Geomorphology 222 (2014) 39–45

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Late Holocene sea-level change and reef-island evolution in New Caledonia

Hiroya Yamano [a,b,*], Guy Cabioch [b], Christophe Chevillon [b,c], Jean-Lambert Join [b,d]

[a] National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki 305-8506, Japan
[b] Institut de Recherche pour le Développement, BP A5, 98848 Nouméa cedex, New Caledonia
[c] Direction de l'Environnement, 19 av. Foch, 98846 Nouméa cedex, New Caledonia
[d] UMR IPGP 7154, Laboratoire GéoSciences Réunion, Université de la Réunion, Réunion, France

ARTICLE INFO

Article history:
Received 31 August 2012
Received in revised form 30 October 2013
Accepted 2 March 2014
Available online 10 March 2014

Keywords:
Sea-level change
Reef island
Foraminifera
New Caledonia

ABSTRACT

In New Caledonia, numerous cays are distributed on platform reefs in the southwest lagoon behind the barrier reef. At Mba Island, a vegetated sand cay in this area, we examined Holocene sea-level change, and reef development and evolution. The late Holocene sea-level curve for the area was updated using newly found fossil microatolls. Component-specific dating of foraminifera tests in the island sediment provided reliable ages of island formation. Mba Island initially formed around ~4500 cal yr B.P., when sea level was ~1.1 m higher than at present. The island formed on the leeward side of the platform reef, where the base had been constructed of lagoon- and reef-derived sediment of the platform reef. Sea-level fall since 2800 cal yr B.P. has likely caused reef-flat emergence at low tide and created a suitable habitat for foraminifera. Such a transition in ecology due to sea-level fall has been observed in other Pacific reefs, suggesting that the interaction between reef-flat formation, sediment production and sea-level fall is one of the critical factors determining island development.

1. Introduction

Reef islands are low-lying and composed of unconsolidated sediments derived from calcareous reef-building organisms. Such islands can be divided into two major groups: motus and cays. Motus develop on coral atolls, and seaward beaches comprise cobbles and gravels that were carried from the reef front by high-energy events. Conversely, cays are generally composed of sands, and are considered to form under mean energy, rather than stormy, conditions. Both types of reef islands provide habitable land for indigenous communities, and appear highly vulnerable to environmental changes, such as sea-level rise (e.g., Woodroffe, 2008).

The interactions among Holocene sea-level change, reef growth, sediment production, and sediment transport exert a fundamental control on the initiation and development of reef islands (McLean and Woodroffe, 1994; Perry et al., 2011). However, in comparison with reef growth studies, detailed chronological studies of reef-island development have been limited since the pioneering work at Cocos (Keeling) Island in the western Indian Ocean (Woodroffe et al., 1999).

Circular platform reefs often support cays, formed by the wave-focused accumulation of calcareous sediments produced on the reef platform (Gourlay, 1988; Mandlier and Kench, 2012). Although platform reefs appear simple in comparison with atolls, there are significant variations in the structure and development of the associated cays (Kench et al., 2005; Woodroffe et al., 2007; McKoy et al., 2010; Kench et al., 2012). Understanding these variations requires further case studies to relate Holocene sea-level change to reef-flat formation and island evolution.

In this study, we examined the relationships among Holocene sea-level change, reef-flat development, and sand cay evolution in New Caledonia. Previous geological research has provided detailed data on sea-level change and reef development (e.g., Cabioch, 2003; Andréfouët et al., 2009). In New Caledonia, there are numerous cays located on platform reefs in the large southwest lagoon, behind the barrier reef (Guilcher, 1988, p. 133). However, unlike similar cays in Australia or the Maldives, their characteristics and development have not been extensively studied. This study thus provides the first detailed examination of reef-island evolution in New Caledonia, and provides an excellent dataset for understanding paleo sea-level changes and associated reef development.

2. Setting

New Caledonia is situated between 15° and 25° south, and between 160° and 170° east (Fig. 1). The main island of New Caledonia, Grande Terre, has a 500-km-long coastline fringed by reefs and mangroves, which constitute one of the longest barrier reefs in the world (Andréfouët et al., 2009). Subsidence is the dominant geologic process around Grande Terre (Fig. 1), except in the southeastern area, which

* Corresponding author at: National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki 305-8506, Japan. Fax: +81 29 850 2219.
E-mail address: hyamano@nies.go.jp (H. Yamano).

http://dx.doi.org/10.1016/j.geomorph.2014.03.002
0169-555X/

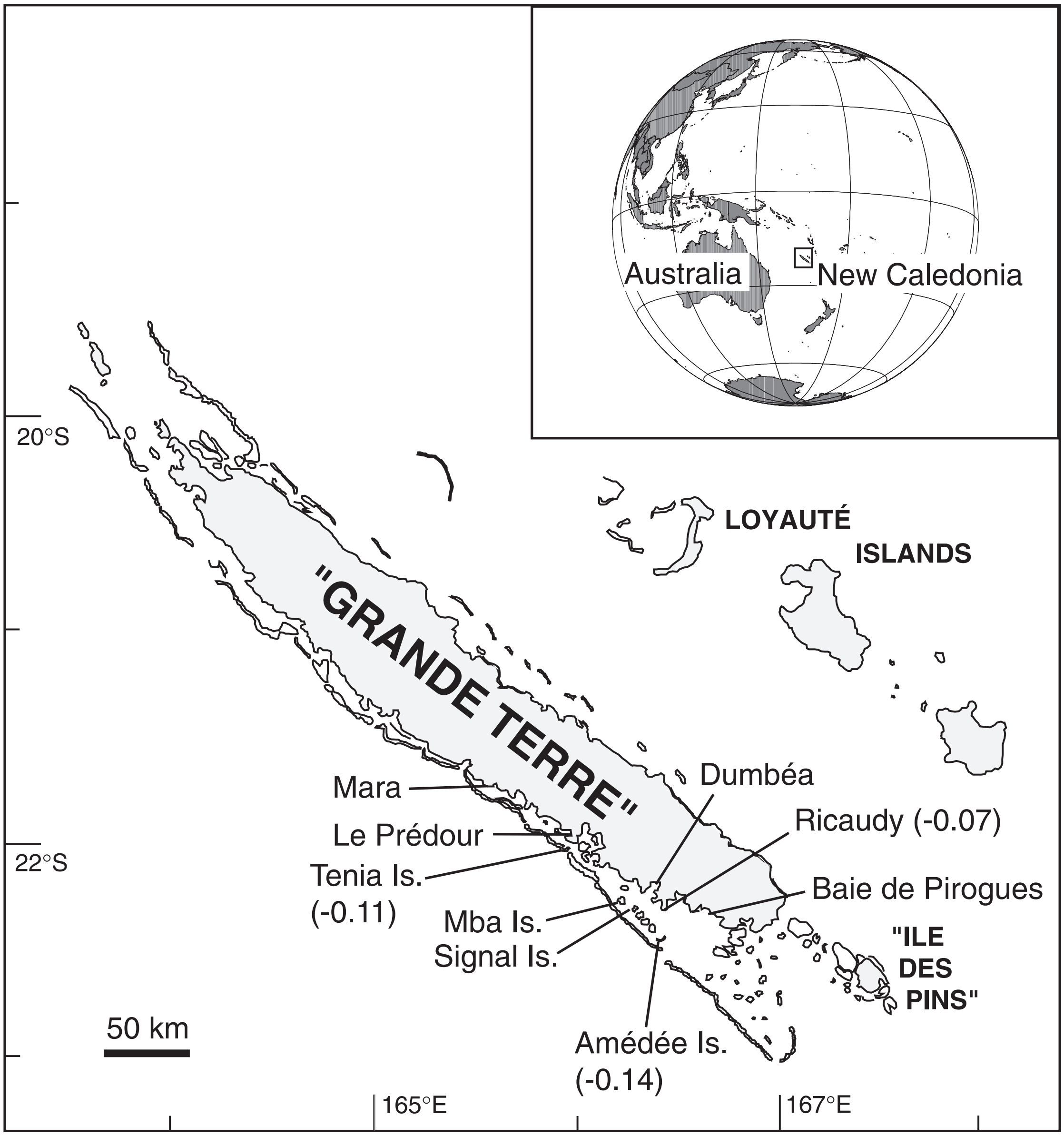

Fig. 1. Map of New Caledonia showing the study sites (Mba Island and Signal Island) and other sites referred to in this study. Numbers in parentheses are subsidence rates (mm/yr) based on Cabioch (2003).

has been subjected to uplift. These spatial variations in vertical motions (subsidence and uplift) explain the modern reef geomorphology. The highest rates of subsidence were found offshore, which correlates to the formation of the large southwest lagoon (Andréfouët et al., 2009).

Numerous cays occur on platform reefs in the large southwest lagoon behind the barrier reef (Guilcher, 1988, p. 133). A sand cay and a shingle cay are located on the leeward and windward sides of a platform reef, respectively. The location of these cays is attributable to wave focusing on the platform reef (Gourlay, 1988; Mandlier and Kench, 2012). The most frequently occurring wind regime is the southeasterly trade wind, with an average speed of 8 m/s and direction of 110°, which comprises more than 2/3 of yearly wind occurrence (Ouillon et al., 2004). During trade wind episodes, the significant wave height and period in the lagoon are typically 0.8–1.4 m and around 3 s, respectively (Jouon et al., 2009). The tidal range is 1.5 m.

Holocene sea-level change in New Caledonia has been examined through peat and reef cores, along with surface fossil coral and oyster samples (Baltzer, 1970; Coudray and Delibrias, 1972; Lecolle and Cabioch, 1988). Cabioch et al. (1989) synthesized the results of several studies and proposed that sea level reached ~1.1 m higher than the present level at ~5500 ^{14}C yr B.P. (~6500 cal yr B.P.), then fell smoothly to the present level. However, due to a lack of reliable sea-level indicators in the late Holocene, the duration of higher sea levels and timing of relative sea-level fall, which affect reef-island evolution, remain unclear.

Reef cores described in previous studies have provided information on Holocene reef development. Modern coral reefs in New Caledonia were initiated at ~8000 cal yr B.P. on a Pleistocene reef foundation (Cabioch et al., 1995; Cabioch, 2003; Frank et al., 2006). The reefs exhibited a catch-up growth pattern in which coral growth postdates the stabilization of sea level (e.g., Cabioch et al., 1995).

Island evolution was examined for Mba Island, a vegetated sand cay located in the southwest lagoon (Fig. 1). The island is ellipsoidal in shape (1000 m long and 350 m wide). The total land area is approximately 0.33 km^2, occupying half of the platform reef surface. Cores