.. and now for something completely different!

Marine geoscientific research in South Africa
& the ‘common heritage of mankind’

Mossel Bay, South Africa continental shelf case study:

Marine geophysics meets palaeoanthropology

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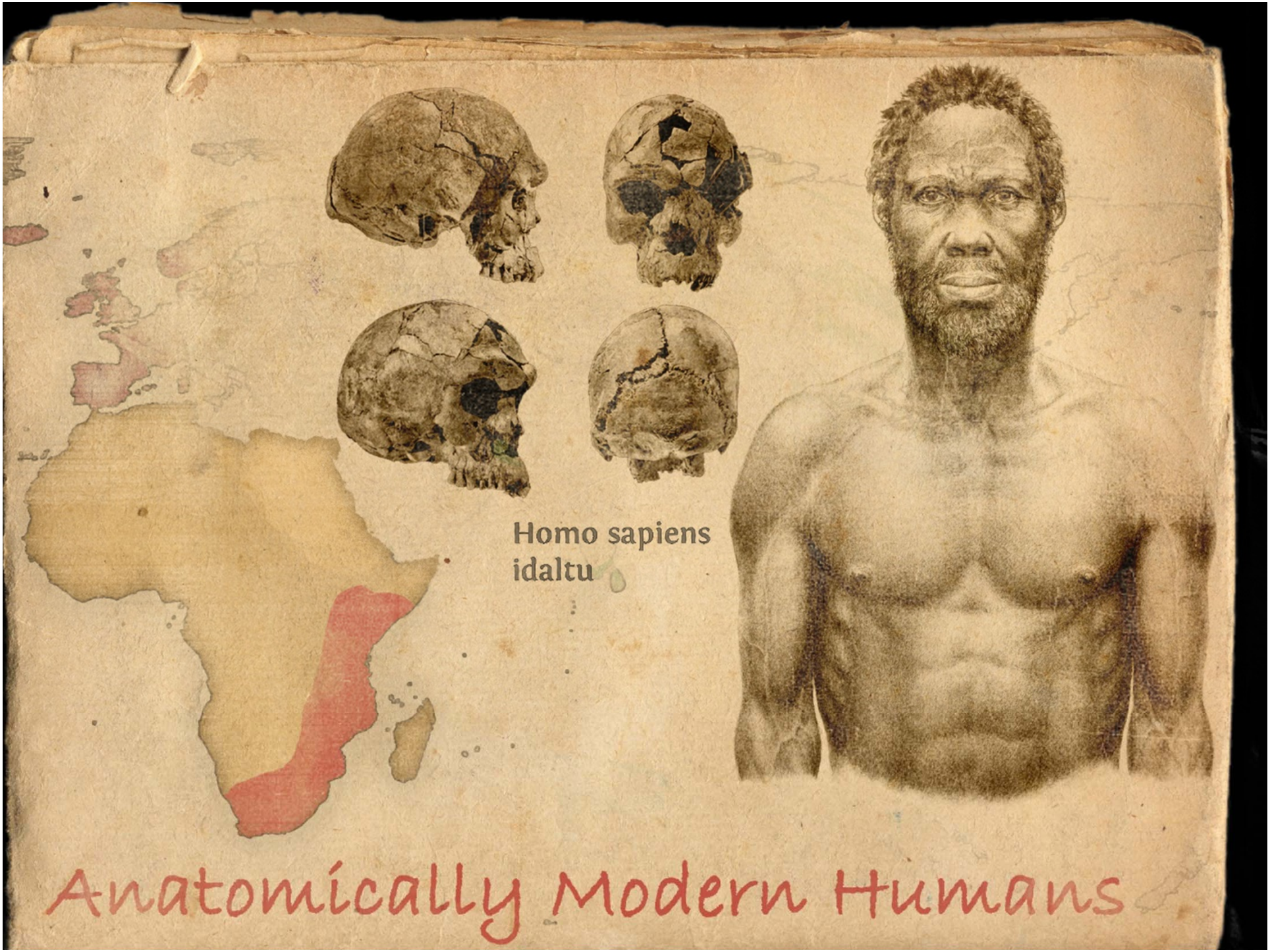
Council for Geoscience

UNIVERSITY OF CAPE TOWN

NATIONAL GEOGRAPHIC

CONTEXT

Variable and very valuable to know



Anatomically Modern Humans

L-Haplogroup in Southern Africa

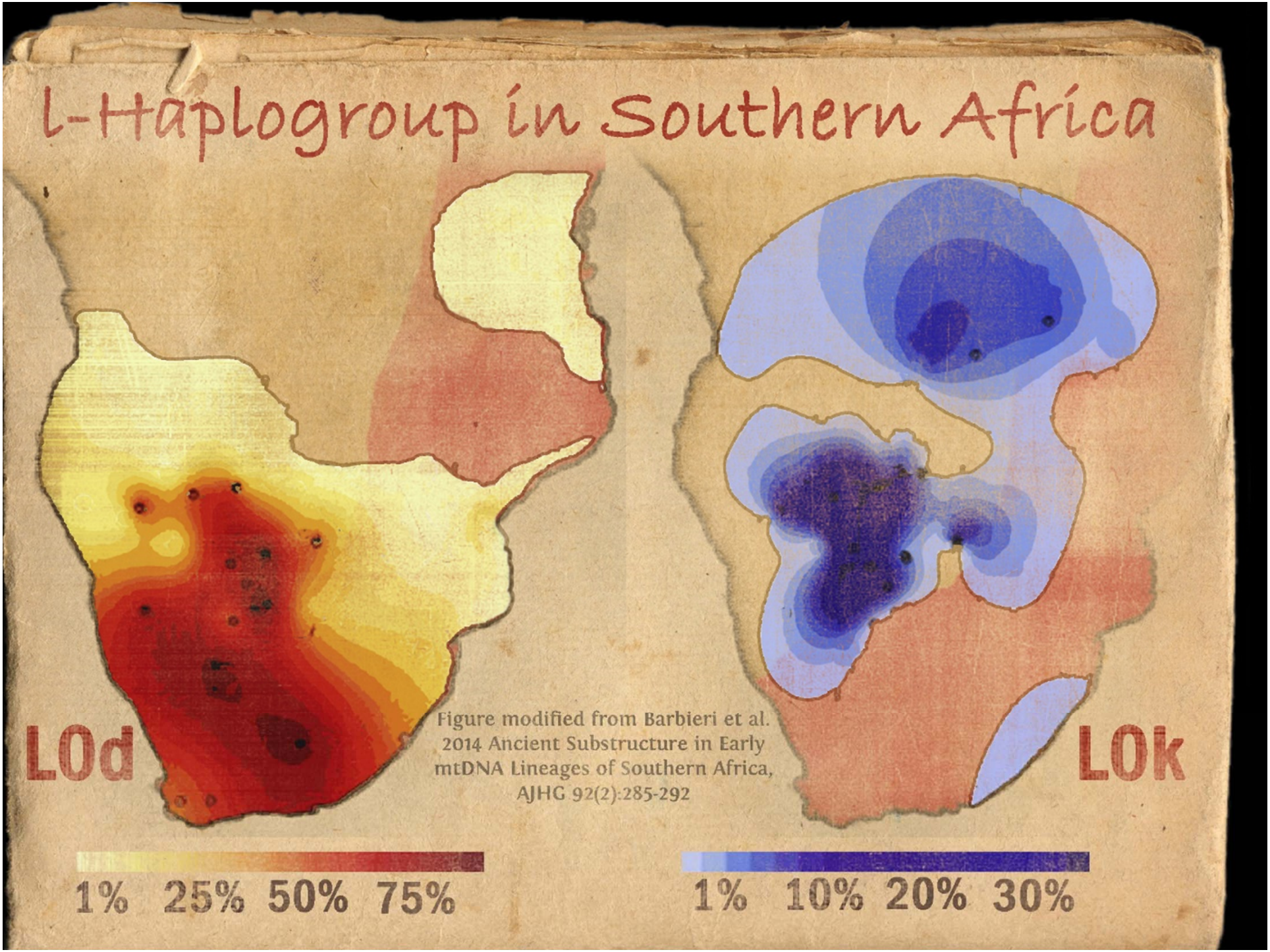
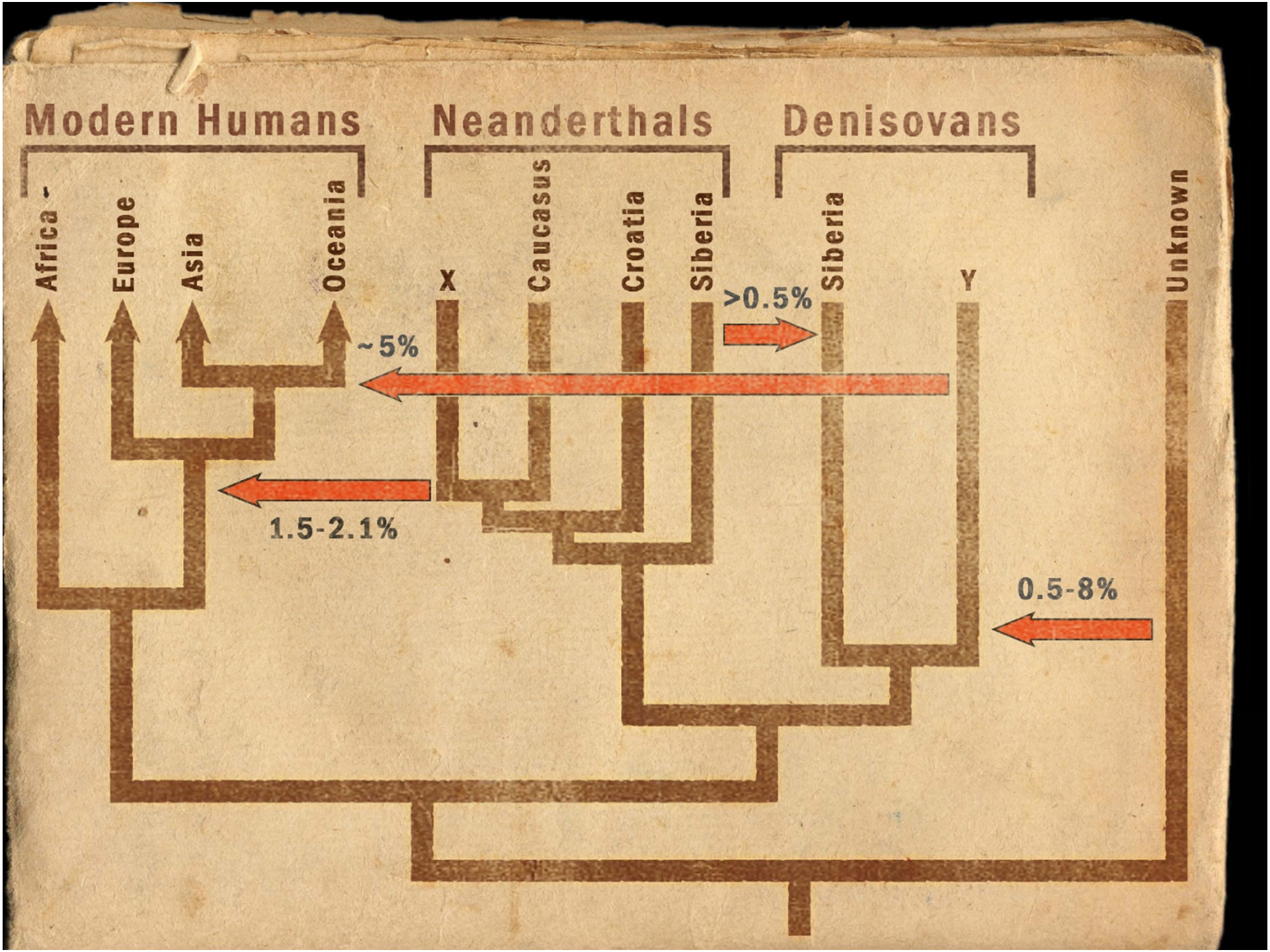
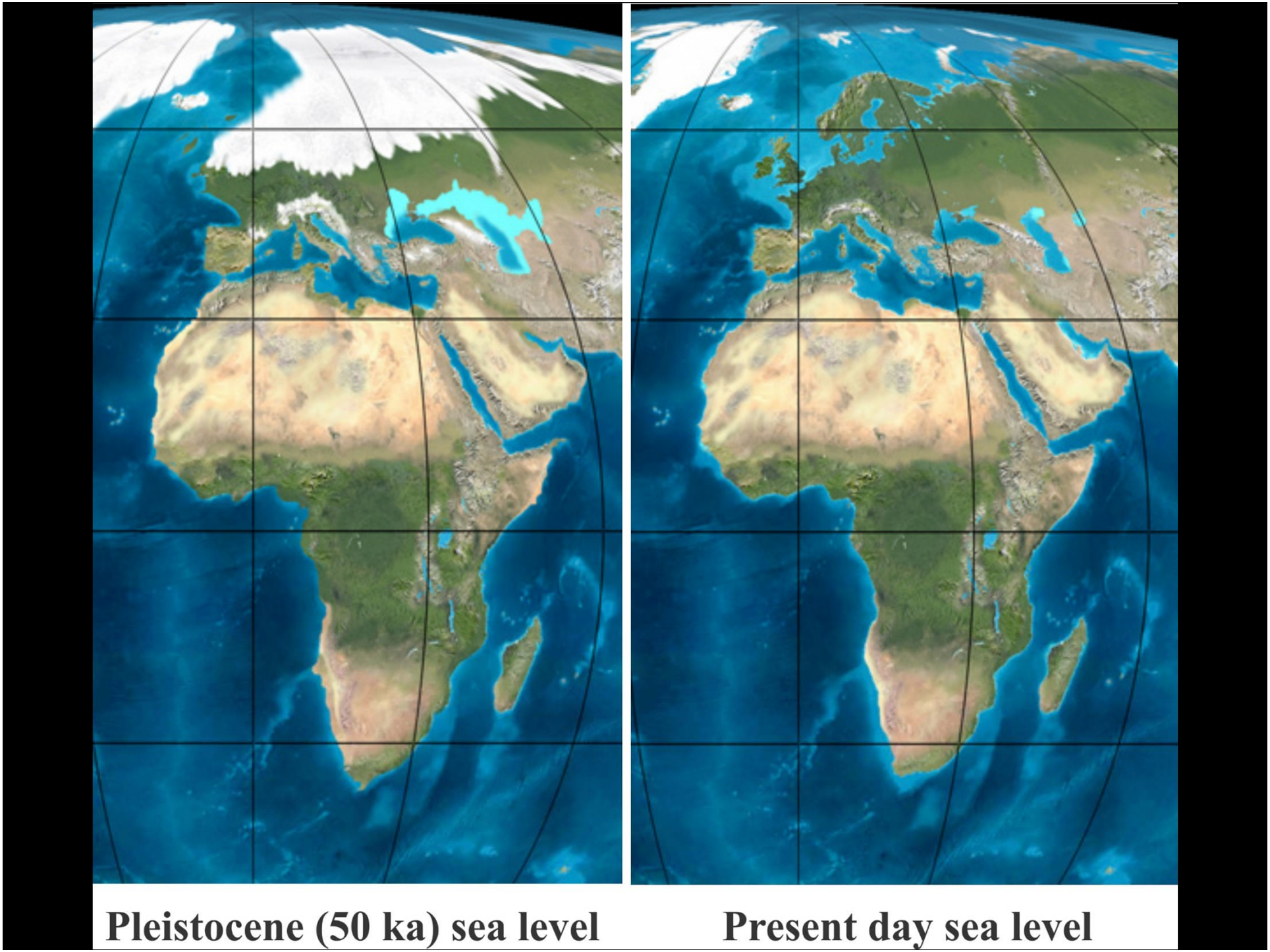


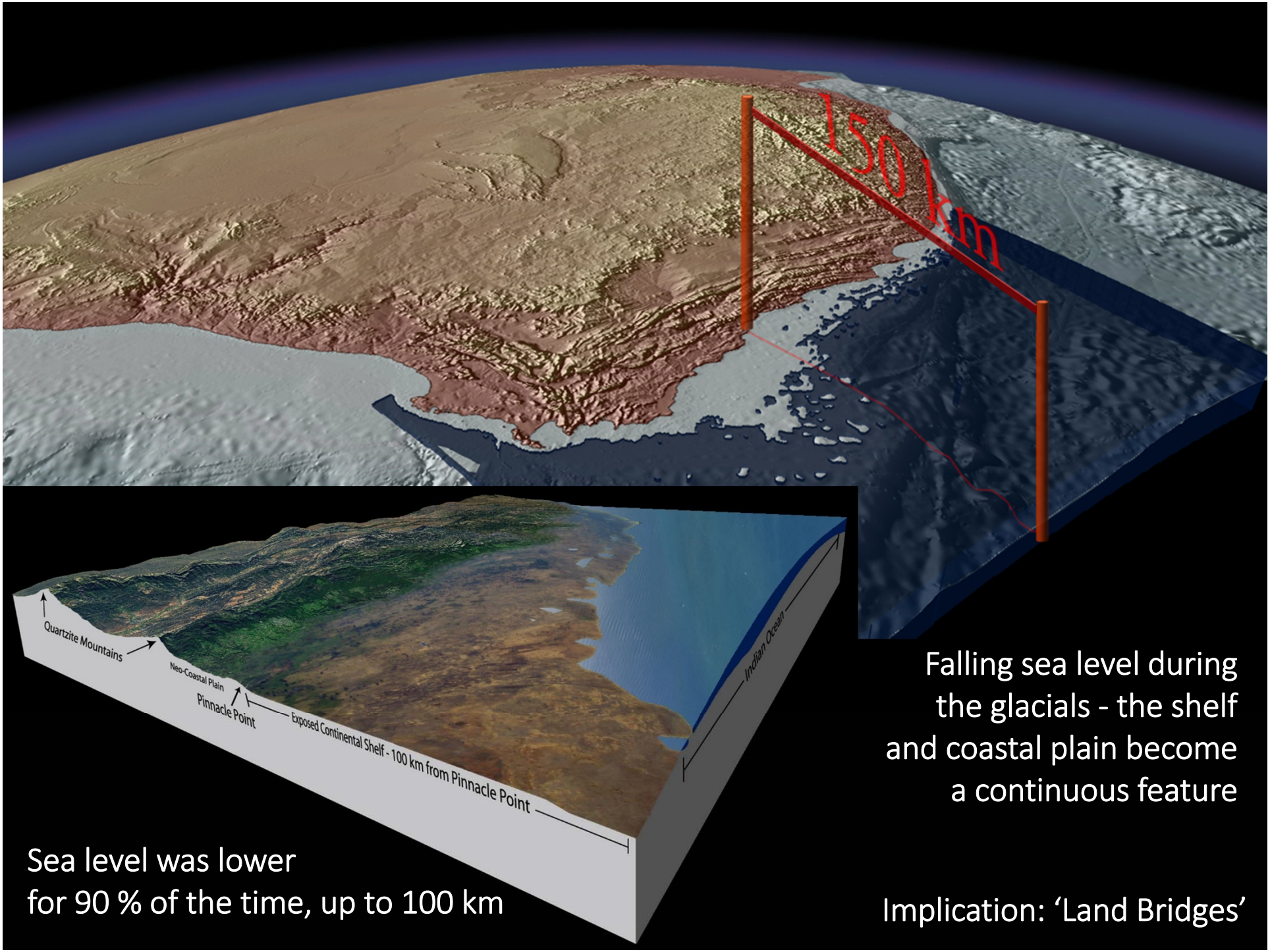
Figure modified from Barbieri et al. 2014 Ancient Substructure in Early mtDNA Lineages of Southern Africa, AJHG 92(2):285-292


Modern Humans
Neanderthals
Denisovans
Africa
Europe
Asia
Oceania
X
Caucasus
Croatia
Siberia
Siberia
Y
Unknown
>0.5%
~5%
1.5-2.1%
0.5-8%

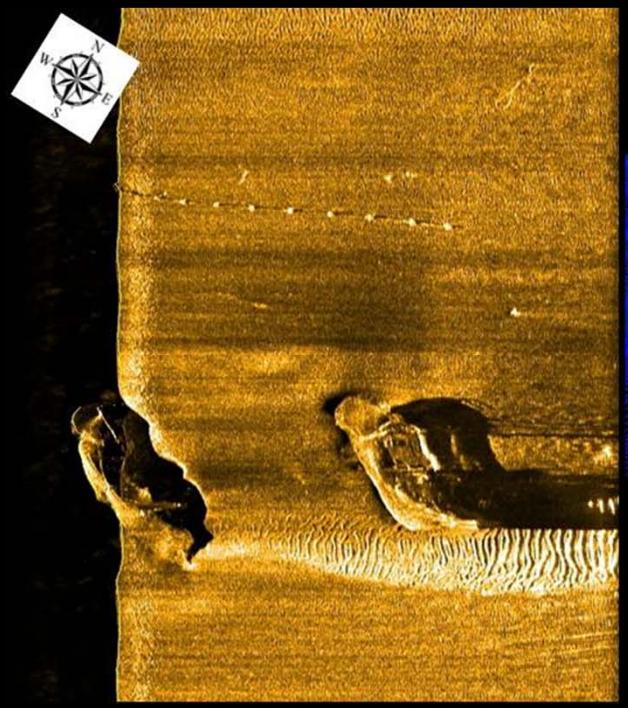

Modern Humans
Africa
Europe
Asia
Oceania
EXTINCT

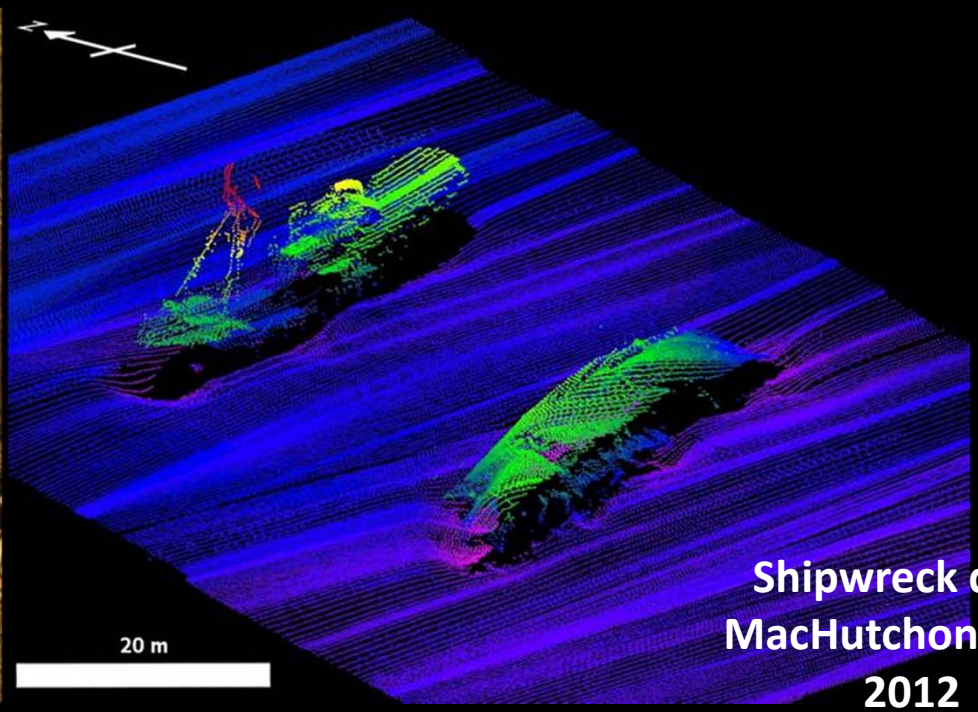

ROCK ART DANCE PARTY


Pleistocene (50 ka) sea level
Present day sea level

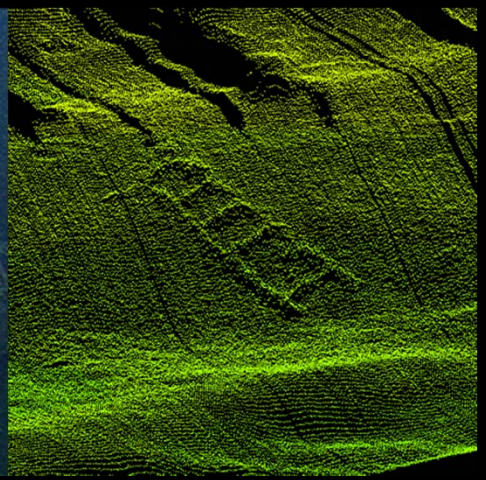

150 km
Quartzite Mountains
Neo-Coastal Plain
Pinnacle Point
Exposed Continental Shelf - 100 km from Pinnacle Point
Indian Ocean
Sea level was lower
for 90 % of the time, up to 100 km
Falling sea level during
the glacials - the shelf
and coastal plain become
a continuous feature
Implication: 'Land Bridges'

Humans and the seafloor





Shipwreck data: MacHutchon M.Sc. 2012



Submerged landscapes

Coastal plain and shelf are continuous

↓

Continental shelf evolution (Marine Geology)

↓

Evidence for Pleistocene sea-level fluctuations

↓

The continental shelf as a terrestrial landscape

↓

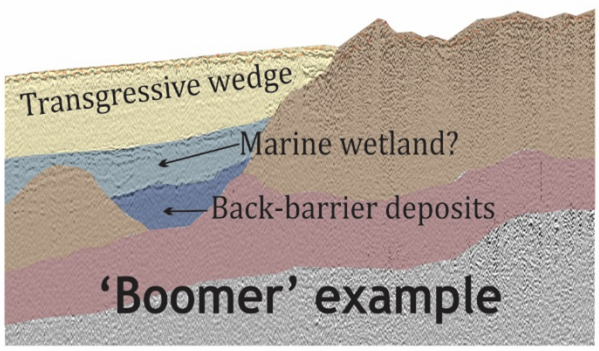
Link to early human use and palaeoenvironments

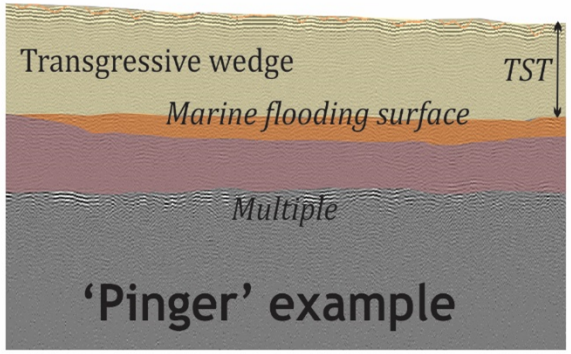
↓

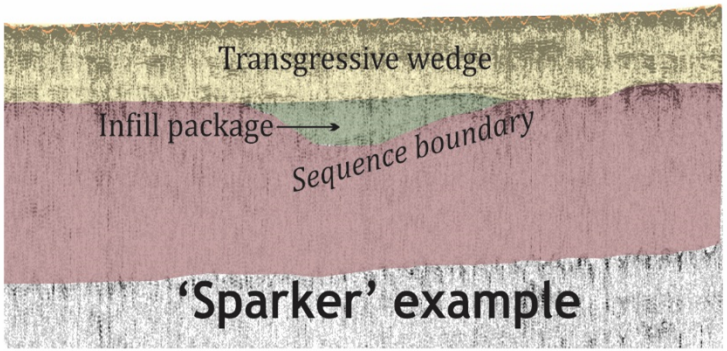
Developing a methodology to do this

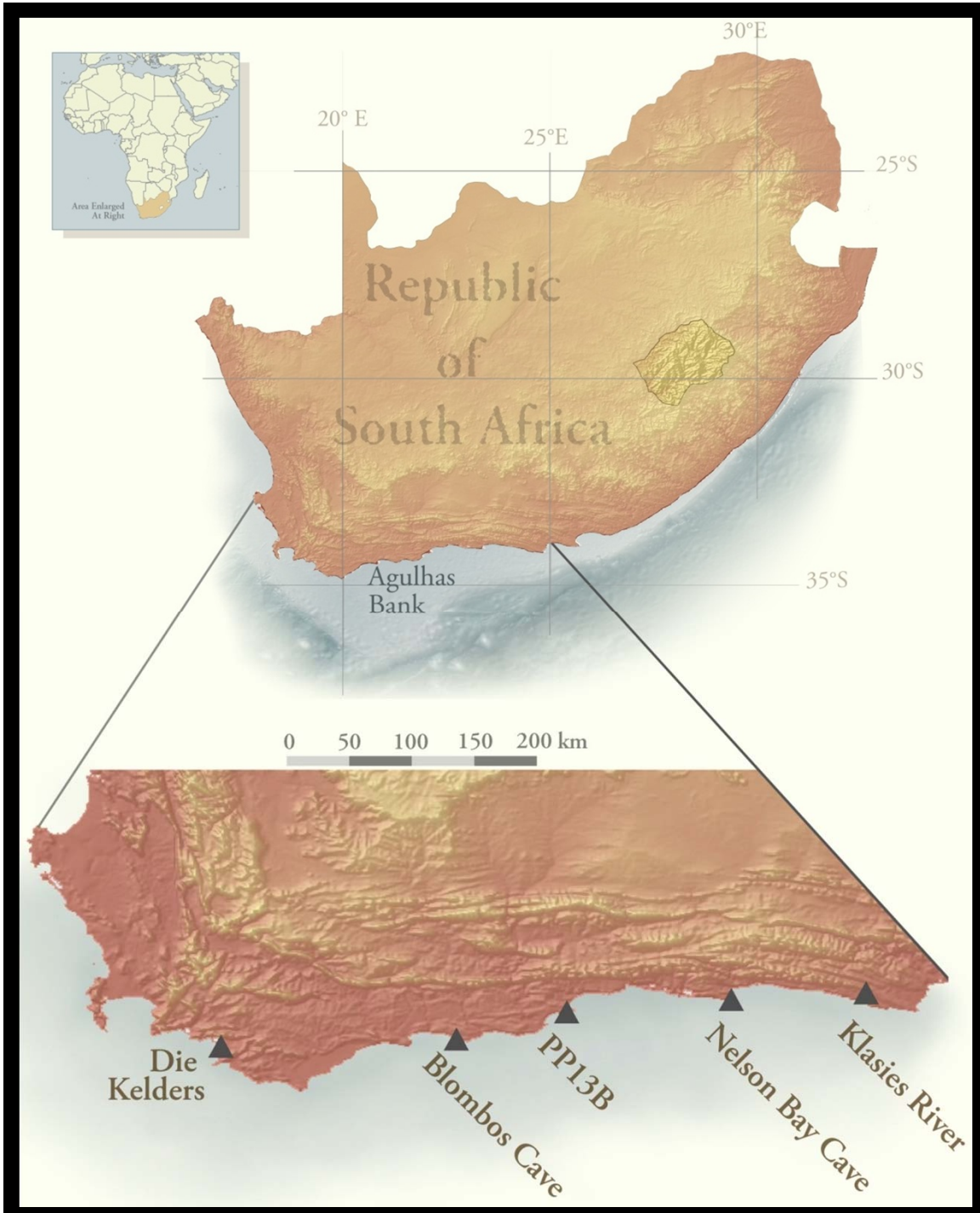
Sea level: -130 to +10 metres, every 100 ka
Geological processes visible through geophysics: testable ..

Geomorphic feature	Sea level regression	Sea level transgression
Rivers	Incision	Sedimentary infilling
Calcareous coastal dune systems	Accretion	Redistribution and erosion
Marine wetland environments	Facies overprinting	Inundation

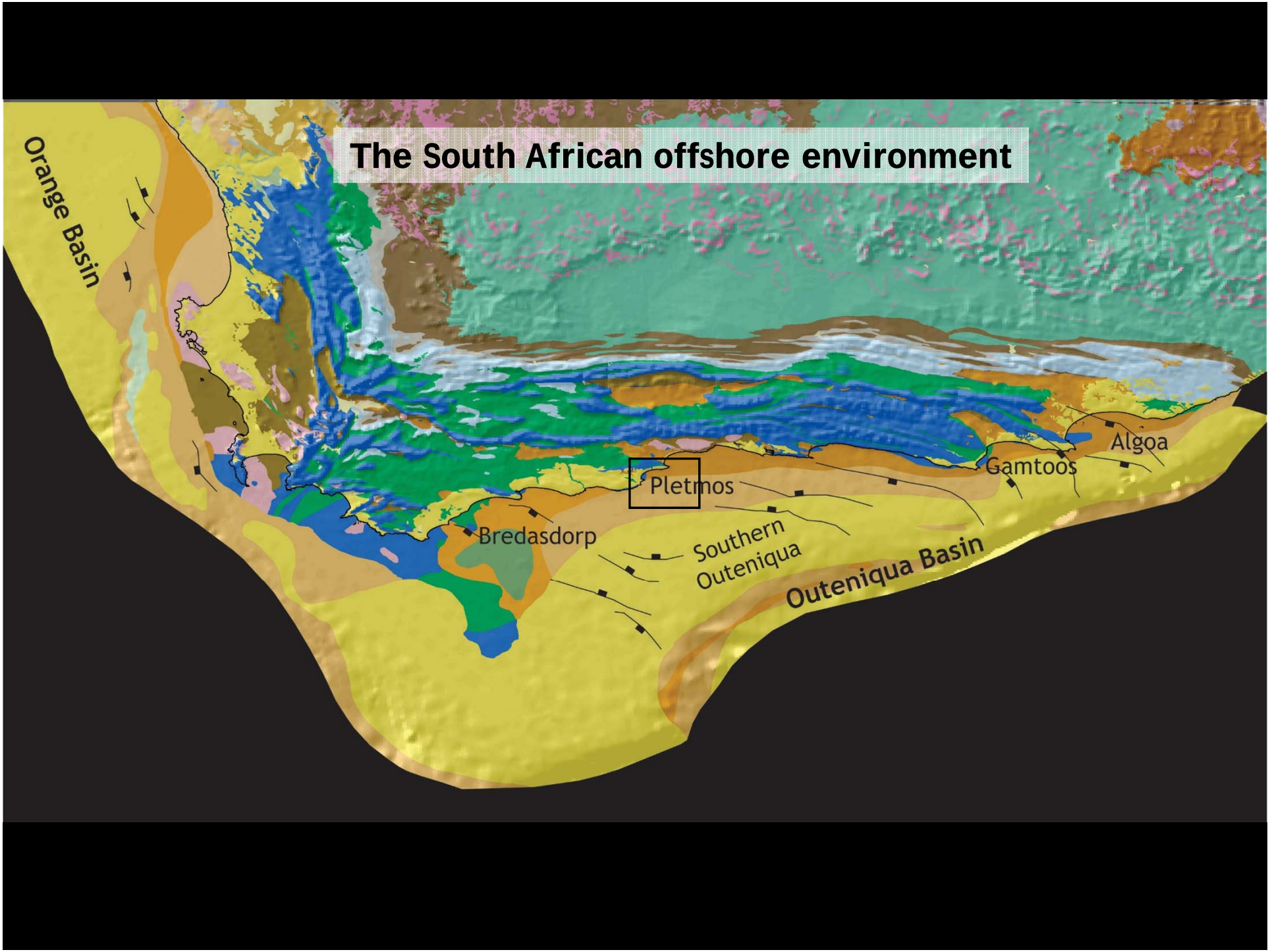




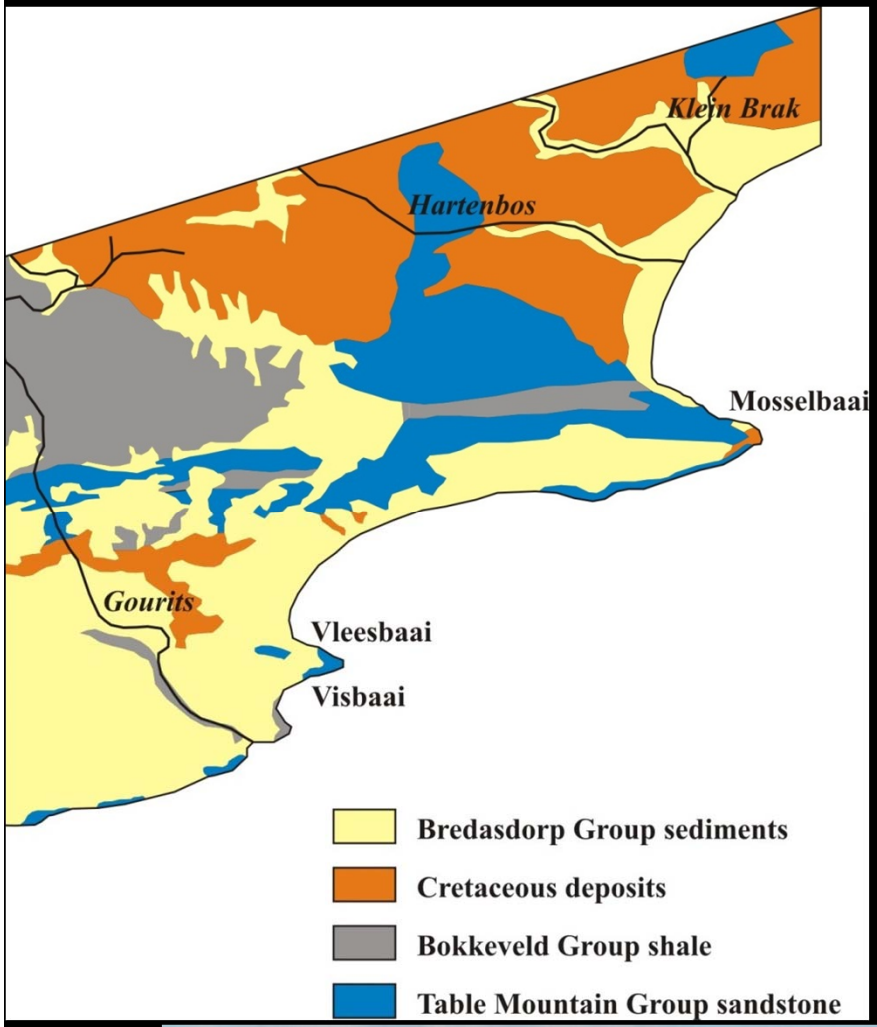


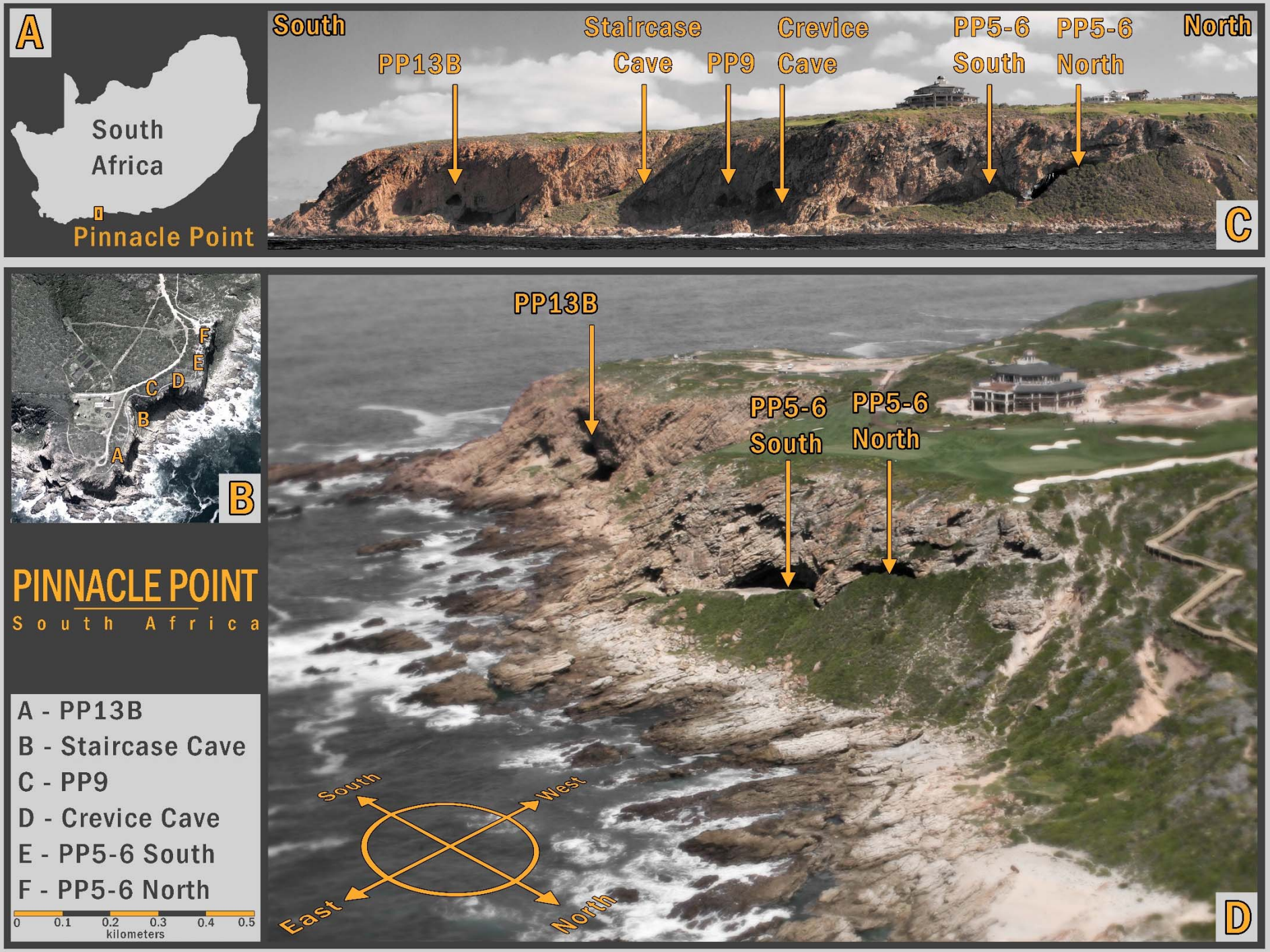


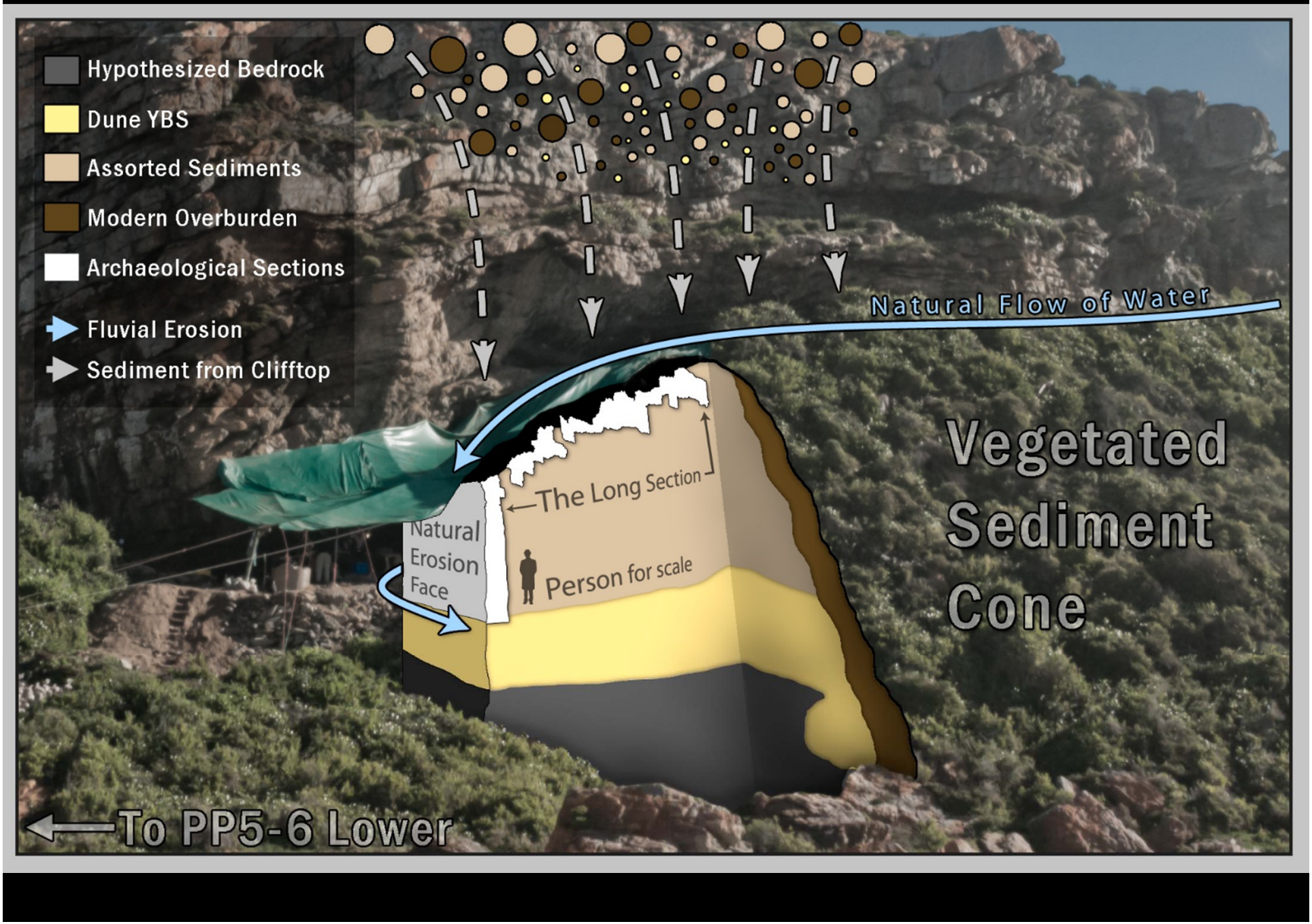
The South African south coast and significant Middle Stone Age archaeological sites


The South African offshore environment
Orange Basin
Pletmos
Bredasdorp
Southern
Outeniqua
Outeniqua Basin
Gamtoos
Algoa

Simplified geology of the area near Mossel Bay




A
South Africa
Pinnacle Point
South
PP13B
Staircase Cave
PP9
Crevice Cave
PP5-6 South
PP5-6 North
North
C
B
A
B
C
D
E
F
PINNACLE POINT
South Africa
A - PP13B
B - Staircase Cave
C - PP9
D - Crevice Cave
E - PP5-6 South
F - PP5-6 North
0 0.1 0.2 0.3 0.4 0.5
kilometers
PP13B
PP5-6 South
PP5-6 North
South
West
East
North
D


Hypothesized Bedrock
Dune YBS
Assorted Sediments
Modern Overburden
Archaeological Sections
Fluvial Erosion
Sediment from Clifftop
Natural Flow of Water
Vegetated Sediment Cone
The Long Section
Natural Erosion Face
Person for scale
To PP5-6 Lower

Why Pinnacle Point?

LETTER

doi:10.1038/nature11660

An early and enduring advanced technology originating 71,000 years ago in South Africa

Kyle S. Brown[1,2], Curtis W. Marean[2], Zenobia Jacobs[3], Benjamin J. Schoville[2], Simen Oestmo[2], Erich C. Fisher[2], Jocelyn Bernatchez[2], Panagiotis Karkanas[4] & Thalassa Matthews[5]

There is consensus that the modern human lineage appeared in Africa before 100,000 years ago[1,2]. But there is debate as to when cultural and cognitive characteristics typical of modern humans first appeared, and the role that these had in the expansion of modern humans out of Africa[3]. Scientists rely on symbolically specific proxies, such as artistic expression, to document the origins of complex cognition. Advanced technologies with elaborate chains of production are also proxies, as these often demand high-fidelity transmission and thus language. Some argue that advanced technologies in Africa appear and disappear and thus do not indicate complex cognition exclusive to early modern humans in Africa[3,4]. The origins of composite tools and advanced projectile weapons figure prominently in modern human evolution research, and the latter have been argued to have been in the exclusive possession of modern humans[5,6]. Here we describe a previously unrecognized advanced stone tool technology from Pinnacle Point Site 5–6 on the south coast of South Africa, originating approximately 71,000 years ago. This technology is dominated by the production of small bladelets (microliths) primarily from heat-treated stone. There is agreement that microlithic technology was used to create composite tool components as part of advanced projectile weapons[7,8]. Microliths were common worldwide by the mid-Holocene epoch, but have a patchy pattern of first appearance that is rarely earlier than 40,000 years ago[9,10], and were thought to appear briefly between 65,000 and 60,000 years ago in South Africa and then disappear. Our research extends this record to ~71,000 years, shows that microlithic technology originated early in South Africa, evolved over a vast time span (~11,000 years), and was typically coupled to complex heat treatment that persisted for nearly 100,000 years. Advanced technologies in Africa were early and enduring; a small sample of excavated sites in Africa is the best explanation for any perceived 'flickering' pattern.

Microlithic technology varies worldwide and is often defined regionally[9]. Microlithic is used to describe small stone blades (bladelets) retouched to create highly standardized shapes (backed blades or segments), or assemblages with high frequencies of small tools[10]. We follow Clark's concise technological definition: the process of manufacture (core reduction) is focused on the production of small flakes and bladelets less than 50 mm in maximum length[7] (Supplementary Discussion). Microlithic technology has been considered more typical of the Later Stone Age (LSA) and Upper Palaeolithic phase postdating 45 kyr in Africa and Eurasia, respectively, atypical for the Middle Stone Age (MSA) in Africa (300–45 kyr), absent in the Middle Palaeolithic in Eurasia, and potentially a universal stage in the evolution of Palaeolithic technologies[10].

Backed blade technology occurs earliest in Africa. The oldest East African sites with microliths are the Naisiusiu Beds at Olduvai Gorge, Enkapune Ya Muto, and Mumba rockshelter. The Naisiusiu Beds have infinite radiocarbon ages of >45 kyr[11] and electron spin resonance (ESR) ages of 59 ± 5 kyr and 62 ± 5 kyr[12]. The earliest Enkapune Ya Muto (Ending) microlithic has a calibrated radiocarbon age of ≥45 kyr[8]. The oldest backed blades at Mumba rockshelter (Tanzania) are dated by optically stimulated luminescence (OSL) to 57 ± 5 kyr[13]. Small numbers of backed blades come from Twin Rivers in Zambia[14], but the age is contested[15,16]. The Howiesons Poort (HP) in southern Africa is well represented by many samples, meets the Clark definition of microlithic technology (Fig. 1), and is well constrained by large numbers of OSL ages to between 60 and 65 kyr[17].

The microlithic technology we report is from Pinnacle Point Site 5–6 (PP5–6) on the south coast of South Africa (Supplementary Fig. 1 and Supplementary Discussion). The deposits we report here come

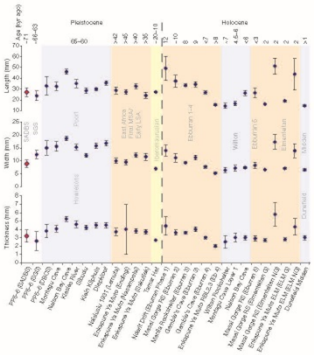


Figure 1 | Segment dimensions from PP5–6 and selected late Pleistocene and Holocene sites. Mean and error bars showing 95% confidence intervals for segment dimensions were calculated for segment length, width and thickness using published sample mean ($\bar{x}$), standard deviation (s) and sample count (n) values from selected African assemblages. The equation for calculating the 95% confidence interval is: $\bar{x} \pm t_{0.05}(n-1) \times s/\sqrt{n}$, in which $t_{0.05}$ is the value at probability 0.05 at $(n-1)$ degrees of freedom from a two-tailed t-table. The values for $t_{0.05}$ were calculated using the TINV function in Microsoft Excel. Sources for data described are in Supplementary Information.

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Oldest evidence for advanced cognition

Oldest evidence for modern Cultural behaviour: 167 ka

Vol 449 | 18 October 2007 | doi:10.1038/nature06204 nature

LETTERS

Early human use of marine resources and pigment in South Africa during the Middle Pleistocene

Curtis W. Marean[1], Miryam Bar-Matthews[2], Jocelyn Bernatchez[2], Erich Fisher[1], Paul Goldberg[3], Andy I. R. Herries[4], Zenobia Jacobs[5], Antonieta Jerardino[6], Panagiotis Karkanas[3], Tom Minichillo[10], Peter J. Nilssen[11], Erin Thompson[1], Ian Watts[12] & Hope M. Williams[2]

Genetic and anatomical evidence suggests that *Homo sapiens* arose in Africa between 200 and 100 thousand years (kyr) ago[1,2], and recent evidence indicates symbolic behaviour may have appeared ~135–75 kyr ago[3,4]. From 195–130 kyr ago, the world was in a fluctuating but predominantly glacial stage (marine isotope stage MIS6)[5]; much of Africa was cooler and drier, and dated archaeological sites are rare[6,7]. Here we show that by ~164 kyr ago (±12 kyr) at Pinnacle Point (on the south coast of South Africa) humans expanded their diet to include marine resources, perhaps as a response to these harsh environmental conditions. The earliest previous evidence for human use of marine resources and coastal habitats was dated to ~125 kyr ago[8–11]. Coincident with this diet and habitat expansion is an early use and modification of pigment, probably for symbolic behaviour, as well as the production of bladelet stone tool technology, previously dated to post-70 kyr ago[12–15]. Shellfish may have been crucial to the survival of these early humans as they expanded their home ranges to include coastlines and followed the shifting position of the coast when sea level fluctuated over the length of MIS6.

The Middle Stone Age (MSA) was the technological phase (appearing as early as 280 kyr ago[3,4]) of the origins of modern humans. South Africa has provided a rich and important MSA archaeological record that mostly post-dates 120 kyr ago, but many of the excavated sites occur at elevations at which the MIS5e high sea stand (~ 6 m above mean sea level at 123 kyr ago) would have washed out earlier deposits[16]. Co-occurring with an increase in the frequency of known coastal sites younger than 120 kyr is a burgeoning of material cultural complexity. In addition to the later appearance of bone tools[17] and beads[3], there is extensive evidence for systematic use of pigment by 120 kyr ago in South Africa[18]. Pigments near this age, or older, are patchily distributed outside South Africa; for example, in Israel some are dated to 92 kyr ago[19], at Twin Rivers in Zambia they are dated to between 141 and > 400 kyr ago[20], and 'red ochres' from the Kapthurin Formation in Kenya are dated to > 285 kyr ago[21].

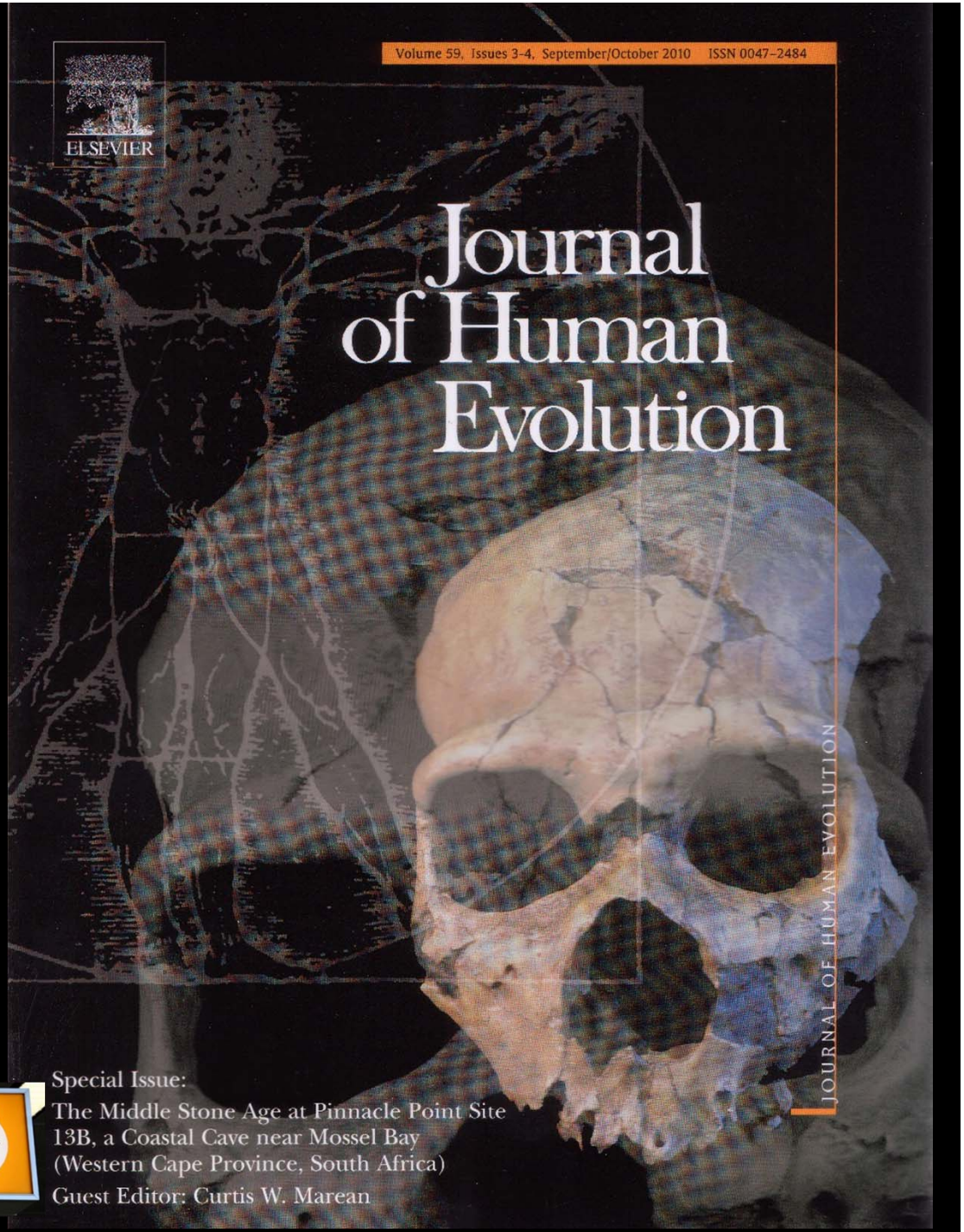
Site PP13B (34° 12′ 44″ E22° 05′ 37″) is a sea cave overlooking the Indian Ocean in the quartzitic coastal cliffs at Pinnacle Point near Mossel Bay (South Africa). It escaped the MIS5e high sea stand by virtue of its elevation (+15 m above mean sea level, see Supplementary Information and Video). On the north and south walls of the cave is a variably cemented MSA deposit (called the LC-MSA), whereas the floor is uncovered by a mostly uncemented MSA deposit (Fig. 1)[15]. We excavated three areas in the cave, but our focus here is on the LC-MSA deposits, which are the oldest sediments with significant anthropogenic input.

We recognize the following stratigraphic sequence in the LC-MSA deposits, from bottom to top. The LC-MSA Lower has a weighted mean optically stimulated luminescence (OSL) age of 164 ± 12 kyr (Table 1 and Supplementary Information, for all ages that we present). It is a sandy deposit, the least cemented of all, with multiple lenses of burnt carbonaceous material; micromorphology and frequency-dependent magnetic susceptibility analysis show that some of these are *in situ* combustion features. Lithics and faunal remains are abundant throughout, but are concentrated in burnt lenses. The plotted finds are inclined mostly between 0 and 15°, with few dramatic changes that would indicate intrusions or disturbances (Supplementary Information). The LC-MSA Middle (weighted-mean OSL age of 132 ± 12 kyr) is mostly ash, has multiple lenses of dark organic material that micromorphology shows are *in situ* hearths, and has a plotted find density less than the LC-MSA Lower. The LC-MSA Upper is a heavily cemented zone with three sub-units: (1) a lower hard sandy and silty layer containing reworked ashes that directly contacts and transitions into the richer anthropogenic deposits of the LC-MSA Middle; (2) a layer of shellfish stratified within an aeolian dune with a weighted mean OSL age of 120 ± 7 kyr; and (3) a dune that sealed the cave, and which has a weighted mean OSL age of 90 ± 6 kyr. Capping the deposit, the LC-MSA Flowstone is a 5-cm-thick laminated flowstone with a rough and wavy microscopically sharp boundary with the underlying LC-MSA Upper. Six uranium series (U-series) ages on separate laminae range from 39 to 92 kyr (Table 1), providing high resolution minimum ages for everything below. Several forms of evidence suggest partial closure of the cave from 39 to 92 kyr ago (Supplementary Information).

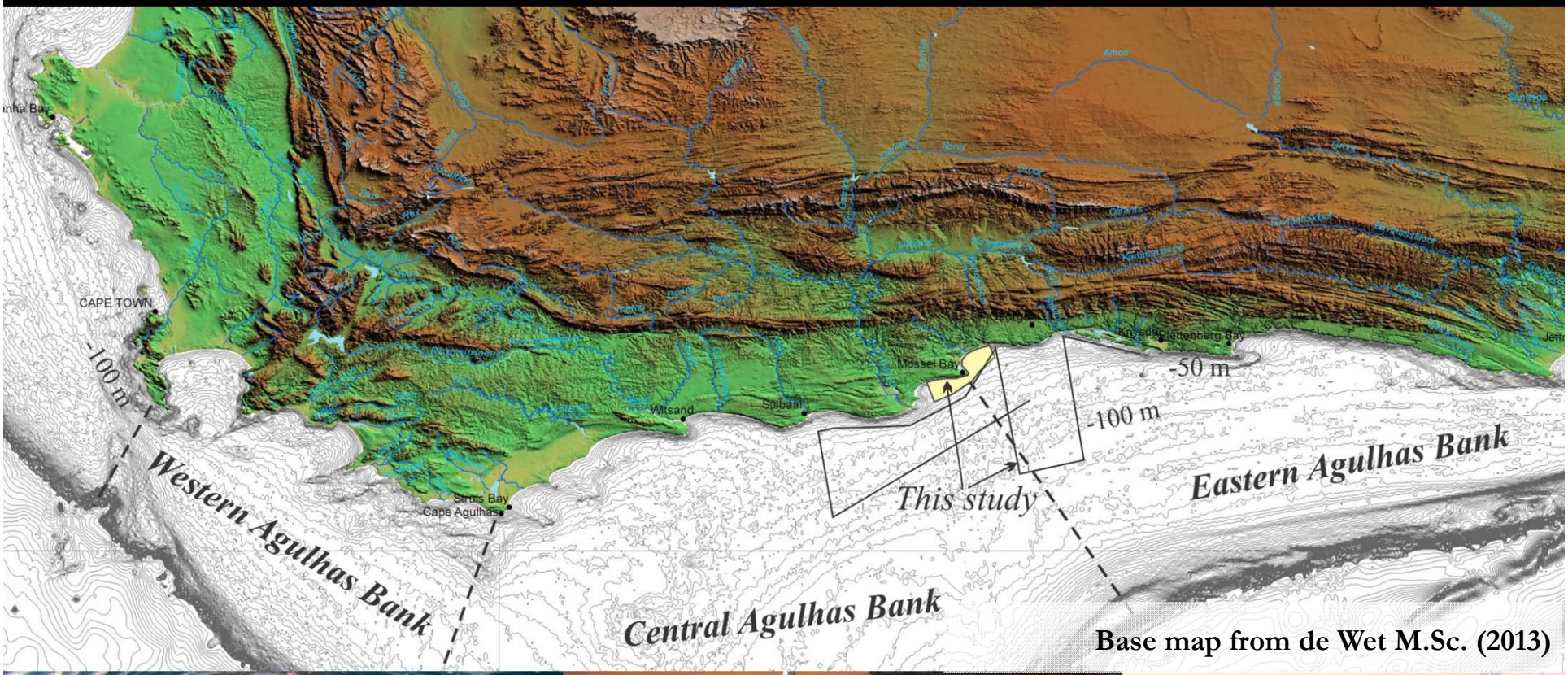
The LC-MSA Lower falls within MIS6, during which sea level was lower than today. We have developed a three-dimensional Geographical Information Systems (GIS) model (Supplementary Video and Information) that joins offshore bathymetry to a relative sea level curve[22] and models the coastline at 1.5-kyr increments for the last 400 kyr. Studies of modern and recent archaeological shellfish transport show that foragers rarely transport shell over more than 5–10 km[23,24]. Our model shows that the coastline was within that distance during MIS6 only at 167 kyr ago—a result concordant with the OSL ages.

The flaked-stone-artefact assemblage ($n = 1836$) is quartzite dominated (78%) and includes Levallois technology, often considered characteristic of the MSA[25], as well as bladelet technology, which is more typical of much later periods[19,26] (Fig. 2). The blades form a continuous size distribution of widths from large blades to bladelets. Bladelets here conform to the formal definition of blades less than

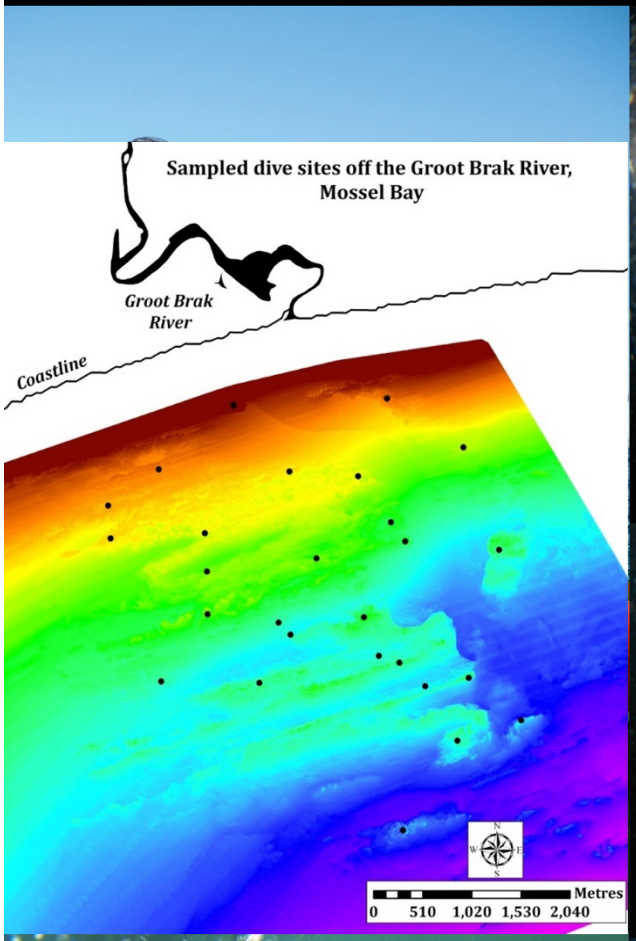
[1]Institute of Human Origins, [2]School of Human Evolution and Social Change, PO Box 872402, Arizona State University, Tempe, Arizona 85287-2402, USA. [3]Geological Survey of Israel, 30 Malkhei Israel Street, Jerusalem 95501, Israel. [4]Department of Anthropology, University of Victoria, Gisborne Building, Victoria V8W 2Y2, USA. [5]Department of Archaeology, Simon Fraser University, 675 Commonwealth Avenue, Burnaby, Massachusetts 02915, USA. [6]Human Origins Group, School of Medical Sciences, The University of New South Wales, Sydney NSW 2052, Australia. [7]School of Earth and Environmental Sciences, University of Wollongong, Wollongong, 2522, Australia. [8]Department of Archaeology, University of Cape Town, Rondebosch 7701, South Africa. [9]Ephoreia of Palaeoanthropology-Speleology, Ministry of Culture, Arsitou 24b, Athens 11636, Greece. [10]Department of Anthropology, University of Washington, Box 353100, Seattle, Washington 98195-3100, USA. [11]Archaeology Division, Iziko South African Museum, PO Box 61, Cape Town 8000, South Africa. [12]58 Basildon House, Sevens Estate, Amhurst Road, London E8 2DA, United Kingdom.

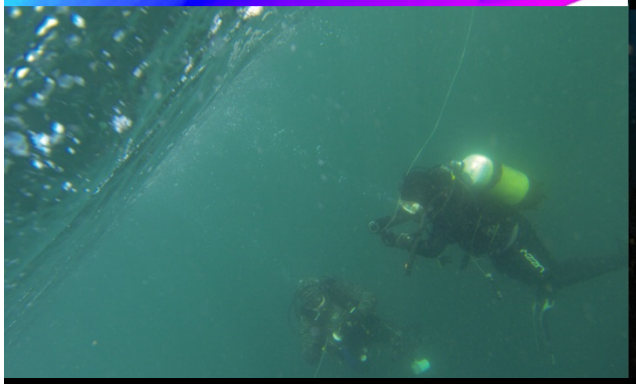


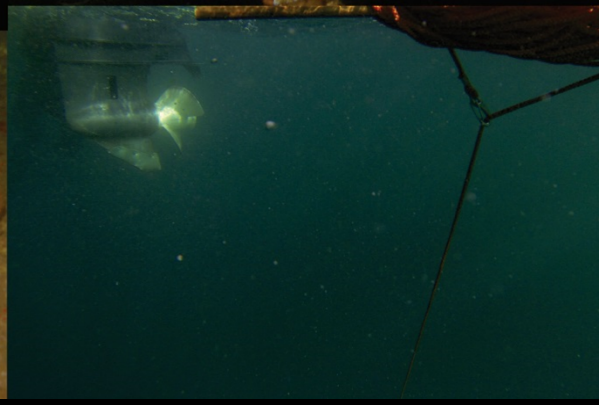
Mossel Bay continental shelf geophysical surveys



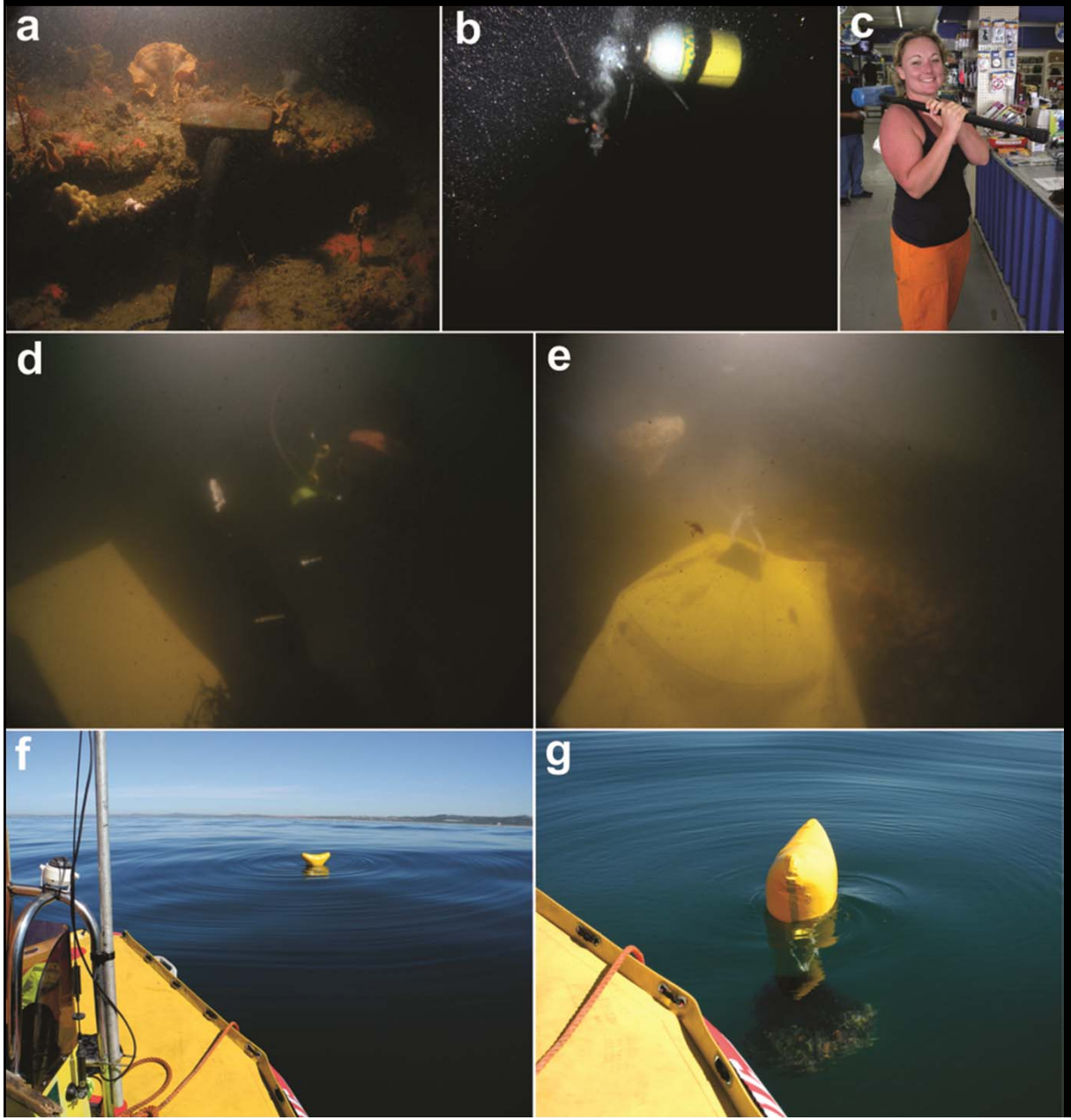
Base map from de Wet M.Sc. (2013)

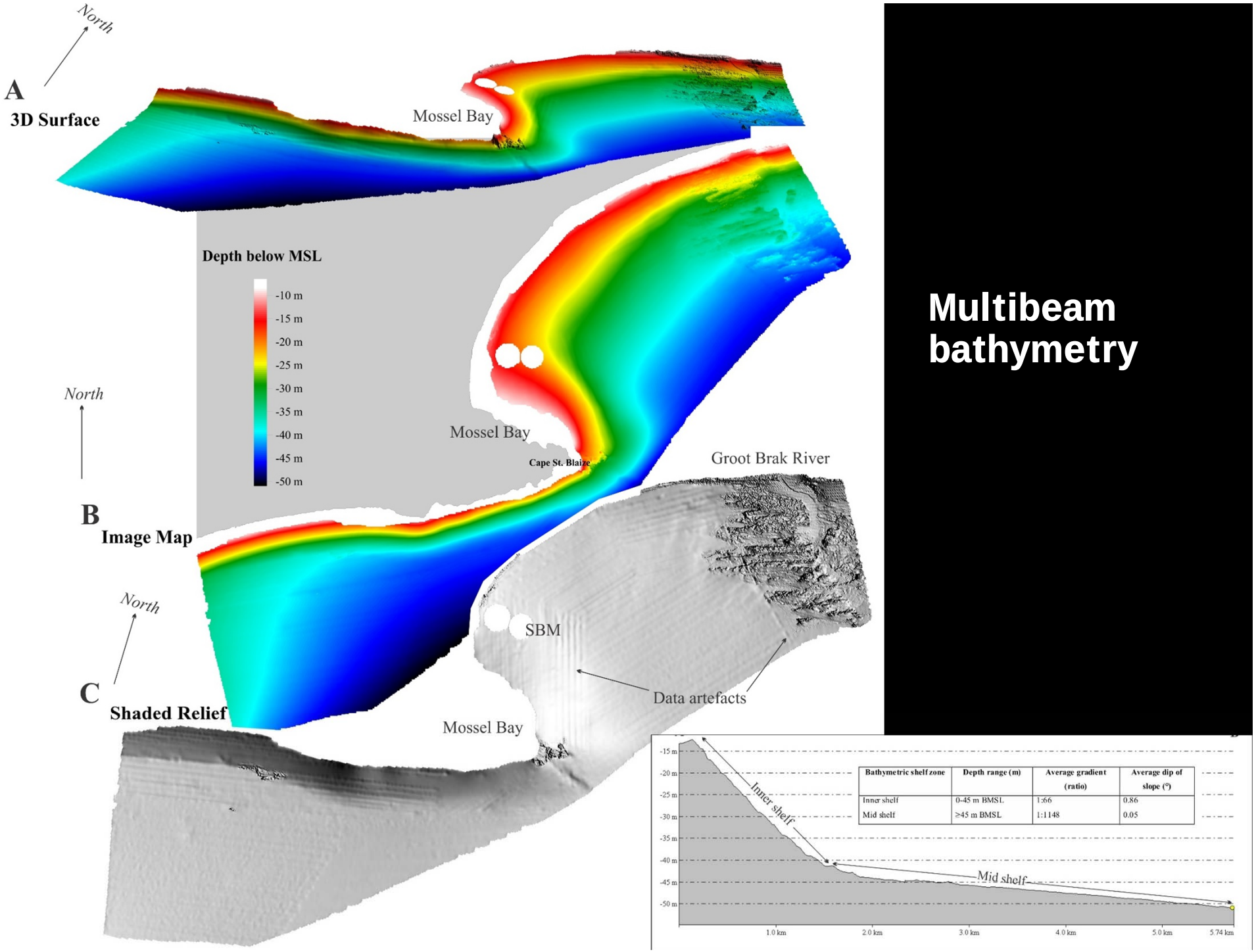

Sampled dive sites off the Groot Brak River, Mossel Bay
Groot Brak River
Coastline
N
W
E
S
Metres
0 510 1,020 1,530 2,040



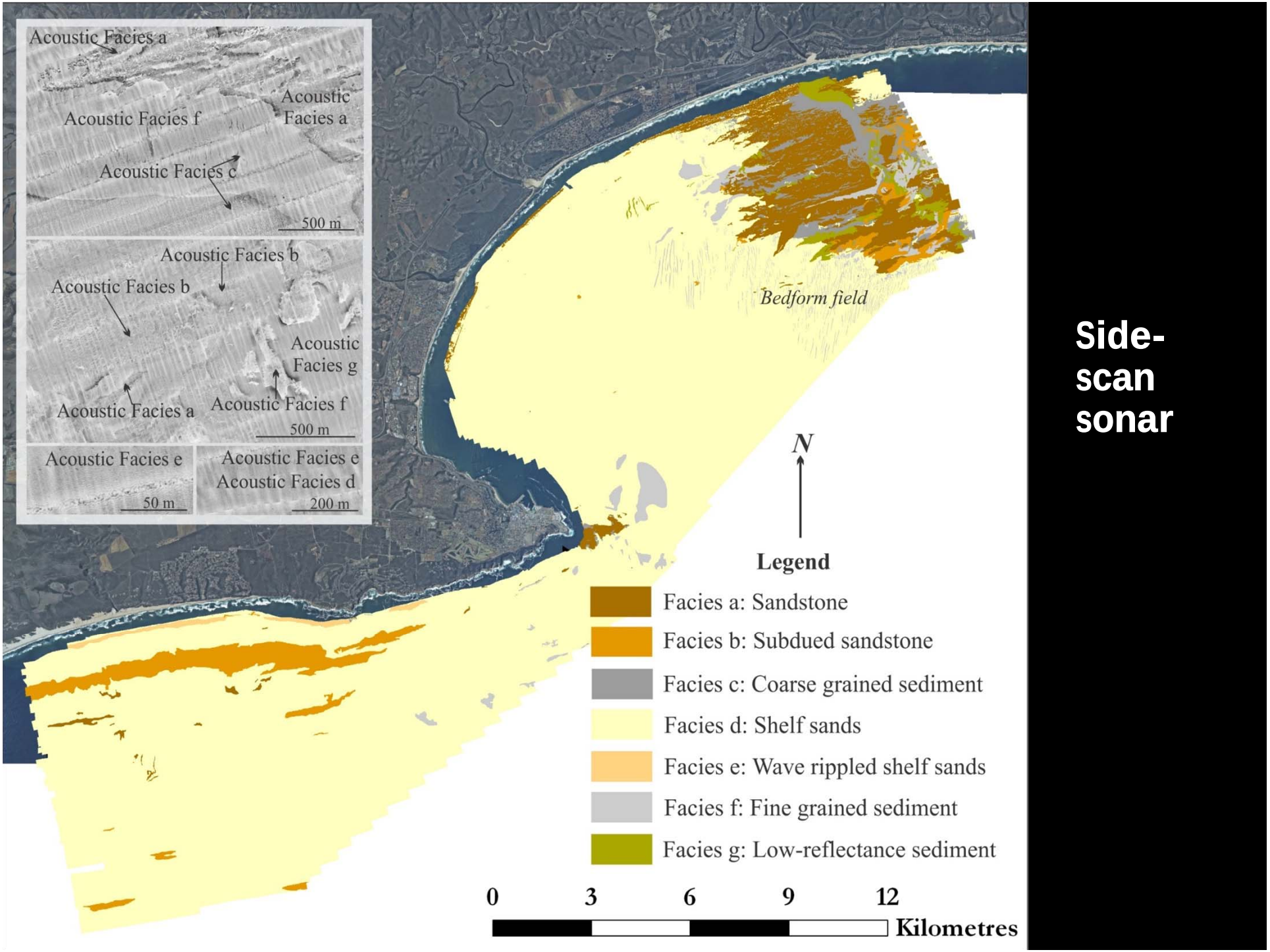


Geological mapping on scuba, facilitated by Oceans Research





Multibeam bathymetry



Side-scan sonar

Geomorphic Features off Mossel Bay

The continental shelf preserves recognisable environments

DEPOSITIONAL-

Evidence for past clastic shorelines:

beaches, dunes, coastal ridges

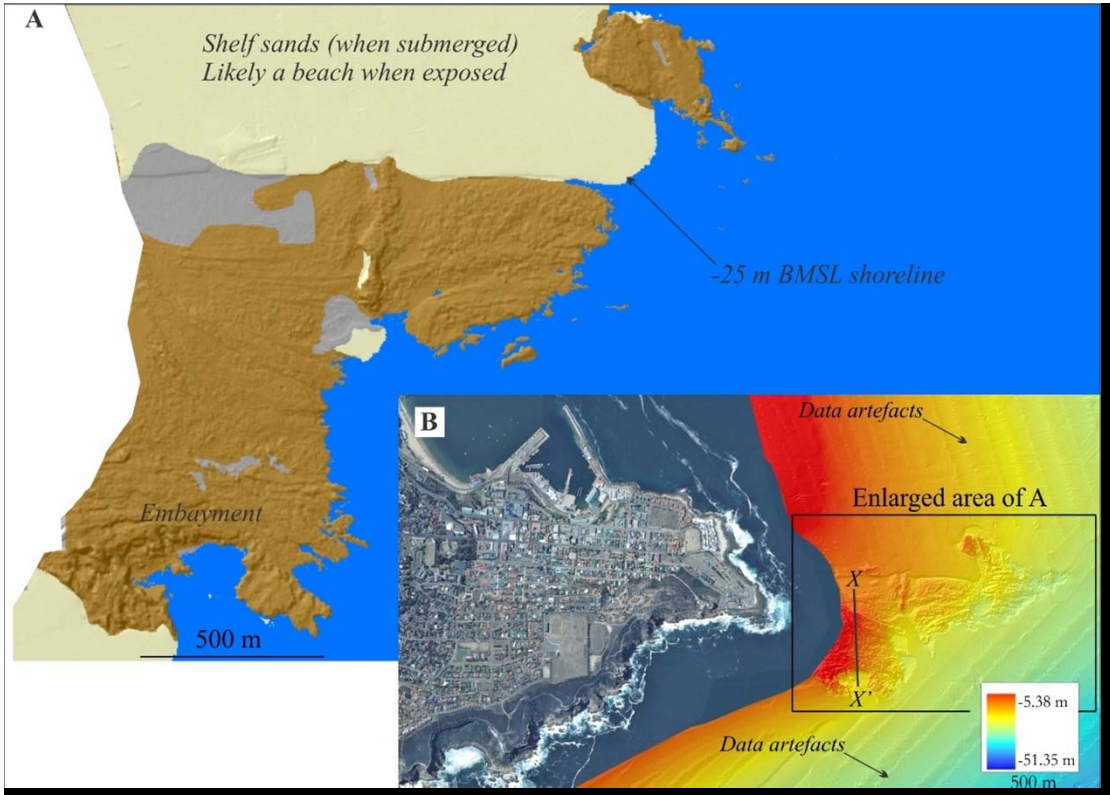
Evidence for fluvial environments:

infilled sequences, estuarine/back barrier, meanders

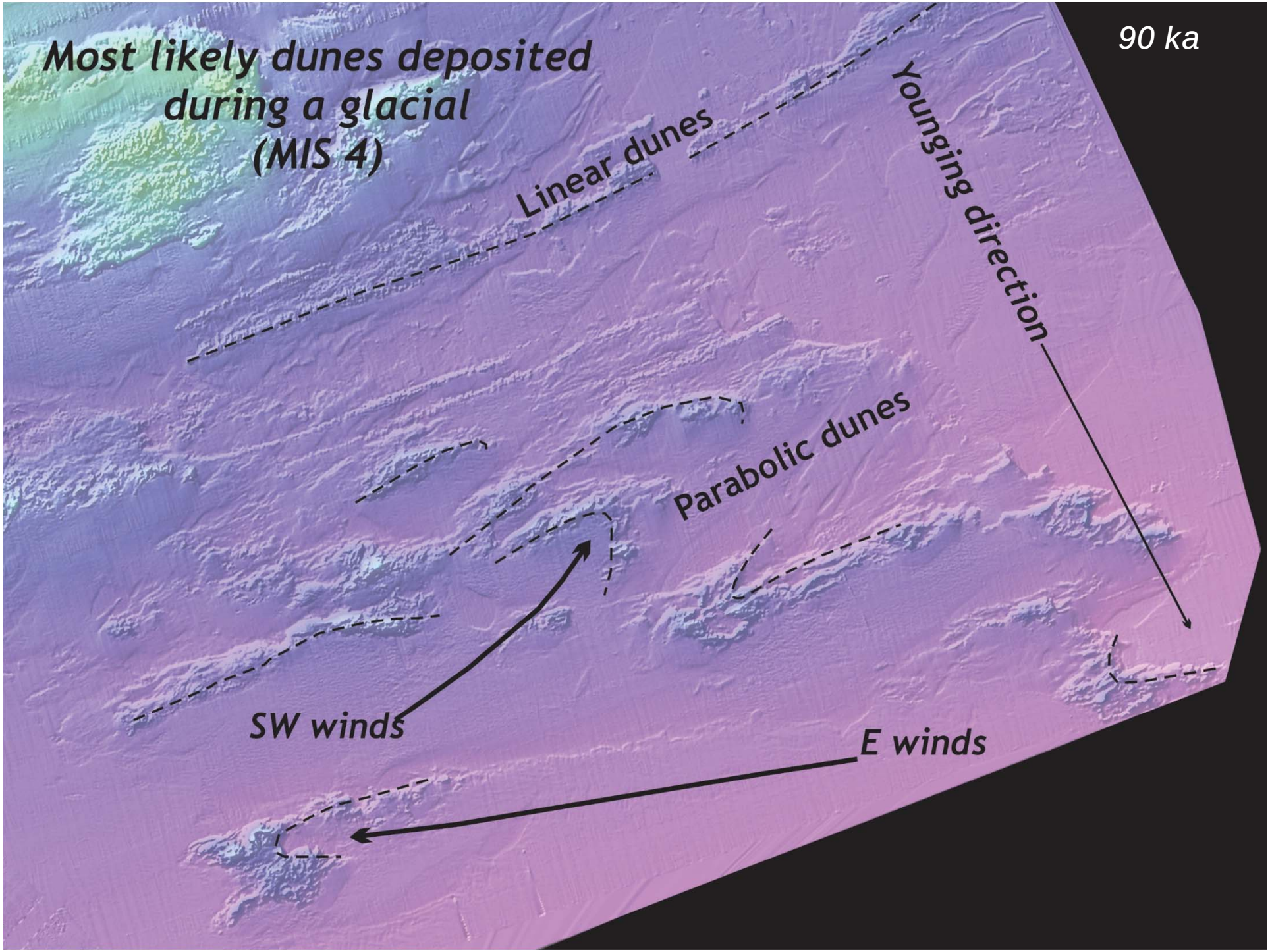
EROSIONAL-

Evidence for past clastic shorelines:

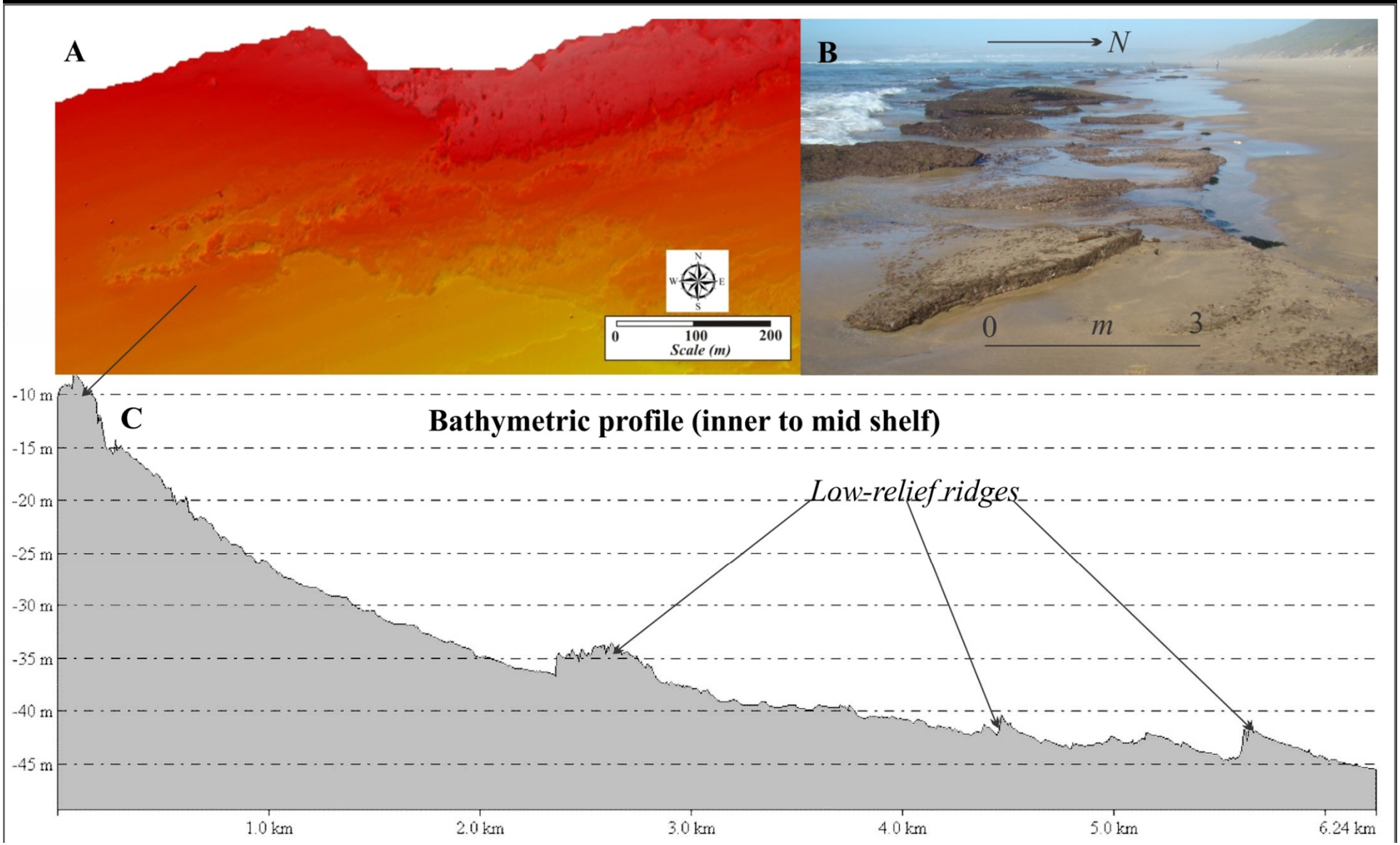
submerged sea cliffs, incised channels, shoreline features of the intertidal zone



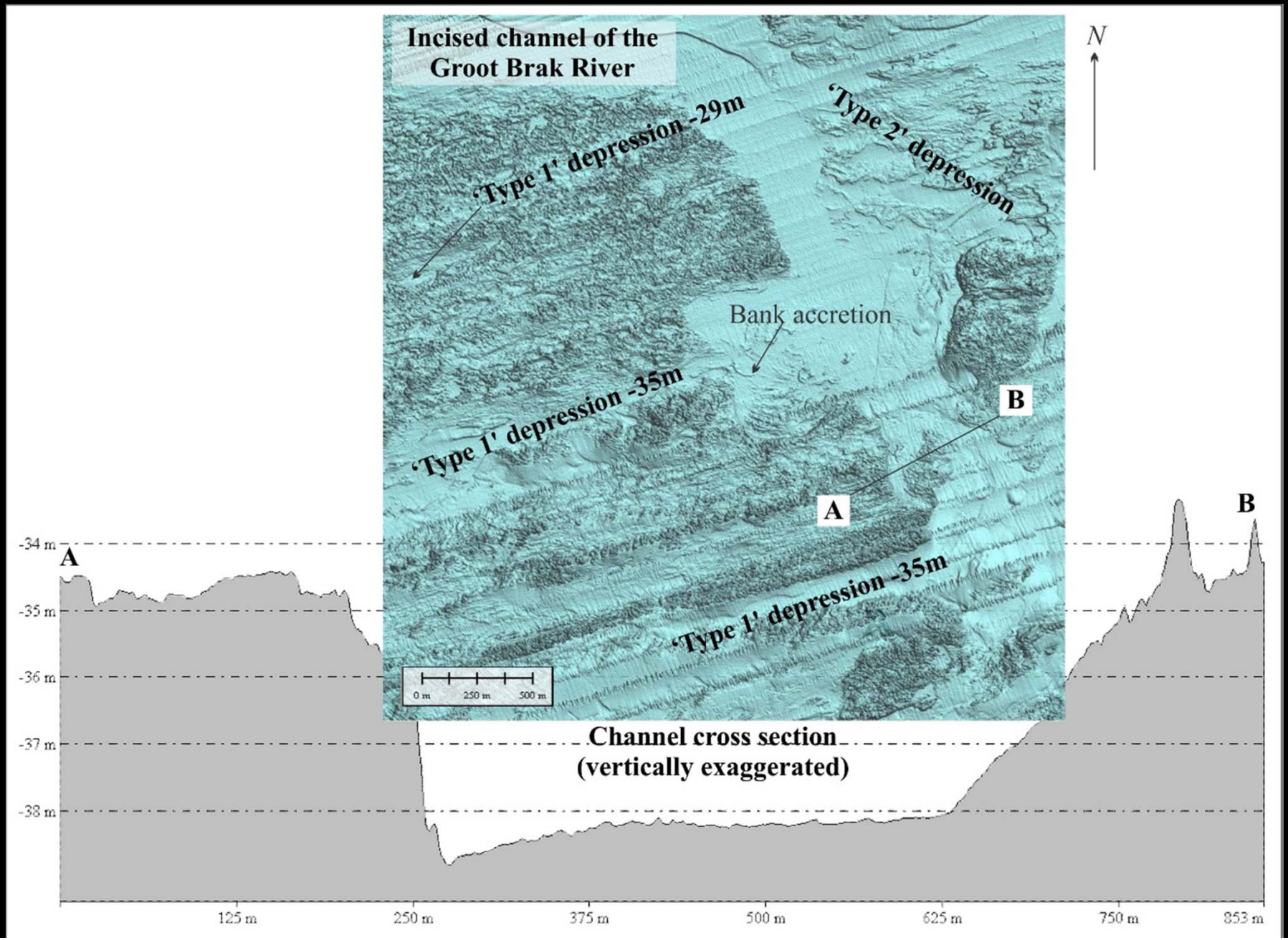
Sea cliffs offshore of Cape St. Blaize


Most likely dunes deposited during a glacial (MIS 4)
90 ka
Linear dunes
Younging direction
Parabolic dunes
SW winds
E winds

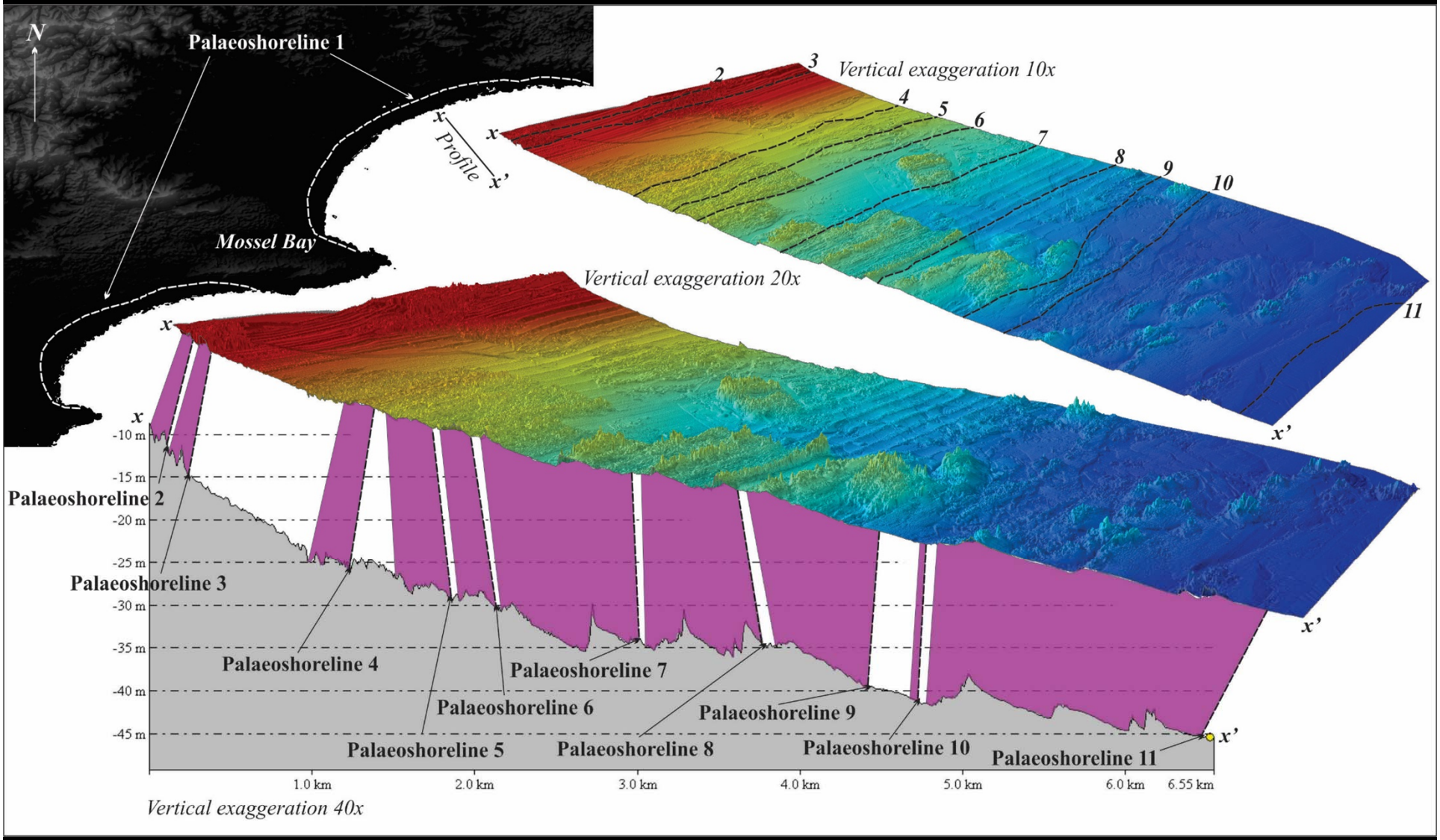
Low relief ridges: palaeobeaches

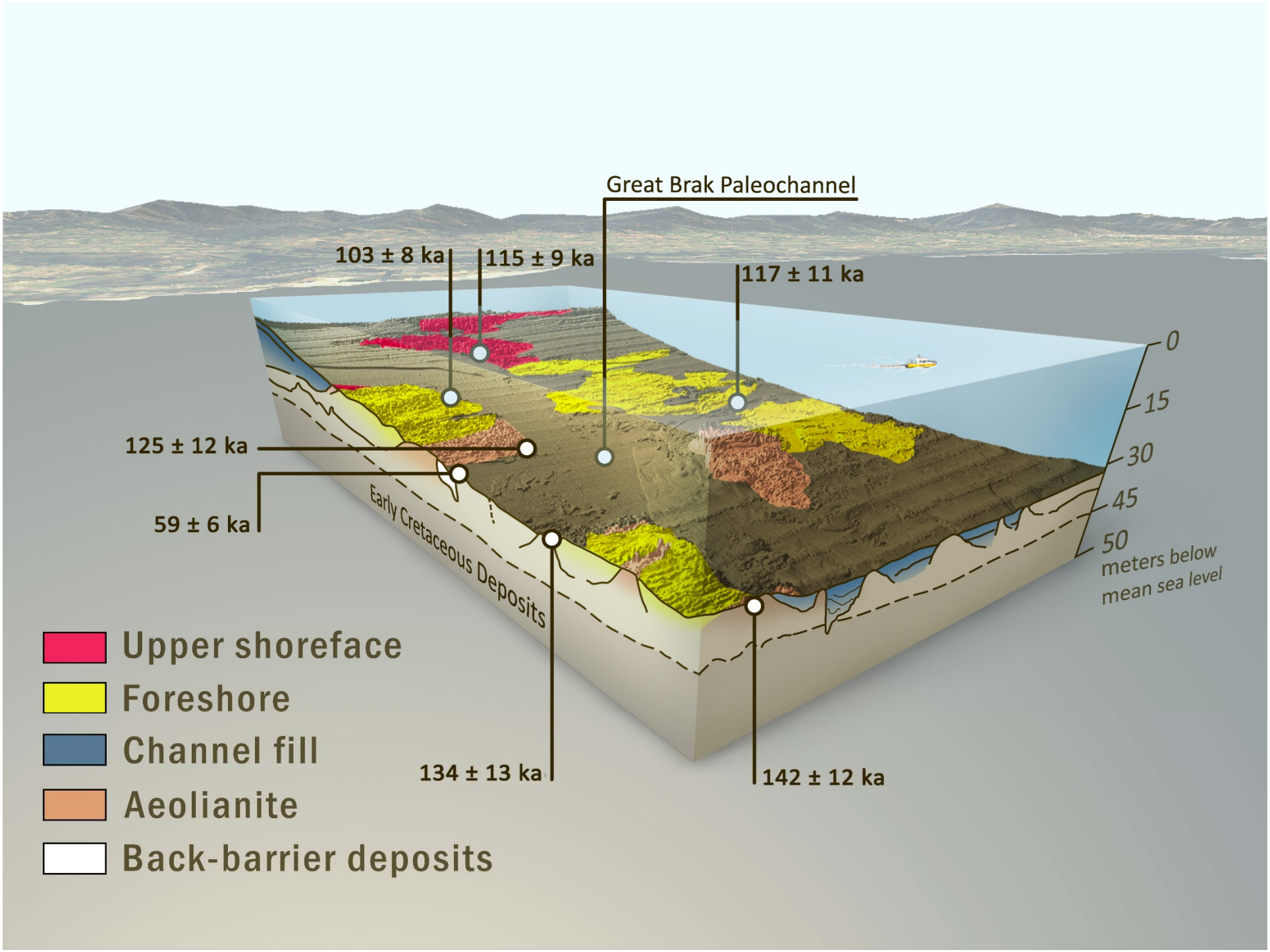


Incised river channels



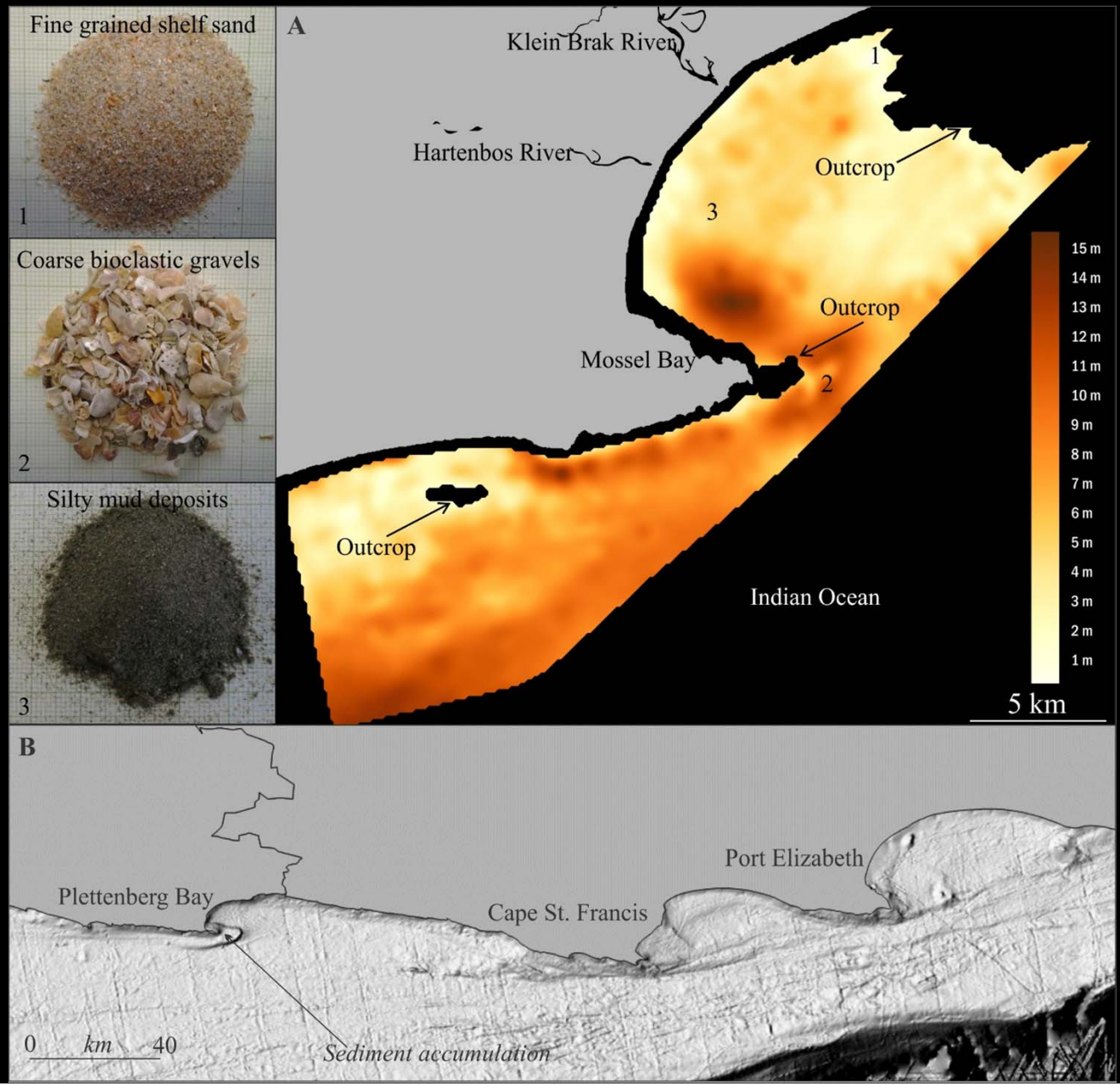
Palaeoshorelines and palaeo-coastal zones

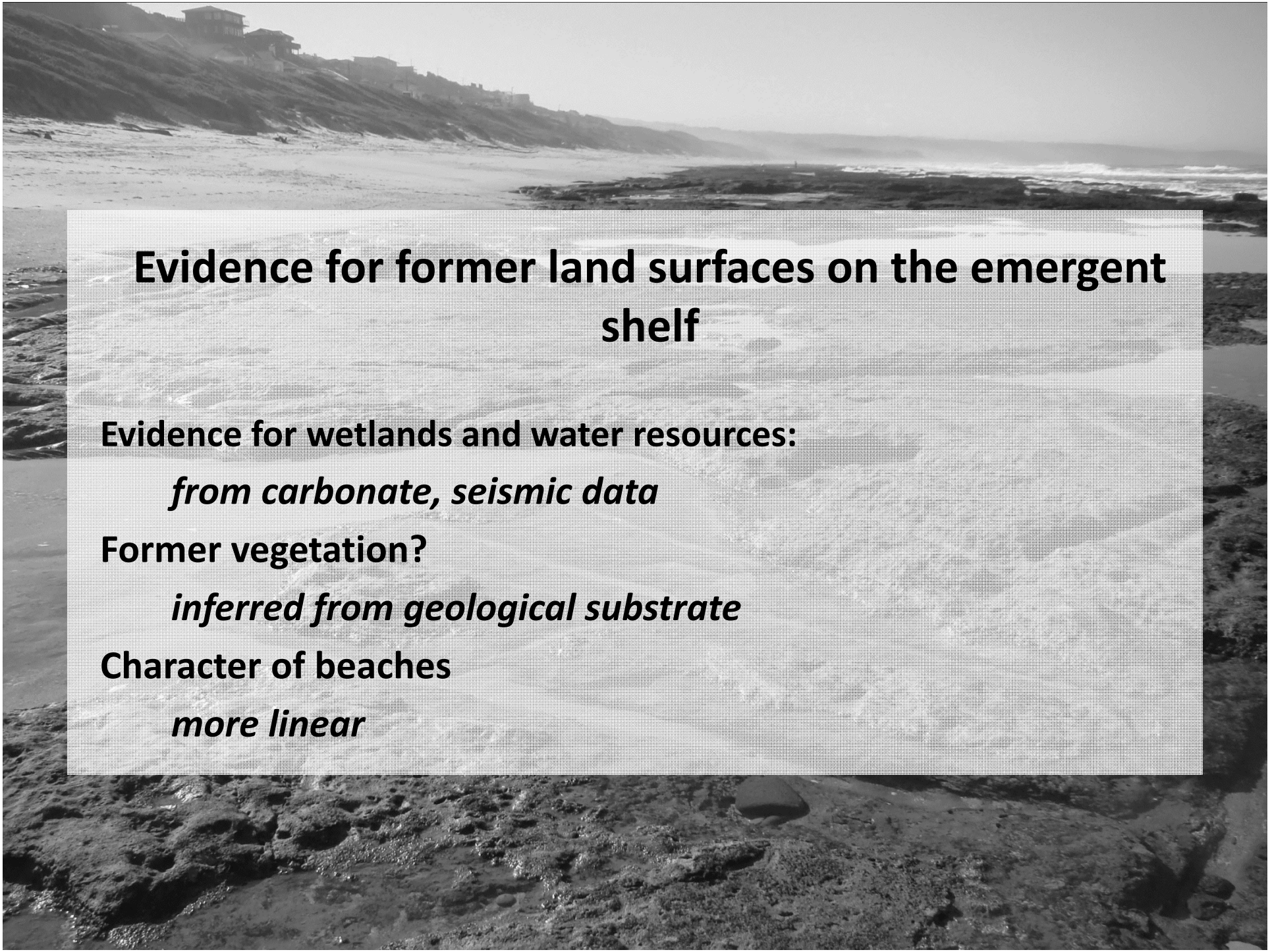



Great Brak Paleochannel
103 ± 8 ka
115 ± 9 ka
117 ± 11 ka
125 ± 12 ka
59 ± 6 ka
Early Cretaceous Deposits
134 ± 13 ka
142 ± 12 ka
0
15
30
45
50
meters below
mean sea level
Upper shoreface
Foreshore
Channel fill
Aeolianite
Back-barrier deposits

Ancient lagoon on the shelf

Modern marine sedimentation





Evidence for former land surfaces on the emergent shelf

Evidence for wetlands and water resources:

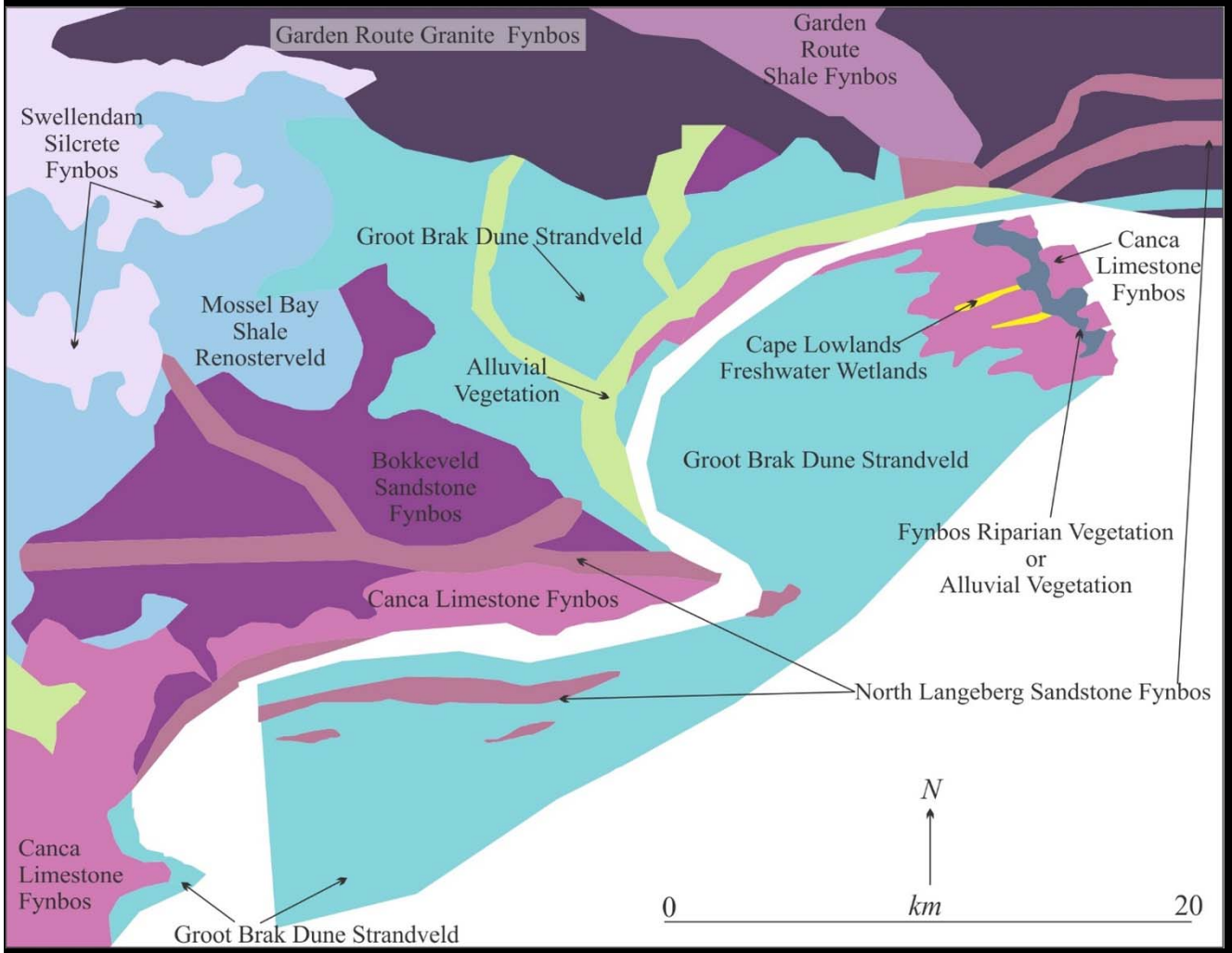
from carbonate, seismic data

Former vegetation?

inferred from geological substrate

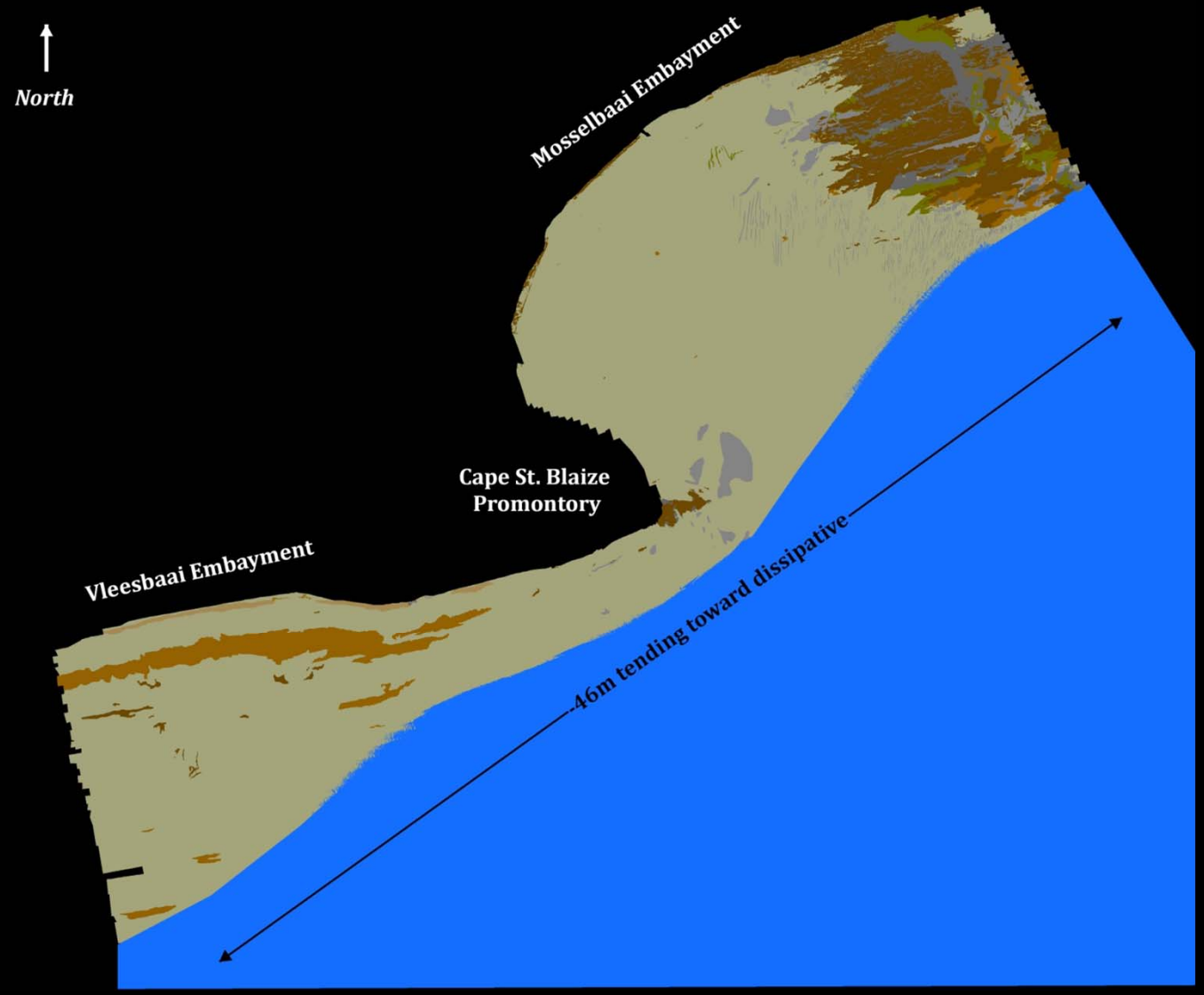
Character of beaches

more linear

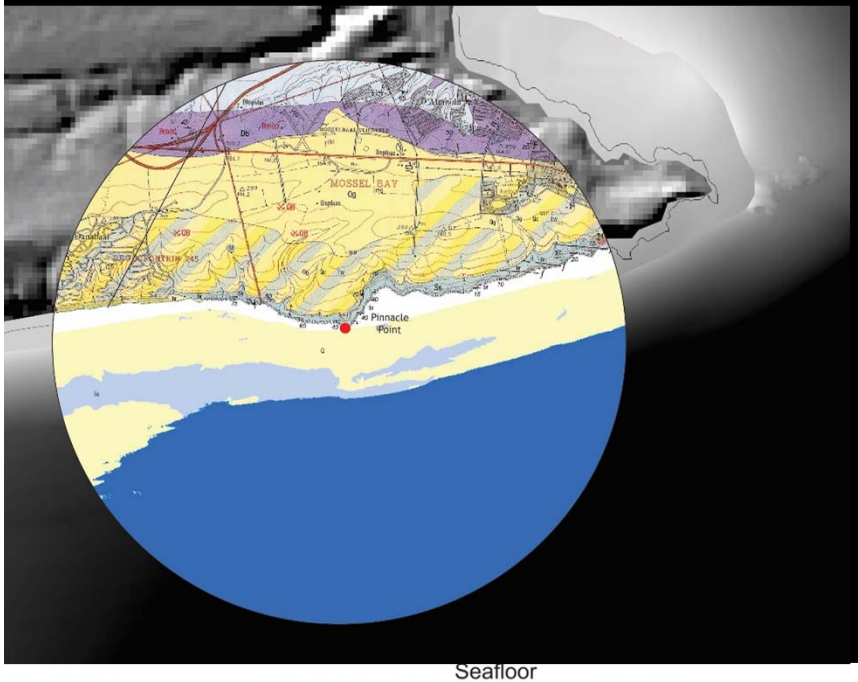


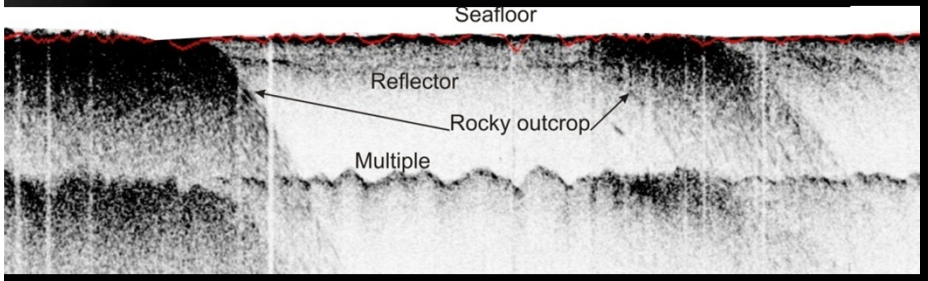
Dr Erich Fisher

Beach morphodynamics through time



Seafloor Geology: shoreline migrations and archaeological influence



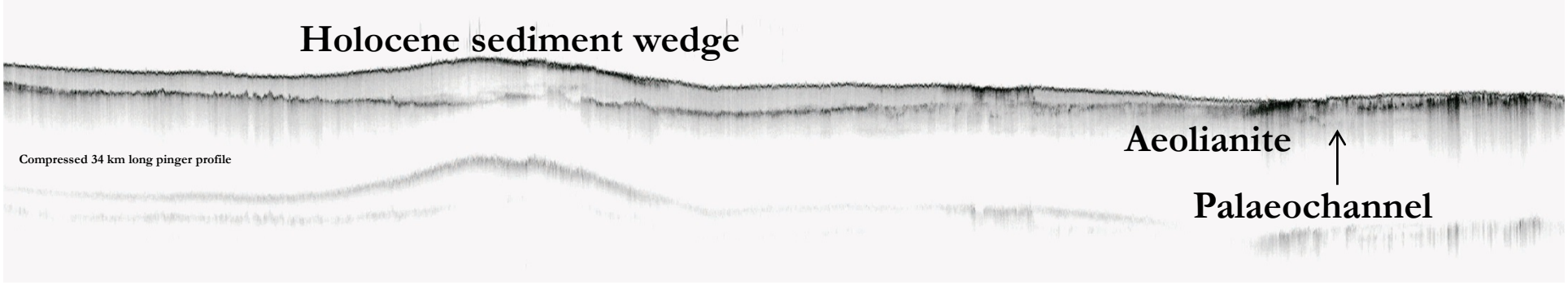


Shellfish at Pinnacle Point show a periodic shift between rocky and sandy intertidal zones, e.g. 112 ka below

Sand mussel (*Donax serra*)

Alikreukal (*Turbo sarmaticus*)

Brown mussel (*Perna Perna*)



Kept close to coastal areas and resources during Marine Isotope Stage 6 (185–135 ka)

↓

Social interactions and terrestrial plant and animal foods promoted development of working memory and executive functions

↓

Ability to link complex phenomena, like tidal and lunar cycles, to schedule foraging trips to the coast and access intertidal areas safely

↓

Systematic Coastal Foraging therefore developed as a consequence of modern human behaviors and cognition.

The Coastal Cognition Hypothesis

Summary

- We have discovered a well preserved submerged Quaternary landscape, shaped by the same processes affecting the modern environment
- The geological deposits on the emergent shelf indicate a greatly expanded glacial coastal plain
- Shallowly incised, broad, meandering rivers
- Wet, flat submerged landscape compared to the present
- Answers some puzzling questions of human use of this landscape from the archaeological record
- These palaeo deposits can be used to project future global change
- 'Source to sink' – the continental shelf processes are NB in considering the deep seafloor
- The continental shelf is important in the 'Common Heritage of Mankind' even in a context of modern human evolution

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