Geological analysis of a fault controlled landslide in brittle Carboniferous ignimbrites

Stephen Fityus
School of Engineering, The University of Newcastle, NSW, Australia
John Gibson
School of Engineering, The University of Newcastle, NSW, Australia

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ABSTRACT

This paper presents a geological analysis of a spectacular landslide that occurred in brittle volcanic ignimbrites of Carboniferous age in the southern New England Fold Belt near Muswellbrook in the Hunter Valley. The morphology of the slide, which involved the collapse of a topographic saddle in hilly terrain producing a talus flow that ran out for a distance of more than 0.4 kilometres, is described in detail. Geological aspects such as lithology and setting and structures such as jointing, bedding and faulting are also detailed. These features are qualitatively analysed in order to understand how up to seven sets of joints and a brecciated fault combined to destabilise what would otherwise be considered to be a stable landform in competent rock with a low risk of instability. A discussion is provided of this slide and its significance for stability in the wider region.

1 INTRODUCTION

The safe development and management of slopes has received much attention in Australia since the Thredbo Landslide (AGS 2000). Following this event a taskforce was convened from within the Australian Geomechanics Society to review slope stability assessment processes and procedures in Australian Practice with a view to consolidating and establishing best practice and identifying areas for improvement. An outcome of this process was the development of a set of three slope risk management guidelines, to become part of the Australian National Disaster Mitigation Programme (NMDP).

One of these documents, the Practice Note Guidelines for Landslide Risk Management (AGS, 2007) outlines the process of quantified slope instability risk assessment to both life and property. The quantification of slope failure hazard and its consequence are essential parts of this process. This is a difficult task, even for experienced practitioners, due to the limitless variety of geological and environmental scenarios that interact to affect slope stability. There is a need for an extensive range of case studies to augment databases of slope instability assessments (AGS, 2007), that will ultimately form the collective experience to underpin consistent and reliable assessments in any situation.

This paper provides such a case study. It illustrates a situation where faulting was the controlling influence on the stability of natural slope in a region of moderately deformed sedimentary rocks.

2 REGIONAL GEOLOGICAL SETTING AND STRUCTURE

The landslide studied in this paper occurred in rocks of the Tamworth Trough (Collins 1991) or Tamworth Belt (Roberts et al. 1990) of the Southern New England Fold Belt (SNEFB) within the Hunter Valley. The extent of the Tamworth Belt is shown in Figure 1. Although this region has been subject to only sparse development to date it is hosting increasing numbers of developments, both large and small, as the region prospers. Projects such as the recently completed Karuah Bypass (Fityus et al 2005) and the proposed Bulahdelah Bypass and Tillegra Dam illustrate the increasing importance of a better understanding of the geological characteristics of the northern Hunter Valley.

The geology of the SNEFB is complex when compared to the adjacent Sydney Basin. The Tamworth Belt refers to a region that is bounded by the major north-west trending regional structures of the

Hunter Mooki Thrust fault system and the Peel Manning fault system. It is characterised by a number of parallel successions of interbedded sedimentary and volcanic rocks of Devonian and Carboniferous ages which have been subsequently folded and faulted in an event referred to as the Hunter Orogeny (Herbert, 1980) or the Hunter-Bowen Orogeny (Collins, 1991). The Tamworth Belt is dissected into hundreds of blocks, ranging from hundreds of metres up to 10km wide, by major normal, thrust and shear faults predominantly oriented in a north-south direction from several episodes of deformation (Collins, 1991). The blocks so formed are also faulted on a variety of scales. The strata typically dip at angles ranging between horizontal and 40 degrees, but may be locally much steeper in the vicinity of faults.

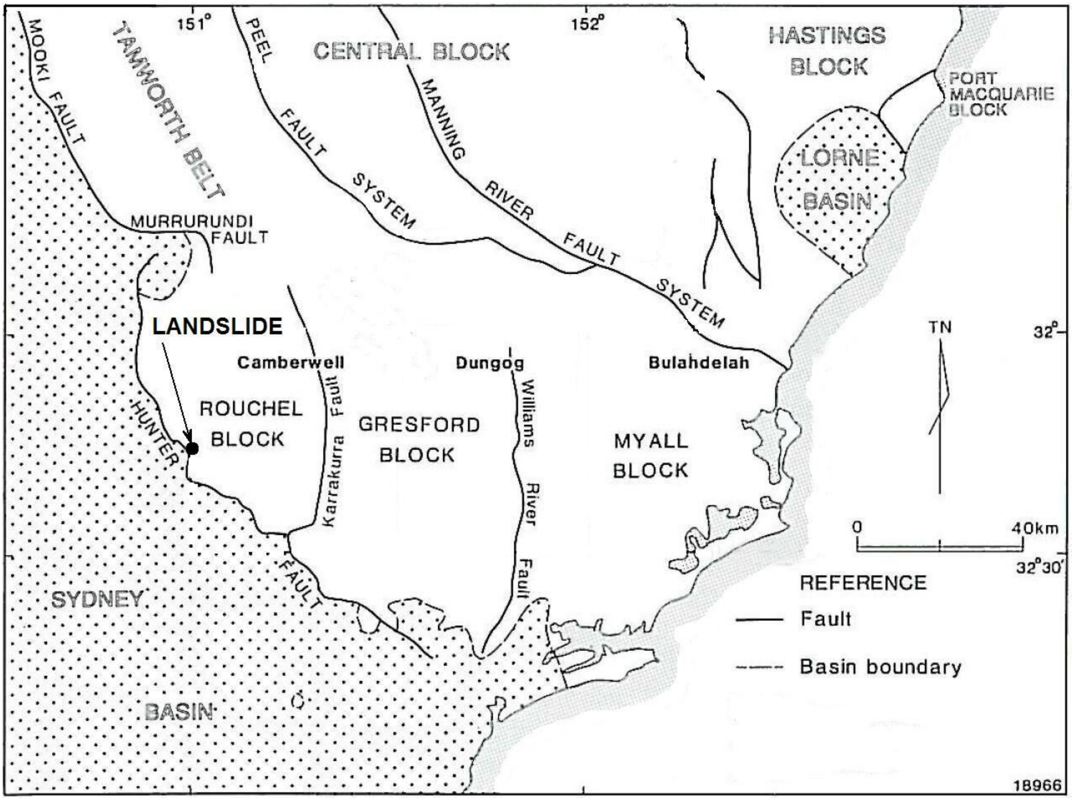

Figure 1: Geological setting of the Southern New England Fold Belt, showing major structural subdivisions and the location of the landslide studied here. (adapted from Roberts et al. 1990)

The major faults that separate the distinct geological blocks are tens to hundreds of metres wide, and often associated with displacements that are so large that the relationship between adjacent blocks cannot be established. The hierarchy of smaller faults that pervade the fault bounded blocks exhibit a number of styles, with widths up to tens of metres and recording displacements from centimetres to hundreds of metres. At the ground surface locally deep and intense weathering is usually associated with faulting leading to deep, red, clayey soils. However in some areas relatively little weathering is observed and the re-cemented fault breccia can form physically resistant outcrops.

Three major regions (referred to as blocks in Figure 1 from Roberts et al (1990), and as super-blocks in the present discussion) are recognised within the SNEFB. They are separated by two dominant north-south trending fault structures, the Williams River Fault to the east and the Kurrakarra fault to the west. These are the Myall super-block east of the Williams River fault; the Gresford super-block between the Williams River and Kurrakarra faults; and the Rouchel super-block west of the Kurrakarra fault.

The landslide described in this work is situated in the southern part of the Rouchel super-block, adjacent to the Hunter Mooki thrust.

3 THE MUSWELLBROOK ROCKSLIDE

A map of the Muswellbrook slide and the surrounding features is presented in Figure 2. A description and discussion of its important characteristics follows.

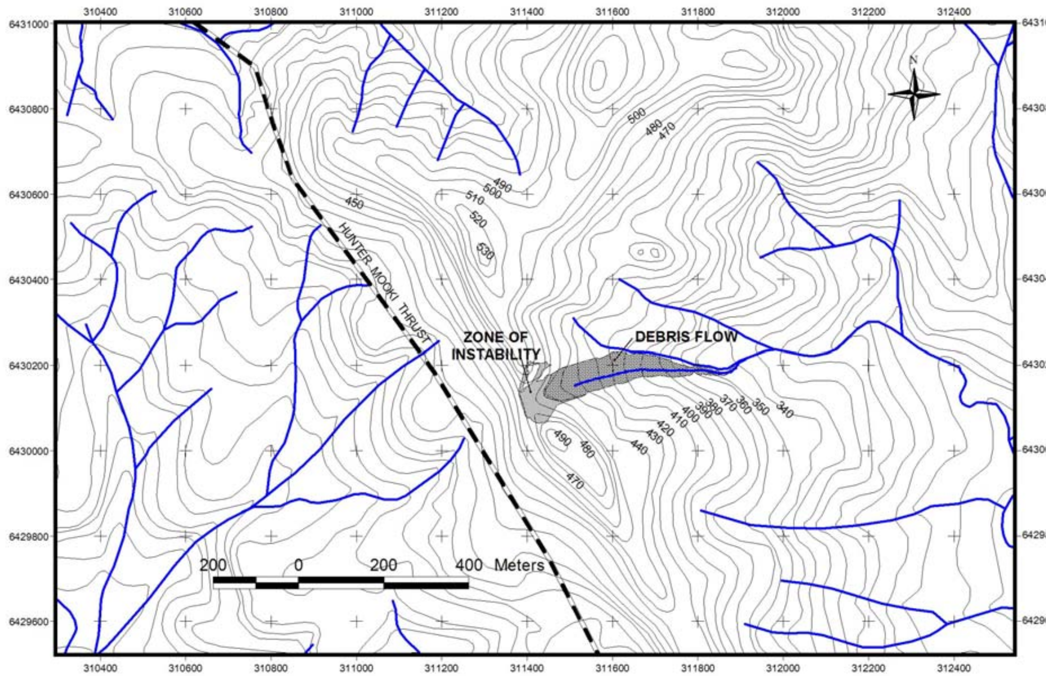

Figure 2: Map of the Muswellbrook rockslide

3.1 Geological setting

As noted above, the slide is situated at the southern margin of the Rouchel super-block just east of its boundary with the Sydney Basin. According to the available geological models (GSNSW, 2003), the Hunter Mooki thrust lies 150m to the southwest of the slide as indicated in Figure 2. The geology in the wider area of the slide is mapped as the Native Dog Member of the Isismurra Formation. This unit is generally described as a massive, cliff forming, buff lithoidal dacitic ignimbrite overlain by purple, red and green lithoidal ignimbrites and tuffs with interbedded lithic sandstone and conglomerate (GSNSW, 2003). In the locality of the slide the lithology exclusively comprises a massive red-brown dacitic ignimbrite with a thickness in excess of 40m and no discernable bedding. It is heavily jointed with at least 4 principal joint sets as shown in Figure 3. Most of these cover a broad range of directions: some of these could readily be further resolved into 2 or 3 adjacent, overlapping sets. At least seven significant sets have been identified.

According to the available geological map information no faults are recorded in the massive Native Dog Member in the vicinity of the slide, however, slightly to the east, where the Isismurra Formation is dominated by interbedded sedimentary rocks punctuated by red dacitic ignimbrite marker beds, many faults have been recorded and a series of fault bounded blocks are recognised. Hence the lack of recorded faults in the Native Dog Member is likely to result not from their absence, but from the difficulty in recognising them in this thick, massive unit.

The ignimbrite at the landslide is assessed to be strong to very strong and resistant to weathering, remaining relatively fresh to within 1m of the ground surface.

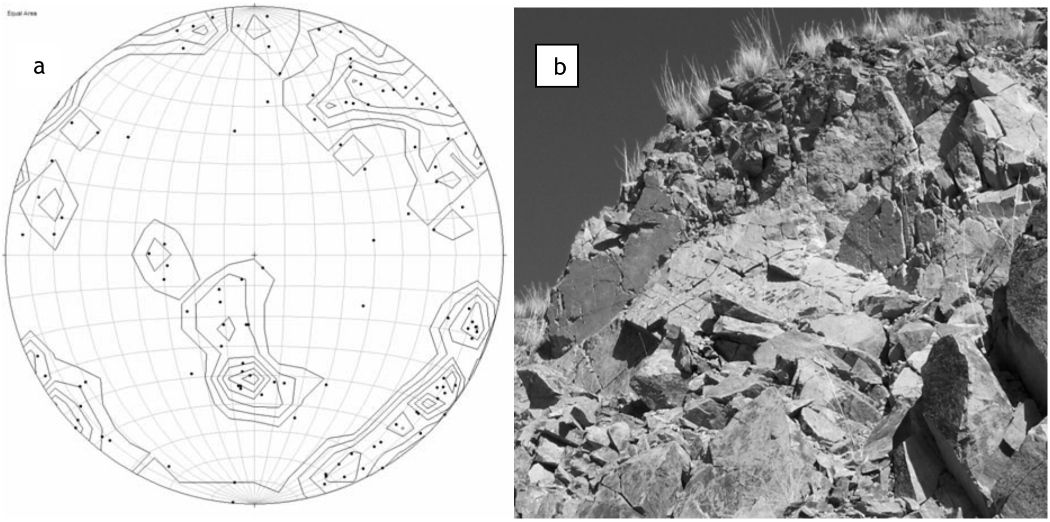

Figure 3 Rockmass Joints. a) poles of 117 measured joints.
b) several sets of joints expressed in an exposure in the northern slide scarp.

3.2 Topographic setting

As is evident from Figure 2, there is a strong demarcation between topographic styles across the Hunter Mooki thrust, with the Whittingham Coal measures of the Sydney Basin (southwest) expressing a much milder topographic relief than the Native Dog Member of the SNEFB (northeast). The slide has developed on the north eastern side of a prominent, steep ridge of the Native Dog Member. Cliffs are weakly developed on the southwestern side of the ridge, which is considerably steeper (around 35°) than the northeastern side (around 25°).

The area of instability is confined to a shallow saddle, between two small knolls. The resulting debris slide has followed a shallow gully to the east.

3.3 Slide Morphology

The Muswellbrook rockslide, as shown in Figures 2 and 4, can be classified in accordance with Crudden and Varnes (1996) as a rock-topple/rock-slide with an associated debris flow. It involved the easterly collapse of a substantial volume of rock from the upper part of a steep northwest-southeast trending ridge at a locality some ten kilometres east of the town of Muswellbrook. The instability directly affected and area of around 95 m x 145 m, leading to a flow of rock debris with an estimated volume in excess of 100000 m^3, that travelled around 425 m down a gully attaining a maximum width of around 75 m.

The slide produced scarps in relatively fresh rock along either side of the zone of instability, each totalling around 25 m in height. These side-scarps are a compendium of joint faces of different orientations, except for the northern side, which contains two distinct, geologically controlled linear faces, as shown in Figure 4. The rear of the slide within the saddle and above the steeper southwest-facing slope, forms only a low scarp.

The debris flow is composed almost exclusively of blocky fresh rock with boulders ranging from 300mm to 1m. The form of these boulders is dominated by planar joint surfaces. There is no indication that the debris ever contained a significant amount of soil material.

Figure 3: Photograph of the Muswellbrook slide showing rock scarp and upper debris slide.

4 DISCUSSION

The factors that led to the condition of instability at this location were not immediately apparent. Little could be discovered regarding the history of the slide, except that the owner of the property believed that the slide occurred during heavy rains in 1949-1950 when the property was owned by someone else. The scattered remains of felled trees (mostly disintegrated) implies an additional significant historical event.

The localisation of the instability to the saddle on the milder side-slopes of a steep ridge is inconsistent with an expectation that the tendency for instability should be greater with increasing steepness and elevation. On first consideration it would seem likely that the saddle between two rocky knolls should be inherently stable. It is also inconsistent with other examples of slope instability in the SNEFB (eg Fityus and Gibson, 2000) where block sliding of gently-dipping, thickly bedded sandstones has occurred by exploiting low strength interbeds, such as seams of clay-mica tuff.

The key to the instability in this situation was a significant fault that could be identified in the slide scarp on the northern side (the lower part of the two-part lineament on the left side of in Figure 3). The fault is present as a body of breccia several metres wide, made up of large angular ignimbrite cobbles in a matrix of fractured and pulverised rock rubble. The breccia, is well cemented and physically resistant, displaying some cementation by zeolites such as heulandite, stilbite and laumontite, but there is little interstitial clay. The breccia is thus highly porous and permeable with the capacity to serve both as a reservoir for groundwater and a conduit for groundwater to enter the highly fractured rock mass.

It is postulated that with few trees to lower the antecedent soil moisture levels and a high capacity to both hold and transmit groundwater the ridge in the vicinity of the fault became saturated and subject to hydrostatic pressures that were sufficient to overcome the rockmass friction and initiate collapse of the slope in the saddle. The numerous joint sets in a diverse range of directions including two low angle joints dipping to the northeast, combined with the major structural weakness of a fault, as illustrated in Figure 4, resulted in the occurrence unstable conditions in what is otherwise a stable landform in a strong, competent rock mass.

As the initial motion of the rock mass is likely to have involved both translation and rotation, ‘topple’ and ‘slide’ are reasonable descriptors of the kinematics of the slide. It is also likely that the initial collapse affected only a small area in the lower part of the gully and that the instability propagated upslope, firstly involving collapse along the fault higher into the saddle and then widening of the slide by the toppling/sliding of slices of rock into the void created. Relict slices of rock at different stages of collapse are clearly discernable on both sides of the slide.

Little is known of the dynamics of the slide, although the distance covered by the highly-frictional debris material would imply significant kinetic energy and momentum and relatively high speed, probably rapid to extremely rapid. Lobes of debris can be discerned within the flow. This supports the idea of a sequence of progressive collapses.

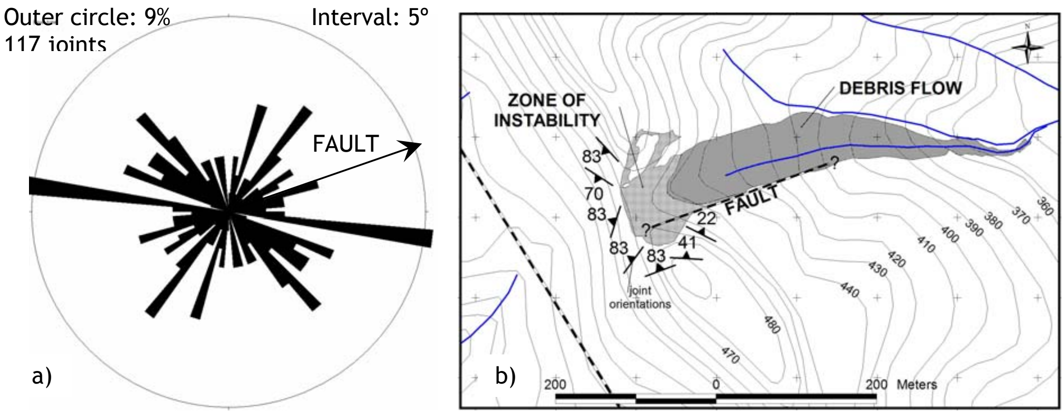

Figure 4: a) rose diagram of joint and fault strike directions;
b) map of slide showing significant joint sets that combine with the fault to result in instability.

5 CONCLUSIONS

The Muswellbrook rock-topple/rock-slide and rock debris flow serves as a demonstration of the diversity of styles of slope instability that may be encountered in different regions of eastern Australia. It supports the contention of AGS (2007) that a database of slope stability analyses/assessments is necessary to underpin good slope assessment and management practices.

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