Using remote sensing and potential field data to interpret basin fill compositional variations and structures

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SUMMARY

Combined mapping of variations in sedimentary basin fill composition and a structural interpretation is a step towards defining significant crustal scale structures and developing tectonic models in basin dominated terranes. The Bresnahan Group, part of the siliclastic Bresnahan Basin in the Capricorn Orogen was deposited in one such region. New geophysical and remote sensing datasets have been processed to interpret the basin composition and structure. Fieldwork to ground truth the interpretations, including mapping, petrophysical measurements and petrographic examination has also been completed. A northwest-trending fault in the eastern part of the Bresnahan Group has been identified as being in close proximity to compositional changes in basin fill observed on hyperspectral mineral maps. The structure has a similar orientation to a fault that cuts the older Hamersley Basin. A previously interpreted northeast-trending basin-controlling fault mapped in the west has observed differences in radiogenic components north to south in the Bresnahan Group that could reflect changes in basin fill composition. Although, the actual fault could not be mapped in any of the datasets. A west-trending fault in the north that bounds the group, is co-incident to a fault that is thought to control the deposition of the underlying Ashburton Basin, which might indicate a degree of depositional control on sedimentation by pre-existing structures. Faults mapped within the Bresnahan Group, mainly by Landsat 8 and hyperspectral datasets, appear to be mostly post basin fill deposition because of compositional offsets observed. Overall, mapping out compositional variations and structures has indicated regions of the basin fill that might have been fault controlled, that is a step towards defining crustal scale structures and tectonic models in the region.

Key words: Bresnahan Group, geophysics, remote sensing

INTRODUCTION

New geophysical and remotely sensed datasets have been used to constrain basin-fill compositional variations and structural interpretations of the Bresnahan Group, which is part of the Capricorn Orogen, Western Australia (**Figure 1**). Integrating the two data interpretations provides a starting point for defining the location of significant crustal scale structures and for developing improved tectonic models for the region. In a basin dominated region, such as the eastern Capricorn Orogen, it can be difficult to interpret significant crustal scale structures from the gravity and magnetic data, due to a lack of contrast between the different units. A method that has been used elsewhere combines sedimentology and sequence stratigraphy with the geophysical datasets within a basin to define significant structures (e.g. Martin and Thorne, 2004; Johnson et al. 2013). A step towards this outcome is to map out the basin-fill compositional variation and distribution, preferable remotely, to then combine with a structural interpretation of the area.

The 1700-1600 Ma Bresnahan Group was deposited in the Bresnahan Basin, within the Capricorn Orogen (**Figure 1**). The eastern Capricorn Orogen is a basin dominated terrane between the Pilbara and Yilgarn Cratons. The current tectonic model is that the orogen is a collisional zone between the two cratons, that has subsequently been affect by one billion years of intracontinental re-working. The reworking period included basin-forming events, one of which resulted in deposition of the Bresnahan Group, and subsequent orogenic events (Johnson et al. 2013). The Bresnahan Group has not been subdivided into formations (Tyler et al. 1990; Hunter, 1990; Thorne and Seymour, 1991). It is described as a siliclastic succession that is dominantly fining upward with conglomerates at the base, overlain by pebbly coarse sandstone, with some mudstones in the east. Detailed mapping of compositional variations and structures does not exist, and consequently, limits the ability to create credible models for the basin-fill deposition.

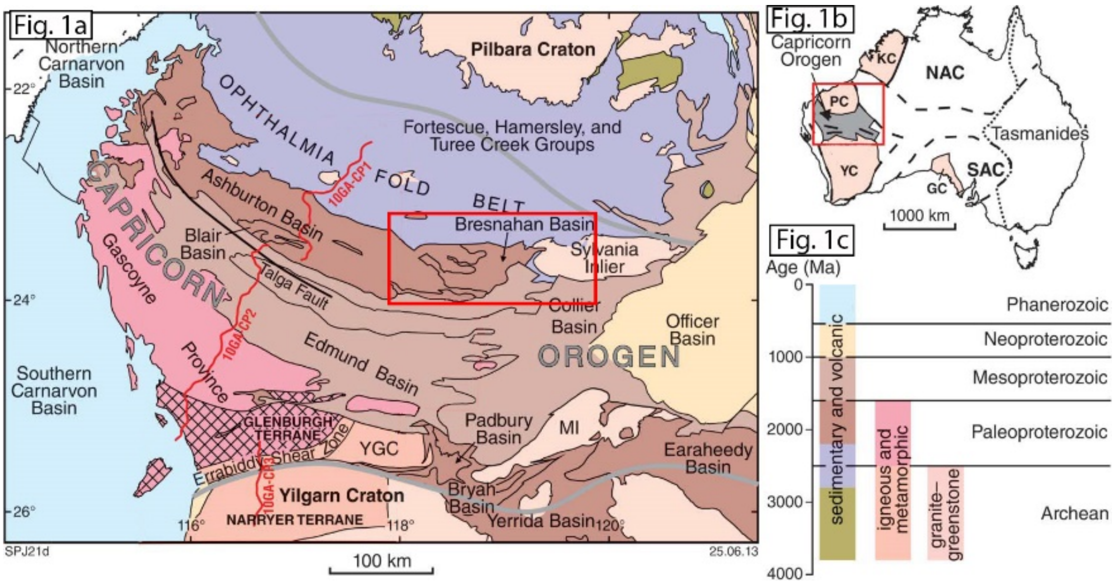

Figure 1: Fig. 1a, Geological provinces of the Capricorn Orogen with the location of the Bresnahan Basin in the NE. Major provinces, namely, the Ashburton Basin (Wyloo Group), Blair Basin (Capricorn Group), Edmund Basin (Edmund Group), Gascoyne Province are also shown, Fig. 1b, Location of the Capricorn Orogen within Australia, PC = Pilbara Craton, YC = Yilgarn Craton, KC = Kimberley Craton, GC = Gawler Craton, NAC = Northern Australian Craton, SAC = Southern Australian Craton, Fig. 1c, Age range and geological age of the tectonic map elements shown in 1a (modified from Johnson et al. 2013).

METHODS

Gravity, magnetic and remote sensing data were integrated to delineate basin fill compositional variations within the Bresnahan Group and structural features like faults and shear zones. The gravity and magnetic datasets were processed in Geosoft© Oasis Montaj software. For the magnetic data to define the shallower features a tilt derivative and vertical derivative was produced. An upward continuation of the magnetic data by 400m was carried out to evaluate the terrane at greater depth.

Airborne hyperspectral mineral maps, provided by Lion One Metals, were processed by HyVista Corporation using an unsupervised statistical end-member unmixing and logical operator supervised classifications (Hussey, 2010). A range of mineral maps were produced with a particular emphasis on white mica abundance and variation. Landsat 8 was utilised by applying a 742 band false colour image with band 7 representing clay minerals, band 4 iron oxides and band 2 the vegetation (Sabins, 1997). Various images were processed from the radiometric data, including single channel abundance and ternary images of U, Th and radiogenic K. ASTER mineral maps produced by CSIRO highlight in particular relative abundance of MgOH for mafic or carbonate occurrences and AlOH for clay or mica distribution (Hewson et al. 2015). Petrophysical measurements were obtained using a magnetic susceptibility meter and radiogenic proportions from a scintillation gamma spectrometer. Density measurements including porosity determination were completed using the procedure outlined in Emerson (1990).

RESULTS

Analysis of remotely sensed datasets illustrates compositional variations in siliclastic units of the Bresnahan Group at surface, which have not been previously mapped. Hyperspectral mineral maps highlight differences in the proportions of mica and montmorillonite (i.e. variations in AlOH and FeO) in various parts of the group, but particularly in the east (**Figure 2**). These variations occur over and along distinct sedimentary horizons whose trend is evident in the hyperspectral maps as well as Landsat 8 satellite imagery. Radiometric data suggests that the western basin fill has significant differences in radiogenic components compared to the more radiogentically homogenous sediment fill in the eastern part of the basin (**Figure 3**). Although, the hyperspectral data in the east does highlight some compositional variations (**Figure 2**). Petrophysical radiogenic responses and detrital compositions observed within thin section analysis of samples, in particular detrital muscovite mica, to a degree support the remote sensing mapping.

A new structural interpretation for the basin indicates the present edges of the Bresnahan Group is dominated by faults. A northwest trending structure is mapped bounding the eastern basin margin in magnetic, gravity and Landsat 8 datasets. The structures orientation is coincident to a fault that offsets units in the northern older Hamersley Basin (**Figure 4**). The Bresnahan Group is bound in the north by a west-trending fault that is mappable in magnetic and gravity datasets. Along strike to the west, the fault appears related to a structure that bounds the underlying Ashburton Basin. A linear feature defined in radiometric and hyperspectral data forms the western boundary of the group, however, the continuity of the structure along strike is not mappable in the potential fields and remote sensing datasets. A number of faults within the Bresnahan Group are mapped by the remotely sensed datasets, with apparent throw indicated by offset of compositional variations, example shown within **Figure 2**. The orientation of the structures vary throughout the basin with west-trending structures dominating in the east and northeast-trending structures dominating in the west basin. The orientation and dip of structures throughout the basin have been checked during field mapping of the region.

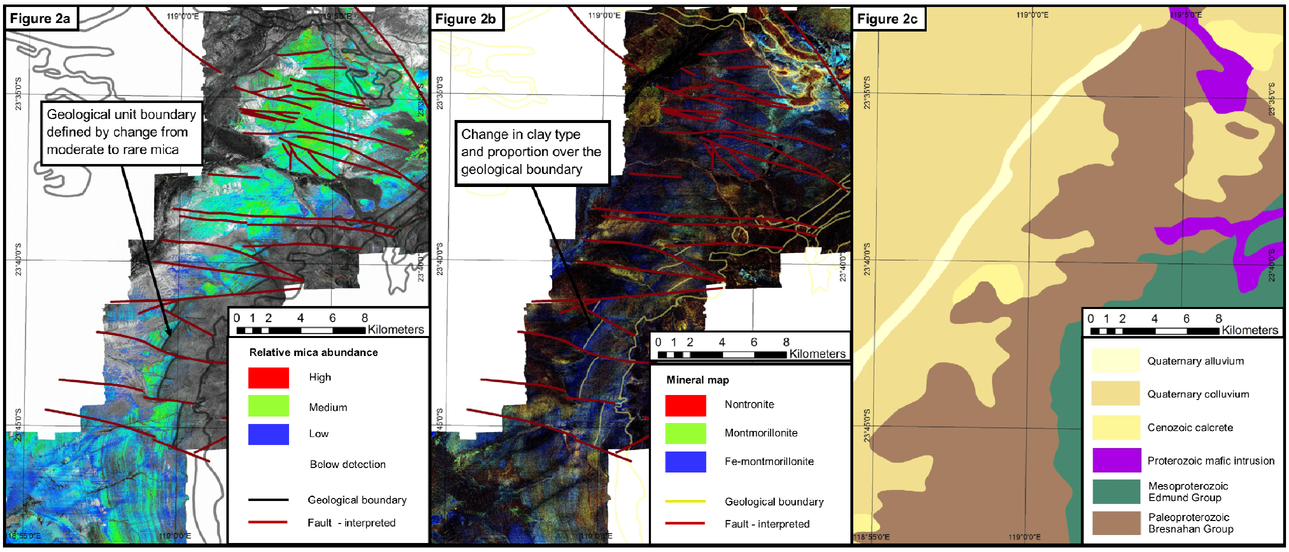

Figure 2: Shows an example of the interpreted basin fill compositional variations in hyperspectral mineral maps, Fig. 2a, mineral map showing a relative abundance of mica with the structural interpretation and geological boundaries overlain, Fig. 2b, a mineral map of different clays of the montmorillonite group overlain by the structural interpretation and geological boundaries, Fig. 2c, an outcrop map highlighting exposed Bresnahan Group. Hyperspectral mineral maps were provided by Lion One Metals who employed HyVista Corporation to process the data.

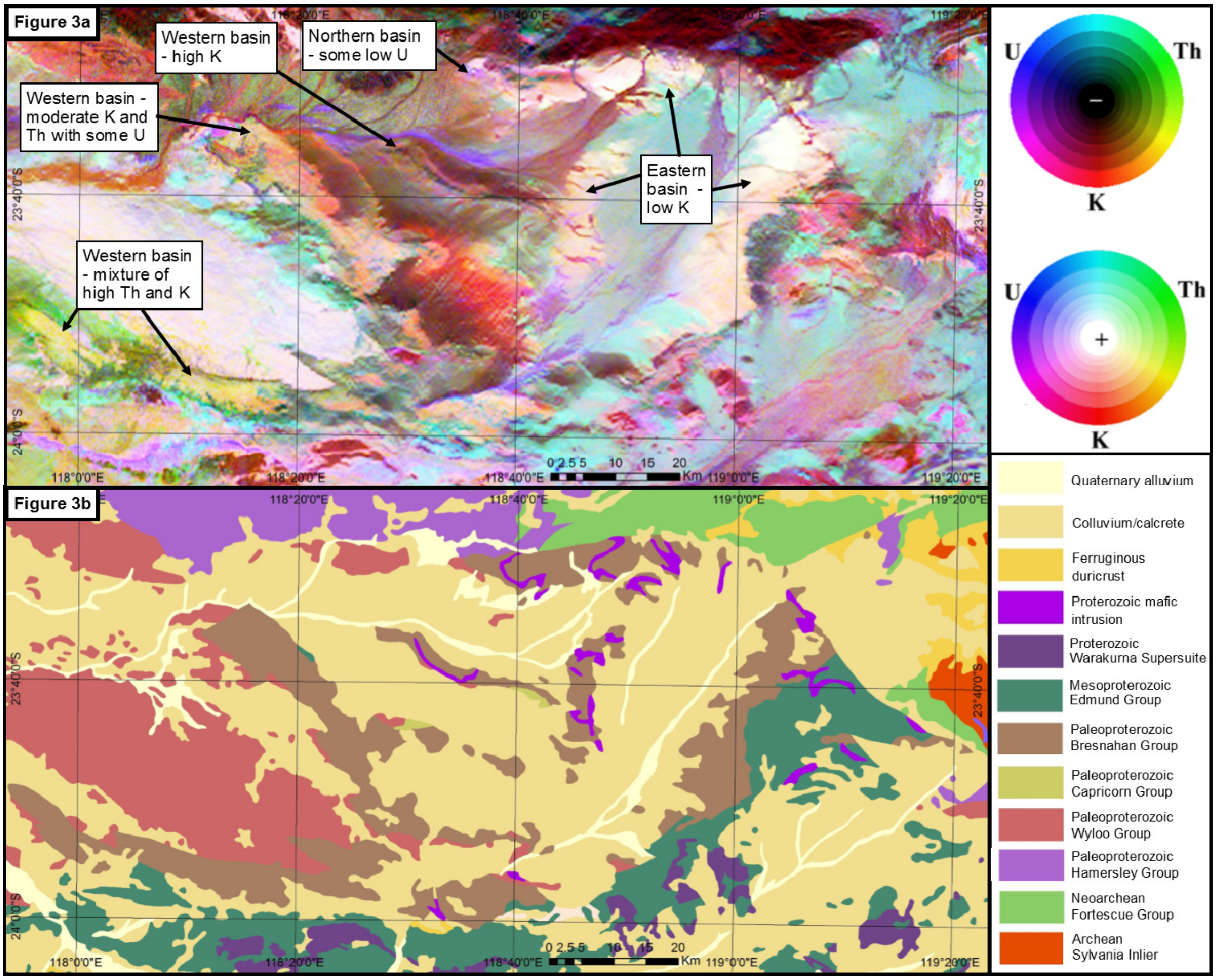

Figure 3: Highlights the radiogenic proportion differences across the basin, in particular the highly variable components in the western portion of the basin, Fig. 3a, a gamma ray coloured image showing the proportions of U, Th and radiogenic K, Fig. 3b, the surface geology for the region.

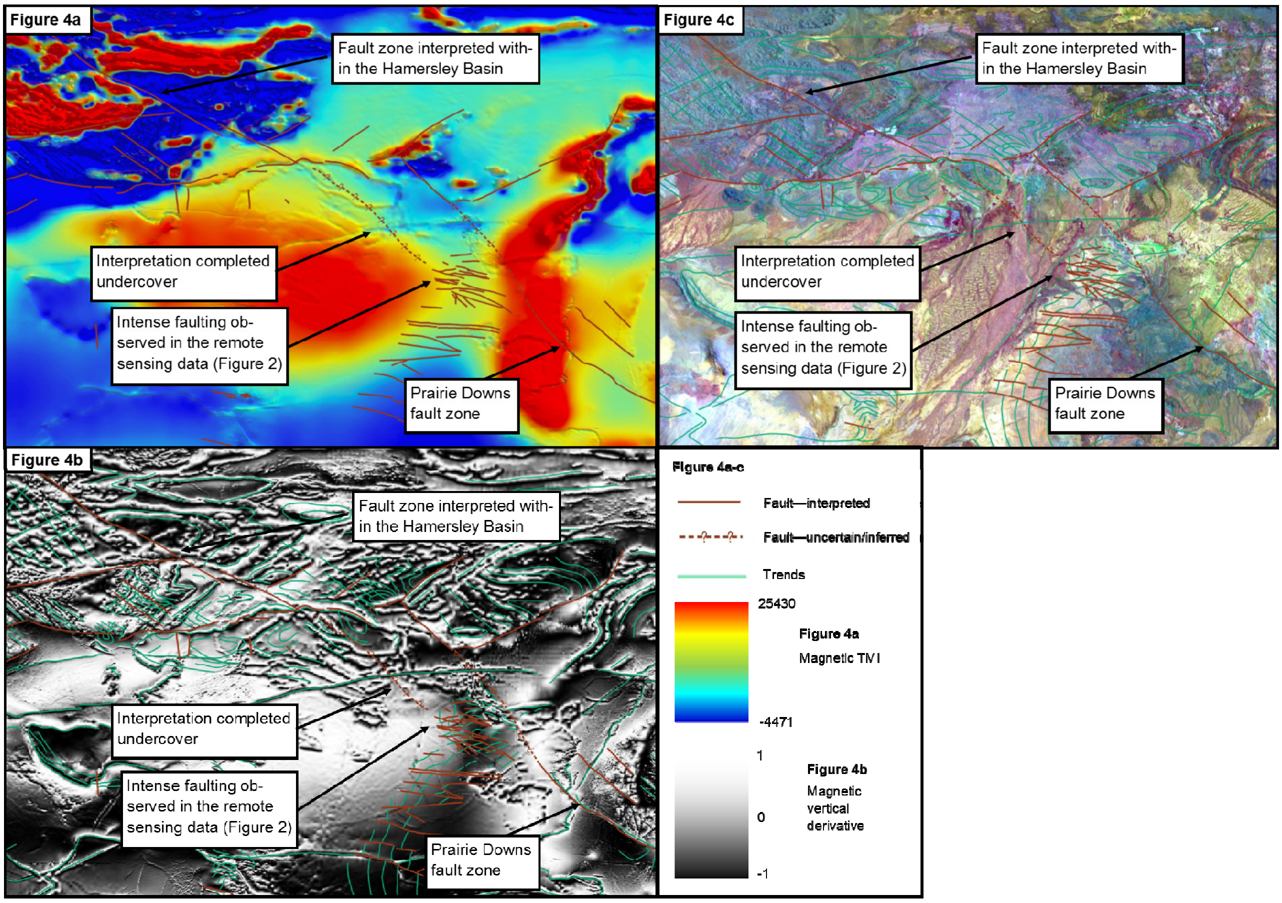

Figure 4: Interpretation of a northwest-trending Prairie Downs fault, partly within or at the margin of the eastern portion of the Bresnahan Group. The orientation of the structure indicates a possible link with a fault interpreted in the older Hamersley Basin. Fig. 4a, Magnetic TMI, Fig. 4b, a processed vertical derivative of the magnetic data, Fig. 4c, Landsat 8 showing a 742 image.

CONCLUSIONS

The remote sensing data was most useful for mapping out the compositional differences where the Bresnahan Group was outcropping. This is compared to the gravity and magnetic datasets that had little use in mapping the internal heterogeneities due to low or no contrast in the petrophysical properties of the basin fill. The compositional variations mapped out are supported by the detrital grain composition of samples, described during thin section analysis. Additional fieldwork and analyses of detrital zircon geochronology are required to constrain the interpretation further, in particular whether the compositional variations have any sequence stratigraphic significance. Both remote sensing and potential fields data sets were used to map out the basin structures, although this was limited in both datasets where the interpretation was carried out in undercover areas of the basin.

The research is a progression to the work completed previously in the area (Tyler et al. 1990; Hunter, 1990; Thorne and Seymour, 1991). Basin fill compositional variations mapped provide a means to subdividing the Bresnahan Group that possibly indicates location of major depocentres and basin-controlling structures. In particular, a previously defined northeast-trending basin bounding fault in the west (Thorne and Seymour, 1991) has interpreted compositional differences along its extent (**Figure 3**), that could indicate some fault control on sedimentation. Hyperspectral mineral maps, in particular those for mica and montmorillonite, (**Figure 2**) show significant compositional changes in the eastern part of the basin, most likely mapping a change from micaceous sandstone to mudstone, which is in close proximity to a northwest-trending fault mapped bounding the group in **Figure 4**. It is presently unclear whether the mudstones in the west could be derived from a depositional fining in the basin west to east, or alternatively were deposited in a depocentre that was partly controlled by the northwest-trending structure. The basin in the north is bound by a west trending fault that is clearly observed in many of the datasets, therefore verifies the previous interpretation (Thorne and Seymour, 1991). The fault is co-incident to a structure that is interpreted to control the deposition of the Ashburton Basin along strike, and therefore, indicating the Bresnahan Basin fill could have been controlled by the pre-existing structure (Thorne and Seymour, 1991). The previous work and fieldwork indicate the structure is near vertical and has evident strike slip shear sense indicators, like fault defined augens (Hunter, 1990). Faults mapped within the Bresnahan Group are likely to be later than the deposition of the basin fill, due to the apparent strike slip throw offset of sediment composition differences observed (e.g. **Figure 2**). Overall, linking together the compositional variations and structural interpretations suggest areas of the basin that could be fault controlled, that is the first step towards defining crustal scale faults and tectonic models in the basin dominated terrane. Further work will involve field mapping, provenance studies of the basin fill, detrital zircon geochronology and gravity and magnetic forward modelling.

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REFERENCES

Emerson, D. W., 1990, Notes on mass properties of rocks - density, porosity, permeability: *Exploration Geophysics,* **21**, 209-216.

Hewson, R., Robson, D., Mauger, A., Cudahy, T., Thomas, M. & Jones, S. 2015. Using the Geoscience Australia-CSIRO ASTER maps and airborne geophysics to explore Australian geoscience: *Journal of Spatial Science,* **60**, 207-231.

Hunter, W. M., 1990, Bresnahan Basin. *Geology and mineral resources of Western Australia.* Perth, Australia: Geological Survey of Western Australia.

Hussey, M. C., 2010, HyMap survey and processing report, Ashburton survey, Western Australia, *unpublished report*, HyVista Corporation.

Johnson, S. P., Thorne, A. M., Tyler, I. M., Korsch, R. J., Kennett, B. L. N., Cutten, H. N., Goodwin, J., Blay, O., Blewett, R. S., Joly, A., Dentith, M. C., Aitken, A. R. A., Holzschuh, J., Salmon, M., Reading, A., Heinson, G., Boren, G., Ross, J., Costelloe, R. D. & Fomin, T., 2013, Crustal architecture of the Capricorn Orogen, Western Australia and associated metallogeny: *Australian Journal of Earth Sciences,* **60,** 681-705.

Martin, D. M. & Thorne, A. M., 2004, Tectonic setting and basin evolution of the Bangemall Supergroup in the northwestern Capricorn Orogen: *Precambrian Research,* **128,** 385-409.

Sabins, F. F., 1999, Remote sensing for mineral exploration: *Ore Geology Reviews,* **14,** 157-183.

Thorne, A. M. & Seymour, D. B., 1991, *Geology of the Ashburton Basin Western Australia*. **Bulletin 139**. Perth, Australia: Geological Survey of Western Australia.

Tyler, I. M., Hunter, W. M. & Williams, I. R., 1990, *Explanatory notes on the Newman 1:250 000 geological sheet Western Australia (second edition)*: **1989/6**. Perth, Australia: Geological Survey of Western Australia.