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Age and dynamics of the Namib Sand Sea: A review of chronological evidence and possible landscape development models

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ABSTRACT

The Namib Sand Sea constitutes a major physiographic feature of the Namib Desert on the west of Namibia, covering a 50–160 km wide region of the coast between Lüderitz and Walvis Bay. It is widely considered to be one of the oldest desert regions, with a Tertiary-aged fossil desert underlying the modern sand sea. The sand sea has been well studied, benefiting from the presence of the Gobabeb Training and Research Centre during the past 50 years. Whilst much is understood about its sediments and geomorphology, it is only recently that new chronological information, using cosmogenic-nuclide burial dating and optically stimulated luminescence dating have offered new insights, and this calls for an updated review of the age and landscape development of the sand sea. This assessment of the geomorphological and Quaternary dynamics of the region is complemented by developments in the description and analysis of sediment composition.

New age control from cosmogenic dating indicates that the sand sea is in excess of a million years old. Initial data from luminescence dating yields depositional ages for dune sediments from three broad areas of the sand sea that include MIS 5, later in the Pleistocene around the Last Glacial Maximum and the Holocene, although it is not expected that these will be the only, or discrete age groupings. Detailed dating and application of ground penetrating radar in the far northern reaches reveals extensive dune migration and deposition during the Holocene. It is important to stress that the upper limit of luminescence dating here is about ~200 ka (depending on the environmental dose rate of the site) and that migration and reworking of dunes resets the luminescence signal (so what is recorded is(are) the last phase(s) of preserved sediment accumulation).

Whilst there are three potential sources of material for the Namib Sand Sea (reworked Tsondab Sandstone (TSS), material from the Great Escarpment derived by rivers and water and wind-derived material from the Orange River delta) the weight of evidence points towards the dominance of an Orange River source, with localised contribution from fluvially-derived escarpment material close to river courses. Despite the fact that it remains difficult to definitively distinguish between recent Orange River sediment and recycled TSS, because of a great mineralogical similarity, an Orange River source contemporaneous with the accumulation of the sand sea appears to be favoured. Models of landscape development rely on an understanding of the source region, and an Orange River source suggests growth and extension from south to north (a wind-displaced Orange Delta), rather than localised reworking of sediment from the TSS. One proposed model, developed for the southern part of the sand sea, divides accumulation into two distinct phases with different palaeoenvironmental conditions: large draas accumulating under enhanced Pleistocene trade winds and superimposed features on the eastern dune flanks formed by westerly winds moving material over the crest. However, the latter phase could equally be explained by a northerly migration of the superimposed features, and there is still too little in the way of chronological control to construct a coherent picture of dune accumulation and migration for the sand sea as a whole. There are also interesting insights from conceptualising dune bedform patterning in sand seas as a time-dependent, self-organising, complex system, rather than necessarily requiring changing palaeoenvironmental conditions for different scales of features, with some of this research referring directly to the Namib Sand Sea. Refining the details of the accumulation of the Namib Sand Sea requires both detailed site-specific studies and joined-up analysis.

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Contents

1. Introduction

The Namib Desert is widely considered to be one of the oldest and most beautiful desert regions. The Namib Sand Sea (Fig. 1) is a major physiographic feature of this coastal desert and stretches between Luderitz (26°39′S, 15°09′E) and the Kuiseb River (at Walvis Bay on the coast, 22°55′S, 14°30′E), in a relatively narrow strip, reaching as far inland as the base of the Great Escarpment (Barnard, 1973; Lancaster, 1989). It covers ~34,000 km^2 and overlies older tertiary desert sediments. The region is under nomination for the World Heritage list, noted with respect to natural and cultural value (Goudie and Seely, 2011). The sand sea has been well studied and much is understood about its dune geomorphology. Interest in its formation and appearance extends into the extra-terrestrial as the dune forms are used as an analogue for both Martian dunefields (e.g. Bourke and Goudie, 2009) and dunes on Titan (e.g. Radebaugh et al., 2010). Nonetheless, a detailed understanding of the age and landscape development of the Namib Sand Sea remains elusive, owing to the paucity of chronological control. However, since 2005 a small number of studies using Optically Stimulated Luminescence (OSL) dating of dunes (Bristow et al., 2005, 2007; Bubenzer et al., 2007) and aeolian sands that interdigitate former water-lain sediments (Stone et al., 2010) and also cosmogenic-nuclide burial dating (Vermeesch et al., 2010) provide useful new insights. Livingstone et al. (2010) provide a summary of 43 OSL ages, and record of dune accumulation, in the dune age database available at the time of producing the Namib Sand Sea digital database of aeolian dunes.

This new chronological information allows us to re-address the history and dynamics of the sand sea since the ideas about sand sea accumulation discussed in Lancaster's (1989) detailed volume about the sand sea, in Goudie's (2002) review of the entire Namib Desert along the west coast of Namibia, and in Livingstone et al.'s (2010) discussion of the Quaternary dune age database. The chronological information is also important for elucidating specific patterns and timing of late Quaternary environmental change; Stone and Thomas (in press) consider how new OSL chronologies revise some previous age estimates and enhance ideas about Namib Desert palaeohydrology (last reviewed by Lancaster (2002)) and they also discuss the results in the context of the sub-continental patterns of palaeoclimate collated in syntheses of Chase and Meadows (2007) and Gasse et al. (2008). When considering the OSL data, it is important point out that the OSL chronologies have an upper limit of ~200 ka (this varies as a function of the environmental dose rate of the site) and that what is recorded is(are) the last phase(s) of preserved dune accumulation, because migrations and reworking and re-deposition of dune material exposes grains to light, resetting any luminescence signal from previous depositional events.

An updated review of the age and dynamics of the Namib Sand Sea and possible models for landscape development is therefore of interest from the perspective of both Quaternary Science and Geomorphology. The emerging chronologies from these suites of Namib Sand Sea geomorphological features, or 'geoproxies' cf. Thomas and Burrough (2012), allow us to develop models for landscape development in response to changes in late Quaternary climatic conditions. This also improves our understanding of the current appearance and diversity of sand seas, and provides a basis to predict the possible future appearance, diversity and extent of these areas that Goudie (2002) reminds us Hobbs (1926, p.198) viewed to be 'self-regulating climatic gauges'. In addition, if we look above the geomorphological features toward the sky, as one is often drawn to do in deserts, this reminds us that understanding Namib Sand Sea geomorphology and landscape development will continue to provide clues to development of sand seas on other celestial bodies.

Challenges remain in putting together holistic models for landscape development, such as: the fact that the landscape is heavily under-sampled (in terms of spatial coverage and sampling in the vertical dimension), the likelihood that the landscape records a combination of long-term (gradual) shifts in climate and extreme events (high magnitude, low frequency), which we try to decipher, and the knowledge that the sediments that make up these geomorphological features are discontinuous, with parts removed from the record by erosion or reworking. These are amongst the ten classic problems experienced during extrapolating past conditions from modern observations, outlined very well by Schuum (1991). This means that differences in opinion (or multiple working hypotheses in a more scientific language) are likely to continue to exist until further research and dating is undertaken in this exciting sand sea. This paper: (i) briefly reviews progress made in understanding and mapping the diversity of dune types in the Namib Sand Sea, (ii) reviews the available chronological control for sand sea dunes from cosmogenic burial dating and luminescence dating, and (iii) outlines and evaluates possible sediment sources and models for accumulation of, or landscape development within, the sand sea.