Disparate Tectonic Settings for Mineralisation in an Active Arc, Eastern Papua New Guinea and the Solomon Islands

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Gideon Rosenbaum
University of Queensland

Carl Spandler
James Cook University

Disparate Tectonic Settings for Mineralisation in an Active Arc, Eastern Papua New Guinea and the Solomon Islands

R J Holm[1], S W Richards[2,3], G Rosenbaum[4] and C Spandler[5]

ABSTRACT

The recent and active magmatic arcs of eastern Papua New Guinea (PNG) and the Solomon Islands are well endowed with sulfide mineralisation and include deposits such as Ladolam, Panguna and Solwara 1. The majority of the mineral systems in this belt are younger than four million years old, with some deposits remaining active to the present day as exemplified by active hydrothermal systems on the island of Lihir. The geodynamic setting that led to the formation of these deposits is still unresolved, with, for example, both the Pacific and Solomon Sea plates considered responsible for the formation of the Ladolam deposit on the island of Lihir under different models. In order to understand and characterise the formation of south-west Pacific mineral deposits, we must first reconstruct the complex geodynamic evolution of the region. New kinematic reconstructions show that while mineral systems in eastern PNG and the Solomon Islands are hosted within a single arc related to subduction at the New Britain and San Cristobal trenches, variable and discrete geodynamic settings exist within both the upper and lower plates throughout this region, which give rise to distinct mineralised corridors. Most notably, this region is host to:

- the Solwara 1 deposit, which occurs within a major transtensional corridor in the eastern Bismarck Sea
- the Ladolam deposit (Lihir), which is interpreted to have formed above but in relation to tearing of the subducting slab
- the Panguna deposit, which is related to structure in the subducting slab marginal to the actively spreading Woodlark Basin.

An evaluation of the nature and variability of these diverse geodynamic settings through time can provide us with a better understanding of the relationship between the active south-west Pacific magmatic arcs and mineral deposit formation. It may also provide insights into the

1. Associate Lecturer, Economic Geology Research Centre, College of Science, Technology and Engineering, James Cook University, 1 James Cook Drive, Townsville Qld 4811. Email: robert.holm@jcu.edu.au

2. Head of Geology, Exploration and Geophysics, Citigold, Gregory Highway, Charters Towers Qld 4820. Email: srichards@citigold.com

3. MAusIMM, Adjunct Lecturer, Economic Geology Research Centre, College of Science, Technology and Engineering, James Cook University, 1 James Cook Drive, Townsville Qld 4811.

4. Associate Professor, School of Earth Sciences, The University of Queensland, Brisbane Qld 4072. Email: g.rosenbaum@uq.edu.au

5. Senior Lecturer, Economic Geology Research Centre, College of Science, Technology and Engineering, James Cook University, 1 James Cook Drive, Townsville Qld 4811. Email: carl.spandler@jcu.edu.au

diverse array of deposit settings at ancient convergent margins, with applications in mineral prospectivity studies.

INTRODUCTION

The south-west Pacific has long been the focus of research towards our understanding of giant ore deposit formation, with New Guinea and the Solomon Islands playing host to deposits such as Grasberg, Ok Tedi, Freida River, Porgera, Lihir and Panguna (Figure 1; Cooke, Hollings and Walshe, 2005; Sillitoe, 2010; Richards, 2013). Changes in regional tectonics at convergent margins have often been viewed as a contributing factor in the formation of mineral deposits. In particular, changes in the subduction regime are commonly considered as crucial parameters triggering mineralising events, associated with, for example, terrane collisions, subduction of slab structure or changes in the slab angle during subduction (Cooke, Hollings and Walshe, 2005; Rosenbaum *et al*, 2005; Richards, 2013; Richards and Holm, 2013; Sillitoe, 2010). At present, Papua New Guinea (PNG) and the Solomon Islands lie within a tectonically complex zone of oblique convergence between the Australian and Pacific plates, trapped between the converging Ontong Java Plateau and Australian continent (Figure 1). Previous tectonic studies provide us with a basic understanding of the geodynamic framework for much of the south-west Pacific (eg Hall, 2002; Schellart, Lister and Toy, 2006). However,

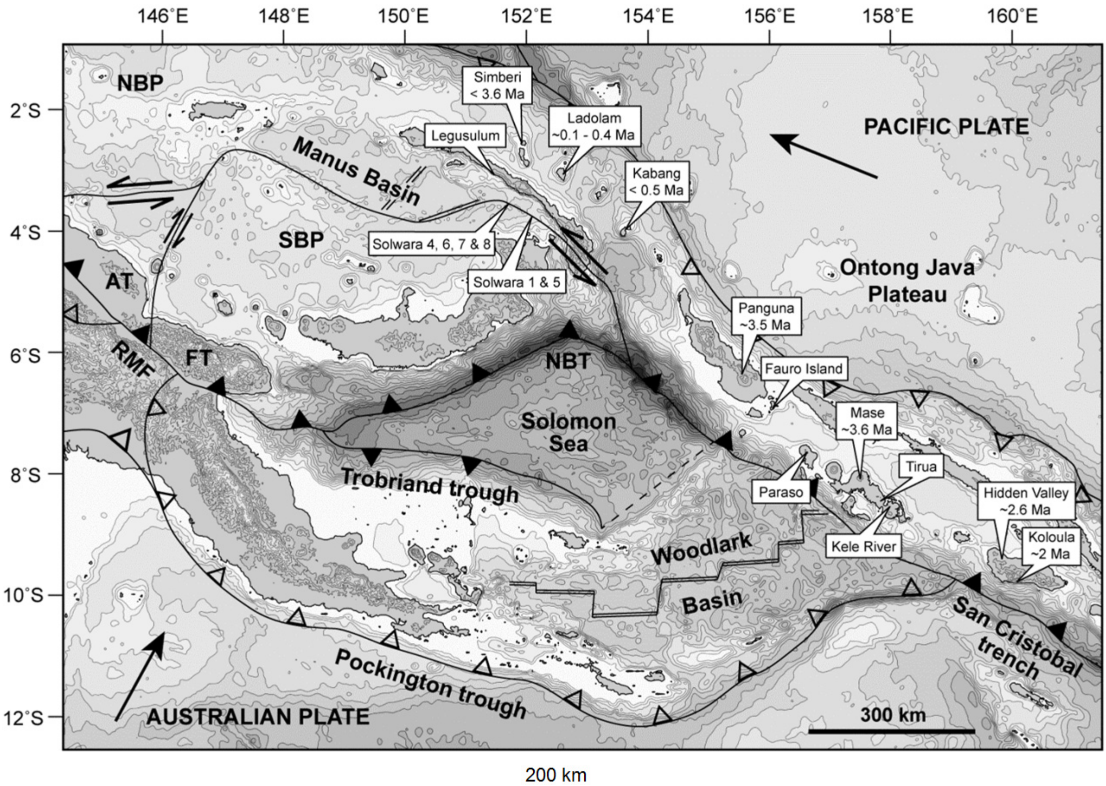

FIG 1 – Tectonic setting and mineral deposits of eastern Papua New Guinea and Solomon Islands. The modern arc setting related to formation of the mineral deposits comprises, from west to east, the West Bismarck arc, the New Britain arc, the Tabar-Lihir-Tanga-Feni Chain and the Solomon arc, associated with north-dipping subduction/underthrusting at the Ramu-Markham fault zone, New Britain trench and San Cristobal trench respectively. Arrows denote plate motion direction of the Australian and Pacific plates. Filled triangles denote active subduction. Outlined triangles denote slow or extinct subduction. NBP: North Bismarck plate; SBP: South Bismarck plate; AT: Adelbert Terrane; FT: Finisterre Terrane; RMF: Ramu-Markham fault zone; NBT: New Britain trench.

our current understanding does not provide sufficient insight into the relationships and feedbacks underpinning the complex tectonic settings. This in turn negates meaningful comparisons between mineral deposit formation and geodynamic setting. In this study, we report on the relationships between the tectonic evolution of eastern PNG and the Solomon Islands established from new reconstructions, and the timing and location of mineral deposit formation.

METHODS

Plate tectonic reconstructions provide us with a mechanism to test kinematic and dynamic relationships throughout this structurally complex region. We developed a new plate tectonic reconstruction for PNG and the Solomon Islands for the Late Neogene and Quaternary using GPlates software (eg Seton *et al*, 2012). The reconstructions were generated in one million year time intervals relative to the hybrid absolute reference frame of Seton *et al* (2012) and tectonic plates were assumed to be rigid and non-deforming. Existing data sets of sea floor magnetic isochrons, subducted slab maps and numerous prior studies into the tectonic history of the region (eg Hall, 2002; Schellart, Lister and Toy, 2006; Holm and Richards, 2013; Holm, Spandler and Richards, 2014) were integrated within GPlates as digitised polygon and polyline features and spatially manipulated to provide constraint on reconstructions at specific geological times. GPlates then interpolated plate motions about a reconstruction pole between known events to produce the reconstruction model. A series of iterations were required to ensure a complete and closed plate circuit. The plate tectonic reconstruction was then correlated with the formation of mineral deposits in time and space (Figure 2), where deposit ages were derived from Cooke, Hollings and Walshe (2005) and Singer, Berger and Moring (2008) and references therein.

RESULTS AND DISCUSSION

Active magmatism in eastern PNG and the Solomon Islands is associated with north-dipping subduction of the Australian plate and several microplates (Figure 1). While the modern-day active arc appears as a single magmatic arc, it comprises several different geodynamic settings. In the west, the continental crust of PNG is underthrust beneath the Adelbert and Finisterre Terranes at the Ramu-Markham fault zone, giving rise to the West Bismarck arc (Holm and Richards, 2013). Subduction of the Solomon Sea plate at the New Britain trench results in magmatism of the New Britain arc, Tabar-Lihir-Tanga-Feni Chain and the western Solomon arc. Subduction of the actively spreading Woodlark Basin and Australian plate at the San Cristobal trench is related to magmatism of the Solomon arc. Similar to the variation in arc development, mineral deposits show a comparable degree of variation along the arc (Figure 1). In the west, there is a distinct lack of reported mineral occurrences, while the eastern Bismarck, Tabar-Lihir-Tanga-Feni and Solomon arcs are well endowed with mineral deposits, including the giant Lihir and Panguna deposits. This suggests that there is a relationship between regional tectonics and ore deposit formation.

A comparison of the location and timing of mineral deposit formation with the tectonic reconstructions (Figure 2) reveals a strong correlation between deposit emplacement and the occurrence or passage of major structures in the upper or lower plate respectively. The Solwara deposits of the eastern Bismarck Sea lie along a major transtensional structure that accommodates sinistral motion between the North and South Bismarck microplates as well as the opening of the Manus Basin (Figure 2). This setting is not unique within the Bismarck Sea; however, this is the only occurrence of a dilational upper plate structure associated with active subduction at depth. To the east, mineral deposits of the Tabar-Lihir-Tanga-Feni chain are interpreted to have formed as the North Bismarck plate tracked over a tear in the subducting

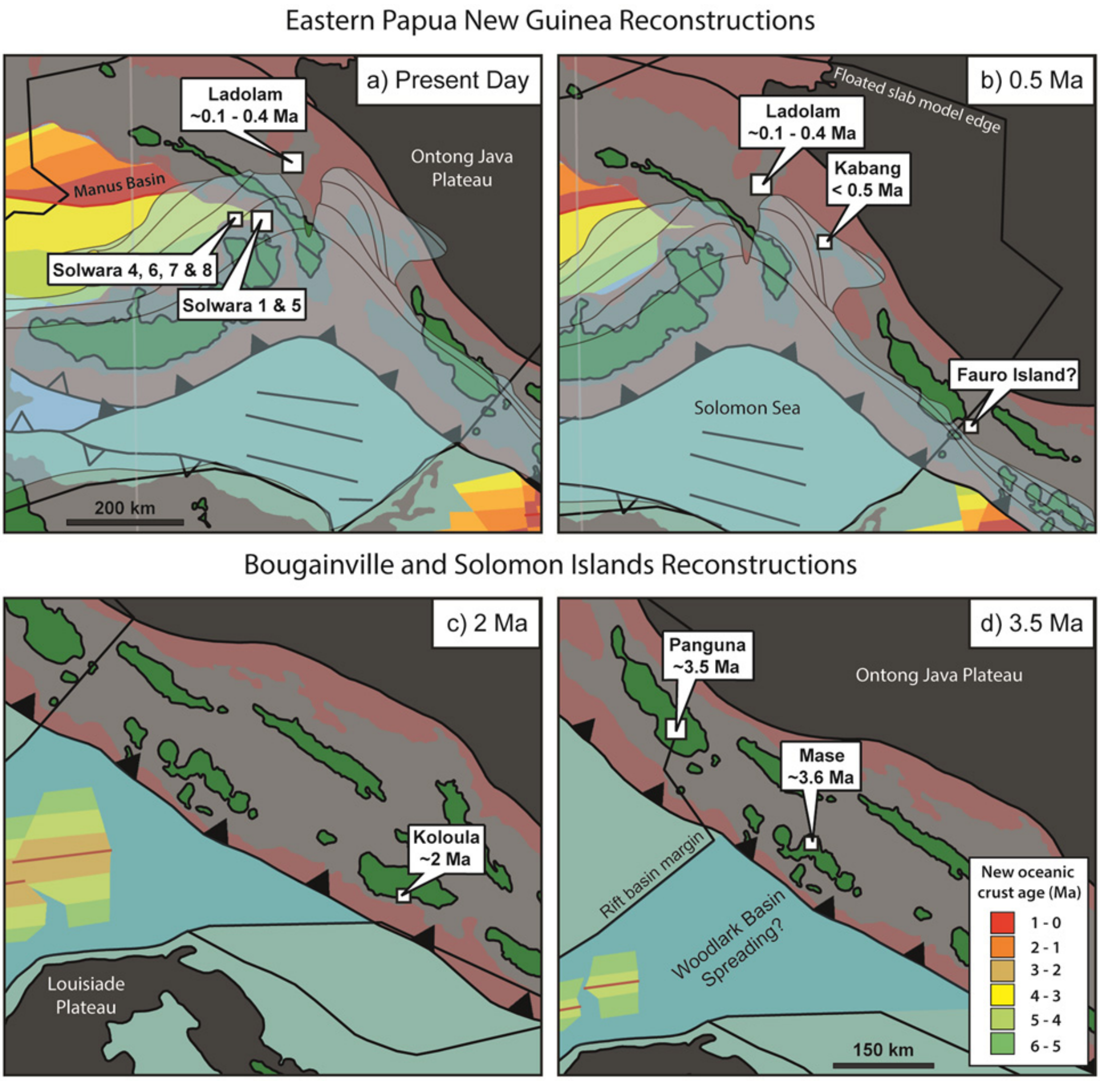

FIG 2 – Selected snapshots from plate tectonic reconstructions with timing of corresponding mineral deposit formation. Reconstruction snapshots are derived from GPlates reconstructions. Reconstructions shown here include aspects of sea floor spreading in the Woodlark Basin and Manus Basin, sea floor magnetic isochrons of the Solomon Sea, subducted slab model for the Solomon Sea with 100 km depth contours (Holm and Richards, 2013) and an associated projection of the subducted slab model area floated to the surface. Oceanic plateaus are shown in dark grey, with the Ontong Java Plateau to the north-east and the Louisiade Plateau to the south. The arc crust is shown in light grey derived from 1000 m bathymetric contour.

Solomon Sea plate (Figure 2). The reasons for development of the slab tear are numerous; however, the two key factors are:

1. accommodating the subduction of a relatively flat oceanic plate into a subduction trench with a 90° bend
2. the left-lateral transpression imposed on the eastern part of the subduction zone caused by the west-directed motion of the Ontong Java Plateau.

In the Solomon Islands, reconstructions showing the subduction of the active Woodlark Basin spreading centre and associated extensional basin structures, such as transform faults, demonstrate a spatial and temporal relationship with the formation of deposits. Specifically, the New Georgia Island group hosting the Mase deposit resides above the projected trend of the subducted Woodlark spreading centre (Figure 1). The reconstructions also show that the deposit has been located adjacent to the subducting spreading centre since at least the mid-Pliocene (Figure 2), suggesting a prolonged influence of ridge subduction on the formation of the deposit. Finally, the location and timing of the Panguna and Fauro Island deposits of and adjacent to Bougainville and the Hidden Valley and Koloula deposits of Guadalcanal correlate well with subduction of lower plate structures marginal to the Woodlark Basin (Figure 2).

Reconstructions of the metalogenic Solomon Islands and eastern PNG subduction margins suggest that the location of favourable structures or the passage of subducting structures contributes to the localisation of mineralisation corridors. The reasons for this relationship require further research, but we hypothesise that these structures either promote increased fluid flux within the mantle resulting from a larger exposure of the subducting slab to the surrounding asthenospheric mantle (Richards and Holm, 2013) or that upper plate structures may act as preferential conduits to promote high fluid flux within the upper crust. Increased fluid flux within either the mantle or upper plate likely promotes the transport of metals, leading to a favourable setting for mineral deposit formation.

CONCLUSIONS

In this extended abstract, we compared the location and timing for ore deposit formation with new plate tectonic reconstructions for eastern PNG and the Solomon Islands. The comparison revealed a correlation between deposit emplacement and the location of major structures through time, where both upper plate and lower plate structures may independently contribute to prospective settings for deposit formation. Favourable structures seen to contribute to the localisation of mineralised corridors are varied in nature, including structures within the subducting slab that comprise slab tearing or slab windows, and possible reactivation of inherited structures as slab tears; or upper plate structures that promote localisation of magmatism and fluid-flow such as transtensional strain in the eastern Bismarck Sea. These findings suggest that a good understanding of geodynamic settings for ore deposit formation have the potential to contribute to prospectivity studies and the generation of new exploration targets at regional scales.

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