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Timing and Estimates of Plio-Pleistocene Sea-Level Highstands from the Republic of South Africa (RSA)

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The rapid rise in atmospheric CO_2 exceeding 400 ppmv is driving an urgent need to better understand past sea level, ice sheet dynamics, and climate change associated with past warmer geological intervals. The LR04 record reveals sustained intervals during the Pliocene (5.6-2.6 Ma) when δ18O exceeded the present levels, indicating a possible decrease in the volume of polar ice sheets. Other shorter intervals of likely decreased ice volume occur during Pleistocene interglacials including MIS 5e, 11, 31, and 37.Here we focus on the middle Pliocene warm period (MPWP; 3.3 to 2.9 Ma), an interval during which Earth experienced CO_2 levels around 400 ppmv (Fedorov et al., 2013).

The intra-plate coastal margin of western South Africa, a region of relative tectonic stability and relative insensitivity to uncertainty in mantle viscosity as is effects corrections for glacial isostatic adjustment, is a promising region for deriving estimates of eustatic sea level (ESL; thus ice volumes) at the end of the MPWP (Rovere et al., 2014). During a field expedition covering several thousand kilometres along coastlines of western and southern coasts of RSA, we documented the stratigraphy, geomorphology, and geochronology of Pliocene and Pleistocene shorelines with differential GPS providing decimeter scale accuracy to stratigraphic contacts and sea-level indicators.

From about twenty sites, precise elevations (as yet uncorrected for GIA) of multiple sea stands were recorded. Strontium isotopes were used to date the shell material from many of the marine sites, but only three sites yielded reliable age data that passed screening criteria for diagenesis. The oldest shoreline evidence, from Cliffs Point on the west coast near the Olifants River, is observed at 34.9 $\pm$0.2 m asl and yields an age 4.70 $\pm$ 0.20 Ma; a younger shoreline from the southern coast Bredasdorp site is observed at >24.0 $\pm$ 1.5 m asl and yields ages from 3.00 $\pm$ 0.45 to 3.55 $\pm$ 0.31 Ma, the interval of the MPWP. . A surprising result from a west coast marine terrace at Donkergat was the identification of an early Pleistocene highstand (MIS 31 or 37?) at 16.5 $\pm$ 0.5 m asl with a mean Sr age of 1.26 $\pm$ 0.15 Ma. These shorelines suggest that a considerable volume of polar ice sheets could have been susceptible to melting when atmospheric CO_2 and global temperatures were only modestly higher than the present but significant uncertainty in elevations due to glacial isostatic adjustment and dynamic topography (e.g. Rovere et al., 2014) precludes a robust assessment of eustatic sea level in the Pliocene and early Pleistocene.

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Patterns and mechanisms of early Pliocene warmth. Nature 496, 43–49.

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