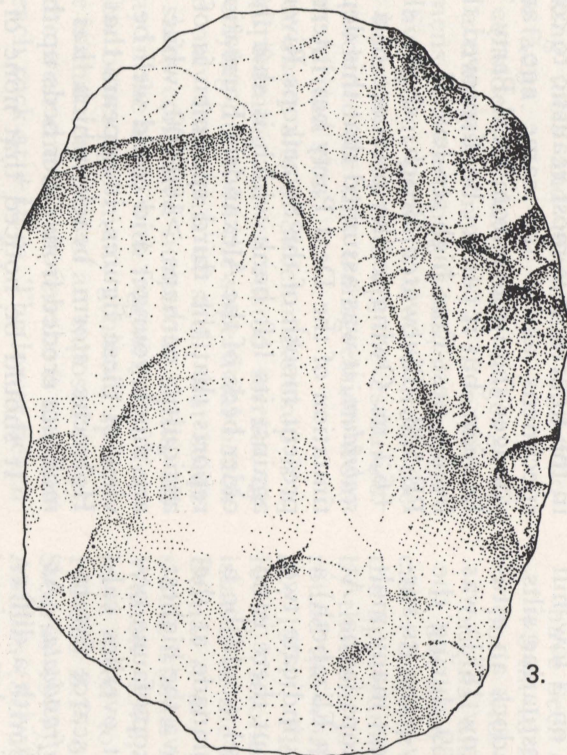
2.

Rolled

Semi-biface chopper

cm

1-2 Reading, Coega Valley. N.M. 68/37
Scattered gravel on gentle rise from river to +15 m m.s.l.



3.

Rolled semi-biface restruck as core.
N.M. 68/38. 15m tributary gravel,
south end of Coega Station.

Figure 7. PE 530, Coega Fossil Estuary: Quartzite Pebbles.

Swartkops fauna. West of Redhouse on a low hill at about +13 m are a few shells in estuarine silts, including *Cerithium scabridum*. At Cradock an estuarine bed recorded a century ago (Stow 1871) was re-exposed for a short while in 1969 during the construction of the Port Elizabeth by-pass; its surface is at +12,7 m. I was able to collect many molluscs, including species of the Swartkops fauna. At Shark River (now Happy Valley, Port Elizabeth) a very confused account by Stow may indicate two marine levels at +18 m and lower; but there is no analysis of the fauna. The lower level would be a +9–10 m beach on Humewood Esplanade at the mouth of the stream. At Coega Salnova the highest estuarine bed with abundant Swartkops fauna occurs up to +7,15 m. At +6,37 m it overlies calcrete which caps sands containing scarce Swartkops species, especially *Diala infrasulcata*. At +4,34 m another calcrete caps a bed with a different fauna not yet analysed except for the extinct *Duplicaria otiosa*; this lowest bed may well have risen inland to >+9 m. In the Kariëga estuary at +18 m is an entirely modern fauna save for one species today not found west of East London.

I previously dated the +18-metre level to Eem I and the widespread beds with Swartkops fauna at +9 m to Eem II. No suitable radiometric test was possible. However, I recently asked Dr. G.H. Miller of Boulder, Colorado, to make racemisation-tests on *Donax serra* from three sites in the Swartkops valley (table 1). He regards the ratio of D-alloisoleucine to L-isoleucine in both free and combined fractions as the most reliable figures for dating:

PE-557, Deal Party, bar at mouth of Swartkops River, contemporary with the +8-metre beds upstream and containing shells washed down the estuary, rising to about +6,7 m. "The first two specimens may be 130 000 B.P. or perhaps in the range 160 000–220 000. The third specimen is rather older, probably 160 000." It may be derived from an older beach.

PE-553, Cradock, estuarine bed up Papkuils River at +12,7 m. "Though there are some discrepancies

in the figures, it is most realistic to consider all the specimens as of the same age, and markedly younger than those from Deal Party. They may be Eemian, but it cannot be disproved that they date from a post-Eem high sea-level."

PE-528, Bluewater Beach, shelly shingle up to +6,1 m. Owing to the presence of a few *Cerithium scabridum*, it was assumed that this deposit is a continuation of the Deal Party bar interrupted by the present mouth of the Swartkops River and banked against its left bank which is sharply incised into older beds of the Alexandria Formation. Dr. Miller reports that the third specimen is of considerable antiquity, perhaps >160 000, while the first two are much younger and could well be Holocene. In view of these figures, it appears that the bed is a Holocene storm beach which has incorporated molluscs eroded from older beds up the valley.

It should be noticed that none of the analysed specimens were of typical Swartkops species. These were too rare from the Cradock site to be spared for dating. *Donax serra* is common today and probably has been for a long time past in the South Cape. Furthermore, racemisation dating is still on trial and is not yet as dependable as radio-carbon.

Generally, the above evidence permits the following conclusions:

- A. A transgression to +8–9 m with some estuarine beds rather lower contains abundant warm water Swartkops fauna in estuaries but hardly any specimens on the open coast.
- B. Previous to this transgression there had been a fluctuation; at Coega Salnova sea level dropped below +6 m to permit formation of thick terrestrial calcrete on underlying estuarine beds. This fluctuation need not have lasted long. Typical Middle Stone Age material was being used at this time.
- C. Before this fluctuation there was a transgression at Coega to at least +6,4 m and at least +5,5 m at the Gamtoos mouth. Warm water Swartkops fauna had already reached the South Cape and several species have been found in beds belonging to this transgression: at Coega *Cerithium scabridum*, *Loripes liratulula*, *Diala infrasulcata*; at Gamtoos mouth *Loripes liratulula*. C.E. Stearns (1976) suggests two peaks of Eem I, the first <3 m below the second, but his dates are unacceptable; so again on Hawaii (H.T. Stearns 1961), New South Wales and probably elsewhere in the Pacific (Marshall and Thom 1976).
- D. Assuming that A–C are part of Eem I, world-wide evidence (Shackleton 1969, Mangion *et al.*, 1974, Ruddiman 1977a) indicates that this was preceded by a rapid transgression from a very low sea level. In Hawaii there was a peak of glaciation about 140 000 B.P. (Porter *et al.*, 1977).
- E. At some earlier stage, probably before the finest Late Acheulian pieces were being made, there was a transgression to +18 m with ar-

TABLE 1

Site	Altitude m.s.l.	% Free Amino-acids			D-alloisoleucine: L-isoleucine	
		valine	isoleucine	leucine	combined	free
DEAL PARTY bar	6,7	66	42	67	0,64	1,09
		96	65	95	0,81	1,26
		70	43	71	0,67	1,18
CRADOCK estuarine silt	12,7	69	42	67	0,41 0,45	0,87
		56	25	42	0,41 0,41	0,90
		57	24	46	0,31	0,87
BLUEWATER BEACH storm-beach	7,5	3	2	4	0,06 0,054	0,17
					0,054	
		12	8	14	0,10 0,10	0,32
		95	72	93	0,78	1,14

chaic looking tools and remnants of a Plio-Pleistocene fauna.

- F. Probably considerably later than stages A–C there was a transgression to +12–15 m with a few specimens of Swartkops fauna, not necessarily still living but perhaps eroded from the +8-metre beds and carried up the estuaries. There is evidence for this transgression from other South African sites:
1. At the open-shore site of Skoenmakerskop is a beach sand forming an encrusted terrace at +15 m overlying dune. In the superficial beach sand were only fragments of shell, but some displaced slabs contained numerous shells, all living today in the area, with fragments of Vermetid, a few bones and many echinoid spines. The whole is characteristic of an exposed rocky coast. At the west end of this terrace is another crust of beach rock at +18 m. The lower beach rock could equate with the F-beds.
2. Confused accounts (Laidler 1933, Macfarlane 1937) of a former exposure at Blind River, East London, describe a boulder bed from +9,0 to +11,58 m, perhaps overlain by white marine sand to +13,7 m, and overlying rolled Middle Stone Age flakes between +8 and +9 m. No significant fauna was found. It would appear that Transgression A overran a surface with Middle Stone Age and was perhaps overrun by Transgression F. The boulder bed should correlate with the cemented beach beneath Nahoon Point 1 km to the east. This beach is exposed up to +1,5 m and passes beneath a dune dated by radiocarbon about 30 000 B.P. (Mountain 1966); it rests on hard aeolianite.
3. On the Atlantic coast Tankard (1975, 1976) found in the Berg River estuary a later transgression lower than the earlier or peak, but claimed that at Churchhaven a lower transgression to +1,5 m was earlier than a higher to >+5 m after a rapid surge.
4. In Natal Hobday (1974) describes at Port Durnford a spit with lignite lenses up to +18 m which he claims are washover deposits, perhaps from an ocean at +8 m. It is difficult to believe that waves 10 m high could be generated regularly on the Indian Ocean. It is easier to suppose that the sands and lignites are largely sub-aerial and freshwater deposits, perhaps contemporary with or later than the 8-metre sea. Subsequently, sea level rose to an altitude from which waves could wash over a bar at +18 m.
5. Hobday (1976) describes on St. Lucia Promontory three fluctuations of a sea level up to +5,3 m. This is probably Eem I because near Durban it appears that in a later stage of Eem a platform was incised slightly below modern M.S.L.
6. At Mbokadweni Mouth there is probably evidence for fluctuation during Eem. The highest exposure is a potholed platform at +6,3 m with no cliff. Since all beach deposits on it

have been eroded, sea level was probably up to +8 m. In front of it at one point is a small deposit with modern fauna up to +2,3 m. The original altitude is unknown.

It has been widely assumed that the South African +8-metre stage A–C is Eem I because this is the approximate level of the peak of Eem I dated by thorium to about 125 000 B.P. at tropical sites round the world; for example in Jamaica (Moore *et al.*, 1974), Florida (Osmond *et al.*, 1965, Lalou 1971), Victoria (Gill and Amin 1975), some stable islands in the Pacific (Marshall and Launay 1978, Bernat *et al.*, 1976, Sterns H.T. 1974) and a few stable islands in the Indian Ocean (Thomson and Walton 1972, Battistini 1976b). Some authors have tried to put back the peak of Eem I to 140 000 B.P. or earlier (Evans 1971; Dai Pra and Stearns 1977); a few dates suggest this also from Antilles (Schubert and Szabo 1978), Tonga (Taylor and Bloom 1977) and New South Wales (Marshall and Thom 1976). But the large statistical errors of thorium-dating (cf. Veeh 1966) incline one to discount occasional markedly aberrant dates (Shackleton 1971); the 20 000 years separation of Reef VIIb from VIIa at Huon Peninsula can be bridged within the statistical limits (Chappell 1974a).

In view of the emergence of the South African coast through the Pleistocene, the identification of the +8-metre stage with Eem I needs to be proved. If it is correct, emergence had ceased by the Eemian stage. At Klasies River Cave bones on the floor at +8 m were dated by racemisation to 89 000–110 000 B.P. (Bada and Deems 1975). This method is under trial, and, until a full report is published, it cannot be proved what unconformity separated the incision of the cave floor from the Middle Stone Age occupation. Butzer's (1978) *a priori* curve of sea level in Eem contradicts all curves from the rest of the world. Thorium-dates have not been obtained from South Africa owing to lack of suitable material, and no archaeological research has been done on the coral fringed East African shorelines. At Border Cave Middle Stone Age deposits occur below the base of a sequence which climatically may be equated with the Eemian sequences of deep sea cores (Beaumont *et al.*, 1978, this volume, Butzer *et al.*, 1978).

Near Ziway in Ethiopia a typologically Middle Stone Age collection has been dated by potassium-argon as older than $181\,000 \pm 6\,000$ B.P. and at a higher level as $149\,000 \pm 13\,000$ B.P. (Wendorf and Schild 1974, Wendorf *et al.*, 1975). These dates are dubious, owing to the very long half life of K_{40} . But if a Middle Stone Age industry was established in the South Cape before 125 000 B.P., the Ethiopian dates do not look outrageous.

It is not certain whether Middle Stone Age techniques reached North Africa before or during any part of the Eem interglacial. Hand axes and pieces claimed to be Mousterian or Acheulian tradition are reported from Morocco on the Harounian beach (+18 m) and beneath the Uljian beach

(+8 m) (Choubert 1962, Biberson 1963). Camps (1974: 27) lists two sites in western Algeria where a very primitive unrolled Aterian industry occurs in a *Strombus* beach; but at Falaises Rouges the Aterian lay in a silt well above the beach dated to $140\,000 \pm 10\,000$ B.P., and the Aterian level was dated to $31\,800 \pm 1\,900$ B.P. (Roubet 1969). There was similar material at La Calle (Morel 1967). I have suggested that the artefacts could have been deposited on the beach between its formation and consolidation and worked down into it (Davies 1964: 41–46).

In Lebanon Mousterian pieces occur between two *Strombus* beaches which may be Eem I and II (Sanlaville 1973). The general opinion in Lebanon and Israel is that the Mousterian started at the beginning of Würm I (Wendorf and Marks 1975), but this seems based on a short chronology which equates the Neotyrrenian with a Würm interstadial.

The evidence from Western Europe is very vague (Bourdier 1969, Agache 1969). Mousterian probably occurs on, but not below, Eem deposits. However, Shackley (1977) reports five sites in England where Mousterian of Acheulian tradition occurs within the Eem deposits at +7.5 m. He dates this beach as Eem III, but its altitude suggests an earlier stage of the Eemian.

So there seems no longer to be any objection to the establishment of Middle Stone Age industries and techniques in South Africa before 125 000 B.P., provided that it is admitted that the Tugela or "Natal Sangoan" Industry is a coastal facies of the Middle Stone Age and is not part of the Acheulian complex. Occasional pieces of Late Acheulian type may have been made or collected by the Tugela people, since such artefacts have been found stratigraphically associated with the Tugela Industry.

Since the Tugela Industry occurs regularly on the older red dunes of the Berea Formation in Natal, and not beneath them (Davies 1976), these dunes must be redated as pre-Eem. They were probably originally calcified, but in Eem I the critical point of warmth and humidity was reached to induce almost complete decalcification.

In the second stage of dune building a calcified cordon was constructed in places nearer the sea, for example Durban Bluff and St. Lucia Promontory. The cordon is still largely calcified. At the same time red sand was probably derived by colluviation or by wind action from the older dune and deposited on the +8-metre terrace and on artefacts of the Tugela Industry. The date of this stage may be after Eem III.

HIGH SEA LEVEL AFTER EEM I

An explanation and date for the Stage F transgression to +12–15 m is still required. The racemisation figures from Cradock imply that it took place a good deal later than Stages A–C, so was not connected with the pre-Eem +18-metre transgression.

I have given some evidence from Natal for this stage. In South Majorca (Butzer and Cuerda 1962) and Lebanon (Sanlaville 1969) a lower transgression is older than a higher, but these may be fluctuations towards the peak of Eem I.

I assume that the Quaternary uplift of the South African coastlands has until the Eem been fairly constant without sharp reversals of the trend. If so, the high sea levels of Stages A–C and F must be due to rise in absolute ocean level. Stages A–C can be explained by the warmth of Eem I, which is documented mainly from deep sea cores (McIntyre *et al.*, 1972) and pollen sequences from temperate Europe (Woillard 1978, Starkel 1977). Stage F cannot be thus explained, since there is much evidence that Eem II and III were cooler than Eem I. Therefore, Transgression F implies a fairly rapid surge which has left traces mainly in sheltered estuaries.

Such a surge could be a tidal wave due to volcanic explosion, but no marker ash layer exists in the South Indian Ocean. It would also be too rapid to leave more than a veneer of silts and molluscs washed up an estuary. At Cradock I could examine only dumps and ditches left by bulldozers. There seemed to have been not less than 30 cm of silt *in situ*, and Stow (1871) implies banks of considerable thickness which must have accumulated over decades or longer.

Wilson (1964, 1969) and Hollin (1965, 1969, 1970, 1972, 1977) have proposed that the Eem interglacial ended in a rapid ice surge from Antarctica which temporarily raised sea level to near +18 m. This theory has been generally rejected (Chappell and Thom 1978) but cautiously approved by Kennett and Huddleston (1972) and Richards (1972) to explain certain poorly dated faunal anomalies in North America. It would also explain anomalous faunal stratigraphy in the Baltic and Netherlands (Van der Heide 1961) and the fact that in south-east England the highest transgression to about +15 m was a good deal later than the maximum warmth indicated by the pollen curve (Sparks and West 1972, West *et al.*, 1964).

A major difficulty is that this theory presupposes a single peak of the Eem interglacial, and Wilson ties the surge to an isolation minimum about 115 000 B.P. It therefore does not fit the racemisation figures from Port Elizabeth which imply that the +12–15 metre transgression was some 40 000 years later than the peak of Eem I (one third of the time 125 000–0 B.P.). Thus the ice-surge might be dated at the end of Eem II (94 000 B.P.) or better of Eem III (79 000 B.P.) but not of Eem I. Wilson and Hollin do not suggest what happened in these later interstadials of Eem and do not show an unconformity between the Eem I marine sequence and the overlying freshwater beds in the Thames estuary. Knox (1969) makes it clear that the highest Eemian sea level was at the very end of Eem after a climatic deterioration in which broad-leaved trees were re-

placed by conifers. Furthermore, there is no evidence from cores in the southern oceans for a great diffusion of Antarctic icebergs (Thom 1973).

Another possible explanation for the rise of sea level in Stage F in the South Cape and possibly elsewhere could be that after the Eem I peak, during the considerable cooling of the Eem stadials, ice accumulated in Antarctica, and the ice-sheet became thicker and wider as sea level dropped. This would slowly cause glacio-isostatic depression under the continent. At the same time the process of ocean deformation described by Clark *et al.* (1978) would operate; and, if the focus was first in Antarctica before the northern ice reached ocean coasts, one may reverse their map (Clark *et al.*, 1978: fig. 15) and expect transgression about 30–40° S and 40–60° N until ice accumulation removed so much water that sea level dropped again. Much slower rheology of the magma would later cause the land to emerge at these latitudes and so depress the coastlands. This could have taken place at the end of Eem III or in Würm I, which would fit the racemisation figures.

This solution may be acceptable until we know more about rheological processes during an anaglacial period.

EEMIAN CURVE OF SEA LEVEL

Within the Eem as I have defined it, there is dispute on the sea level curve, due to lack of agreement on methods of temperature evaluation, quantity of global ice and the use of foraminifera and molluscs as indicators of water temperature (Ericson *et al.*, 1961, 1964, Kennet and Huddleston 1972, Zinsmeister 1974). It is widely believed that the O_{18} content of molluscs, foraminifera and corals is directly correlated with global ice (Shackleton 1977a). But Mörner (1974b) points out that it depends on the quantity in ocean water, which is a mixture of several variables (Savin and Stehli 1974). Ocean water contaminated by melt water contains less O_{18} than ocean water elsewhere. Nor does ice-volume necessarily reflect temperature accurately. Very rapid cooling may traverse the temperature range so quickly where snow fall is abundant that no glaciers grow. It appears that in Ireland there was little glacier expansion in the Younger Dryas because temperature fell too fast (Mitchell 1977). Temperature charts deduced from speleothems seem markedly unreliable (Harmon *et al.*, 1978).

Several areas are quoted as standard indicators of sea level fluctuation during the Eem: Greenland, Barbados, New Guinea and California.

Camp Century ice core, Greenland

The base of the Greenland sequence was dated on a time scale which was subsequently reduced for unexplained reasons (Dansgaard *et al.*, 1971). Temperature changes were deduced from increase of O_{18} in warmer periods. The logic of this is not clear. O_{18} in the core should decrease with heavy falls of deficient snow, but these would occur to-

wards the end of an interstadial and would diminish as the North American ice sheet spread (Andrews *et al.*, 1974). The base of the core is compressed, and apparently the stratigraphy is mixed and valueless (Thompson 1976). Mörner (1974a) shows that the core cannot be used for the chronology of the Eem interglacial (cf. Kukla 1977).

Barbados

Calculations of absolute sea level from modern elevations of coral reef peaks on the slowly emerging island of Barbados have been used to construct a curve which is dated by thorium in the corals. Temperature has been estimated by O_{18} and global ice volume from temperature. It is claimed that down to -55 m polar ice had practically no effect on local temperature, so the O_{18} values are a reliable measure of global ice and of ocean level (Fairbanks and Matthews 1978, Matthews 1978). Dates of the calculated sea level curve are approximate, based on averages of a number of samples; statistical errors are 4 000–10 000 years (table 2). Dates by Broecker *et al.* (1968) and Ku (1968) vary within the statistical errors. Sea levels were the tops of the reefs about low water neap, i.e. about -2 m M.S.L. (Russell 1967).

TABLE 2
Eemian Neap Low-Tide Sea Levels
calculated from O_{18} at Barbados
(after Fairbanks, R.G. and Matthews, R.K., 1978:
Quat. Res. 10 181–96)

Stage	B.P.	Coral	Molluscs	M.S.L. (m)
6 nadir pre-Eem	135 000	-125		
5e peak Eem I	124 000	+5	+10	+7
5d nadir I-II	114 000	-71		
5c peak Eem II	103 000	-43	-28	-41
5b nadir II-III	92 000	-75		
5a peak Eem III	82 000	-42	-47	-40
4 nadir Würm I	69 000	-120		
Statistical errors 4 000–10 000 years				

These figures make assumptions which it is difficult to justify from other parts of the world. First, that local temperature varied little throughout the Eem. One would expect masses of global ice, mostly on land in the northern hemisphere, to have modified winds and currents in the tropical Atlantic even if the ice sheets had not spread far enough to introduce melt water into the Caribbean. Secondly, that the uplift of Barbados has been uniform. This is by no means proved. The reefs are warped and not at constant levels (Neumann 1971, Stearns C.E. 1976). A regression of 70 m should alter the isostatic pressure on the ocean floor and so lessen the uplift of ocean islands. Different calculations from Barbados (e.g. Steinen *et al.*, 1973) give very different figures for sea level except for Eem I which is widely accepted as around +8 m over much of the world.

Huon Peninsula, New Guinea

Uplift since the beginning of Eem has exposed a series of reefs in north New Guinea which have been dated (Chappell 1974a, b), and from modern altitudes contemporary sea level has been calculated on the supposition that reef building occurred only close to transgression peaks and that uplift has been constant (Bloom *et al.*, 1974). This is unlikely because the reefs are much faulted and are tilted both to the west and east (Veeh and Chappell 1970, Ruddiman *et al.*, 1977b). Dates are comparable with those from Barbados and California. Reefs V and VI are reasonably equated with Eem III and II; but for Reef VII there are two clusters of dates, about 117 000 and 140 000 B.P. By stretching these dates to the limits of their statistical errors, one can nearly combine them into a single phase about 126 000 B.P.

California

Recalculated dates from Palos Verdes (Szabo and Rosholt 1969, Ku and Kern 1974) indicate Eem peaks about 130 000, 104 000 and 86 000 B.P., with large statistical errors. Dates which can be correlated have been obtained from other sites on this coast. The area is tectonically active; though divergent present altitudes of the terraces are known, it is not possible to calculate contemporary sea levels.

General

There is good evidence that in stable areas in the tropics as far as 35° Lat. mean sea level in Eem I was about +8 m (Shackleton 1977b). A lower platform about +6 m in South Africa (Davies 1970, 1972) cannot be dated and may not belong to the Eemian. So global ice was in Eem I considerably less than today, and perhaps the ice sheet of west Antarctica broke up (Mercer 1978). Only at this stage did sub-tropical water in the Atlantic penetrate as far as 51° N (McIntyre *et al.*, 1972).

On the other hand, recent studies (Clark *et al.*, 1978) on the gravitational attraction of ocean water by an ice-field indicate geoid deformation of the ocean surface; and glacio-isostatic adjustment of the magma is a slow process which is not yet completed in the Arctic though we seem to be long past the peak of the present interglacial. In temperate and sub-polar regions these trends would work in opposition. At a given latitude, as an ice sheet retreated ocean level would first fall and then rise as magma flowed poleward from the sub-tropics, while in the tropics it would fall. It has been suggested that this would account for mid-Holocene sea levels at +2–4 m, for example the Nouakchottian in Mauritania and Senegal (Faure and Hébrard 1975), the South Cape (Davies 1972), Brazil (Fairbridge 1976) and south-east Australia (Gill 1970).

Based on the Blake Event in loess, Eem I is taken to have ended about 115 000 B.P. (Kukla and Koči 1972). Contradictory calculations have

been made regarding subsequent temperature curves on land and ocean and of sea level. Apparently oceans reacted differently, presumably according to currents, to geographical access from the Arctic and for reasons which are not understood. Moreover, dates by extrapolation and by thorium do not give the required accuracy.

In Eem I–II the north-east part of the Atlantic tropical gyre west of Africa was cooled 6–8°, while in the Sargasso Sea there was little difference between stadial and interstadial (Crowley 1976). On the disputed assumptions of regular uplift of Barbados and that the O_{18} curve can be correlated directly with accumulation of global ice (Shackleton and Opdyke 1973), sea level has been reckoned to have dropped to –71 m; but Shackleton (1969) considers that the drop in temperature indicated by O_{18} was too rapid for ice sheets to have spread widely if indeed much ice was able to form (cf. Mitchell 1977). If the temperature curve from the Orgnac stalactite is reliable (Duplessy *et al.*, 1970, 1971, cf. Shackleton 1971), cooling in southern France was slight. In Moravia between 115 000 and 104 000 B.P. there were several peaks of a sub-arctic stadial (Kukla and Koči 1972). The pollen diagram from Macedonia shows sharp cooling, and broad-leaved trees disappeared in Holland (Starkel 1977). There were a few icebergs in the mid Atlantic about 107 000 B.P., but they may have come from Greenland on a southward swinging current and need not imply ice formation on continents now unglaciated (Sancetta *et al.*, 1972). But though the great ocean-drop postulated for Barbados is supported elsewhere (> -55 m in South Crete, a tectonic area, Angelier *et al.*, 1976; between –30 and –59 m off Corfu, Sordinas 1973 and 1974), it is calculated that an ice sheet 1 000 m thick in East Canada would depress sea level only 14 m (Andrews and Mahaffy 1976). Taking other northern ice sheets into account, sea level would drop at most 30 m. In Bermuda the drop is taken to be about 8 m (Harmon *et al.*, 1978), in Guernsey possibly not more than 12 m (George 1977). I have seen no evidence for coastal gullying which would be expected if sea level had dropped as much as 70 m, but it may be masked by renewed gullying during the deeper drop in the Würm glaciation.

Eem II lasted about 104 000–94 000 B.P. O_{18} and foraminiferal evidence indicates that it was less warm than Eem I. On some coasts there is no emerged shoreline between Eem I and the Holocene, for example Madagascar (Battistini 1976a), Indian Ocean islands (Veeh 1966, Thomson and Walton 1972) New South Wales (Thom 1976), Marshall Islands (Szabo *et al.*, 1977) and Hawaii (Stearns H.T. 1978). Its altitude has been calculated on the assumption of constant uplift: on the Ryukyu Islands, –10 m (Machida 1975); on Barbados, –28 to –41 m, which is unlikely (Fairbanks and Matthews 1978), or –10 to –13 m (Steinen *et al.*, 1973). It is not agreed whether it was cooler or warmer than Eem III. Mörner

(1971) suggests that it was the coldest of the Eem interstadials, but in Florida its shoreline is slightly higher than that of Eem I (Multer *et al.*, 1968, Osmond *et al.*, 1970). In the Mediterranean there are two emerged shorelines 5–10 m apart (Cuerda 1965–7, Solé Sabaris 1962, Cotecchia *et al.*, 1969, Sanlaville 1969). On faunal and geological grounds the lower cannot be Holocene, and it carries an impoverished Senegalese fauna but hardly ever *Strombus bubonius*. On the Atlantic coast of France neither the Haut nor the Bas Normannien are datable (Guilcher 1969, Ters 1968). Because the lower in places rests on periglacial material, the higher may be pre-Eem. In Asturia there were two transgressions to the same level (Mary 1975). In Natal a platform just below M.S.L. occurs below a higher beach at +7–8 m. At Die Kelders Cave a platform at +8 m and a storm beach up to +2 m are claimed without evidence on which is the older (Tankard and Schweitzer 1974). On the emergent Atlantic coast of the United States there seem to be two pairs of shorelines (Colquhoun D.J. *in litt.*, cf. Hoyt 1975), but dates run on molluscs do not support this interpretation. It is reasonable to assume that the upper shoreline is Eem I, but there is less evidence whether the lower is Eem II or III. Dates from other regions suggest Eem II, for example the Antilles (Herweijer and Focke 1978), Bermuda (Harmon *et al.*, 1976, Vacher *et al.*, 1971), Victoria (Gill and Amin 1975), Timor (Chappell and Veeh 1978) and the Mediterranean (Bernat *et al.*, 1978, Bonadonna and Bigazzi 1971, Sanlaville 1973, Lalou *et al.*, 1971).

There is much evidence for a sharp drop of temperature in the Atlantic Ocean about 92 000 B.P. (Ruddiman and McIntyre 1976) with a rapid change of fauna in the Gulf of Mexico (Kennett and Huddleston 1972), a temperature drop on the continents (Duplessy *et al.*, 1970, 1971, Woillard 1975) and loess and gullying in Moravia (Kukla and Koči 1972). It has been suggested that large ice sheets in Europe provided the fresh water for the sapropel layer in the East Mediterranean (Williams *et al.*, 1978). Conditions then slowly improved near 83 000 B.P., a control date being provided by an ash fall over much of the Caribbean about 85 000. Elsewhere there has been little evidence in this stadial for sharp cooling or for a large marine regression (Butzer 1968, Butzer and Cuerda 1962, McIntyre *et al.*, 1972, Sancetta *et al.*, 1972), and it has been thought that Eem II–III was less cold than Eem I–II (Suggate 1974). This

divergence of opinion may be due to the brevity of the cold snap.

The last interstadial before rapid climatic deterioration with heavy snow and rain was Eem III. Its peak was probably a little after 80 000 B.P. It is dated by a tephra from the Bay of Bengal resulting from the explosion of Mount Toba in Sumatra. This occurs in sediments after the peak, about halfway to the nadir of Würm I, and there is a K/Ar date of $73\,500 \pm 3\,000$ (Ninkovich *et al.*, 1978).

Eem III was as warm or perhaps warmer than Eem II as shown at Orgnac. Red earth developed in the Mediterranean (Butzer and Cuerda 1962), and some cores from there show greater depletion of O_{18} than in Eem I (Thunell *et al.*, 1977). The same is found in the north-east Pacific (Shackleton 1977a), but in the North Atlantic Eem III was slightly cooler than Eem I (Sancetta *et al.*, 1972).

On many coasts there are two Eem shorelines. A few dates, especially from the Mediterranean (Stearns and Thurber 1965, 1967, Dai Pra and Stearns 1977, Bonadonna and Bigazzi 1971), indicate that the lower was Eem III, whereas most of the Red Sea dates point to Eem II (Berry *et al.*, 1966, Veeh and Giegengack 1970, Hoang *et al.*, 1973). The unreliability and large statistical errors of Thorium dating make it difficult to distinguish the two interstadials. Equally unreliable calculations (Savin and Stehli 1974, Mörner 1974b, Van Donk 1976) of glacier ice from oceanic O_{18} have been published to show that Eem III sea level was well below present (Shackleton 1977b, Steinen *et al.*, 1973, Machida 1973, 1975). On the whole I am inclined to think that the absolute sea level of Eem III was below present. Where there has been slight uplift or where geoid deformation has changed in relation to the present because of the long preceding interglacial or semi-interglacial period the Eem II shoreline may be slightly emerged.

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EVOLUTION OF THE ACTUAL RELIEF PATTERN OF COASTAL CENTRAL AND NORTHERN NAMIB DESERT

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ABSTRACT

Field and laboratory results gained at various SWA/Namibian sites between the Kunene river in the south and the Unjui river in the north are presented. At the Namib coast nearly two low stands of sea level and two high stands, one of them of late-Weissian age, can be proved. From Tossanini northward a third (?) Holocene high stand exists besides the other two. The former shore lines can be linked spatially and temporally in the vertical relief sequences by means of fluvial and eolian land forms and sediments. Thus the changing patterns of inter-arid or more humid environments at different morphogenetic stages up to the present one can be described. Furthermore, it is evident that the geomorphic processes themselves change regionally, and it is seen that the Central Namib desert is a geomorphologically unique area in comparison with the Skeleton Coast and the southern dune area. Finally, the tendencies of Quaternary landscape evolution even enable us to deduce some geoeological consequences concerning man's activities in this desert.

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INTRODUCTION

The subject of the geomorphological field work which I carried out together with my friend and colleague Doz. Dr. F. Wienieke, München, has been the study of the interrelationships of fluvial, eolian, and marine-littoral morphogenesis along the Central and Northern Namib desert coast. Spatially and chronologically, the actual relief pattern is the result of these three morphogenetic sequences. Results for the central Namib have been published elsewhere (Wienieke and Rust 1973, Rust and Wienieke 1976). This paper presents some of the syntheses of that work and a number of results concerning the Skeleton Coast area are documented for the first time. The major evidence regarding purely marine-littoral and purely eolian results, as well as mixed results, is emphasized.

SIX MODELS — THE FRAMEWORK OF THE GEOMORPHOLOGICAL ARGUMENT

Six major conceptual models exist concerning landscape evolution of the Namib desert coast. Some of the models are contradictory, and the theoretical consequences are, of course, evident. No single model can explain exclusively all land forms. Consequently, it is important to recognise that any interpretation will be limited.

Model 1 — Eustatic changes of sea level

This model has been generally accepted. At least the younger changes of sea level were induced by northern hemispheric glacial and deglaciations (Flönn 1970, Schwabach 1972).

Model 2 — Littoral migration by storms and means of high water events (Fig. 1)

Wienieke (in Rust and Wienieke 1976) has pro-