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Multi-proxy reconstruction of environmental dynamics and colonization impacts in the Mauritian uplands

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ABSTRACT

A 115 cm long sediment core retrieved from the exposed uplands of Mauritius, a small oceanic island in the Indian Ocean, shows environmental change from the uninhabited era into post-colonization times. Well-preserved fossil pollen and diatoms in the uppermost 30 cm of the core reflect environmental conditions during the last 1000 years. Granulometric analysis along the core shows that the sediments below 30 cm consist of weathered material and that the record may contain hiatuses. This is also illustrated by a ^{14}C date at 96 cm depth of 35,000 calibrated years before AD 1950 (35.0 cal ka). The pollen record shows that pristine vegetation at 650 m elevation consisted of ericaceous heathland and *Pandanus* marsh. Around 0.9 cal ka wet montane forest and fern-rich marsh replaced heathland vegetation, indicating higher moisture availability. Natural changes in upland vegetation associations are mainly driven by changes in sediment accumulation causing changes in soil properties and drainage conditions. The historically well-dated start of colonization (AD 1638) is reflected by the sudden arrival of exotic plant taxa *Camellia sinensis* (tea), *Pinus* spp. (pine), *Casuarina equisetifolia* (coastal she-oak), *Psidium cattleianum* (strawberry guava), *Homalanthus* (Queensland poplar) and *Saccharum officinarum* (sugar cane), as well as an increase in charcoal, indicating deforestation.

1. Introduction

Human impact on the environment already began, in places, in pre-Holocene times and is often well documented by paleoecological and archeological records (Roberts, 1998; Mackay et al., 2003; Oldfield and Dearing, 2003; Hughes, 2005; Ruddiman, 2005). Only few places maintained their pristine environments up to a few centuries ago, amongst which a small number of oceanic islands (Whittaker and Fernández-Palacios, 2007). These islands experienced rapid and distinctive transformations after human arrival (Burney and Burney, 2007; Van Leeuwen et al., 2008; Florens et al., 2012; Restrepo et al., 2012; Van der Knaap et al., 2012) resulting in biodiversity loss and extinction of many endemic species (Burney, 1997; Biber, 2002; Whittaker and Fernández-Palacios, 2007; Caujapé-Castells et al., 2010).

A comparison between the natural settings before and after human arrival indicates the full magnitude of biodiversity loss and ecological transformation that resulted from human impact (Burney and Burney, 2007). Paleoecology plays an important role in documenting these changes, as it provides insight into the natural ecosystem dynamics and vegetation composition prior to human arrival, the so-called 'baseline' environmental setting (Willis and Birks, 2006; Willis et al., 2007; Figueroa-Rangel et al., 2008). It can furthermore show the scales, rates and processes of human impact after colonization (Willis et al., 2007). Examples of paleoecological baseline studies were performed in the Galápagos Islands (Van Leeuwen et al., 2008; Restrepo et al., 2012), Tenerife (de Nascimento et al., 2009), and in the Azores (Connor et al., 2012) where, after colonization, dramatic changes were documented in vegetation cover and composition. A better understanding of the difference between natural and human induced ecological changes is essential to assess major current and future threats for island species (Diamond, 1989; Caujapé-Castells et al., 2010) and to provide scientific justifications for conservation efforts (Burney and Burney, 2007).

The small tropical island of Mauritius is one of the most recently colonized areas of the world (Cheke and Hume, 2008). After colonization by the Dutch in AD 1638, Mauritius rapidly became deforested (Vaughan and Wiehe, 1937) and several endemic species, such as the enigmatic dodo, went extinct (Cheke and Hume, 2008). Today, native vegetation suffers from many introduced invasive alien plants (Lorence and Sussman, 1986; Safford, 1997; Florens, 2008; Caujapé-Castells et al.,

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2010; Baider and Florens, 2011). The number of introduced plants (1675 species; Kueffer and Mauremootoo, 2004) far outnumbers the number of native species (691 species of which 39.5% are endemics; Bosser et al., 1976–onwards; Baider et al., 2010). Despite the small size of the island (ca. 40 × 55 km) and the long history of botanical inventories, species new to the Mauritian flora, including endemics, are still being discovered (Florens and Baider, 2006; Le Péchon et al., 2011; Baider et al., 2012; Baider and Florens, 2013). Due to the rapid deforestation of Mauritius, little is known about natural ecosystem dynamics, whereas the ongoing discovery of new species stresses the gaps in the current botanical knowledge and underlines the uncertainties as to which part of the present flora can be considered native.

This paper presents a study of vegetational and environmental changes from a site at 650 m elevation in the uplands of Mauritius. The objective is to reconstruct the biotic and abiotic environments from the pristine recent past (pre-AD 1638) into the current era of human disturbance. We infer vegetation change from a pollen record, hydrological changes from a diatom record, and changes in sediment transport from a record of grain size distributions. The combined results provide a reconstruction of the previously unknown pre-human baseline history and post-colonization environmental development of the Mauritian uplands.

2. Setting

2.1. Geology and geography

The island of Mauritius is situated in the southwest Indian Ocean approximately 830 km east of Madagascar (Fig. 1). Together with the islands of Réunion and Rodrigues it comprises the Mascarene Islands. Mauritius was formed between 7.8 and 6.8 million years ago (McDougall and Chamalaun, 1969) from a hotspot that is currently situated off the southeast coast of Réunion. Volcanic activity in Mauritius lasted until 25 thousand years ago (Saddul, 2002). The soils of the island are largely formed in basaltic lava (Craig, 1934). The highest peak in Mauritius reaches 828 m elevation. The studied heathland of Le Pétrin, part of Black River Gorges National Park, is situated in the southern uplands at 650 m elevation. The site is characterized by a flat area, with small ~0.5 m deep waterlogged depressions formed in tropically weathered basaltic rocks. Duricrust formation in the soils, i.e. tropical iron pan formation, is common in the study area. The soils are weathered and range from humic ferrigenous latosols on hilly and convex slopes to ground water laterites in the plains and depressions where the water table is permanently high (Saddul, 2002).

2.2. Climate

Mean annual temperature in Mauritius at sea level is 22 °C and mean annual precipitation (MAP) is 2100 mm. Depending on relief and the orientation of the slopes to the prevailing wind direction, MAP varies from 800 mm in the western coastal lowlands, to more than 4000 mm in the uplands including the study area. Precipitation is seasonal, with a dry season from May to October under influence of the cool and dry easterly trade winds, and a wetter and warmer season from November to April when the inter-tropical convergence zone (ITCZ) has its southernmost position (Senapathi et al., 2010).

2.3. Vegetation

About 95% of Mauritius has been deforested and an outline of the natural vegetation distribution must therefore rely on early historical records and small remnants of degraded natural vegetation. The pristine island of Mauritius was fringed by a variety of coastal communities such as mangroves, coastal marshes and vegetation types associated with basaltic cliffs and coralline sand dunes (Cheke and Hume, 2008). Dry palm-rich woodland occurred on the driest leeward side of the island. A larger area of semi-dry evergreen forest occurred inland

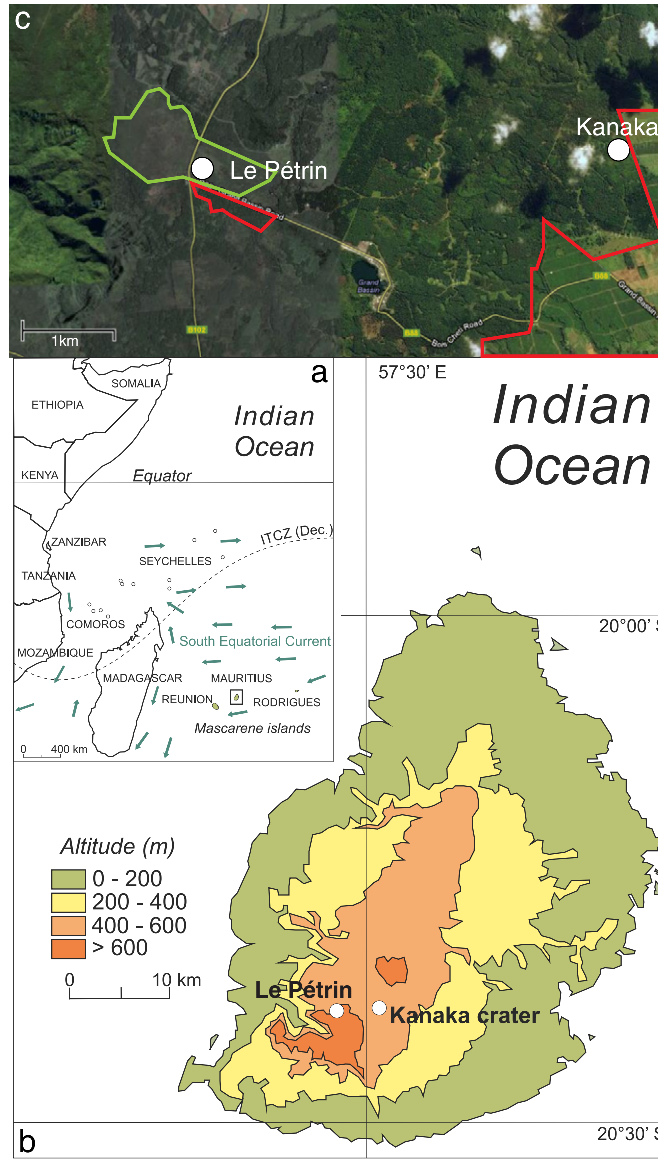

Fig. 1. (a) Map showing the location of the Mascarene Islands in the Indian Ocean, the southernmost position of the Intertropical Convergence Zone (ITCZ) and the South Equatorial Current (in blue arrows); (b) Elevation map of Mauritius showing the location of pollen sites Le Pétrin and Kanaka Crater; (c) Map showing sites Le Pétrin and Kanaka Crater in a partially deforested landscape with pine plantations and crop fields. The border of the current heathland vegetation is shown in green; plantations are shown in red.
Map courtesy: Google Maps.

(Vaughan and Wiehe, 1937; Cheke and Hume, 2008). Wet forest covered about 50% of the island and grew on slopes and on higher and wetter grounds. Azonal vegetation included heath formations or stunted thickets on shallow rocky soils, and marshes with screw pine (*Pandanus*) in wet areas on poorly drained soils (Vaughan and Wiehe, 1937; Cheke and Hume, 2008). Dense, stunted vegetation grew on exposed mountainous ridges with sparse herbaceous and scrubby vegetation occurring on the steeper cliffs. The distribution of many plant taxa is poorly altitudinally constrained (De Boer et al., 2013), resulting in a mosaic-pattern vegetation cover rather than a zonal pattern.

In this paper, we focus on the upland vegetation in the southern uplands where MAP exceeds 2500 mm. This flat and exposed area is covered by heath and thicket vegetation on well drained soils, while stagnant water leads to the formation of marshy vegetation (Fig. 2). The heath and marshy areas in Le Pétrin form a mosaic depending