STRUCTURAL EVOLUTION OF THE THIRLMERE AND MOUNT TOMAH MONOCLINES: SOUTHERN SYDNEY BASIN NSW

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SUMMARY

The Southern Sydney Basin is a geological region of sub-horizontal conforming strata, including significant coal measures that have been mined for over 100 years. This apparently simple 'layer-cake' geology has overlooked many complexities associated with intrusions and a variety of geological structures. This over-simplification of geology has contributed to uncertainty in groundwater model outcomes, and impacts to surface hydrology and groundwater systems that have occurred at some sites. The aim of this study was to identify and characterize geological complexities within the Southern Sydney Basin with a particular focus on near surface groundwater and wetlands which could be sensitive to these direct or indirect disturbances.
An initial desk top review of existing drill-hole data, outcrop maps and typical spatial data was undertaken to highlight areas of possible structural inconsistency and areas with a high probability of faults or other structures such as monoclines. This data was then used in combination with field based geological mapping and high quality digital terrain modelling to assist the current development of a series of kinematic (geologically restored) cross-sections.
This has enabled the preliminary modelling of fault propagation folds associated with the inversion of growth faults, which will be important in the development of a framework to better identify and define the geometry of aquitards, associated with the Thirlmere Lakes and groundwater surface expression dependent ecosystems (swamps) over the Southern Sydney Basin. This greater understanding of the features around the Thirlmere Lakes area will lead to the development of a structural evolution model that further explains the incision of Blue Gum Creek and the development of Thirlmere Lakes within an entrenched meander.

Key words: Structural Geology, Hydrogeology, Sydney Basin, Mt Tomah Monocline, Thirlmere Monocline

INTRODUCTION

The Southern Sydney Basin is a geological region of almost flat lying conforming strata, with significant coal measures that have been mined for over 100 years. This apparently simple 'layer-cake' geology has resulted in the overlooking of many complexities associated with intrusions and a variety of geological structures. The regional deformation around the Thirlmere area has historically been associated to the Nepean, Oakdale and Lapstone Structural complexes. All of which comprise of a series of faults and monoclinic structures associated with the uplifting of the Blue Mountains Plateau. The transmissivity of these structures is still poorly understood within the region, although it appears that in many cases, faults that are identified at depth or seam level appear to be barriers to groundwater flow (Tonkin and Timms 2015).

Very little information can be found within the literature of either the Thirlmere or Mt Tomah monoclines. The main mentions can be found in the regional geological map explanatory notes (Stroud et al. 1885, Moffitt 1998). The Thirlmere Monocline is described as having a throw of several tens of metres down to the north, with speculation it may be a northerly continuation of the Nepean Monocline whereas the Mt Tomah Monocline is attributed to as being a more westerly expression similar the that of the Lapstone Monocline (Stroud et al. 1885, Moffitt 1998). If we assume that the deformation and uplift along the eastern margin of the basin occurred within the same relative time frame, we can also assume similarities with the Lapstone Monocline; where structural development is suggested to have occurred as a part of an east-west contraction during the mid-cretaceous to mid-Cenozoic, based on seismic reflection data combined with field interpretations (Fergusson 2006, Bray et al. 2010, Fergusson et al. 2011). This is supported by the dating of uplifted semi-consolidated gravels and fault gouge, as well as evidence of additional neo-tectonic activities which have been shown to correspond with the modern regional stress fields (Och et al. 2009, Bray et al. 2010, Fergusson et al. 2011, Och et al. 2014, Rajabi et al. 2016). Some of the dated illites from the gouge however are dated to be within the Cretaceous, which although not Cenozoic still supports post depositional tectonic activity (Och et al. 2009, Bray et al. 2010, Och et al. 2014).

The regional aquifer of significance can be divided into the upper or lower Hawkesbury Sandstone. This unit is the most dominate outcropping unit around the Thirlmere region and may be unconfined, confined when remnant Wianamatta Group shales are present or more typically semi-confined from internal deposition heterogeneities (Ross 2014). The Bald Hill Claystone which is typically identified as the interface between the Hawkesbury Sandstone and the underlying Narrabeen Group is often assumed to behave as the regional aquitard, varying in thickness between a few metres and a few tens of metres and marked by a distinctive red colouring. The Narrabeen Group itself is comprised of alternating sandstones and shales and possesses substantial sealing properties. Below the

Narrabeen are the Illawarra Coal Measures and subsequently the Shoalhaven Group. The basement in this region of the Sydney Basin is the Lachlan Fold Belt (LFB).

METHOD

An initial desk top review of numerous existing drill-hole data, outcrop maps and typical spatial data (digital elevation model (DEM ±0.8m Horizontal, ±0.3m vertical), satellite imagery, digitized geological maps) was undertaken to highlight areas of possible structural inconsistency. This allowed areas with a high probability of faults or other structures such as monoclines to be identified. This data was then used in combination with field based geological mapping and high quality digital terrain modelling (Figure 1) to produce preliminary kinematic cross-sections (i.e. geological restoration to pre-deformation).

The spatial data interpretation relied on geomorphological principles of stream forms and typical river patterning. Abnormal river forms and topographic features unrelated to weathering processes constituted the two main interpretative tools. This method is support by the analogue established by features already mapped in the region expressing these abnormalities such as the Bargo fault and Lapstone Monocline. The interpreted structures were then given a level of confidence as strong, medium or weak, as well as marking the prominent tie points which were used for the interpretations. The position of Figures 2 and 3 are also marked from left to right in Figure 1 respectively.

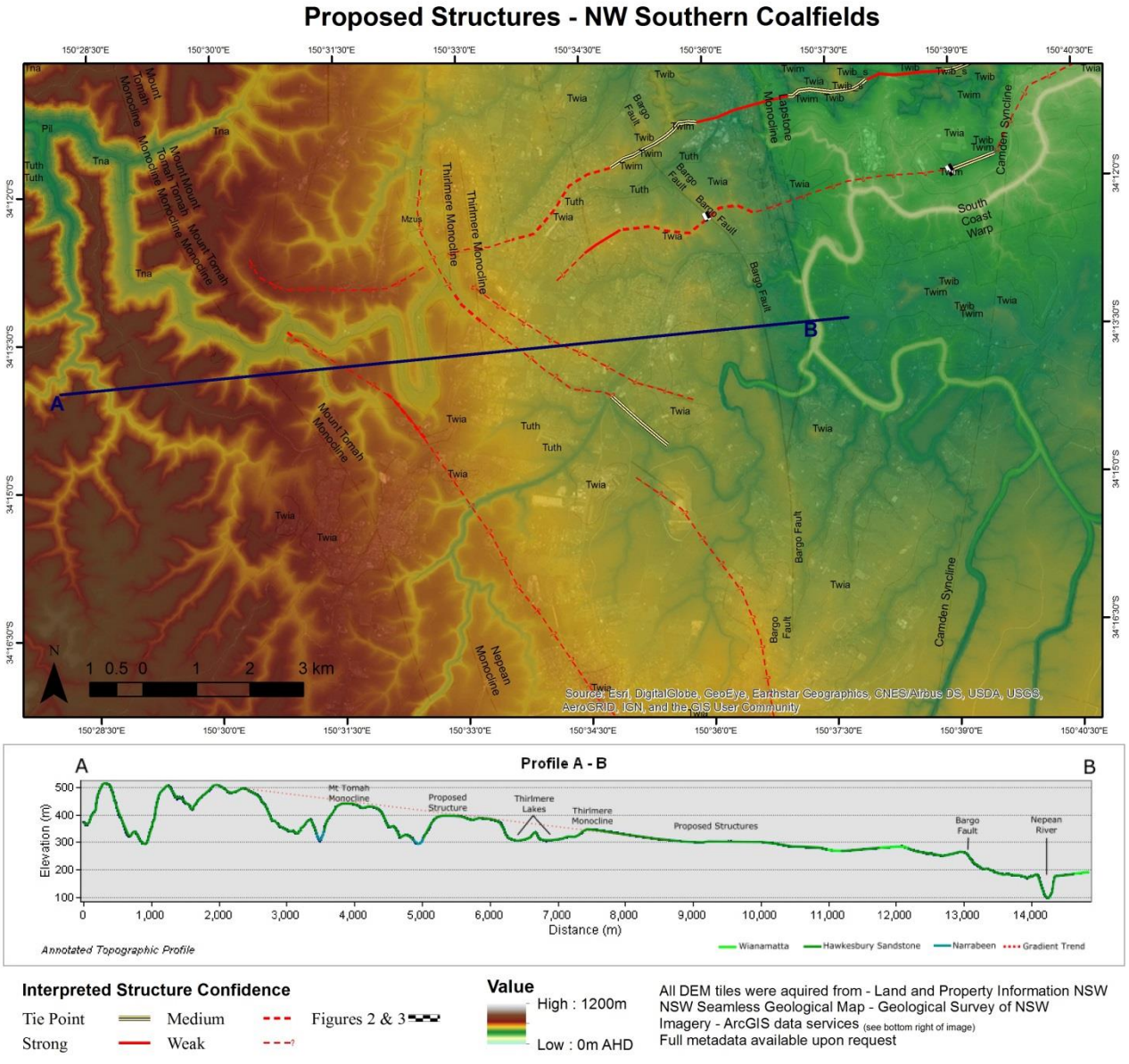

Figure 1: Digital Elevation Model and topographic profile (A – B) with interpreted geological structure locations and confidence, superimposed on zone 56 seamless geological map with named major structures and world imagery (Colquhoun et al. 2015, Land and Property Information 2016).

RESULTS

Two primary sets of possible additional geological structures were identified that could have influenced the incision and entrenchment of the Thirlmere Lakes System. The east-west structures shown in Figure 1 can be seen very prominently on the eastern side of the Lapstone Structural complex, however become increasingly less expressed approaching the Thirlmere Lake system. The southern of these two suggested structures is characterized by a minor displacement along the fault itself, with gentle dipping beds away from the location if displacement (see Figures 2 & 3). The Figure 2 fault has previously been identified by Tonkin and Timms (2015) as a surface fault, which we propose exist as subsidiaries of fault propagated folds. It is noted that the bedding dip of the Wianamatta shale is often parallel to the road grade when traversing the topography in this region. Figure 2 is currently attributed to the Bargo Fault; however on the high resolution DEM the consistent topographic relief provided by the Bargo Fault can be seen to continue trending north to north northeast from Myrtle Creek. The northern of these two proposed structures forms the southern extent of the Razorback Ranges and Bringelly Shale outcrops. If projected through to either the Thirlmere or Mt Tomah Monoclines, it is plausible that this structure divides the watershed between Lake Gandangarra and The Dry Lake, however no substantial field evidence has yet been identified to support this. It is proposed that southern of these two structures is related to the northern structure as a fault propagated fold with minor fault along anticlinal ridges. Further investigations including geophysical surveys, and dip measurements are planed where outcrop is accessible. It is also acknowledged that using this method many more features within Figure 1 can be seen, and will be further investigated in ongoing research.

Unlike the east-west trending structure set, the north-south trending structure set is more likely to be two distinct features. The most western of these structures very clearly forms a continuous ridge line which can be project up from the south to approximately one kilometre west of the Thirlmere Lakes system and incredibly close to the Mt Tomah Monocline. It is possible that this structure is responsible for the development of the Thirlmere Lakes overflow point into Blue Gum creek, but further characterization of its geometry is required. The eastern north-south trending structure presents very little surface expression, however a section of river straightening and already mapped parallel structures provide strong evidence for a structural feature. It is also possible that this structure may have played a role in creating a preferential surface flow path for the valley incision that now accommodates The Dry Lake. The development of the kinematic cross-sections is still underway, although preliminary results have been obtained. These show the typical thickening of the Shoalhaven and thinning of all other Sydney Basin units at the edge of the basin. They have also suggested at further possible structures which are yet to be investigated. These have been identified through changes in stratigraphy thicknesses which are out of trend with the mention typical basin thinning. These sections are based off outcrop ties from the NSW Geologic Survey Southern Coal Field Map & Notes, publicly available borehole data located at the NSW geological survey DIGS portal and field observations.

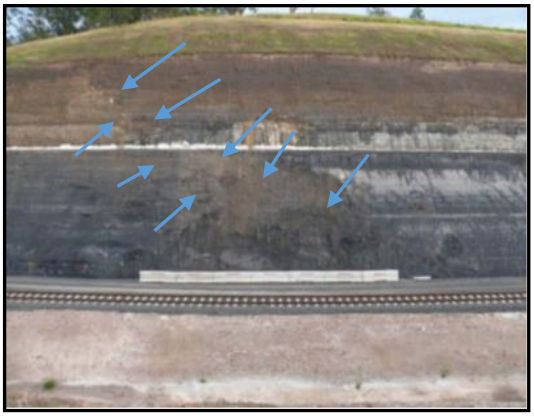

Figure 3: Image from (GHD Geotechnics 2013, Tonkin and Timms 2015), "A view of the fault towards the western batter from the down side." Currently attributed to the Bargo Fault.

Figure 2: Fault in eastern side of road cutting, Picton Rd near the Nepean River.

CONCLUSIONS

On the basis of available evidence the persistence of the Mt Tomah Monocline from its more northerly expressions could not be confirmed within our study region, the north-west part of the Southern Coalfields. The local occurrence of the Thirlmere Monocline structure was also inconclusive, with no direct evidence found to either refute or confirm its exact position. It was however noted that the Thirlmere Monocline has no discernible topographic grade increase difference than that of the gradual rise seen in the westerly projection from its location (Profile A-B, Figure 1). The presence of either the Mt Tomah or Thirlmere Monocline structures is currently considered to be inconclusive and requires further investigation to determine their characteristics, persistence and relationships to other regional structures.

From the preliminary results there are strong indications of unmapped geological structures, some of which may be associated as fault propagation folds as subsidiaries to larger regional structures. It is likely however that if structures are confirmed, that the most westerly proposed structure is associated with the uplift which caused the entrapment of the Thirlmere Lakes system as well as its iconic shape. It is possible that if these structures occur around the Thirlmere Lakes system, that they may play a role

compartmentalizing of groundwater flow into and out of the lake system. However the negligible fault offset identified, and lack of clearly define fault infilled cores has implications for the degree of connectivity or barrier nature of these structures to groundwater flow.

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