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High-resolution pollen record from Efate Island, central Vanuatu: Highlighting climatic and human influences on Late Holocene vegetation dynamics

Pollinique à haute résolution de l'île d'Efate Vanuatu central : mise en évidence des influences climatique et humaine sur la dynamique de végétation de l'Holocène récent

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ABSTRACT

Climate changes, sea-level variations, volcanism and human activity have influenced the environment of the southwest Pacific Islands during the Holocene. The high-resolution palynological analysis presented here concerns two specific levels (main lithological changes) of a well-dated Holocene core, Tfer06, collected from Emaotfer Swamp, Efate Island (Vanuatu). Our aim is to understand the role of climatic variability and human activities in shaping vegetation during these changes. Between 3790–3600 cal yr BP, the development of vegetation marked by disturbance is a marker of an increase in sustained El Niño events, also observed in many Asian-West Pacific areas. Between 1500–900 cal yr BP, the increase in introduced taxa and in microcharcoal particles is interpreted as human impact. In a forthcoming paper, the ongoing high-resolution palynological analysis of the whole core will be compared and integrated into regional palaeoecological data.

RÉSUMÉ

Les changements climatiques, les variations du niveau de la mer, le volcanisme et les activités humaines ont influencé l'environnement du Sud-Ouest Pacifique pendant l'Holocène. L'analyse palynologique à haute résolution proposée dans ce papier se focalise sur deux niveaux spécifiques (changements lithologiques) d'une carotte bien datée, Tfer06, prélevée dans le marais d'Émaotfer, sur l'île d'Efate (Vanuatu). Le but est de comprendre le rôle des variations climatiques et des activités humaines sur le développement de la végétation durant ces changements. Entre 3750–3600 ans cal BP, l'essor d'une végétation secondaire

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est interprété comme un marqueur d'une intensification des phénomènes El Niño, observée aussi dans la région Asie-Pacifique. Entre 1500–990 ans cal BP, l'augmentation des taxons introduits et des microcharbons est probablement un témoin des activités humaines. Dans un prochain article, l'analyse palynologique de la carotte complète sera comparée aux données paléoécologiques de la région.

1. Introduction

During the Late Holocene, environmental conditions have principally been impacted by abrupt climate changes, volcanic eruptions, tectonic uplift and/or human activities (Goudie, 2013; Wanner et al., 2008). Palynology has the potential to be an effective tool to understand how the vegetation responds to these events. Although the majority of palaeoenvironmental studies principally concerns Europe and North America (Clement et al., 2001; Mackay et al., 2003), the amount of palaeoecological research across the Pacific has continuously increased in the last decade (Cabioch et al., 2008; Donders et al., 2007; Haberle et al., 2012; Hope et al., 2009; Rowe et al., 2013; Stevenson and Hope, 2005). The first humans (Lapita culture) settled Remote Oceania (Southeast of the Solomon Islands archipelago), *ca.* 3000 cal yr BP (Petchey et al., 2014; Sand, 2010, for a review). These human groups have probably been affected by climate changes (Anderson et al., 2013; Brázdil et al., 2005; Field and Lape, 2010), but have also certainly impacted the natural environment of pristine islands in many ways (Anderson, 2009; Fall, 2005; Horrocks et al., 2009; Prebble and Wilmshurst, 2008; Stevenson, 2004; Summerhayes et al., 2009).

Most research in the Vanuatu region have focused on submarine geology (Lecolle et al., 1990; Pineda and Galipaud, 1998; Woodroffea and Horton, 2005), volcanology (Ash et al., 1978; Robin et al., 1993; Witter and Self, 2007), archaeology (Bedford et al., 2006; Galipaud et al., 2014; Valentin et al., 2010) and palaeoclimatic changes based on models and marine data (Asami et al., 2013; Corrège et al., 2000; Donders et al., 2008). However, the relation between climate, vegetation and human activity still remains unclear.

Wirrmann et al. (2011a) conducted one of the first terrestrial multi-proxy analyses of mid-Holocene environmental changes in Vanuatu, based on the study of the core Tfer06 retrieved from Emaotfer Swamp (Efate Island, central Vanuatu). The results indicate environmental changes, correlated with climatic variations over the last 6670 cal yr BP. Three main vegetation groups were observed, based on the preliminary pollen analysis. In order to understand the pattern of vegetation change, our high-resolution palynological study covers specific sections of the core Tfer06, at *ca.* 3790–3600 and 1500–900 cal yr BP, respectively. These sections, characterized by proxies variations (lithology, microfauna-flora) indicate high environmental transformations. In this paper, our aim is to distinguish the role of climatic changes from human activities in shaping vegetation during these particular periods, to further comparing our data with results obtained across the Southwest Pacific area.

2. Natural and archaeological settings

2.1. Natural settings

The Vanuatu Archipelago is located between the Australian and Pacific tectonic plates, at the eastern margin of the Vanuatu Arc (Fig. 1). It comprises both subaerial and submarine volcanoes (Ash et al., 1978), some of which are still active. These islands consist of lava formed by basalt volcanoes dating from Late Miocene to Holocene. Efate Island, located in the central part of Vanuatu, consists mainly of volcanic rocks levelled by erosion, and limestone terraces issued from tectonic uplifts. Emaotfer Swamp, located on the southern coast of Efate, lies on a Pleistocene limestone terrace (Ash et al., 1967–1970). It is close to the Teouma Graben, on the left side of Teouma River. The water depth is currently less than 1 m throughout the swamp. During the wettest season (December through April), the water level rises and decreases during the drier season (July through September).

The oceanic context and the oceanic-atmosphere coupling (West Pacific Warm Pool, WPWP and South Pacific Convergence Zone, SPCZ) mainly influence the subtropical climate of the archipelago (Vincent, 1994). The location and the magnitude variability of WPWP and SPCZ control the alternation of wet (summer) and relatively dry (winter) season, the wet season being often marked by strong cyclones. Annual rainfall on Efate Island varies, on average, between 2400 mm on the western coast and 3000 mm on the eastern coast (Cillaurren et al., 2001). The El Niño Southern Oscillation (ENSO) (Wyrtki, 1975), the primary cause of long-term climate variability in the western Pacific (Kilbourne et al., 2004; Moy et al., 2002), influences rainfall and sea surface temperatures (SSTs). The wind-driven ocean currents move warm water in the ocean, eastward during the warm phase (El Niño) and westward during the cool phase (La Niña). The strengthening of El Niño-like conditions causes the northward shift of the SPCZ, consequently Vanuatu becomes relatively drier; conversely, under La Niña-like conditions, the SPCZ is shifted southward and precipitation increases on Vanuatu. Palaeo-ENSO records throughout the tropical Pacific region identify the onset of modern ENSO periodicities after 5000 yr BP, with abrupt increases in ENSO magnitude around 3700 and 3300 yr BP (Brijker et al., 2007; Donders et al., 2007, 2008; Gagan et al., 2004; Griffiths et al., 2010).

During Late Quaternary, sea-level changes have occurred in relation to tectonic uplifts and eustatic variations. In Vanuatu, the sea-level has risen by 120 m since the Last Glacial Maximum to 6 ka due to eustatic variations, with a sudden acceleration after 11.3 ka (Cabioch et al., 2003). Important forearc tectonic effects vary with