

Revised tectono-stratigraphy of the Kimberley Basin, northern Western Australia

by

C Phillips, DW Maidment, and Y Lu

The Kimberley region of northern Western Australia is dominated by sedimentary rocks of the Paleoproterozoic Speewah and Kimberley Groups that currently comprise the Speewah and Kimberley Basins, respectively. The Speewah Group unconformably overlies older Paleoproterozoic meta-igneous and metasedimentary rocks of the Lamboo Province and is in turn overlain by the Kimberley Group (Figs 1, 2; Griffin et al., 1993; Tyler et al., 1995; Sheppard et al., 2012). The Speewah and lower Kimberley Groups are intruded by sills of the Hart Dolerite which has an average SHRIMP U–Pb zircon and baddeleyite age of 1795 ± 15 Ma (Sheppard et al., 2012; Wingate et al., in prep.). The Hart Dolerite is correlated with mafic volcanism in the Carson Volcanics (Fig. 2; Kimberley Group) and together constitutes the Hart–Carson Large Igneous Province. The age of igneous activity is considered a good approximation for the timing of deposition of the Speewah and lower Kimberley Groups.

Kimberley Basin — revised nomenclature

Field relationships, comparative lithofacies and detrital zircon U–Pb geochronology suggest that the Kimberley Basin should be redefined to incorporate both the Speewah and Kimberley Groups.

There is low-angle unconformity or disconformity locally between the Bedford Sandstone at the top of the Speewah Group and the overlying King Leopold Sandstone (Fig. 2; Williams, 1969). However, recent mapping by the Geological Survey of Western Australia (GSWA) found that at most localities the transition between the two groups is conformable and locally gradational with no distinct change in paleocurrent direction (i.e. from the northeast; Gellatly et al., 1970). These low-angle unconformities are not considered here to be a basinwide feature, but rather a series of local erosive surfaces between coarse-grained quartz sandstone at the top of the Bedford Sandstone and cobble to boulder conglomerates at the base of the King Leopold Sandstone. Conglomeratic lithofacies in the lower King Leopold Sandstone have previously been interpreted as glacial outwash following a low-latitude glaciation — the King Leopold glaciation (Williams, 2005; Schmidt and Williams, 2008). Features

described as glacial striations, frost fissures and tillite produced by the westward flow of ice (Williams, 2005) are reinterpreted here to be a part of a broad, prograding fluvial, partly deltaic plain, derived from the northeast. This system fines to the west, as is evident by the presence of granule and pebble sandstones that were deposited with a shallow-marine influence, and no evidence of glaciation has been observed.

North and east of the Mueller Range, the Kimberley Group rests unconformably on the Lamboo Province (Fig. 1). Since the Speewah Group does not crop out east of the Greenvale–Dunham–Ivanhoe Fault system (Fig. 1) it has previously been interpreted to have been deposited in a fault-bound trough. There is no obvious change in thickness of Speewah Group sedimentary rocks toward the faults suggesting that they might not have controlled deposition. It is possible that uplift of the Lamboo Province exerted a strong topographic control on deposition of the fluvial rocks at the base of the Speewah Group. Areas north and east of the Mueller Range might represent former topographic highs that were onlapped by Speewah Group sedimentary rocks that were subsequently drowned during deposition of the laterally extensive Kimberley Group.

Detrital zircon geochronology

Detrital zircon geochronology of the Speewah and Kimberley Groups (Hollis et al., 2014), including recent SHRIMP U–Pb and laser ablation (LA-ICP-MS) data, is broadly dominated by Paleoproterozoic (1880–1850 Ma) and Neoarchean (2525–2480 Ma) detrital components (Fig. 3). There is an increase in Neoarchean-dominated age components from Speewah to Kimberley Group samples possibly indicating a change in provenance, possibly linked to basin-forming processes (Hollis et al., 2014). However, this pattern is reinterpreted here as a gradual increase in sedimentary detritus supplied from a Neoarchean magmatic source or reworking of older sedimentary units. A Neoarchean source is evident throughout the Speewah Group but it is generally in low abundance (Fig. 3). Additional information from the Bedford Sandstone at the top of the Speewah Group, for which no data currently exist, would help resolve these conflicting hypotheses.

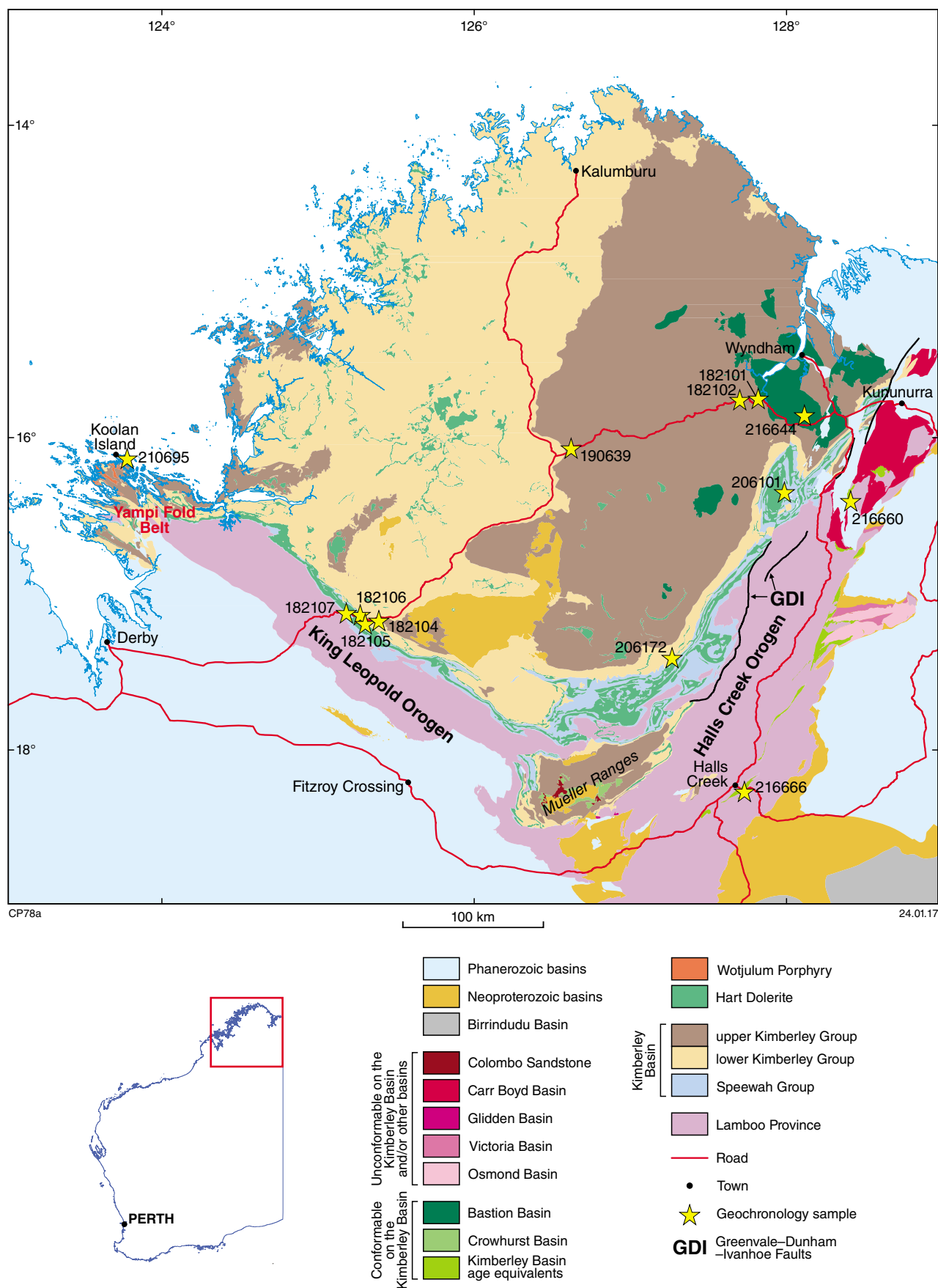


Figure 1. Simplified geology of the Kimberley region showing the sites of samples taken for detrital zircon geochronology (results presented in Figure 3)

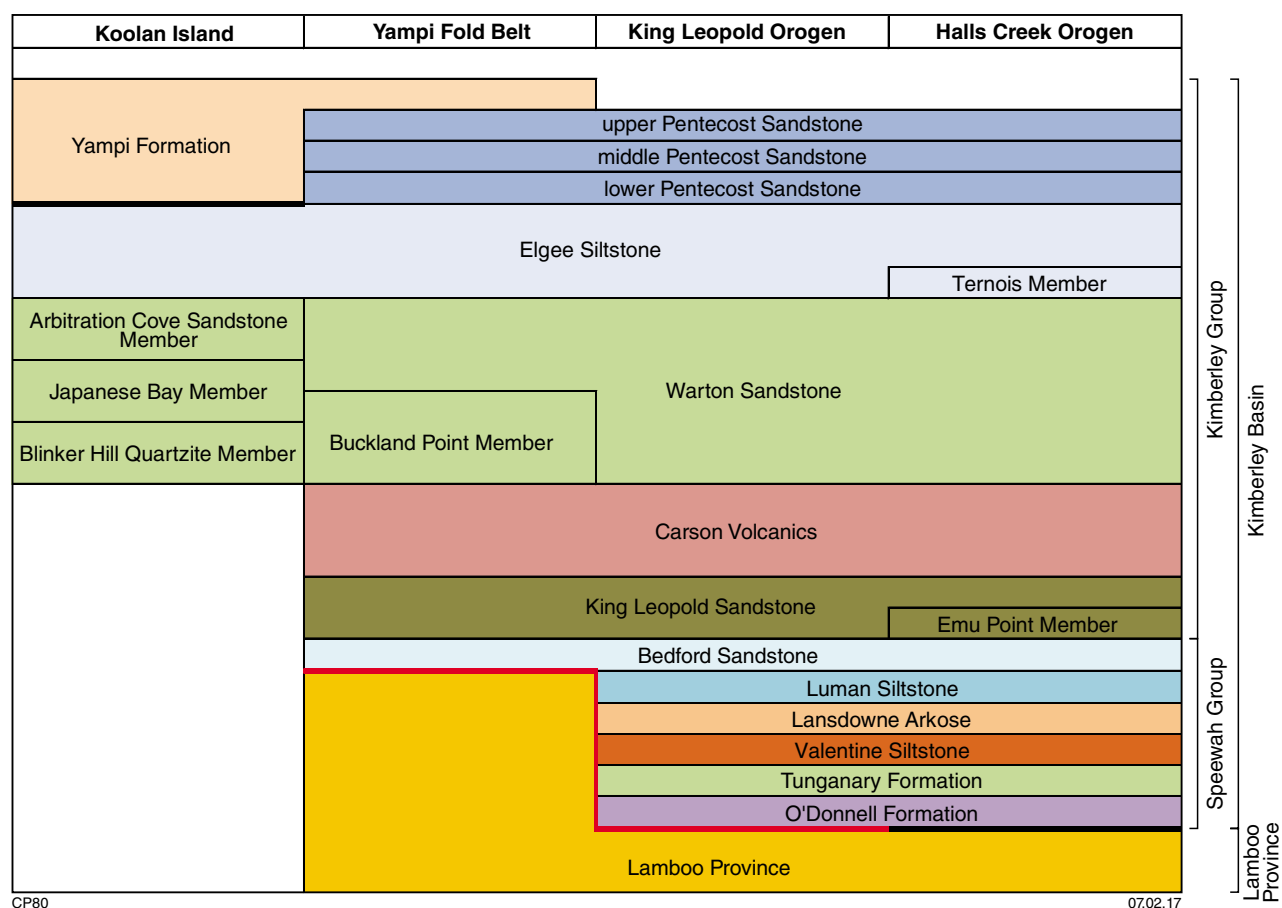


Figure 2. A time–space plot showing the revised stratigraphy and distribution of Kimberley Basin units. Thick black lines represent dominantly unconformable contacts, and thick red lines indicate a fault contact between units.

The broad similarity in the ages of source regions for the Speewah and lower Kimberley Groups, coupled with similar paleocurrent directions, is further evidence that there was no major change in basin dynamics during their deposition, which can be viewed in terms of a progressive evolution within a single basin on top of complex basement topography. It is therefore suggested the use of the term ‘Speewah Basin’ should be discontinued.

Paleoproterozoic– Mesoproterozoic basins

Recent work by GSWA in the east Kimberley region has focused on a number of smaller Paleoproterozoic–Mesoproterozoic sedimentary basin remnants (Fig. 1) for which there are little or no previous geochronological data. New LA-ICP-MS detrital zircon geochronology provides initial constraints on the tectono-stratigraphy of some of these basins.

Revolver Creek Formation

The Revolver Creek Formation is a >1000 m-thick succession of quartz sandstone, feldspathic sandstone, siltstone and shale intercalated with basaltic rocks that rest unconformably on the Lamboo Province (Fig. 1;

Dow et al., 1964; Thorne et al., 1999). The formation is currently assigned to the Revolver Creek Basin but is considered to be equivalent of the Kimberley Basin based on similar lithological associations (Plumb et al., 1985; Thorne et al., 1999). This interpretation is supported by paleocurrent measurements from the Revolver Creek Formation, which are consistent with those from the Speewah and lower Kimberley Groups (i.e. from the northeast). New LA-ICP-MS detrital zircon U–Pb geochronology from the Revolver Creek Formation (GSWA 216660) indicates a significant, almost unimodal, Paleoproterozoic age component consistent with data (albeit with lower analytical precision) from the Speewah and lower Kimberley Groups, particularly the O'Donnell Formation (Fig. 3). Although these data do not allow detailed comparison with the lower Kimberley Group, they are consistent with deposition of the Revolver Creek Formation as the first stage of deposition in the Kimberley Basin in the local area, and as a lateral equivalent of the King Leopold Sandstone and Carson Volcanics.

Moola Bulla Formation

Currently assigned to the Moola Bulla Basin, the Moola Bulla Formation is a succession of conglomerate, sandstone and siltstone unconformable on the Lamboo Province and conformably overlain by the Kimberley

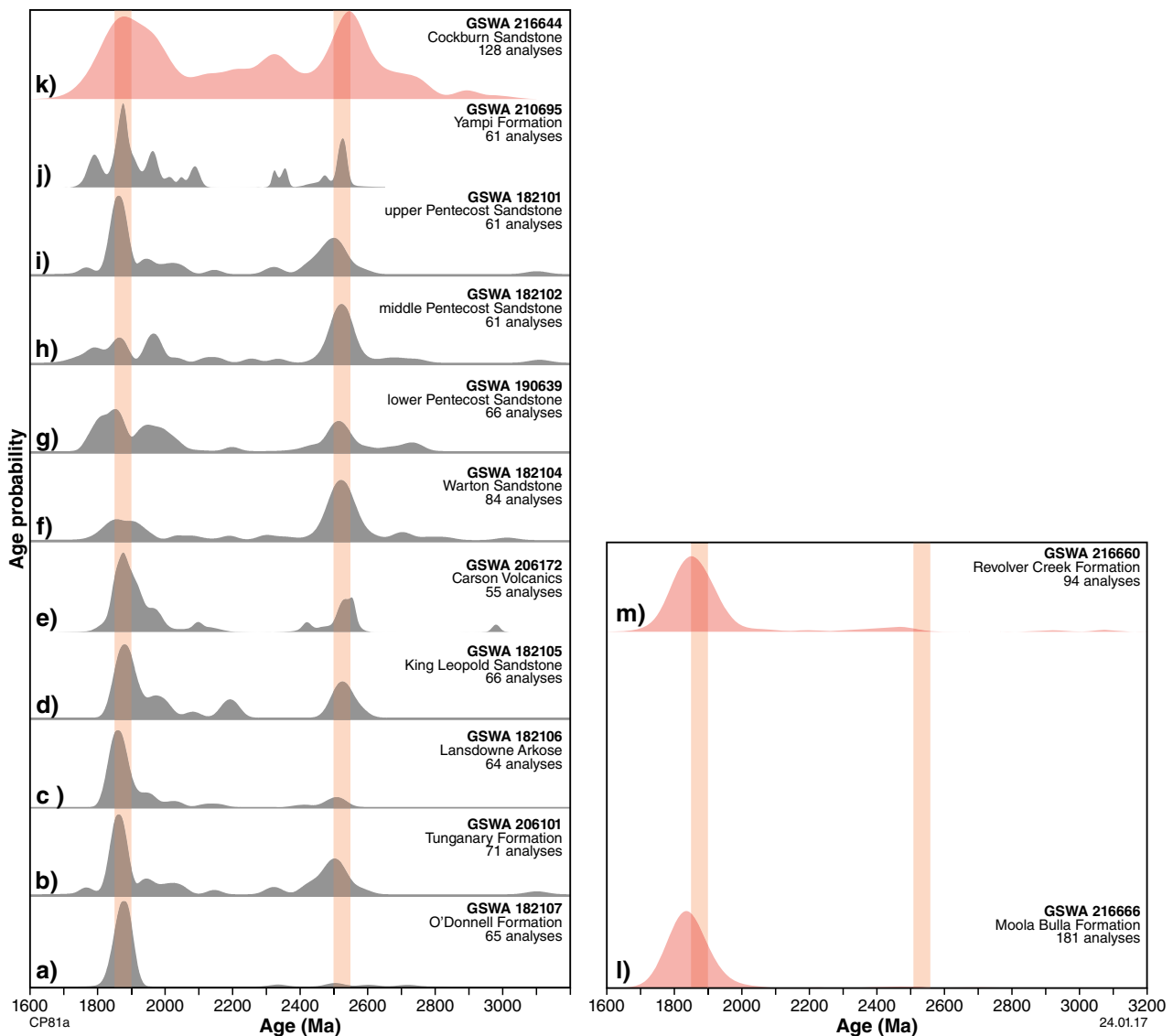


Figure 3. Normalized probability density diagrams of detrital zircon ages (<5% discordant) for sandstone samples from the Speewah and Kimberley Groups. SHRIMP U–Pb data from Hollis et al. (2014) and new SHRIMP U–Pb dating of the Carson Volcanics and Yampi Formation, shown in grey. New LA-ICP-MS detrital zircon geochronology is shown in pink.

Group (Fig. 1). Tentative correlations have been made with the Speewah Group despite contrasting paleocurrent data whereby northeasterly currents dominate the Speewah Group (Gellatly et al., 1970) and southwesterly currents dominate in the Moola Bulla Formation (Blake et al., 1999). New LA-ICP-MS detrital zircon geochronology from the Moola Bulla Formation (GSWA 216666) indicates an almost unimodal Paleoproterozoic detrital zircon population, consistent with detrital age data from the lower Speewah Group (Fig. 3). The Moola Bulla Formation is thus interpreted as an age equivalent to the Speewah Group within the lower Kimberley Basin. Differences in paleocurrent directions can be ascribed to localized irregularities in basement topography, which is likely to have had a significant influence on these fluvial to shallow-marine units.

Bastion and Crowhurst Groups

The Bastion Group consists of fine-grained siliciclastic rocks and quartz sandstone that conformably rest on the Kimberley Group, except west of the Durack Range where unconformable relationships have been described (Thorne et al., 1999). This is the only instance of this relationship which may be locally erosive. Despite the relatively large analytical uncertainties associated with the laser-derived data, new LA-ICP-MS detrital zircon geochronology from the Cockburn Sandstone (GSWA 216644) shows age components at 1880–1850 Ma and 2525–2480 Ma, consistent with detrital age data from the upper Kimberley Group. Likewise, dominantly north and northwest paleocurrent measurements from the Bastion Group are consistent with those from the upper Kimberley Group.

The Crowhurst Group, exposed to the south of the Bastion Group, is conformably overlain by the Kimberley Group; locally, the contact is gradational. The two groups have comparable lithofacies and paleocurrent data (i.e. sediment sourced from the north and northwest; Gellatly et al., 1970). Samples for detrital zircon geochronology collected by GSWA in 2016 are currently being processed.

Based on the conformable relationships, similarity and continuity of sedimentary lithofacies, consistency of paleocurrent data (and with the Bastion Group, consistent detrital zircon age components), it is suggested that the Bastion and Crowhurst Groups represent continued sedimentation in the Kimberley Basin and may, in parts, be correlative.

Future detrital zircon geochronology

Sampling for detrital zircon geochronology in younger Proterozoic sedimentary basins in the east Kimberley region was completed by GSWA during 2015 and 2016. The results of these studies will focus on defining a more robust tectono-stratigraphy for sedimentary succession in the region, including the Glidden, Osmond, Carr Boyd and Victoria Basins, and will be used to construct broader correlations across the Proterozoic of northern Australia.

References

- Blake, DH, Tyler, IM, Griffin, TJ, Sheppard, S, Thorne, AM and Warren, RG 1999, Geology of the Halls Creek 1:100 000 Sheet area (4461), Western Australia: Australian Geological Survey Organisation, Explanatory Notes, 36p.
- Dow, DB, Gemuts, I, Plumb, KA and Dunnet, D 1964, The Geology of the Ord River region, Western Australia: Australian Bureau of Mineral Resources, Geology and Geophysics, Record 1964/104, 164p.
- Gellatly, DC, Derrick, GM and Plumb, KA 1970, Proterozoic palaeocurrent directions in the Kimberley region, northwestern Australia: Geological Magazine, v. 107, p. 249–257.
- Griffin, TJ, Tyler, IM and Playford, PE 1993, Explanatory notes on the Lennard River 1:250 000 geological sheet SE/51-8, Western Australia (3rd edition): Geological Survey of Western Australia, Record 1992/5, 85p.
- Hollis, JA, Kemp, AIS, Tyler, IM, Kirkland, CL, Wingate, MTD, Phillips, C, Sheppard, S, Belousova, E and Greau, Y 2014, Basin formation by orogenic collapse: zircon U–Pb and Lu–Hf isotope evidence from the Kimberley and Speewah Groups, northern Australia: Geological Survey of Western Australia, Report 137, 46p.
- Plumb, KA, Allen, R and Hancock, SL 1985, Proterozoic evolution of the Halls Creek Province, Western Australia: Bureau of Mineral Resources, Geology and Geophysics, Record 1985/25, 87p.
- Schmidt, PW and Williams, GE 2008, Palaeomagnetism of red beds from the Kimberley Group, Western Australia: implications for the palaeogeography of the 1.8 Ga King Leopold Glaciation: Precambrian Research, v. 167, p. 267–280.
- Sheppard, S, Page, RW, Griffin, TJ, Rasmussen, B, Fletcher, IR, Tyler, IM, Kirkland, CL, Wingate, MTD, Hollis, J and Thorne, AM 2012, Geochronological and isotopic constraints on the tectonic setting of the c. 1800 Ma Hart Dolerite and the Kimberley and Speewah Basins, northern Western Australia: Geological Survey of Western Australia, Record 2012/7, 28p.
- Thorne, AM, Sheppard, S and Tyler, IM 1999, Lissadell, Western Australia (2nd edition): Geological Survey of Western Australia, 1:250 000 Geological Series Explanatory Notes, 68p.
- Tyler, IM, Griffin, TJ, Page, RW and Shaw, RD 1995, Are there terranes within the Lamboo Complex of the Halls Creek Orogen?, in Geological Survey of Western Australia Annual Review 1993–94: Geological Survey of Western Australia, p. 37–46.
- Williams, GE 1969, Stratigraphy and sedimentation in the Mount Bedford area, WA: Melbourne, Report to The Broken Hill Proprietary Company Limited (unpublished).
- Williams, GE 2005, Subglacial meltwater channels and fluvio-glacial deposits in the Kimberley Basin, WA: 1.8 Ga low-latitude glaciation coeval with continental assembly: Journal of the Geological Society of London, v. 162, p. 111–124.