# Basin analysis and the geochemical signature of Paleoproterozoic sedimentary successions in northern Australia: Constraints on basin development in respect to mineralisation and paleoreconstruction models

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## Abstract

Secular changes in the characteristics of sedimentary basins and their associated mineral deposits in Proterozoic Australia are directly related to the evolving global tectonic regimes and global changes in atmospheric and oceanic redox states. Identifying these secular changes provides critical information to assist in applying first pass techniques for regional exploration in Australia. The break-up and formation of the Nuna supercontinent is recorded within sedimentary basins within Proterozoic Australia. Sedimentary basins deposited between 1910 Ma and 1810 Ma formed during the Nuna supercontinent amalgamation and host orogenic gold mineralisation, whereas those deposited between 1710 Ma ─ 1575 Ma are directly associated with the break-up of Nuna and host lead-zinc mineralisation.

Sediments in northern Australia deposited during the Nuna amalgamation, and before the Great Oxidation Event, consist of fine-grained iron-rich/mafic mudstones and siltstones which are geochemically characterised by high FeO contents, high Cr/Th and low Th/Sc values. This sedimentary assemblage includes the gold-bearing succession of the Dead Bullock Formation, Tanami region and Koolpin Formation, Pine Creek Orogen. This contrasts with the regionally overlying stratigraphy, which is characterised by low Cr/Th and FeO values and high Th/Sc values. These rocks are also characterised by lower abundances of gold deposits. These geochemical characteristics have successfully been applied by Newmont Tanami Operations to help design future drill programs in the Tanami region.

Sedimentological analysis has been applied in the poorly exposed Tanami basin. The results of these studies, in combination with isopach maps derived from seismic data, lithogeochemistry and U-Pb SHRIMP geochronology, have been used to establish a depositional model for gold-bearing Palaeoproterozoic rocks of the Tanami region. The identification of stratal surfaces between the Dead Bullock Formation (Callie Member) and the Killi Killi Formation permits a better understanding of stratigraphic architecture. The Killi Killi Formation consists of coarser grains in the northwest compared to the southeast which suggests that sediment was transported from the northwest. The maximum thickness of the Tanami Group is recorded in the northwest which then fines/thins to the southeast to a position south of the Callie Mine. The Callie Member was deposited as part of a condensed section below storm wave base. The conformably overlying Killi Killi Formation was also deposited below storm wave base and forms part of a low stand system tract.

Claystone and mudstone within the Killi Killi Formation are prospective for epigenetic gold deposits hosted by reduced mudstones (i.e., Callie style deposits). Within the Killi Killi Formation and the Callie Member, gold potential is enhanced by deep crustal faults that intersect black claystone forming overbank deposits of the Killi Killi Formation or condensed sections of the Callie Member. The claystone forms potential redox boundaries for oxidised gold bearing-fluid. Targeting the position of these thrust faults within claystone environments could help refine gold exploration methods in the Killi Killi Formation.

Possible analogies to iron-rich claystone in the Tanami province are suggested with similar iron-rich successions in the Pine Creek Orogen. Deposition of these iron-rich rocks in northern Australia may have involved similar processes that deposited iron-rich rocks between 2100 to 1800 Ma at Homestake, U.S.A., Ghana, West Africa, and Guyana, South America. Between ~2400 Ma to ~1850 Ma Superior-style BIF deposit were

deposited in many areas around the world, but after about 1800 Ma a global rise in oxygen content of the oceans led to the end of deposition of banded iron formations and iron-rich sediments. This transition from iron-rich sediments to iron-poor sediments corresponds to a general change in mineralisation style and correlates with the Nuna supercontinent break-up. Orogenic gold in northern Australia halted by ~1810 Ma, replaced by a major period of lead-zinc mineralisation between 1710 – 1575 Ma which is associated with the Nuna supercontinent break-up.

Basins that formed in the present day eastern part of Proterozoic Australia during Nuna break-up are characterised by an abrupt change in Sm-Nd isotopic characteristics of sediments at ~1650 Ma. Prior to ~1650 Ma, these rocks have bulk $\varepsilon_{Nd}$(1650 Ma) values of -8 to -6, interpreted to imply a relatively evolved sedimentary source. Sedimentary rocks that accumulated between 1650 Ma – 1600 Ma are characterised by bulk $\varepsilon_{Nd}$ (1650 Ma) values of -2 to -1, indicating a more juvenile sedimentary source. Although Proterozoic felsic magmatism is known in eastern and central Australia, these rocks are either too young or too evolved to have acted as a source for juvenile detritus that characterises the sedimentary successions after ~1650 Ma, which indicates either a source exogenous to present day Australia or a source that was present within Proterozoic Australia that has been lost from the geological record. Juvenile felsic magmatic rocks with ages of around 1650 Ma are known in Laurentia and Baltica, both of which have been interpreted to have been adjacent to Australia at ~1650 Ma. Either of these sources could have been a source of juvenile detritus into Australian Proterozoic basins, but existing data are insufficient to be able to distinguish between these possibilities. Alternatively, the source could have been an endogenous source within Proterozoic Australia. Evidence of such a source may be preserved as "pinkites", thin felsic layers with a probable magmatic origin that are present in parts of the stratigraphy of interest. Present data do not allow discrimination of these three possible sources of juvenile detritus that were introduced into Proterozoic Australian basins at ~1650 Ma.

Sediment hosted Mt Isa-style Zn-Pb-Ag sediments can potentially be fingerprinted by Sm-Nd isotopic data. Future exploration could use this important isotopic boundary at 1650 Ma as an exploration tool for Mt Isa-style deposits in the Mt Isa Inlier, the Etheridge Province, and elsewhere in Proterozoic Australia.

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## Publications and selected conference Abstracts

### Peer reviewed Journal Articles

**Lambeck, A**., Huston, D., and Barovich, K., 2010, Typecasting prospective Au-bearing sedimentary lithologies using sedimentary geochemistry and Nd isotopes in poorly exposed Proterozoic basins of the Tanami region, Northern Australia: Mineralium Deposita, v. 4, p. 497–515.

**Lambeck, A**., Mernagh, T. and Wyborn, L., A, I., 2011. Are iron-rich sedimentary rocks the key to the spike in orogenic gold mineralization in the Paleoproterozoic? Economic Geology 106 (3): 321-330.

**Lambeck, A**., Barovich, K., George, A.D., Cross, A. Huston, D., and Meixner T. Defining basin architecture in the poorly exposed Tanami Proterozoic turbiditic basin, northern Australia with implications for gold mineralisation (in press, Australian Journal of Earth Science)

**Lambeck, A**., Barovich, K., Gibson, G.M. and Huston, D., in review. An abrupt change in Nd isotopic composition in Australian basins at 1650 Ma: implications for the tectonic evolution of Australia and its place in Nuna. (in review. Precambrian Research).

**Lambeck, A**., C**ross, A.,** SHRIMP U-Pb detrital & volcanic zircon results, Georgetown Inlier, Mt Isa, Eastern Succession. (will form a future GA Record).

### Selected Conference Abstracts

**Lambeck, A.**, Gibson, G., Neumann, N., Huston, D. 2008, An integrated sedimentological, geochemical and geochronological analysis of Georgetown: Constraints on basin development and paleo reconstructions. Abstracts. Australian Earth Sciences Convention 2008.

**Lambeck, A.**, Parsons, P., Barovich, K., Hand, M., Withnall, I., Huston, D., Neumann, N. and Carson, C. 2009, Sm-Nd isotopic fingerprinting defining a ~1650 Ma reference boundary in Mt Isa and Georgetown: Implications for Zn-Pb exploration. Digging Deeper, Abstracts, 2 December 2009, pg 12-15.

**Lambeck, A.**, Huston, D., Neumann, N., Barovich, K. and Hand M., 2010, Reconstruction of the Australia-Laurentia link at 1650 Ma: constraints from Sm-Nd data from the Georgetown, Mount Isa, Curnamona, Yavapai and Mazatzal Provinces . Specialist Group in Tectonics and Structural Geology, Geological Society of Australia, Abstracts 25–29 January 2010, pg. 39.

**Lambeck, A**., Neumann, N., Barovich, K., Hand, M., Huston, D., Carson, C., Gibson, G., Withnall, I., and Parson, A., 2010, An Australian tectonic reconstruction at ~1650 Ma: A Baltica link. Abstracts. Australian Earth Sciences Convention 2010, pg. 132.

**Lambeck, A**., Mernagh, T. and Wyborn, L., A,I., 2010. The Spike in Orogenic Gold Mineralization in the Paleoproterozoic: Linked to Anomalously Iron-Rich Sedimentary rocks? Society of Economic Geology annual conference Keystone, Colorado pg 13.

## Declaration

This thesis contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by any other person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University and Geoscience Australia libraries, being available for loan and photocopying.

Alexis Lambeck