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The role of deep Earth dynamics in driving the flooding and emergence of New Guinea since the Jurassic

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ABSTRACT

The paleogeography of New Guinea indicates fluctuating periods of flooding and emergence since the Jurassic, which are inconsistent with estimates of global sea level change since the Eocene. The role of deep Earth dynamics in explaining these discrepancies has not been explored, despite the strongly time-dependent geodynamic setting within which New Guinea has evolved. We aim to investigate the role of subduction-driven mantle flow in controlling long-wavelength dynamic topography and its manifestation in the regional sedimentary record, within a tectonically complex region leading to orogeny. We couple regionally refined global plate reconstructions with forward geodynamic models to compare trends of dynamic topography with estimates of eustasy and regional paleogeography. Qualitative corroboration of modelled mantle structure with equivalent tomographic profiles allows us to ground-truth the models. We show that predicted dynamic topography correlates with the paleogeographic record of New Guinea from the Jurassic to the present. We find that subduction at the East Gondwana margin locally enhanced the high eustatic sea levels from the Early Cretaceous (~145 Ma) to generate long-term regional flooding. During the Miocene, however, dynamic subsidence associated with subduction of the Maramuni Arc played a fundamental role in causing long-term inundation of New Guinea during a period of global sea level fall.

1. Introduction

The New Guinea margin is arguably one of the most tectonically complex settings in the world, comprising a diverse assemblage of accreted arc terranes, continental fragments, and obducted ophiolite belts (Baldwin et al., 2012). The geodynamic evolution of New Guinea in the post-Pangea period has been dominated by the long-term convergence between the Australian Plate in the southwest and the Pacific Plate in the northeast (Baldwin et al., 2012; Dow, 1977; Hill and Hall, 2003). The rapid north-northeast motion of the Australian Plate relative to the Pacific Plate since the Eocene, and the interaction with the Sunda continental promontory has resulted in oblique, arc-continent collisions and the slow growth of the island through successive accretionary episodes (Baldwin et al., 2012; van Ufford and Cloos, 2005). Such episodes include the accretion of ribbon terranes, which can be continental or oceanic such as the Torricelli–Finisterre Arc accreted in the middle to late Miocene, or a composite continental–oceanic terrane such as the Sepik terrane accreted during the Eocene-Oligocene (Zahirovic et al., 2014, 2016b). These accreted terranes are typically ~100 km across, and more than ~1000 km long. Northern New Guinea has also undergone periods of rifting and lithospheric rupture to form ocean basins including the Sepik back-arc ocean basin in the Late Mesozoic supported by syn-rift sedimentation in the Early-Mid Jurassic followed by a breakup unconformity (Davies, 2012; Zahirovic et al., 2014, 2016b). The region has also experienced intra-oceanic subduction and proposed subduction polarity reversal episodes, including those associated with the consumption of the Sepik back-arc in the latest Cretaceous (Baldwin et al., 2012; Hill and Hall, 2003). This subduction history has resulted in a lack of preserved seafloor, compounded by poor outcrop due to weathering, vegetation cover and inaccessible terrain on the continent, which results in significantly uncertain tectonic reconstructions (Hill and Hall, 2003; van Ufford and Cloos, 2005; Zahirovic et al., 2014). Geologically, the northern half of the island overlies Mesozoic crystalline basement of ocean crust with arc affinities derived from the Pacific basin (Hill and Hall, 2003; van Ufford and Cloos, 2005), whilst the southern portion comprises Mesozoic and Tertiary passive margin strata underlain by Australian continental crust (Dow, 1977).

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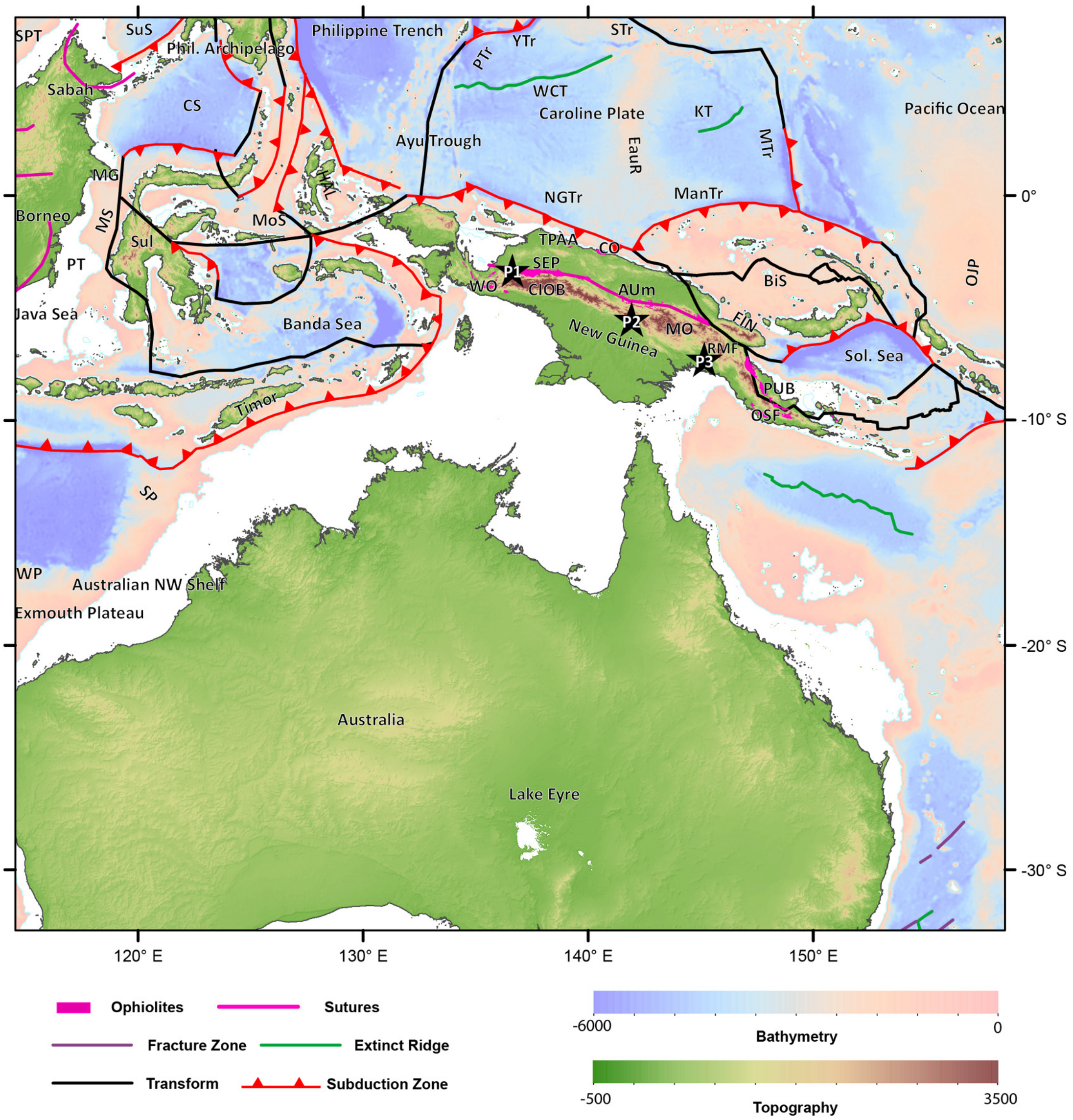

Fig. 1. Regional tectonic setting of New Guinea and the northern Australian continental margin. Plate boundaries are modified from Bird (2003), ophiolites derived from Hill and Hall (2003) and Baldwin et al. (2012), and fracture zones from Matthews et al. (2011). Black stars with labels P1, P2 and P3 indicate locations from which dynamic topography values were extracted throughout time. Locations represent Irian Jaya, central New Guinea and Papua New Guinea respectively (see Fig. 7). AUm – April Ultramafics, BiS – Bismarck Sea, CIOB – Central (Irian) Ophiolite Belt, CO – Cyclops Ophiolite, CS – Celebes Sea, EauR – Eauripik Ridge, FIN – Finisterre Terrane, HAL – Halmahera, KB – Ketungau Basin, KT – Kiilsgaard Trough, ManTr – Manus Trench, MG – Mangkalihat, MTr – Mariana Trench, MO – Marum Ophiolites, MoS – Molucca Sea, MS – Makassar Straits, NGTr – New Guinea Trench, OJP – Ontong Java Plateau, OSF – Owen Stanley Fault, PT – Paternoster Platform, PUB – Papuan Ultramafic Belt, RMF – Ramu – Markham Fault, Sol. Sea – Solomon Sea, SP – Scott Plateau – SEP – Sepik, Sul – Sulawesi, TPAA – Torricelli-Prince Alexander Arc, WCT – W Caroline Trench, WO – Weyland Overthrust, WP – Wombat Plateau.

The mountainous spine of the island comprising the highly deformed Mobile Belt delineates the north and south of New Guinea (Fig. 1).

In addition to the changing tectonic framework of New Guinea, the island also experienced alternating periods of short-term (related to Milankovitch cycles) and long-term (related to eustasy and mantle processes) inundation and emergence that remain preserved in the sedimentary record (Fig. 2). Throughout Mesozoic times, the continent was almost entirely inundated by shallow to deep seas with shelf-type and deep-marine sediments dispersed across the island (Dow, 1977). In contrast, the late-Eocene to early-Oligocene record is characterised by almost a total cessation in sedimentation, with a distinct lack of lower to middle Oligocene fossils throughout the oceanic crust and island arc terranes, particularly ordinarily pervasive foraminifera (Dow, 1977). This is likely attributable to the combined effects of global sea level fall (Haq, 2014; Haq et al., 1987) as well as the uplift and erosion corresponding to the late Eocene-early Oligocene orogeny (Dow, 1977; van Ufford and Cloos, 2005). The manifestation of this in the geological record is a pervasive, regional unconformity (Fig. 2) (Norvick, 2001) except for a belt of mixed-grade metamorphics, in south-eastern Papua New Guinea including the Owen Stanley and Emo metamorphics which have been dated to between the Late Cretaceous and early Eocene (Worthing and Crawford, 1996). This tectonic uplift is further supported by the late Eocene intrusions in the north Sepik region along the marginal trough, and further south by the vertical displacement of the Papuan Ultramafic Belt, along the Owen Stanley Fault System (Davies, 2012; Dow, 1977). This non-depositional environment is geologically short-lived with sedimentation resuming in the late Oligocene. Shallow-water carbonates varying between 500 and 1500 m in thickness suggests flooding peaked during the early- to mid-Miocene, despite inconsistencies with global sea level estimates (Haq, 2014; Haq et al., 1987). From the Pliocene to the present, the flood-