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Research paper

Relative sea-level change in western New Guinea recorded by regional biostratigraphic data

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ABSTRACT

We present new biostratigraphic analyses of approximately 200 outcrop samples and review biostratigraphic data from 136 public domain exploration wells across western New Guinea. Biostratigraphic ages and palaeodepositional environments were interpreted from occurrences of planktonic and larger benthic foraminifera, together with other fossils and environmental indicators where possible. These data were compared with existing geological maps and exploration well data to reconstruct the palaeogeography of western New Guinea from the Carboniferous to present day. In addition, we used the known bathyal preferences of fossils to generate a regional sea-level curve and compared this with global records of sea-level change over the same period. Our analyses of the biostratigraphic data identified two major transgressive-regressive cycles in regional relative sea-level, with the highest sea levels recorded during the Late Cretaceous and Late Miocene and terrestrial deposition prevalent across much of western New Guinea during the Late Paleozoic and Early Mesozoic. An increase in the abundance of carinate planktonic foraminifera indicates a subsequent phase of relative sea-level rise during a regional transgressive event between the Late Jurassic and Late Cretaceous. However, sea-levels dropped once more during a regressive event between the Late Cretaceous and the Paleogene. This resulted in widespread shallow water carbonate platform development in the Middle to Late Eocene. A minor transgressive event occurred during the Oligocene, but this ceased in the Early Miocene, likely due to the collision of the Australian continent with intra-Pacific island arcs. This Miocene collision event resulted in widespread uplift that is marked by a regional unconformity. Carbonate deposition continued in platforms that developed in shallow marine settings until these were drowned during another transgressive event in the Middle Miocene. This transgression reached its peak in the Late Miocene and was followed by a further regression culminating in the present day topographic expression of western New Guinea.

1. Introduction

New Guinea has represented the northernmost boundary of the Australian Plate from the present until at least the Permian (perhaps as early as the Carboniferous). During this time New Guinea was part of an Andean-style continental arc system that extended around a large portion of Gondwana (Charlton, 2001; Hall, 2002, 2012; Hill and Hall, 2003; Crowhurst et al., 2004; Metcalfe, 1998, 2009; Gunawan et al., 2012, 2014; Webb and White, 2016). This long-lived plate boundary records evidence of numerous tectono-thermal events during the Paleozoic, Mesozoic and Cenozoic (e.g. Visser and Hermes, 1962; Pieters et al., 1983; Davies and Jaques, 1984; Pigram and Davies, 1987; Pigram and Symonds, 1991; Baldwin and Ireland, 1995; Baldwin et al., 2004, 2012; Davies, 2012; Bailly et al., 2009; Holm and Richards, 2013; Holm et al., 2015, 2016; François et al., 2016). However, much of the geology of New Guinea is also dominated by siliciclastic and carbonate deposition during seemingly long periods of quiescence (Pieters et al., 1983; Pigram; Visser and Hermes, 1962; Fraser et al., 1993; Hill, 1991; Davies, 2012; Baldwin et al., 2012). We focus on the age and depositional environment of these sediments in western New Guinea, an area that is relatively underexplored, with the last major geological mapping campaign being conducted in the 1980's

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(e.g. Masria et al., 1981; Pieters et al., 1983; Dow et al., 1986; Atmawinata et al., 1989; Pieters et al., 1989; Dow et al., 1990; Harahap et al., 1990; Pieters et al., 1990; Robinson et al., 1990; Panggabean et al., 1995). We present new biostratigraphic age data based on benthic and planktonic foraminifera, as well as facies analyses from nearly 200 outcrop samples from western New Guinea. Where possible, we compared these results with publicly available hydrocarbon exploration well locations, biostratigraphic analyses and interpreted depositional environments (e.g. Visser and Hermes, 1962; Fraser et al., 1993). The aim of this work was to better establish the duration and facies distribution of strata to better understand the spatio-temporal distribution of periods of queisence at the northern margin of the Australian Plate between the Carboniferous and present day. We begin by reviewing the existing literature on the geology of western New Guinea. We then discuss the newly obtained biostratigraphic data as well as data obtained from a meta-study of publically available biostratigraphic data from exploration wells, and what these mean for our understanding of changing palaeo-environments.

1.1. Geological mapping of western New Guinea

The first comprehensive geological mapping of Indonesian New Guinea was conducted between 1935 and 1960 by geologists of the Nederlandsche Nieuw Guinee Petroleum Maatschappij. The results of this work are compiled and summarised in Visser and Hermes (1962). The observations reported in this work lay the foundation for the stratigraphy of western New Guinea and remain highly relevant, despite this work being completed before the advent of plate tectonics. The stratigraphy and tectonic development of western New Guinea was refined by Indonesian and Australian government geologists between 1978 and 1982; the results of which are summarised in Pieters et al. (1983). Subsequent work has predominantly been driven by hydrocarbon or mineral exploration in the region (e.g. White et al., 2014) and broadly consists of reviews of the stratigraphy (e.g. Fraser et al., 1993), the regional tectonic evolution (e.g. Decker et al., 2009; Baldwin et al., 2012; Davies, 2012) or targeted geological studies that have broadly focused on the evolution and uplift of basement rocks (e.g. Bailly et al., 2009; François et al., 2016; Webb and White, 2016).

1.2. The Bird's Head, Neck, Body and Tail

New Guinea is often described to reflect the shape of a bird, comprising the Bird's Head, Neck, Body, and Tail from west to east, respectively (Fig. 1). The Bird's Head and Neck, and part of the Body are within the Indonesian provinces of West Papua and Papua (formerly known as Irian Jaya). The rest of the Bird's Body and the Tail are found in Papua New Guinea. The island's peculiar morphology largely reflects the geology and tectonic evolution of the island. For example, the Bird's Neck is largely composed of limestones and siliciclastic rocks shortened during the development of the Lengguru Fold and Thrust Belt (e.g. Bailly et al., 2009; François et al., 2016)(Fig. 1). These deformed rocks form part of a mountain belt that extends from western New Guinea (the Bird's Head), along the Lengguru Fold and Thrust Belt (the Bird's Neck), continuing along the Central Range (the Bird's Body) to the eastern tip of the island (Bird's Tail) (Fig. 1). Rocks to the south of New Guinea are primarily of Australian continental affinity whereas those to the north consist of ophiolite and island arc volcanics of Pacific Plate provenance. The two domains are separated by a central, complex region of juxtaposed fault slices of sediments together with variably metamorphosed and granitic rocks. This juxtaposition marks a suture that formed during arc-continent collision between the Oligocene and Early Miocene (Fig. 1), (e.g. Pieters et al., 1983; Milsom, 1992). Thus the stratigraphy of the Bird's Head can be broadly described as intra-Pacific island arc material to the north and east, which accreted to Australian continental material to the south and west. The post-collisional stratigraphy of both domains is reasonably contiguous.

2. Depositional history of western New Guinea sediments

2.1. Australian plate stratigraphy

A simplified map showing the distribution of sedimentary, igneous and metamorphic rocks mapped by Masria et al. (1981); Pieters et al. (1983); Dow et al. (1986); Atmawinata et al. (1989); Pieters et al. (1989); Dow et al. (1990); Harahap et al. (1990); Pieters et al. (1990); Robinson et al. (1990); Panggabean et al. (1995) is shown in Fig. 2. The oldest strata within the Bird's Head consist of variably metamorphosed siliciclastic rocks that were most likely derived from rocks to the south (i.e. eroded Australian/Gondwanan crust) (e.g. Decker et al., 2017) (Figs. 2 and 3). The variably metamorphosed rocks in the Bird's Head Peninsula have poor age control, but were assigned a Silurian-Devonian age from several graptolites and because these rocks are cross-cut by Carboniferous and Permian intrusions (Visser and Hermes, 1962; Pieters et al., 1983) (Figs. 2 and 3). These sequences are known as the Kemum and Aisasjur Formations (Fig. 3) and are considered to represent distal and proximal turbidite deposits, respectively (Visser and Hermes, 1962; Pieters et al., 1983). The low metamorphic grade turbidite sequences of the pre-Middle Triassic Ligu Formation in Misool are potentially equivalent to those classified as the Kemum Formation (Hasibuan, 2012). Other Devonian to Late Proterozoic siliciclastic and carbonate sequences are exposed in parts of Papua New Guinea (e.g. Modio Formation, Tuaba Formation, Karieum Formation) along with the Late Proterozoic–Cambrian metamorphosed basaltic rocks of the Awitagoh and Nerewip formations (Davies, 2012 and references therein) (Fig. 3). The oldest carbonate unit in western New Guinea is the Modio Dolomite of the Central Ranges. This was deposited during the Devonian or possibly as early as the Silurian (Fig. 3; Pieters et al., 1983; Nicoll and Bladon, 1991; Oliver et al., 1995; Parris, 1994; Cloos et al., 2005; Davies, 2012).

During the Carboniferous, a phase of magmatism was suggested from K-Ar dating of porphyritic dacite and altered porphyritic igneous rocks from the Melaiurna Granite (Bladon, 1988). Despite this volcanism, the Carboniferous to Permian was a period of relatively stable paralic sediment deposition, with occasional shallow marine incursions marked by thin limestone beds in New Guinea's Central Range. The Permo-Carboniferous Aifam Group (Fig. 3) contains various terrestrial and marine deposits (Visser and Hermes, 1962; Chevallier and Bordenave, 1986; Dow et al., 1986). This group consists of the Aimau, Ainim and Aiduna formations which collectively consist of conglomerates, red beds and coal seams that were likely deposited in a terrestrially influenced, possibly deltaic and/or lacustrine setting (Norvick, 2003). The Aifat Mudstone, which also forms part of the Aifam Group however most likely represents deposition in deeper water, perhaps in a basinal setting (Pieters et al., 1983).

Volcanic activity recommenced or became much more extensive during the Triassic. The evidence for this is taken from various granitoids found in the Bird's Head Peninsula and on the western and southwestern sections of Cenderawasih Bay (Fig. 2). The granitoids include the Netoni Intrusive Complex, Anggi Granite, Wariki Granodiorite, Warjori Granite and this magmatic belt likely continues further to the east, along the length of New Guinea (e.g. Bladon, 1988; Crowhurst et al., 2004; Webb and White, 2016). Additional supporting evidence for this Triassic magmatism comes