First observations of sea-level indicators related to glacial maxima at Sodwana Bay, northern KwaZulu-Natal

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RECENT OBSERVATIONS MADE FROM THE submersible *Jago* have shed new light on palaeo-sea levels found off the continental margins of southeastern Africa. The discovery of deep-water caves within the northern KwaZulu-Natal submarine canyon system, and their corresponding intertidal erosional features, indicates three deeper than present sea levels at depths of 106 m, 124 m and 130 m. A clast-supported, cobble conglomerate is associated with caves of 124 m depth. This is interpreted as a beach deposit that formed during the Last Glacial Maximum (LGM) at 18 000 BP. This is the first evidence of the LGM for the east coast, and suggests tectonic stability throughout southern Africa since that time.

Introduction

Relative sea-level fluctuations during the Late Pleistocene–Holocene period have been described by a number of authors for the South African coast and continental shelf. Well-constrained sea-level curves have been presented for the west coast,[1] the last 50 000 yr[2] and the late Holocene.[3] Recent work[4] has provided an amalgamation of existing sea-level indicators along the entire South African coast spanning the penultimate interglacial period (around 182 000 BP) to modern-day sea levels (Fig. 1). There is a lack of evidence constraining sea levels that span the Penultimate Glaciation and the Last Interglacial periods of between 182 000 ± 18 000[4] and 112 000 ± 23 000 BP.[5] Evidence for a penultimate Glacial Maximum has not been described for the South African coast. Similarly, records for the Last Glacial Maximum (LGM, 16 000–18 000 BP) are scarce, limited only to those indicators discovered on the west coast. Recently,

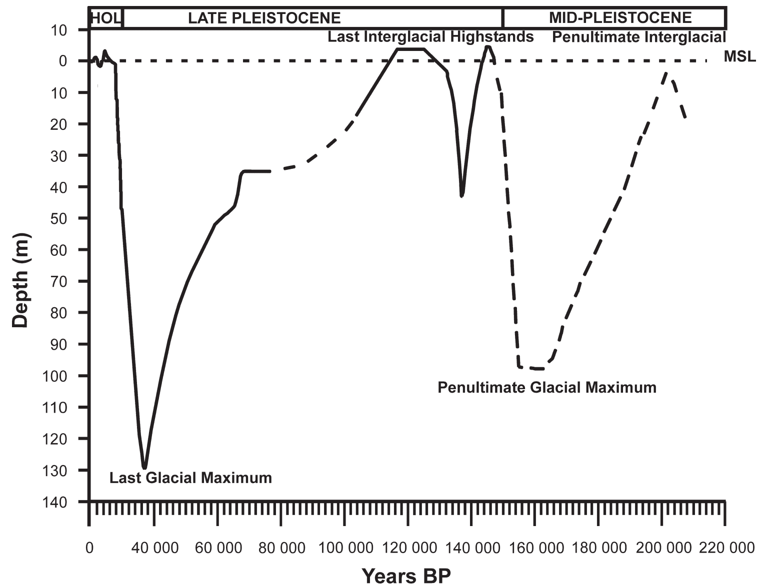

Fig. 1. Sea-level curve for the past 220 000 years, based on indicators from the South African coastline.[4] Inferred sea-level data are defined by the dashed curve. Lowstands indicate previous glacial maxima. MSL, present mean sea level.

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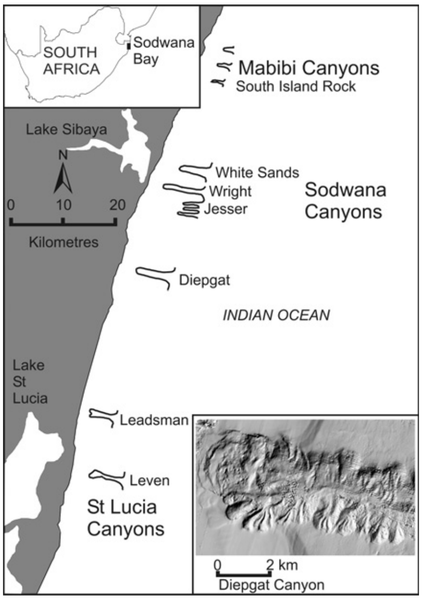

Fig. 2. Locality map of the Sodwana Bay area, detailing canyon localities with respect to major coastal waterbodies. The inset shows a sunshaded bathymetric map of Diepgat Canyon, where the most recent geological exploration took place.

observations made from the German submersible *Jago* within a series of incised submarine canyons off the Sodwana Bay continental shelf, northern KwaZulu-Natal (Fig. 2), have revealed a number of lower than present sea-level indicators at depths that have been either little explored, or completely unexplored, by traditional methods. In particular, we can present strong evidence for sea levels at depths greater than that corresponding to the LGM. This article thus aims to substantiate previous evidence for sea levels that occurred within the depth bracket proposed for the Last Glacial Maximum.

Indicators of glacial maxima along the South African coastline

Several dates circumscribe the Last Glacial Maximum, the maximum depth of 130 m of the corresponding sea level being derived from relict rhodolites of 16 990 ± 100 yr BP.[6] The probable vertical accuracy is considered to be within 5 m of mean sea level.[4] Seismic profiling off the Orange River revealed preliminary evidence for a lowstand shoreline at 120 m depth.[7] The sequence was not dated, but assigned to the Last Glacial Maximum. Similarly, coarse-grained sands with 'typical littoral grain surfaces' were recorded at comparable depths offshore of the Orange.[8] No data exist for an east coast LGM. Evidence for a penultimate Glacial Maximum is not described for the South African coast, though isotope evidence from the Huon Peninsula, New Guinea, suggests sea levels of between –130 m and –145 m at 135 000 BP.[9] No physical observations have been made regarding sea levels lower than that at the LGM or corresponding to a glacial period prior to the Oxygen Isotope Stage 5e high stand (125 000 BP).

New evidence for east coast sea levels

The continental shelf of northern KwaZulu-Natal is characterized by a Holocene sediment wedge mantling late Pleistocene hardgrounds that extend from a depth of 90 m to the present shoreline.[10] The shelf comprises a trailing edge margin, with a narrow shelf and relatively gently inclined (2–3°) continental slope. Multi-beam bathymetry surveys indicate that a number of submarine canyons in varying stages of growth have cut into the continental shelf from Leven Point in the south to South Island Rock in the north of the study area (P.J. Ramsay and W.R. Miller, in prep.).

The recent introduction of the German submersible *Jago* to the area has allowed observations to be made at depths greater than those attainable by traditional SCUBA methods. First observations suggest that the canyons have cut into older rocks of Tertiary and late Cretaceous age, which can be correlated with the recognized seismic stratigraphy of the continental shelf.[11,12]

Within the canyons, a number of deeply notched caves with erosional features typical of sub-aerial intertidal environments are found. In addition, overhangs, planed terraces and notches indicating palaeoshorelines[13] are found at various depths along the exposed sections of the canyon walls. As these features are not contemporaneous with deposition, they may be considered to post-date the deposition of the Tertiary rocks in the study area during the Early to Late Miocene transgression.[14] Sea levels indicated by these features thus span the time period from Early Pliocene to Late Pleistocene.

Submarine cave localities across six mature canyons can thus be analysed in terms of their cluster relationships, based on depth and location. This implies that only genetically related caves, formed by massive events such as glacial maxima, should be targeted as possible sea-level indicators. The Jesser, Diepgat, Wright, White Sands, South Island Rock and Mabibi canyons have so far been explored for caves and their suitability as habitats for coelacanths.

Forty-two caves were recorded as depth versus canyon locality plots (Fig. 3). From these, three distinct clusters are recognizable at depths of 106 m, 125 m, and 130 m. Though caves at these depths do not occur uniformly throughout the various canyons, they appear to be good indicators of lower sea levels in the past than at present. The two deepest sea-level indicators are characteristically absent from Jesser Canyon, which is the youngest and least incised of the sample group. This indicates that the two lowest sea levels prevailed before Jesser Canyon was cut to a depth of 125 m and confirms that the 105 m depth indicators are younger than both the –130 m and –125 m sea levels. The absence of the deeper indicators from Diepgat is attributed to scarp slumping within the canyon head, features recognized from the bathymetry of the canyon margins (Fig. 4).

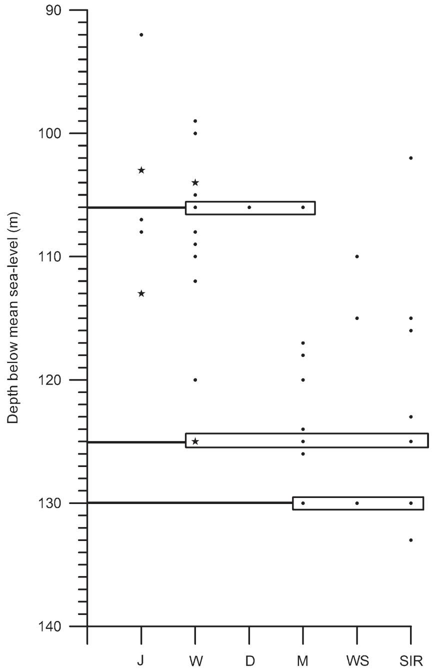

Fig. 3. Cave clusters relative to the various canyon localities found in the study area. Abbreviations: J, Jesser; W, Wright; D, Diepgat; M, Mabibi; WS, White Sands; SIR, South Island Rock.

Within South Island Rock Canyon, a partially cemented cobble conglomerate was discovered within a cave at a depth of 125 m (Fig. 5). The overlying stratigraphy comprises trough cross-bedded beachrocks and planar bedded aeolianites, with grain size restricted to that between the fine sand and gravel fractions (Fig. 6), suggesting that this deposit, without appreciable transport and smoothing, could not have been derived from the upper canyon margins as a weathering product. We therefore suggest that this deposit is *in situ* and was emplaced either contemporaneously with or just after cave formation at 125 m depth. Further observations are needed to ascertain whether this deposit is the product of a

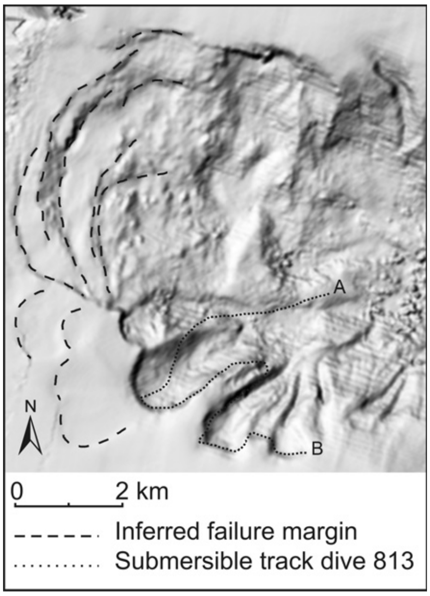

Fig. 4. Sunshaded digital terrain model of Diepgat Canyon, showing inferred failure margins in the canyon head. The sedimentary log outlined in Fig. 6 is derived from transect A–B.

re-cemented gravity flow or if it was formed by storm action in the intertidal zone. Initial observations suggest that the conglomerate is clast supported, typical of beach deposits emplaced during storm events.

We consider that newly interpreted sea levels at –125 m and –130 m can be correlated with established sea-level curves. The event at a depth of 125 m can possibly be assigned to the Last Glacial Maximum lowstand of 16 000–18 000 BP. Depths of 130 m are probably the expression of sea-level oscillations during the LGM. Shallower sea-level indicators at 105 m depth can possibly be assigned a much younger age, and can be correlated with *in situ* estuarine molluscan material from the southwest coast inferred as a palaeo-sea level of between 90 m and 102 m below mean sea level and related to the onset of sea-level rise during the Flandrian transgression.[15]

Conclusions

The submarine canyons off Sodwana Bay provide an ideal window onto the Quaternary history of the continental shelf. New evidence for lower than present sea levels is described from submarine caves, and *in situ* deposits that suggest intertidal weathering and sedimentation at depths unexplored along the east coast of South Africa. Preliminary interpretations indicate a depth at the time of the LGM of between 125 m and 130 m along the coast. These data are the most solid observable evidence for glacial maxima along the South African coastline and can contribute significantly to the understanding of global sea-level variability. Close matches in LGM sea level between the east and west coasts indicate negligible tectonic activity during the last 18 000 years.

Fig. 5. A cobble conglomerate found within a cave at a depth of 124 m in South Island Rock Canyon deposited during a sea-level lowstand under storm conditions.

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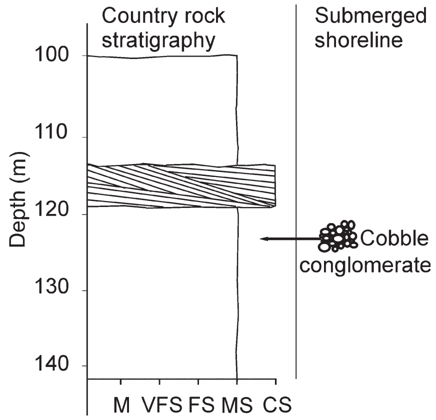

Fig. 6. A sedimentary log detailing the country rock sedimentology upon which the conglomeritic deposit has been superimposed. Note the absence of coarse material from the upper levels, precluding the deposition of the cobble conglomerate as a product of gravity flow.

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