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Provenance and Tectonics of the Allochthonous New Guinea Terranes: Implications for the Formation and Evolution of Regional Basins

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1. Introduction

Papua New Guinea resides in a complex tectonic junction between the Australian continent, the Southwest Pacific, and Southeast Asia. Resolving the plate tectonic evolution and basin history of this region has proven difficult to date due to the plethora of contradicting geologic models that stem from a lack of constraining regional datasets. A growing body of geochronologic, geochemical and isotopic data acquired over the past decade has led to a progressive shift from a largely autochthonous terrane model, to one of continental breakup, allochthonous terranes and late Cenozoic terrane accretion. Findings from a compilation of regional zircon and biostratigraphic age data provide a robust evidence-based provenance model that confirms many of the terranes are allochthonous in nature and indicates that existing tectonic reconstructions require major revision.

2. Material and methodology

Zircon U-Pb geochronologic data for this study includes new results from the Papuan Peninsula, combined with regional datasets from PNG, eastern Australia, New Caledonia and West Papua (Fig. 1; Blewitt et al., 1998; Van Wyck and Williams, 2002; Kopi et al., 2004; Murgulov et al., 2007; Bodorkos et al., 2013; Tucker et al., 2013, 2016; Decker et al., 2017; Shaanan et al., 2017; Campbell et al., 2018; Holm and Poke, 2018; Webb et al., 2019). The compiled geochronologic data includes zircon grains derived from sedimentary, metamorphic and igneous rocks with a known context. For example, the new Papuan Peninsula provenance samples comprise Miocene-Pliocene volcanic and volcaniclastic samples where inherited zircon grains are derived from the underlying Owen Stanley Metamorphics.

Biostratigraphic data from wells in PNG were compared to wells in Australia, Papua and West Papua (Fig. 1). Well information was accessed through Geoscience Australia's National Offshore Petroleum Information Management System (NOPIMS) and compared to public domain stratigraphic information from regional basins, namely the Salawati, Bintuni, Papuan, Laura, Carpentaria, Eromanga and Surat Basins (Visser and Hermes, 1962; Day, 1969; Haig, 1979; Chevallier and Bordenave, 1986; Carman, 1993; Tucker et al., 2013). In total, 43 exploration wells were reviewed for this study, including six wells from the Bintuni Basin, three wells from the Salawati Basin, 23 wells from PNG and seven from Australia.

Biostratigraphic data was used to provide an additional constraint and independent validation on the geochronologic data and timing of formation of volcaniclastic basement of the Papuan Peninsula and magmatic rocks in eastern Papua New Guinea through identification of the maximum depositional age of overlying sediments and hiatuses associated with rifting episodes. Biostratigraphic data comprised predominantly palynological events over the Cretaceous interval of interest. Regional palynological zonation schemes for the Papuan and Australian Basins of Dettman and Playford (1969), Helby et al. (1987), Davey (1987; 1999), Morgan et al. (2002), Partridge (2006) were translated to the BP Zonation scheme for the Papuan Peninsula (Welsh, 1991) for consistency and to aid in regional correlations.

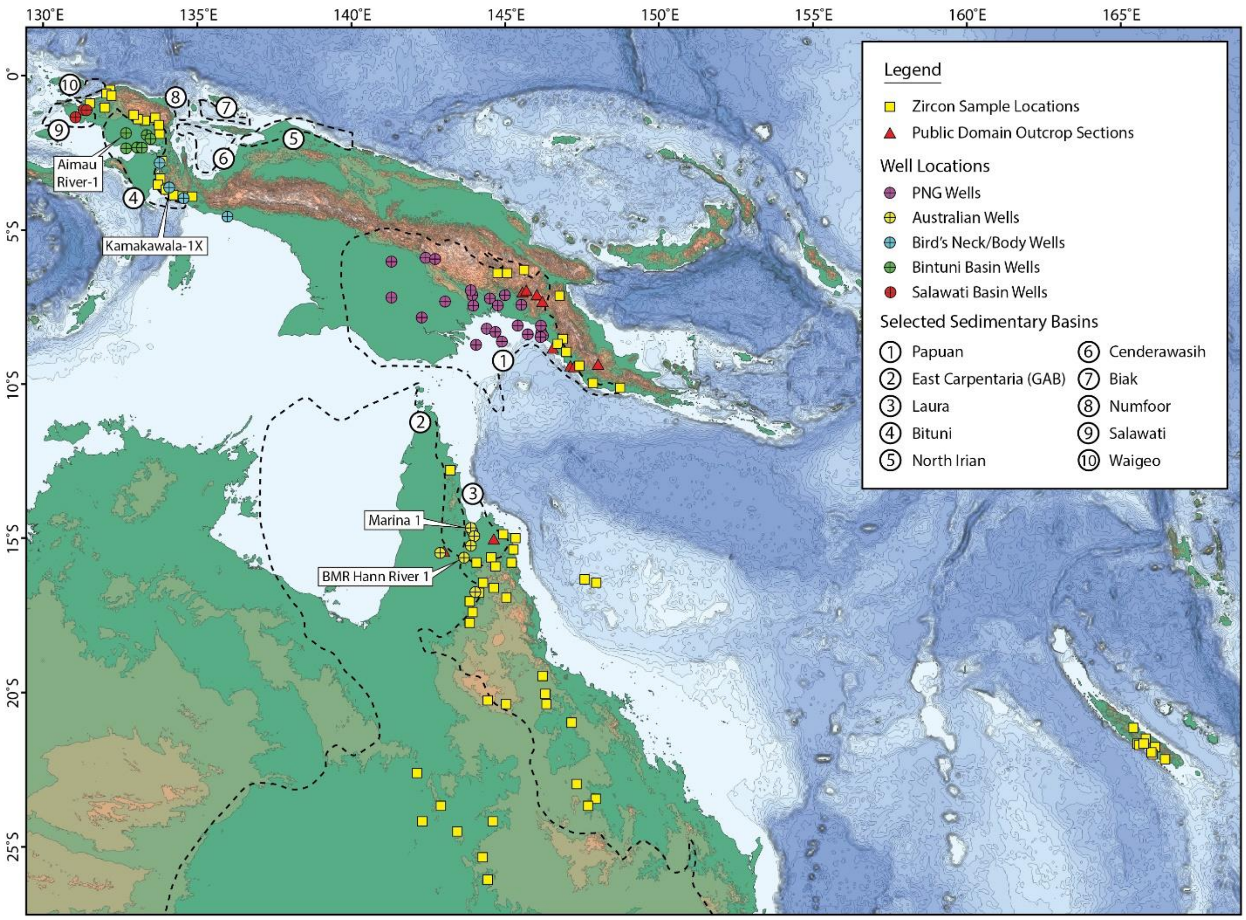

Figure 1. Present day regional setting displaying selected regional basins (black dashed outlines), zircon sample locations, outcrop sections and wells used in this study. Well locations that are further outlined in the text are labelled; only samples with a sufficient number of relevant U-Pb analyses were used. GAB: Great Artesian Basin.

3. Results and discussion

The results of the geochronologic age data and biostratigraphic review indicate there is a need to develop new tectonic reconstructions to explain the history of terrane evolution during and after the Cretaceous. The use of these new provenance and biostratigraphic data is best explained if some of the allochthonous terranes were actually blocks that were once closer to eastern Australia (Fig. 2), which have subsequently been translated north, and westward along the Australian-Pacific plate boundary. This interpretation differs to previous tectonic models of this region (e.g. Hill and Hall, 2003; Hall, 2002; Davies, 2012; Zahirovic et al., 2016), but is further supported by new isotopic, biostratigraphic and geochemical data from Papua and West Papua (Webb et al, 2019; White et al., 2019), which are interpreted to also be of North Queensland derivation (Fig. 2 and Fig. 3).

3.1 Eastern Australia and the Papuan Peninsula

Previous reconstructions suggest a Far North Queensland provenance for clastic rocks of the Papuan Peninsula based on closure of the Coral Sea (Hill and Hall, 2003; Hall, 2002; Davies, 2012). This interpretation is no longer supported by this study. Age populations of zircon derived from the basement of the Papuan Peninsula, the Owen Stanley Metamorphics, cannot be explained by current reconstructions (Hill and Hall, 2003; Hall, 2002; Davies, 2012). Instead, age populations of inherited zircon are a better match with mixed source regions around the Central Queensland coast (Anakie Inlier, Charters Towers Block, Mossman Orogen; Fig. 2) and share a comparable age spectrum to New Caledonia (Campbell et al., 2018). In this model, the Papuan Peninsula rifts from the Australian margin at approximately 100 Ma, which is reasonably constrained as the end of deposition/rift volcanism that contributes zircon and is also the approximate depositional age for the protolith of the Owen Stanley Metamorphics (Kopi et al., 2004). The 100 Ma maximum depositional age for the Papuan Peninsula volcaniclastic basement protolith correlates with rifting of the terrane from eastern Australia and opening of the Tasman Sea, with breakup complete around 70 to 60 Ma.

Review of biostratigraphic data from Australia and Papua New Guinea reveals a reasonably contiguous stratigraphy between eastern Australia and the Papuan Peninsula. In the Eromanga and Surat basins of eastern Australia and the Papuan Basin, the onset of rifting is constrained by palynological data to occur at the Cenomanian-Albian boundary (approximately 100 Ma) and supports the age of the detrital zircon contributed by the rifting of the Papuan Peninsula from the Australian margin at this time. There is a stratigraphic hiatus in the Australian and Papuan Basins until the Campanian to Maastrichtian.

3.2 West Papua

The Bird's Head of West Papua has not been previously directly linked to Papua New Guinea and northeast Australia. Preliminary provenance studies from the Bintuni Basin indicate that Miocene–Recent sedimentation into the basin is derived dominantly from adjacent uplifted granitoids and metamorphic basement (Gunawan et al., 2013). However, recent detrital zircon studies imply that sedimentation of the main hydrocarbon-bearing Jurassic–Cretaceous clastic deposits (Kembelangan Group) were not derived from the same Palaeozoic basement rocks (Decker et al., 2017; Webb et al., 2019). Instead, age populations of zircons recorded from the Jurassic Tamrau Formation of the northern Bird's Head and Lengguru Fold and Thrust Belt of the Bird's Neck share similar peaks to those from northern Queensland and the Queensland Plateau (Fig. 2). Comparisons of the biostratigraphy of wells from the Laura Basin, Queensland, (e.g. Marina-1) and the Lengguru Fold and Thrust Belt (e.g.

Kamakawala-1X) indicate a shared stratigraphy including similar biostratigraphic (palynological) events during the Early Cretaceous (Fig. 3). This supports the new reconstruction of this study, where the Lengguru Fold and Thrust Belt would have been situated close to North Queensland during the Cenomanian-Albian (Figs. 2 and Fig. 3).

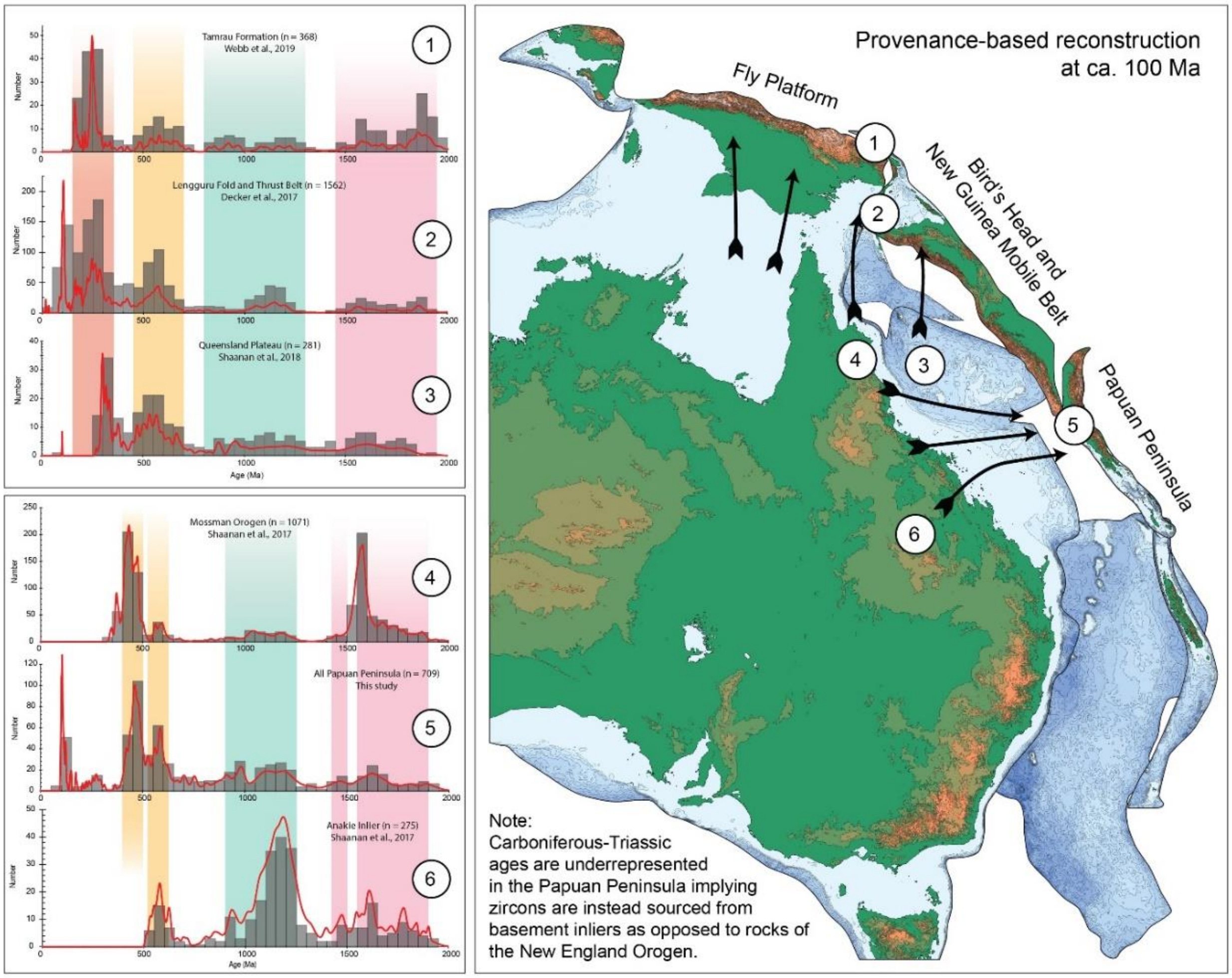

Figure 2. Schematic provenance-based reconstruction at ca. 100 Ma. Representative comparisons are shown for zircon age populations from the Tamrau Formation of the northern Bird's Head, Lengguru Fold and Thrust Belt of the Bird's Neck, and the Queensland Plateau (top left), and Papuan Peninsula with interpreted mixed source regions including the Anakie Inlier and Mossman Orogen of Central Queensland (lower left).

In both the Lengguru Fold and Thrust Belt and northern Queensland, several correlative and contemporaneous palynological events are recorded. In the Marina-1 and Kamakawala-1X wells, the appearance of a combination of dinoflagellate cysts and spores record a near identical succession of biozones, sequences and unconformities throughout the Early Cretaceous (Fig. 3). The stratigraphy of wells from the Bintuni Basin (e.g. Aimau River Deep-1, which contains a typical stratigraphic succession for this basin) is different to that of the Lengguru Fold and Thrust Belt (e.g. Kamakawala-1X) as Early Cretaceous strata are completely absent from wells in the Bintuni Basin. In the Kamakawala-1X well, early Campanian age strata are separated from early Cenomanian and older strata by a local unconformity (Fig. 3). This unconformity is equivalent to those recorded in northeastern Australia, for example in the BMR Hann River-1 well where Paleogene-Late Cretaceous age strata are separated from Albian age strata. This is a marked difference to the Bintuni Basin, where in the Aimau River Deep-1 well the entire Early Cretaceous succession is missing, unlike the Papuan Basin and northern/eastern Australia.

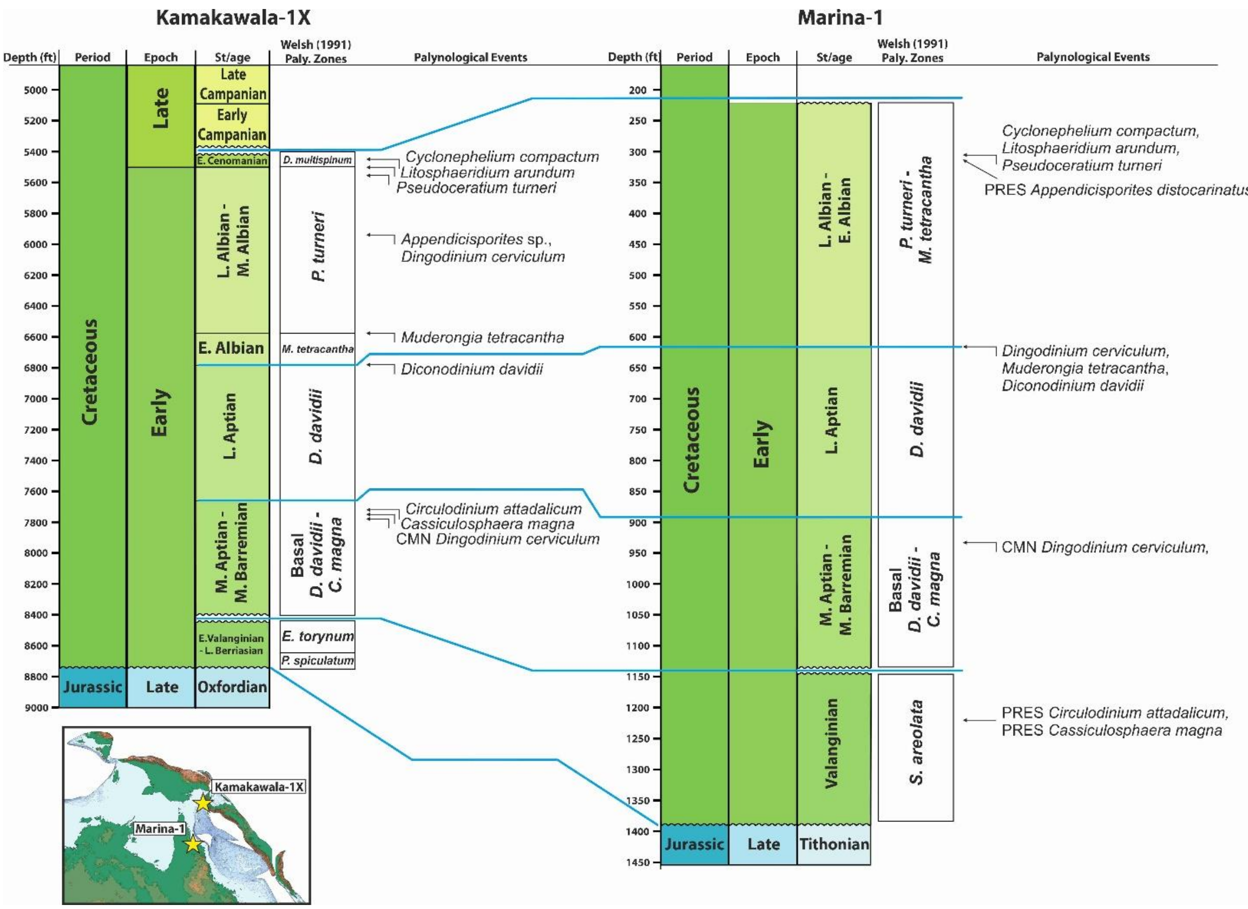

Figure 3. Comparison of palynological events from Cretaceous well successions in the Lengguru Fold and Thrust Belt (Kamakawala-1X) and Laura Basin (Marina-1). Both wells share similar sequences and biostratigraphic events supporting a position of the Bird's Neck closer to northern Queensland during the Cenomanian-Albian.

Conclusions

Our assessment of the available provenance information derived from regional zircon, together with biostratigraphic data from exploration wells, has led to new insights into the tectonic evolution of this region. These findings emphasise the need for basic science in New Guinea and the collection of new information to drive knowledge-based exploration. Rifting of the allochthonous New Guinea terranes from their interpreted position along eastern Australia likely did not occur until the Late Cretaceous, constrained by the maximum depositional age of volcaniclastic basement of the Papuan Peninsula at ca.

100 Ma. Rifting at this time would have resulted in widespread extension and basin formation, including basement crust of the Papuan and Eastern Plateaus, and finally formation of the Coral Sea Basin. Construction of a comprehensive and robust evidence-based tectonic model for the history of New Guinea basins is essential for our geological understanding of the region and to drive successful exploration models.

References

Blewitt, R.S., Black, L.P., Sun, S-s., Knutson, J., Hutton, L.J. and Bain, J.H.C., 1998. U-Pb zircon and Sm-Nd geochronology of the Mesoproterozoic of North Queensland: implications for a Rodian connection with the Belt supergroup of North America. Precambrian Research, 89, 101-127.

Bodorkos, S., Sheppard, S., Saroa, D., Tsiperau, C.U. and Sircombe, K.N., 2013. New SHRIMP U-Pb zircon ages from the Wau-Bulolo region, Papua New Guinea. Geoscience Australia Record 2013/25, MRA of PNG Technical Note TN 2013/05.

Campbell, M.J., Shaanan, U., Rosenbaum, G., Allen, C.M., Cluzel, D. and Maurizot, P., 2018. Permian rifting and isolation of New Caledonia: Evidence from detrital zircon geochronology. Gondwana Research, 60, 54-68.

Carman, G.J., 1993. Palaeogeography of the Coral Sea, Darai and Foreland megasequences in the eastern Papuan Basin. Papua New Guinea (PNG) Petroleum Convention Proceedings.

Chevallier, B. and Bordenave, M.L., 1986. Contribution of geochemistry to the exploration in the Bintuni Basin, Irian Jaya. Proceedings, Indonesian Petroleum Association Fifteenth Annual Convention and Exhibition, 439-460

Davey, R.J., 1987. Palynological zonation of the Lower Cretaceous, Upper and uppermost Middle Jurassic in the northwestern Papuan Basin of Papua New Guinea. Memoir of Geological Survey of Papua New Guinea, 13, pp.1-77.

Davey, R.J., 1999. Revised Palynological Zonation of the Late Cretaceous, Early Cretaceous and Late Jurassic of Papua New Guinea (Vol. 17). Geological Survey of Papua New Guinea.

Davies, H.L., 2012. The geology of New Guinea-the cordilleran margin of the Australian continent. Episodes 35, 87-102.

Day, R.W., 1969. The Lower Cretaceous of the Great Artesian Basin. Stratigraphy and palaeontology: essays in honour of Dorothy Hill, pp.140-173.

Decker, J., Ferdian, F., Morton, A., Fanning, M., White, L. T., 2017. New geochronology data from eastern Indonesia – an aid to understanding sedimentary provenance in a frontier region. Proceedings Indonesian Petroleum Association 41st Annual Convention & Exhibition, IPA17-551-G, 18pp.

Dettmann, M.E. and Playford, G., 1969. Palynology of the Australian Cretaceous: a review. Stratigraphy and palaeontology: essays in honour of Dorothy Hill, pp.174-210.

Gunawan, I., Hall., R. and Augustsson, C., 2013. Metamorphic and volcanic quartz of the siliciclastic Tipuma Formation, West Papua, Indonesia: an insight into Triassic palaeogeography of northern Australia. EGU General Assembly 2013, Vienna, Austria.

Haig, D.W., 1979. Cretaceous foraminiferal biostratigraphy of Queensland. Alcheringa, 3(3), pp.171-187.

Hall, R., 2002. Cenozoic geological and plate tectonic evolution of SE Asia and the SW Pacific: computer-based reconstructions, model and animations. Journal of Asian Earth Sciences 20, 353-431.

Helby, R.J., Morgan, R., and Partridge, A.D., 1987. A palynological zonation of the Australian Mesozoic. Memoirs of the Association of Australasian Palaeontologists, 4, pp.1-94.

Hill, K. C. and Hall, R., 2003. Mesozoic-Cainozoic evolution of Australia's New Guinea Margin in a west Pacific context. In: Hillis, R. and Müller, R. D. (Eds) Defining Australia: The Australian Plate as part of Planet Earth. Geological Society of America Special Paper/Geological Society of Australia Special Publication 372, 265-290.

Holm, R.J. and Poke, B., 2018. Petrology and crustal inheritance of the Cloudy Bay Volcanics as derived from a fluvial conglomerate, Papuan Peninsula (Papua New Guinea): An example of geological inquiry in the absence of in situ outcrop. Cogent Geoscience, 4:1450198.

Kopi, G., Williams, I. and Findlay, R.H., 2004. New detrital zircon data from the Wau-Bulolo region, Morobe Province, Papua New Guinea. MRA of PNG Technical Note 16/2004.

Morgan, R., Hooker, N. and Ingram, B., 2002. Towards higher palynological resolution in the Australian Mesozoic. Morgan Palaeo & Associates Report, 10p. Unpublished.

Murgulov, V., Beyer, E., Griffin, W.L., O'Reilly, S.Y., Walters, S.G. and Stephens, D., 2007. Crustal evolution in the Georgetown Inlier, North Queensland, Australia: a detrital zircon grain study. Chemical Geology, 245, 198-218.

Partridge, A.D., 2006. Jurassic-Early Cretaceous dinocyst zonation NWS Australia: 983 1st update of HMP 2004. In: Monteil, E. (coordinator), Australian Mesozoic and 984 Cenozoic Palynology Zonations - updated to the 2004 Geologic Time Scale. 985 Geoscience Australia Record, 2006/23 (chart 2 of 4)

Shaanan, U., Rosenbaum, G. and Sihombing, F.M.H., 2017. Continuation of the Ross-Delamerian Orogen: insights from eastern Australian detrital-zircon data. Australian Journal of Earth Sciences, doi: 10.1080/08120099.2017.1354916.

Tucker, R.T., Roberts, E.M., Hu, Y., Kemp, A.I. and Salisbury, S.W., 2013. Detrital zircon age constraints for the Winton Formation, Queensland: contextualizing Australia's Late Cretaceous dinosaur faunas. Gondwana Research, 24(2), pp.767-779.

Tucker, R.T., Roberts, E.M., Henderson, R.A. and Kemp, A.I.S., 2016. Large igneous province or long-lived magmatic arc along the eastern margin of Australia during the Cretaceous? Insights from the sedimentary record. GSA Bulletin, 128, 1461-1480.

Van Wyck, N. and Williams, I.S., 2002. Age and provenance of basement metasediments from the Kubor and Bena Bena Blocks, central Highlands, Papua New Guinea: constraints on the tectonic evolution of the northern Australian cratonic margin. Australian Journal of Earth Sciences, 49, 565-577.

Visser, W.A. and Hermes, J.J., 1962. Koninklijk Nederlands Geologisch Mijnbouwkundig genootschap Verhandelingen Geologische (Geological results of the search for oil in Netherlands New Guinea). Nederlandsche Nieuw Guinee Petroleum Maatschappij.

Webb, M., White, L.T., Jost, B.M. and Tiranda, H., 2019. The Tamrau Block of NW New Guinea records late Miocene–Pliocene collision at the northern tip of the Australian Plate. Journal of Asian Earth Sciences, 179, pp. 238-260.

Welsh, A., 1991. Applied Mesozoic biostratigraphy in the western Papuan Basin. Papua New Guinea (PNG) Petroleum Convention Proceedings.

White, L.T., Webb, M., Jost, B.M., Gold, D. P., Gunawan, I. and Tiranda, H., 2019. New Insights into the Geological Evolution of West Papua From Recent Field and Laboratory Studies. Proceedings 2nd International Conference on Earth Science, Minerals and Energy. 3rd October, Yogyakarta

Zahirovic, S., Flament, N., Dietmar Müller, R., Seton, M. and Gurnis, M., 2016. Large fluctuations of shallow seas in low-lying Southeast Asia driven by mantle flow. Geochemistry, Geophysics, Geosystems 17(9), 3589-3607.

CVs

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