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Establishing a chronological framework for a late Quaternary seasonal swamp in the Australian 'Top End'

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ABSTRACT

Swamps in the seasonal tropics have good potential for the reconstruction of late Quaternary monsoonal dynamics. Their successful use, however, has often been compromised by chronological limitations introduced by a variety of depositional and post-depositional processes actively modifying the swamp deposits. We here present and discuss the results of a multiple dating approach at Table Top Swamp (TTS) in northern Australia (the 'Top End'). Single-grain luminescence dating of quartz was successfully used to provide chronology in the lowermost core where insufficient organic material prevents the application of radiocarbon dating. In the uppermost, fine-grained and peaty section of the core, two different organic fractions (pollen concentrate and humins) were dated with AMS radiocarbon yielding significantly different chronologies. While this could point to the incorporation of younger pollen into the profile along seasonal dry cracks, older humins may also move up in the profile due to vertical mixing. Additional, spatially highly resolved measurements of the bulk OSL signal (Ln and Ln/Tn) combined with data on down-core variation in K, Th, and U concentration, grain size and moisture content were used to (i) guide the development of an age-depth relationship (i.e. age model) for the entire core based on three different data input scenarios, and (ii) test the applicability of novel luminescence screening techniques in seasonal swamp settings. Results suggest only minor differences among the applied models and scenarios, providing an overall reliable representation of the depositional history in the swamp. Even though all resulting age-depth models have relatively large uncertainties in the lower part of the core, there are significant changes in sedimentation rate over time, providing a chronological basis for a more detailed palaeoenvironmental analysis at TTS. The approach used may also be useful in developing age models in other complex environments, and has shown the importance of understanding carbon pathways as well as controls on luminescence signals when developing age models.

1. Introduction

The monsoon is one of the defining elements of the global climate system and is the fundamental source of water for ~70% of the worlds' population (Chang et al., 2011; Ramage, 1971; Zhisheng et al., 2015). Understanding the long-term behaviour of the monsoon system is therefore critical for understanding global climate change (de Carvalho, 2016). Consequently, a variety of palaeoclimate proxies stored in marine sediments, speleothems or lake sediments have been used to examine monsoon behaviour through time (Cronin, 2009; Lowe and Walker, 2014).

The Australian Summer Monsoon (ASM) is part of the global monsoon system. It influences approximately one fifth of the Australian continent (McDonald and McAlpine, 1991; Sturman and Tapper, 1996; Suppiah, 1992), yet despite this, there are very few terrestrial records of late Quaternary ASM behaviour. This is particularly true for the core monsoon region in northernmost Australia (the 'Top End'; Fig. 1a) where precipitation is dominantly controlled by the ASM (McDonald and McAlpine, 1991; Taylor and Tulloch, 1985). The lack of records from this region reflects, to some extent, the scarcity of accessible and reliable palaeoclimate archives, such as perennial lakes or speleothems (Reeves et al., 2013). In this context, seasonal swamps on the extensive sandstone plateaus of the 'Top End' (e.g. Nott and Roberts, 1996) represent potentially valuable, but largely unexplored, sedimentary archives for the application of multi-proxy palaeoclimate studies of past ASM activity, if reliable chronologies can be established.

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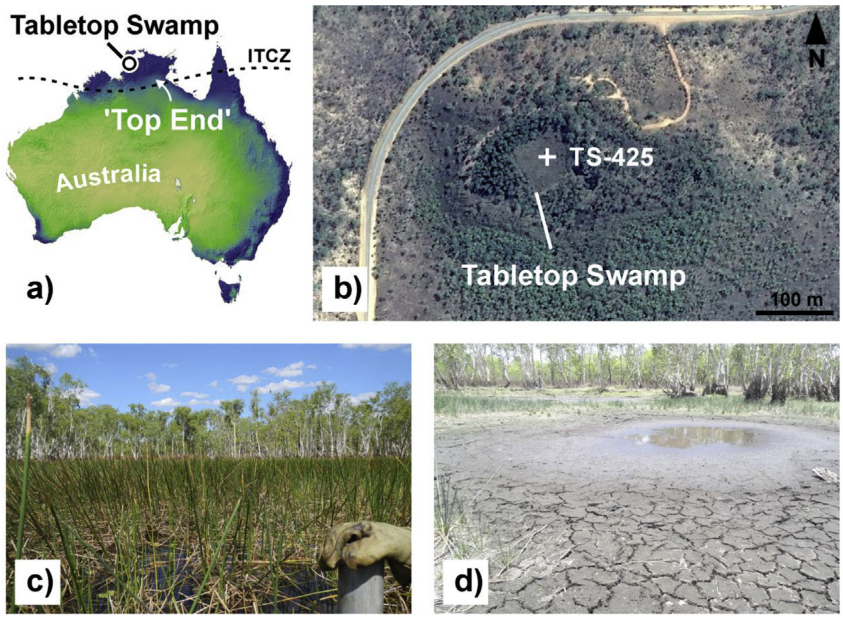

Fig. 1. Geographical Setting of Table Top Swamp. a) Location in Australia (note the approximate position of the Intertropical Convergence Zone (ITCZ) during the Austral summer is shown on the map); b) Google image showing the vicinity of the swamp with mesic rainforest surrounding the central swamp occurring within the broader savannah landscape of TTS; c) TTS in the wet season when the swamp contains water and supports dense reed (*Typha* spp.) growth; d) The surface of TTS containing cracks toward the end of the dry season in November 2014.

Developing chronologies in highly seasonal tropical environments, such as Australia's ‘Top End’ is not trivial (Field et al., 2018). Marked hydrological seasonality, in combination with high annual average temperatures, result in high weathering rates and variable pH and redox conditions. Similarly, high hydrologic seasonality also leads to high rates of geomorphic activity and seasonal biological productivity (e.g. vegetation growth and die-back). These conditions give rise to multiple and complex pathways of C (carbon) input into swamps and high rates of C cycling, i.e. variable C preservation. Consequently, carbon-14 age determinations in seasonal swamps are commonly problematic (Anshari et al., 2001; Brncic et al., 2009; Field et al., 2018; Shulmeister, 1992). Applying ^{14}C dating in these settings, therefore, requires careful consideration of the conditions outlined above.

Luminescence dating of fine-grained and organic-rich sediments in high weathering and highly seasonal environments can also be problematic. For example, fluctuating seasonal water tables complicate the determination of appropriate, long-term average water content and dose rate attenuation in the sediment. They can also facilitate solution, transport and precipitation of soluble radionuclides (in particular U) through the substrate, which can influence dose rates, i.e. samples may experience variable dose rates through time (Berger et al., 2001; Jeong et al., 2007; Olley et al., 1997; Preusser and Degering, 2007; Zander et al., 2007). Alternatively, dose rates can be seasonally affected by contact with groundwater containing high concentrations of radionuclides (Chabaux et al., 2003; Porcelli and Swarzenski, 2003; Prescott and Habermehl, 2008) and are particularly challenging to determine in organic-rich sediment. In addition, sediment heterogeneity can complicate the determination of dose rates, causing gamma-ray dose inhomogeneity and/or micro-dosimetric ‘hot spots’ due to inclusions of clays or minerals hosting radionuclides (e.g. zircon) (Mayya et al., 2006). The latter effect has been demonstrated to affect dose rates in the study area (May et al., 2015). Finally, the presence of hiatuses or unconformities is particularly hard to detect in the fine-grained and often structureless swamp sediments. In this context, novel luminescence screening techniques have been employed in a variety of sedimentary environments to explore the down-profile variability of the bulk luminescence signal with high spatial resolution, and thus increase spatial resolution required to characterize changes in deposition rate or detect the presence of hiatuses or unconformities in a sedimentary sequence (Bateman et al., 2015; Portenga and Bishop, 2015; Sanderson and Murphy, 2010; Stone et al., 2015).

As a consequence of the various factors that can influence dating results in highly seasonal environments, future use of the seasonal swamps of the ‘Top End’ as palaeoclimatic archives requires careful application of dating approaches in order to develop a chronological framework for the sediments contained in them. In this paper, we apply a range of complementary dating techniques to a sediment core extracted from Table Top Swamp – a seasonal swamp on a sandstone plateau in the Litchfield National Park in the Northern Territory, Australia. Our approach includes the use of (i) different organic fractions for ^{14}C dating to account for differential behaviour in the dynamic swamp environment, (ii) Optically Stimulated Luminescence (OSL) to determine depositional ages for less organic sediments, (iii) complementary luminescence screening techniques in combination with geochemical data to provide additional chrono-stratigraphical information and test the usefulness of luminescence screening approaches in complex sedimentary environments, (iv) high-resolution gamma spectrometry to check for potential dose rate equilibria, (v) additional sedimentary and geochemical data to further investigate depositional and post-depositional processes, as well as (vi) modelling to establish the final age model. Finally, we discuss all results with the objective of establishing a reliable chronological framework for the evolution of this swamp.

2. Physical setting

2.1. Table Top Swamp

Table Top Swamp (TTS) is located in Australia's monsoonal 'Top End' at 13.1782°S and 130.7459°E. As its name implies, TTS is situated atop the Table Top Ranges, a sandstone plateau at 209 m above sea level in Litchfield National Park (Northern Territory), ~90 km south of Darwin and ~75 km inland from Joseph Bonaparte Gulf (Fig. 1a). The swamp has a diameter of ~250–300 m (Fig. 1b) and occupies a small depression within an internally draining catchment of about 0.75 km^2. The TTS catchment consists entirely from medium to very coarse-grained, clean quartzitic sandstone with minor quartz pebble conglomerate beds summarized in the Neoproterozoic Depot Creek Sandstone (Ahmad et al., 1993; Hollis and Glass, 2011). At the surface, extensive iron oxide cemented ferruginous sandstone rubble laterites (up to boulder size) occur (Pietsch, 1989). Soils in the catchment are shallow and well drained while the vegetation surrounding the swamp consists of savannah, comprised of low woodland with a hummocky grass understorey. The dominant tree species is highly variable with