Understanding the architecture of the Batten Fault Zone from the regional to sub-basin scale. Insights from geophysical interpretation and modelling

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Introduction

The Batten Fault Zone, located in the southeastern McArthur Basin is a 50–80 km wide, north-south trending fault zone that preserves sedimentary and volcanic sequences from the Palaeo to Mesoproterozoic Tawallah, McArthur, Nathan, and Roper Groups (**Figure 1**; Ahmad *et al* 2013). The fault zone is host to the McArthur River Pb-Zn-Ag mine and the Teena Pb-Zn deposit. Structurally controlled sub-basins containing locally thick sequences of the Barney Creek Formation (McArthur Group) host the base metals mineralisation. The controlling structures of these sub-basins are generally not evident at the surface; their exploration therefore requires geophysical techniques.

Government and industry have acquired a range of geophysical datasets across the Batten Fault Zone. Publically available data includes aeromagnetics and radiometrics at 500 m line spacing, two deep seismic profiles (Rawlings *et al* 2004), and a complete coverage of the fault zone with gravity between 4 km and 500 m spacing. Available data also includes industry-submitted airborne electromagnetics (AEM) covering the majority of the fault zone, which has been reprocessed (Munday *et al* 2017). Interpretation of all these datasets and their integration with existing geological data offers the ability to map structure and stratigraphy under cover, and model the 3D architecture of the basin at the regional to sub-basin scale.

Knowledge of the structural framework of the basin at the time of deposition of the McArthur Group is important to determine how and where sub-basins develop. This information is also critical for numerical simulations of fluid flow and understanding the mechanisms that may lead to mineralisation (Sheldon and Schaubs, this volume). This abstract discusses preliminary results from the interpretation and modelling of new and historical geophysical data across the Batten Fault Zone. The work forms part of a 3-year collaborative project between CSIRO and Northern Territory Geological Survey on the architecture and prospectivity of the McArthur Basin.

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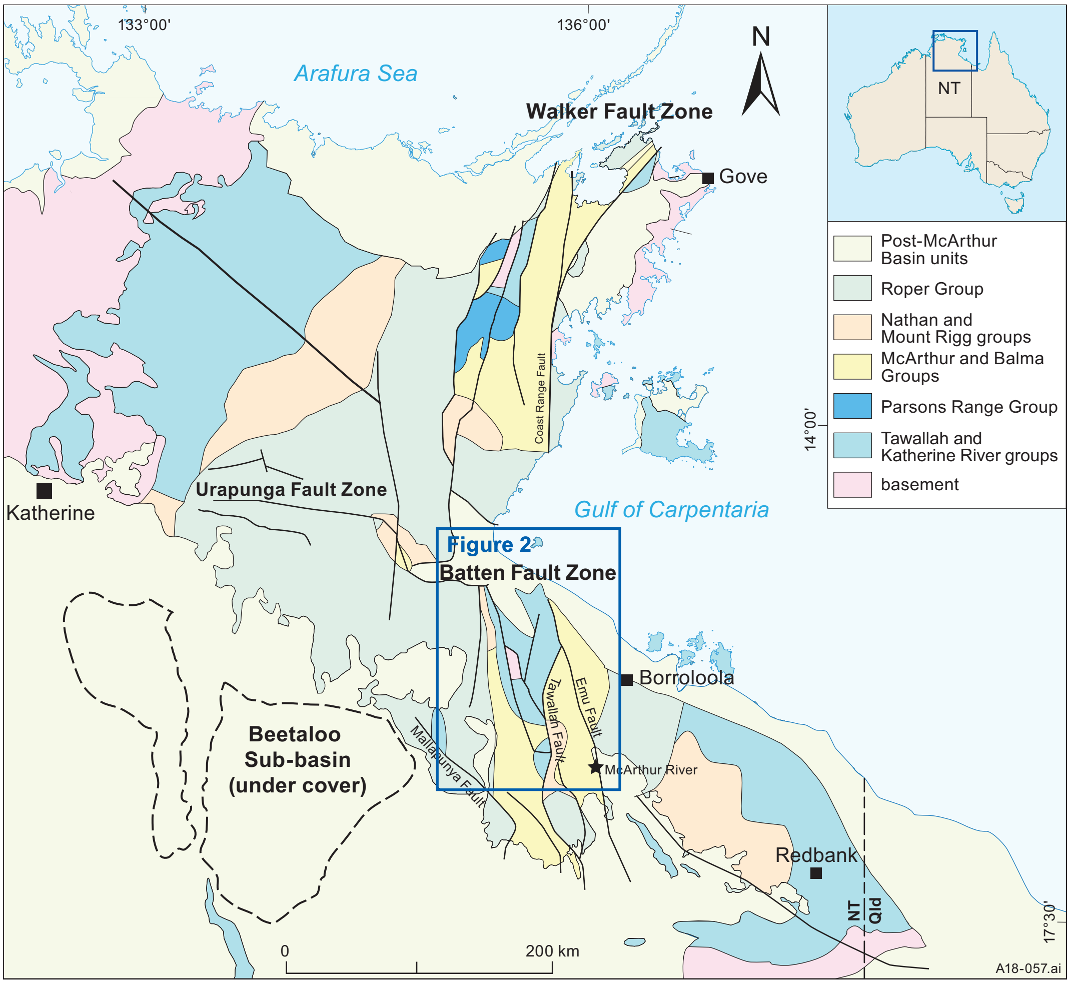

Figure 1. Regional geological map of the greater McArthur Basin (modified from Ahmad *et al* 2013).

Geophysical interpretation and modelling of the Batten Fault Zone

A structural and lithological interpretation of the Batten Fault Zone (**Figure 2**) focused on mapping the distribution of Proterozoic stratigraphy under cover. The interpretation was derived from gravity, magnetic, radiometric and AEM data, with constraints provided by existing geological mapping, drillholes, and satellite photos. The majority of the Batten Fault Zone has been interpreted down to formation scale; however, there are some regions under significant cover with poor geophysical contrast in the underlying stratigraphy. Interpretations in these regions are constrained to sub-group or group level and are still subject to some uncertainty.

This interpretation constrained forward modelling of geological cross-sections. Sections were constructed using 500 m spaced gravity data acquired along several profiles as part of the Batten Fault Zone gravity survey (Dhu 2018). Two models have currently been constructed to better define the 3D geometry of the fault zone, the distribution of depositional packages and architecture of the basement. One profile is orientated north-south through the central Batten Fault Zone (between Tawallah and Emu faults); the other is east-west. Seismic data located along or close to the sections helped constrain the model geometry. Drillhole and rock property data provided additional geological constraints. The models were constructed at the group scale and an average density for each group was applied during modelling. The rock property data were sourced from Hallet (2017), however measurements were largely derived from variably weathered drill core and hand samples. During modelling, the densities of each group were increased slightly to account for both measurements made on weathered samples and the increase in density due to water saturation and lithostatic loading. Contrasts between average group densities in the model were kept consistent with observed data.

The east-west section highlights the geometry of the fault zone, including that of the west-dipping Tawallah and Hot Spring faults, the central Batten Fault Zone and the Broadmere sub-basin (**Figure 3**). Modelling and constraints from seismic data suggests the McArthur Group is relatively thin in the Broadmere region and thickens towards the central Batten Fault Zone against the north-trending Emu Fault. A lack of drillhole and seismic information make it difficult to determine whether thinner stratigraphy in the Broadmere region represents a thinning of the McArthur Group towards the west or if the sequence was eroded prior to deposition of the Nathan and Roper Groups.

The north-south profile suggests northwest–southeast orientated faults influenced the architecture of the basin at the time of McArthur Group deposition. The McArthur Group appears to thicken from the north towards the central

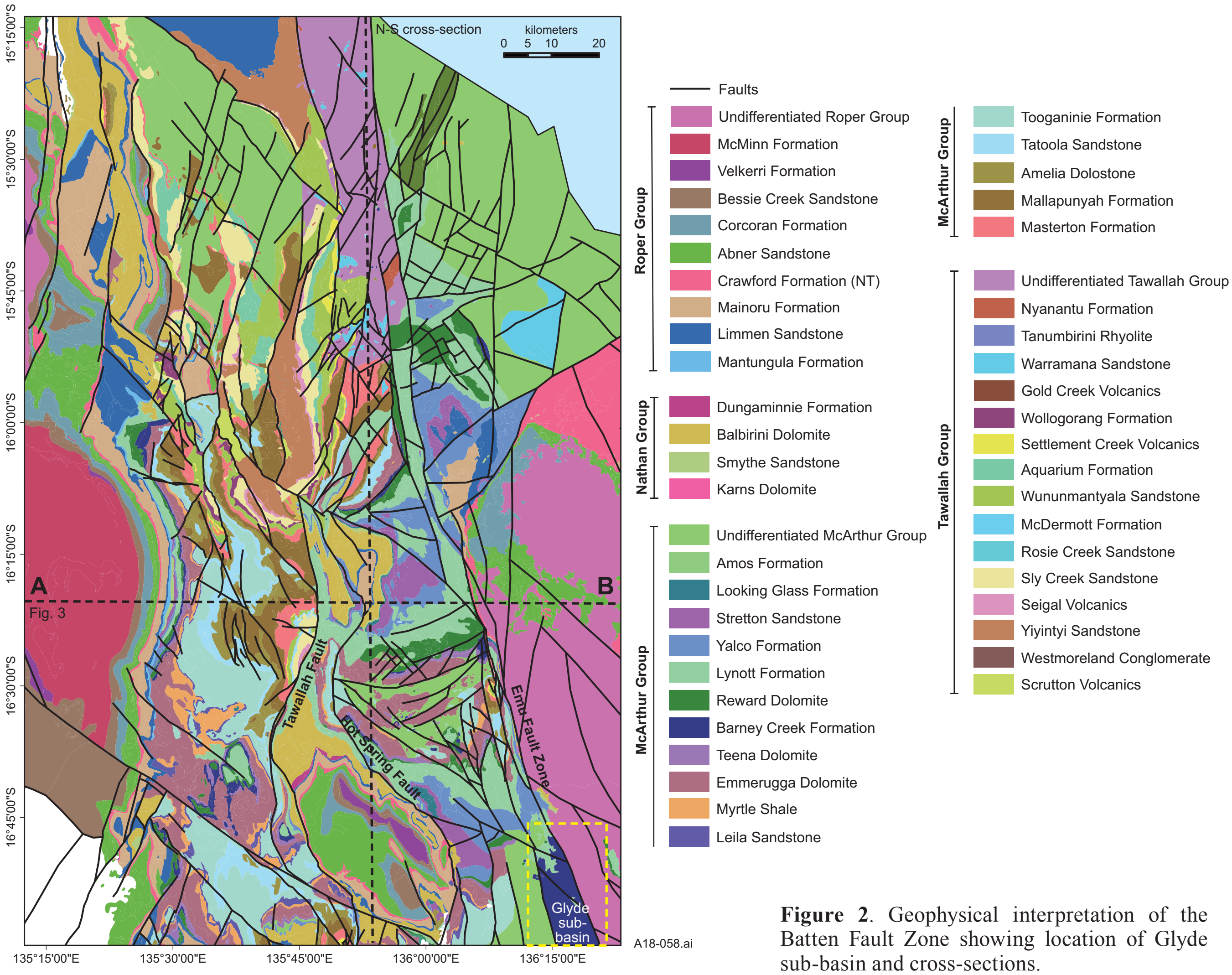

Figure 2. Geophysical interpretation of the Batten Fault Zone showing location of Glyde sub-basin and cross-sections.

Batten Fault Zone where it thins against a palaeo high and then immediately thickens again between the Hot Spring and Mallapunyah faults. The preserved thickness of the McArthur Group gradually thins south of the Mallapunyah Fault.

Modelling also provides some insight into the nature of the basement to the McArthur Basin. Some long-wavelength gravity anomalies in both the north-south and the east-west profiles could not be reproduced through variations in stratigraphic thickness or minor changes to the density of the McArthur and Tawallah groups. As a result, oval-shaped gravity lows located within the central Batten Fault Zone are intetrpreted as granites within the basement. These granites may have influenced how strain was accommodated in the crust during extension and where sub-basins formed.

Modelling sub-basins

Lateral thickness and facies variations of the Barney Creek Formation developed within fault-bounded sub-basins between the Emu and Tawallah faults (McGoldrick *et al* 2010). The Glyde sub-basin (**Figure 2**), in the southeast of the Batten Fault Zone, is a north-south trending depocentre that preserves up to 900 m of Barney Creek Formation. The sub-basin was been interpreted to have formed in a transtensional region along segments of the Emu Fault Zone (**Figure 3**). It is well-imaged in geophysical data with good coverage of magnetics, Falcon airborne gravity gradiometry (AGG) acquired by Armour Energy (2012), and AEM data (Munday 2017). This has allowed modelling of structures controlling the architecture of the sub-basin, as well as imaging of conductive elements of the Barney Creek Formation.

Geophysical interpretation and modelling results are integrated with information from detailed stratigraphic logging and geochemical analysis (Kunzmann 2018). Results indicate a thickening of the Barney Creek Formation from west to east towards the Emu Fault, and a deepening of the basin from the south towards to the north. This is consistent with the interpreted architecture of the McArthur Group at the regional scale.

Summary and future work

The architecture of the fault zone and the McArthur Group suggests north-south to northeast-southwest directed extension was accommodated along major northwest-southeast trending normal faults and along north trending strike-slip fault zones. The north-south trending strike slip faults were reactivated as west-dipping thrust faults during later deformation.

Sub-basins within the Batten Fault Zone developed in north-south trending transtensional segments of the Emu Fault zone; they also formed adjacent to east-west trending cross-faults between the Hot Spring and Emu Fault. Geophysical modelling suggests the basement to the central Batten Fault Zone may be granitic in parts, which may have influenced how strain was accommodated in the crust and where sub-basins were forming.

Ongoing work within the Batten Fault Zone will include additional forward modelling to better constrain the fault zone architecture, including that of the basement. These results will be integrated with high-resolution case studies that focus on local sub-basin architecture, including the subsurface extent and thickness of the Barney Creek Formation. Combining regional and local scale interpretations will assist in the reconstruction of the basin architecture at the time of McArthur Group deposition.

Approaches described here can be applied to other areas of the greater McArthur Basin (such as the Walker Fault Zone and Birrindudu Basin) to determine if they are equally prospective for base metals mineralisation.

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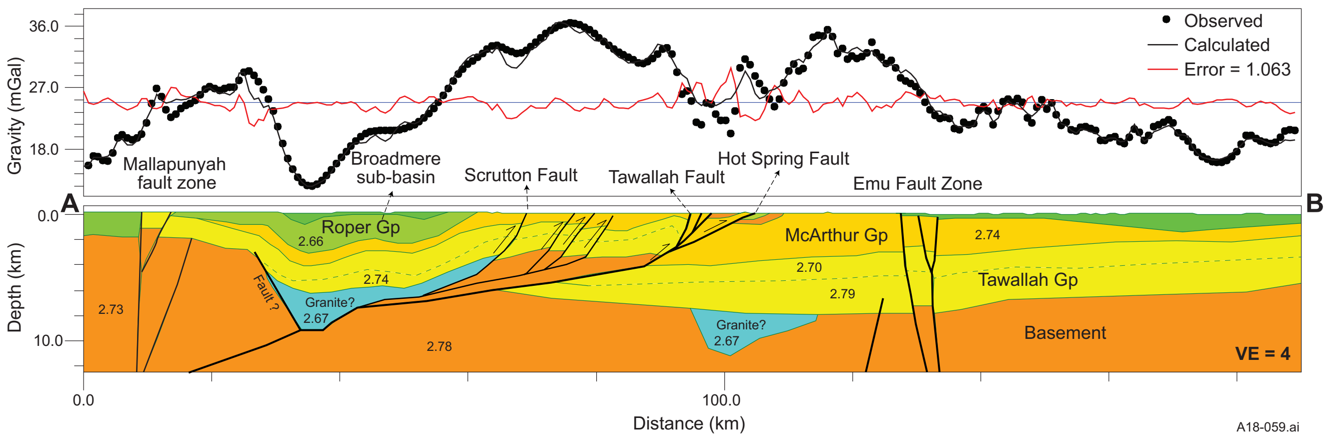

Figure 3. East-west orientated cross-section, modelled against gravity data (density units are g cm^{-3}). Location of cross-section shown in **Figure 2**.

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