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# Mega-Lake in the Kalahari: A Late Pleistocene record of the Palaeolake Makgadikgadi system

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ABSTRACT

A distinct series of beach ridges marking the former shorelines of large inter-connected lacustrine basins in the Kalahari can be clearly identified from Landsat imagery and Shuttle Radar Topography Mission (SRTM) data. These basins, which form the terminal sump of the Okavango system in northern Botswana, are now almost completely dry. During the Quaternary they were intermittently occupied by large stable lake bodies and are thought to have periodically filled to a point of coalescence inundating an area that, at its largest extent, encompassed 66,000 km$^2$. Poor chronological control has previously limited the utility of this important palaeo-archive. As part of a region-wide lake palaeo-shoreline research programme, a systematic optically stimulated luminescence (OSL) dating programme has utilised a light-weight hydraulic auger to take samples at depth from relict shoreline features. Twenty drill-sites have generated 140 samples for dating, establishing a firm chronology for multiple lake full phases in all three component basins (Ngami, Mababe and Makgadikgadi) of this mega-lake. This paper presents the final set of ages in the programme, derived from four cores from the western and north-eastern shorelines of Makgadikgadi, and uses these ages to establish a chronology of mega-lake high-stands during the last ~300 ka providing a rare directly dated, long terrestrial record of positive hydrological excursions within the southern hemisphere.



## 1. Introduction

Geomorphological evidence of former extensive lake bodies in the Middle Kalahari has long been recognised (Grove, 1969). This evidence, in the form of relict shorelines, is part of a suite of records including fossilised fluvial channels (Shaw et al., 1992), limited pollen records (Nash et al., 2006) and diatom beds (Shaw et al., 2003), that testifies to wetter-than-present climate phases in the region in the late Quaternary. Whilst over 100 inorganic carbonate radiocarbon ages have attempted to place a chronology on these wet phases, questions about both the suitability of this material for dating and the highly variable conditions under which duricrust carbonates can form have frequently led to doubts about their use as palaeo-environmental proxies. In light of these uncertainties, a systematic optically stimulated luminescence (OSL) dating programme carried out on deep-drilled sandy sediments from relict lake shorelines has enabled a detailed chronology to be placed on the two smallest component basins in the Palaeolake Makgadikgadi system (Burrough et al., 2007; Burrough and Thomas, 2008). Here we present OSL ages from the third of these inter-connected basins, the Makgadikgadi depression, and examine the dated late Pleistocene 'mega-lake' transgressions (resulting from the unification of sub-basin palaeolakes) in the context of other long lacustrine records on the African continent.

## 2. Regional setting

### 2.1. Climate and hydrology of the Middle Kalahari

The Kalahari is located within the southern hemisphere subtropical high pressure belt, influenced by the seasonal movement of the Intertropical Convergence Zone (ITCZ) and Congo Air Boundary (CAB) and the interaction of these convergence zones with both South Atlantic air masses and the north-east monsoon penetrating from East Africa and the Indian Ocean (Tyson, 1986; Thomas and Shaw, 1991). Precipitation in the Kalahari today occurs principally as convective rainfall in response to the seasonal southerly migration of the ITCZ between October and March, increasing in duration and becoming earlier in onset along

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a northerly gradient. In the Middle and Northern Kalahari, rainfall associated with these low pressure troughs tends to occur in conjunction with recurved South Atlantic air, whereas in more southerly parts of the Kalahari rainfall events are typically associated with easterlies originating from the Indian Ocean. Whilst the Makgadikgadi basin is located sufficiently far south to experience a relatively low mean annual rainfall (c.300 mm $yr^{-1}$) during the 20th century (Helgren, 1984), it lies at the end point of a hydrological system where flow is largely dominated by headwaters sourced in the Angolan highlands of the Benguela Plateau where mean annual precipitation is in the range of 1300–1400 mm $yr^{-1}$. The lag time between the seasonal summer rainfall that dominates the catchment and the arrival of the flood peak at the terminus of the hydrological system is typically 6–7 months, introducing an antiphase relationship between summer precipitation maxima and winter discharge peak. The dominant easterly winds in the Makgadikgadi region have apparently been a persistent feature of the Quaternary climate of the middle Kalahari, influencing both the ENE–WSW direction of linear dune forms (Thomas, 1984) and the orientation of shoreline features along the western margins of palaeo-lake basins.

### 2.2. The Makgadikgadi basin

The Makgadikgadi depression is the largest of three discreet component basins making up the palaeo-mega-lake system of the Middle Kalahari (Fig. 1A). It is a structural basin covering approximately 37,000 $km^2$ (Cooke and Verstappen, 1984) (more than twelve times the size of the Ngami basin – the smallest of the sub-basins). Evidence from drainage patterns, mineral distribution and offshore delta deposits suggest that crustal flexuring along the Okavango–Kalahari–Zimbabwe Axis cut off the Cubango–Okavango, Cuando and Upper Zambezi–Luangwa–Kafue from the downstream Limpopo during the end-Cretaceous to early Tertiary (Moore et al., 1999; Moore and Larkin, 2001). This formed a major endoreic drainage system that contributed to the formation of the Kalahari Group sediments and the existence of a permanent lake body in the Makgadikgadi basin. Progressive capture of the Kafue, upper Zambezi and Kwando Rivers by the lower Zambezi in the mid to late Plesitocene (due to the displacement along major north-east trending faults related to the East African Rift), caused perennial flow to the basin to be severely reduced and rendered Makgadikgadi a seasonally inundated salt-pan (McCarthy and Rubidge,

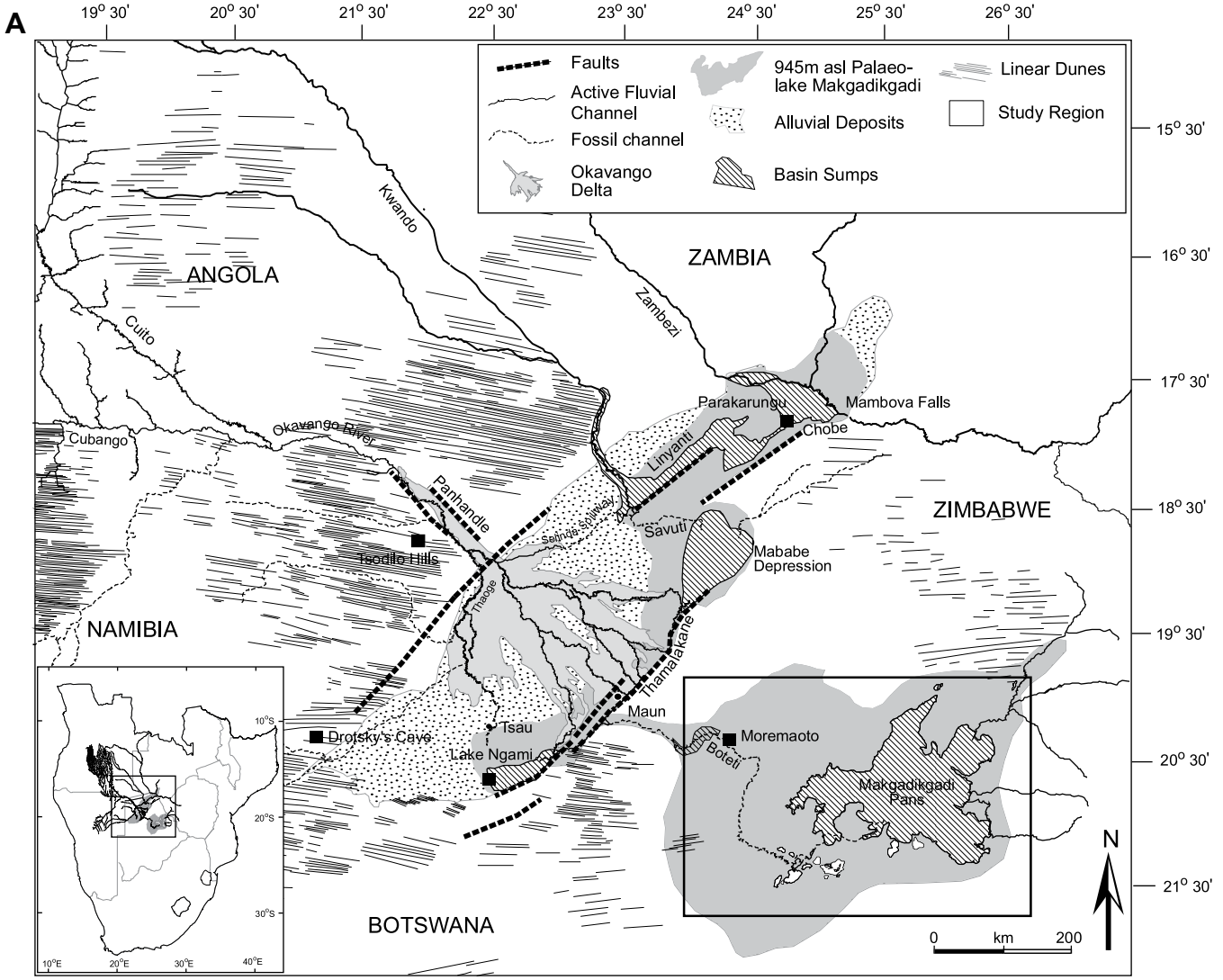


**Fig. 1.** A): Location map of Palaeolake Makgadikgadi. B) Detailed map of shoreline sampling sites used to construct high lake stand chronology. Sites of previous studies are also indicated.