Fieldwork work in geo-engineering

Shaking the Foundations of Geo-engineering Education – McCabe, Pantazidou & Phillips (eds)

The BMG ignimbrite quarry: Case study of an undergraduate field exercise in engineering geology

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ABSTRACT: Field-based exercises are logistically difficult but essential elements in the teaching of engineering geology at any level. The degree of difficulty has increased in recent times by increasing student numbers, reduced teaching budgets and more stringently defined university policies. This paper presents a case study of a field exercise of a dacitic ignimbrite exposure in the abandoned BMG quarry near Raymond Terrace, Australia, which has been re-commissioned as a landfill. It describes how important phenomena such as columnar jointing can be used to interpret structural orientations of thick volcanic beds, which are subsequently confirmed by wider regional mapping. The interpreted structure is then used as a basis for assessing why the quarrying operations ceased, demonstrating how an understanding of engineering geology is critical for resource management in civil engineering. Discussion is provided on how the field studies have been adapted to cope with growing student cohorts of mixed background and issues that arise from visiting the same location every year. The importance of having a suitable site with cooperative owners/management is recognised.

1 INTRODUCTION

Perhaps more so than in any aspect of engineering study, field work is a key element in the teaching of engineering geology (Kern and Carpenter, 1984; Orion and Hoffstein, 1991; James and Clark, 1993). However, the approach to field trips must change as the needs of students and the operation environments of learning institutions change (Prather, 1989; Giles and Whitworth, 2006).

This paper presents the second year engineering geology excursion to the BMG dacitic ignimbrite quarry near Newcastle, NSW, Australia as a case study of a field trip that has been adapted to provide a positive learning experience in the modern Australian tertiary education environment.

2 ENGINEERING GEOLOGY AT THE UoN

The University of Newcastle (UoN) has Faculties of Engineering and the Built Environment, and Science and IT, which contain Disciplines of Civil, Surveying and Environmental Engineering, and Earth Science, respectively. Although mainstream geology is taught through the Discipline of Earth Science, there has not been a specialist engineering geologist in that Discipline for over 15 years. The teaching of engineering geology has fallen directly to the authors in the Discipline of Civil, Surveying and Environmental Engineering, who each, fortunately have qualifications in geology and experience in its application to engineering.

Engineering geology at the UoN is taught as half of the Geomechanics 1 course and it makes up only 1/64th of the entire civil engineering degree. The scope of the engineering geology part of Geomechanics 1 is to provide civil and environmental engineering students with a basic grounding in geology, in support of an understanding of its importance to geotechnical and geoenvironmental engineering. It covers the structure of the earth, geologic materials, the basic rock types and their formation, sedimentary and tectonic structures, weathering and basic mapping.

Historically, the engineering geology studies were supported by two field trips (one full day and one half day), but due to logistical difficulties arising from growth in student numbers without a matching increase in funding, this has been reduced to a half day excursion only, repeated on two occasions. This excursion forms the subject of this paper.

3 FACTORS AFFECTING EFFECTIVE FIELD TRIPS

Many factors influence the way in which field trips can be conducted to achieve effective outcomes. These are discussed here. These factors may be considered as “boundary conditions” in the formulation and configuration of field work exercises. Those identified below have all shaped the format for the case described in this study.

3.1 *Student numbers and teaching resources*

When a cohort of students is taken into the field, it is essential that each has the opportunity to hear and see what is being demonstrated and participate in exercises. It follows that situations of larger cohorts with fewer demonstrators lead to a degradation of the fieldwork experience for students.

3.2 *Availability of suitable and convenient destinations*

To illustrate geological principles to inexperienced students, it is important that the field expressions be clear and relatively uncomplicated by anomalies.

3.2.1 *Suitable sites*

Field trips are conducted to expose students to rocks in the context in which they occur (with all of their inherent variability, exceptions and anomalies), to teach observational and field skills and to illustrate concepts related to structure and conformity that cannot be demonstrated with hand specimens. A suitable excursion site must display the features of interest in such a way that they are readily related to the theory provided to the students. If the aim is to show how three exposures of the same bed can be used to formulate a three point problem, then the exposures need to be clearly recognizable as belonging to the same bed; if the aim is to observe mutually perpendicular jointing in undeformed sedimentary beds, then there should be few if any tectonic joints present to confuse the arrangement; etc.

Most importantly, it must be appreciated that what experienced geologists are willing to accept on the basis of incomplete and disparate exposures, may do more to perpetuate the mysteries of geology for a student than to clarify them.

3.2.2 *Convenient sites*

If one looks widely enough, one can find field locations to illustrate almost any geological concept, however one is very lucky if a suitable location is close enough to make the travel time a suitably small proportion of the total excursion time, and access to the site is unrestricted. If one is even luckier, the site owners are obliging enough to allow the site to be used. The BMG site is now owned by SITA Australia, who have been extremely generous and accommodating in allowing the excursion to proceed.

3.3 *University policy*

Many aspects of university policy directly affect the practicality and potential effectiveness of excursions. Some of these are discussed below.

3.3.1 *Policy in regard to student travel*

Because of the funding arrangements in Australian Universities, it is theoretically illegal to compel students to pay specific additional fees for excursion transport. Students may be asked to pay for their university-arranged transport costs, but only if they are given the opportunity to arrange their own alternative transport. This makes organization and cost-recovery budgeting of field trips difficult, since it is always difficult to predict in advance, how many students will choose to travel with the arranged transport and how many will choose to make their own way.

Students may be compelled to use university arranged transport, but only if the university bears the full cost.

3.3.2 *Policy in regard to attendance*

According to current UoN policy, a student cannot be made to attend a field trip (or failed because of non-attendance). Students can be prevented from passing a course, however, on the grounds that they did not complete an assessment item. Hence, attendance of an excursion can be made compulsory if the associated assessment item is deemed a compulsory requirement to pass the course. (Students unable to attend for good reasons are given an alternative literature-based exercise (essay) aimed at achieving related learning outcomes).

3.3.3 *Policy in regard to student feedback*

Policy at the UoN (and indeed good teaching and learning practice) requires that any assessment item be returned to students with a grade and useful feedback. In general, this amounts to giving the students the correct answers to the questions after they have been marked. Whilst there is no problem with this in conceptual courses, it is problematic for practical courses. For a site visit to a suitable and convenient location, there is a real danger that once the correct answers have been made available to students in a given year, then the same answers will be passed to successive cohorts of students in subsequent years to be resubmitted, undermining the value of the assessment item as a grading tool. It is generally not possible to continue to set new questions to test previously untested concepts, for the same geological site, and suitable and convenient sites are generally in limited supply.

3.3.4 *Policy in regard to student safety*

This important and necessary factor is not particularly significant in that the constraints it imposes are generally no more severe than those that would apply in research or practice. Fortunately, the UoN maintains a comprehensive insurance policy that covers students in most activities related to their enrolment, and so, safety related liabilities do not generally preclude field trips.

4 THE BMG QUARRY SITE

The Blue Metal Gravels quarry is located around 5 km north of the town of Raymond Terrace, which is around 21 km from the UoN. It can be reached by vehicle in around half an hour.

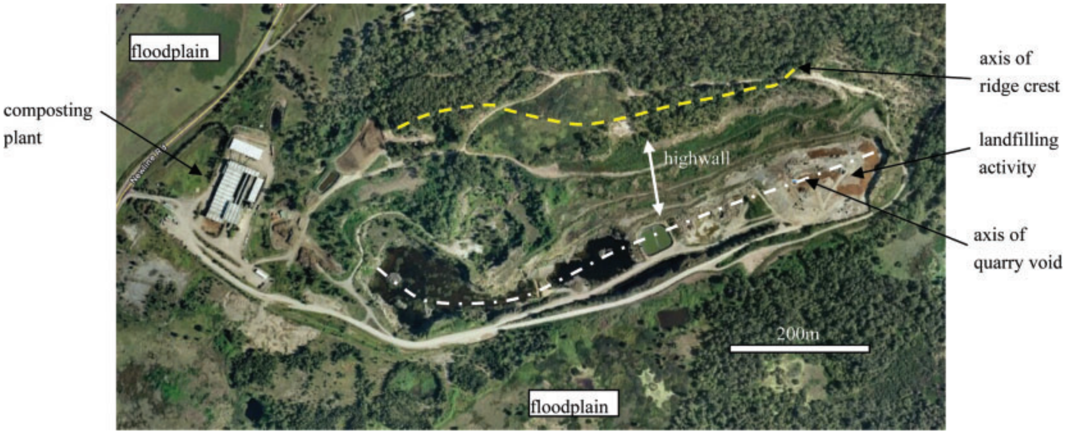

Figure 1. Overview of the BMG quarry site (from Google Earth, 2011).

4.1 *Geological setting of the BMG site*

The site comprises a sequence of beds from the Grahamstown Lake Formation of late Carboniferous/early Permian age (Offler et al, 1974). The section exposed in the quarry consists of 3 beds: a very thick (>20 m) bed of conglomerate, overlain by a thin unit (~4 m) of shaley and pebbly tuff, and then by a thick (>20 m) layer of dacitic ignimbrite.

The conglomerate is a matrix-supported pebble-cobble conglomerate. Vertical jointing is very widely spaced (>10 m). The tuff layer comprises a thin lower layer of tuffaceous shale, displaying rhythmic bedding dramatically defined by red and green zeolites, and slump-induced folding and faulting. The upper part of the tuff is a disturbed and altered pebbly shale, recording a variety of textures and structures consistent with being buried by a flow of lava. The porphyritic dacite layer displays a poorly, but consistently developed columnar jointing, perpendicular to the bed surface. Columns vary from three to eight sided, from 0.3 m to 1.5 m across. A second set of shrinkage induced fractures breaks the columns inconsistently perpendicular to their axes.

The sequence of beds dips at 15 degrees to the southeast. Consequently, the axes of the dacite columns plunge at 75 degrees to the northwest.

4.2 *Physical setting of the BMG site*

The quarry is located on the southeast side of a strike ridge, where the dacite bed would have subcropped as a dip slope, prior to quarrying. The toe of the slope intersects the floodplain of the Williams river, where it is likely that the slope extends beneath an increasing thickness of saturated sediment, which is likely to exceed 20 m. The floodplain in this location has the characteristics of a wetland, and it extends across a width of 1.5 km, to suburban developments on the other side.

Quarrying at this site has focused only on the dacite, which has been worked over the 1 km long side of the ridge, in a series of stepped benches which extend up almost to the ridge crest. These constitute a highwall of around 50 m high. An additional thickness of dacite has been quarried from below floodplain level, to produce a pit of around 12 m deep, which maintains a depth of standing water due to seepage from the adjacent wetland (see Figure 1).

At the southwestern end, the ridge plunges, disappearing into an extension of the floodplain. To the northeast, the ridge weakens to a saddle, and the dacite dip slope is interrupted by an incised creek. From there, the line of the ridge is offset westward and the dacite bed is discontinuous.

4.3 *History of the BMG site*

Quarrying in the vicinity of the site began around 100 years ago, in an adjacent area where a shale bed was quarried. Subsequent to this, conglomerate was quarried in a different area, before quarrying of the dacite began in the 1950s. There is no evidence of the shale or conglomerate quarry areas in the area used for the excursion.

Quarrying of the dacite ceased in the 1980s. Following this, the site lay idle for around 10 years, before a composting and waste disposal facility was established. Since then, the site has received inert waste materials, which are gradually filling the abandoned quarry void. Prior to placement of waste, liners and leachate collection facilities are established in the base of the void, and an array of water sampling piezometers have been installed around the site.

The engineering geology excursion described here has been conducted every year since 1996.

5 FORMAT AND STRUCTURE OF THE BMG QUARRY SITE EXCURSION

5.1 *Aims*

The BMG quarry excursion was created to illustrate the following aspects of engineering geology:

- The mapping of a sequence of tilted beds

- Manifestations of weathering in a fractured volcanic rock mass
- Rock mass structures resulting from cooling-induced cracking in volcanic rocks
- Mechanical behaviours of excavated rock slopes
- The factors affecting quarry operations
- Estimation of quarry reserves from an understanding of the structure of geological units
- Geoenvironmental considerations in relation to waste disposal in abandoned quarries

5.2 *Course coordination*

The excursion is conducted in a 4 hour session, which is the largest that can be practically timetabled for a midweek session in the second year timetable. Four hours is sufficient to accommodate travel (2 × 1/2 hour) and 3 hours on site.

When the BMG excursion was first conceived, it was designed for a cohort of students of between 70 and 80. Current cohorts have increased to around 140 students. Unfortunately, like in many other universities (Donovan, 2002), there has been little, if any, increase in the matching support, and in real terms, the support per student has decreased significantly. Accordingly, the approach to conducting the excursion has had to evolve.

Experience with this excursion has proven that the maximum number of students per group to enable students to see, hear, participate and be kept safe, is around 25. To accommodate larger numbers, multiple demonstrators leading separate groups are required. For numbers exceeding 100, conduct of the excursion becomes impractical, as 5 or 6 experienced demonstrators are required, and even if these could be arranged, it is not feasible for more than three groups to tour the site in a logical way in a three hour visit. To accommodate this, the excursion is now repeated on two occasions, with partial cohorts of students.

The success of this field trip relies upon the cooperation of the site owners. A reasonable condition imposed by the site owner is that the site should not be cluttered by a flood of private vehicles. As it is an operating industrial site, with frequent heavy vehicle movements, there are simply too many risks associated with the arrival of a large number of light vehicles. Hence, students are conveyed to site on prearranged coach buses. In response to university policy, an amount of the financial support for this course is allocated to the cost of hiring these.

To encourage full attendance, subject to the constraints of university policy, an assessment item is associated with the excursion. The assessment item is worth 10% of the Geomechanics 1 final grade. This value was chosen to make it large enough that students appreciate that it is a worthwhile component of the course. It is not necessarily a reflection of the importance of the excursion, but in a course which includes 6 assessment items (final exam, soil mechanics laboratories, geology practical quiz, assignments and a reading exercise), it represents an allocation that is consistent with both the importance and the amount of work involved.

Another consequence of increasing student numbers is an increase in the amount of marking that must be completed. To compensate for this, the assessment item is weighted heavily toward the graphical expression of what the students have observed. This will be discussed in a following section. Since students need (and deserve) feedback (Kent et al. 1997), and since it is difficult to vary the content of the assessment item from year to year, the assessment items are not returned to the students, but rather, students are provided with a feedback sheet that reports to them how well or how poorly they have answered a particular question. Students are invited to approach demonstrators or the course coordinator if they feel they need explanation of their shortcomings.

5.3 *Excursion format*

It is expected that most students will need assistance to interpret what they are seeing. However, rather than lecturing to them, the learning experience is structured as an interactive question session, where students are led, through a series of strategically arranged questions, to interpret the features of the site and draw conclusions. Any reluctance to answer on the part of the students is readily overcome by reminding students that the excursion will not conclude until all of the questions have been answered.

The following are the approximate sequence of questions used to elicit an understanding of the excursion site from the students.

<u>Stop 1: somewhere at the western end of the quarry.</u>

What colour is the rock in the quarry? (lead students to observe weathering and opening along joints).
What kind of rock is in the quarry? (make students aware of the nature of the fresh rock).
Is the structure of the rock the same on both sides of the quarry? (note the effect of angle of excavation).
What is the reason for the apparent difference/structure? (students recognize columns, their inclination and inferred bed orientation).
What is spacing and arrangement of fractures?

<u>Stop 2: on access ramp</u>

What are mechanisms of block instability on each side of the quarry? (identify sliding along column faces – SE; and toppling of column sections – NW, as shown in Figure 2).
What are reasons quarrying stopped? (look at material quality consequences of weathering).
Observe current activity: landfill management, contaminant management practice.

<u>Stop 3: opposite highwall</u>

Time to make sketches.
Note landfill liners, leachate ponds and piezometers/sampling standpipes.

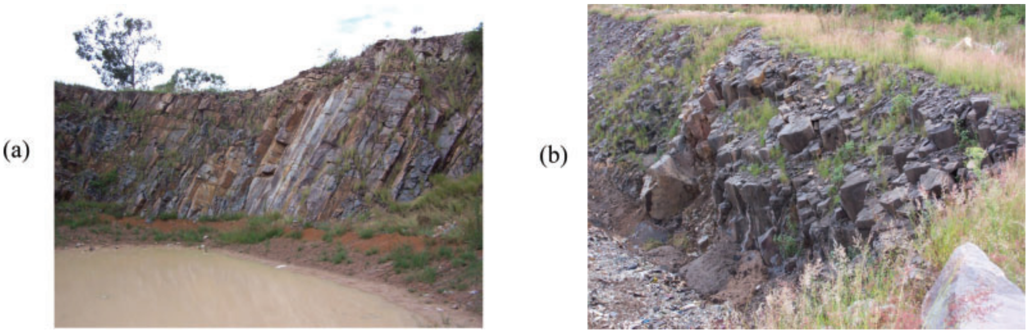

Figure 2. View of columnar rock mass expressions on the southeast (a) and northwest (b) sides of the quarry.

Stop 4: on shale/conglomerate outcrops

Where did the dacite go?

What is the geological arrangement (sequence of beds)?

Is it consistent with presumptions from the first stop (tilting layer of dacite?).

Describe shale and conglomerate in situ.

What is joint spacing in conglomerate (wide, implying very thick bed).

Observe contacts with shale: dacite and conglomerate.

What do you expect we should see as we climb the ridge? (shale on the exposed dip slope and conglomerate after reaching the crest of the ridge).

Stop 5: Highwall: good view of geological arrangement and surrounding district.

Why did quarrying stop? Note encroaching suburbia.

Why did quarrying stop? Note relative water levels of wetland and pit base and permeability of rocks (observe that total head difference drives flow).

Stop 6 (last) Highwall Failure.

What has happened: where is igneous rock, what is exposed?

Why did quarry stop? Where could they get more dacite from on this site?

Back to busses: note conglomerate underfoot along the crest of the ridge.

5.4 *Assessment item*

The assessment item comprises a series of short questions and two sketching exercises. As sketching of plans, cross sections and structures key communication skills in both engineering and earth science, these have been given prominence in the assessment process. There is also some efficiency in marking such tasks, so it has been a useful strategy to managing the increase in student numbers.

Originally, for the principal sketch, students were asked to draw a plan view map of the quarry site, based on their observations in traversing the perimeter of the void. However, with the emergence of Google Earth, students quickly found they could download a photographic image of the site and trace it, undermining the integrity of the task.

Hence, the sketch was changed to a cross section through the centre of the quarry, extending from the failure at the crest of the highwall, across the void, to the wetland. Students are expected to include profiles of the pre-quarrying surface, the existing quarried surface and the dipping rock units below the surface. The location of the section is chosen so that it is not possible to view it squarely from any specific location during the excursion. Rather, it can be viewed obliquely and partially from any number of locations. The students are encouraged to make a series of working sketches from each available vantage point, and then, to combine these in an interpretive cross section in their submission. If this is done successfully, it is possible to show the cause and arrangement of the highwall failure, which consisted of a wedge of dacite sliding on the tuff bed when the bench below was extended too far and it punched through the base of the dacite, into the weaker shale.

Initially, the sketching exercise was done poorly, as the students did not appreciate the importance of site sketches or the level of detail expected. To prepare students for the sketching exercise, they are now given a simpler sketching exercise in the geology practical class in the week prior to the excursion.

The primary written exercise is a discussion of the possible reasons that quarrying ceased at this site. These include difficulties with water management, encroachment of urban development, difficulties in meeting product quality specifications, and the more basic issue of a depleted resource. Each of these issues is teased out of the discussions at each stop around the excursion, as was described in the previous section.

6 OUTCOMES AND EFFECTIVENESS

Outcomes achieved by this excursion are:

- Students have seen how an understanding of localised rock mass structures (inclined columnar jointing) can be used to infer broader geological structures (tilted beds).

- Students have seen this inference confirmed by locating clearly expressed rock contacts in numerous locations.
- Students have observed the diverse textural variations that occur in a weathered, jointed, crystalline rock mass, from fresh to extremely weathered.
- Students have seen how geological mapping principles can be used to estimate location and distribution of geological units, and in turn, how this can be used for resource estimation
- From the overview from the top of the highwall, students have observed the relationship between the wetland and the deep void in fractured rock, and appreciated the consequences of rock mass permeability
- Students have considered the consequences of rock mass permeability and the proximity of the adjacent wetlands in the context of the site's new function as a landfill, and considered the measures being employed to manage the potential for groundwater contamination.
- Students are aware of the various technical, social and environmental issues that can potentially constrain developments involving excavations.

These outcomes span from the more traditional aspects of engineering geology to the more modern of geoenvironmental considerations, reflecting the changing needs of modern graduates (Giles and Whitworth, 2006).

The overall effectiveness of this excursion in the learning process is difficult to quantify. Whilst course outcomes are regularly assessed through student questionnaires, the standard question sets have varied significantly over time, and few are specifically directed at field work. Consistently, in the course surveys of 2006 and 2007, only 12% of students gave negative responses to the assertion that the fieldwork in the course "provided an effective learning experience" indicating that the majority of students see the value in this activity. In the survey of the course in 2009, 92% of students responded favorably to the assertion that "there have been sufficient references made to practice and real life" which can be mostly attributed to this excursion, as it is the most substantial practically-oriented activity in the course.

The likely degradations in the student experience that might occur from an increase in the cohort size have been effectively offset by running the excursion on two occasions, with manageable numbers in each.

Perhaps the most reassuring feedback comes from graduates who, after many years in the profession, express surprise about how useful their geological studies and associated field activities have been to them.

7 CONCLUDING COMMENTS

The excursion to the BMG quarry site is an important and valuable part of the Geomechanics 1 course. Engineering geology, without field trips, lacks context. Whilst many engineering students find such activities well outside their comfort zone, they respond positively to the additional stimulation that field teaching provides.

The format of the excursion has evolved to optimise its outcomes relative to its opportunities, and in many aspects it has adopted practices that lead to clear objectives and outcomes, in accordance with the principles identified by Lonergan, and Andresen (1988) for effective field trips.

With increasing student numbers, and ever-increasing policy restrictions, the conduct of undergraduate excursions is becoming onerous for the course coordinator. The conduct of successful excursions requires commitment from the course coordinator, the availably of suitably experienced assistant demonstrators and a generous and cooperative site owner. This course has been fortunate to have found all of these, and provided they prevail, it will continue to serve as a key element in the teaching of engineering principles at the University of Newcastle.

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