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COAL MINE ENGINEERING GEOLOGY AS A TRANS-TASMAN LEARNING EXPERIENCE IN A UNIVERSITY POSTGRADUATE COURSE

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ABSTRACT

Fieldwork is at the heart of engineering geology, viewed by academics, students and industry as a ubiquitous element of geoscience tertiary education. Fieldwork is considered an extremely effective experiential (i.e. "learning-by-doing") teaching and learning method. In engineering geology, much of the learning pedagogy is focused on applied problems such as dams, tunnels, state highways and landslides, dealing with issues of "ground risk". Due to the obvious safety (and legal) implications of students visiting operating mine sites, such applied learning experiences are often confined to PowerPoint slides in classrooms, or sometimes virtual fieldtrips using a range of technologies. This can produce challenges to fostering engagement. Here, the development of a one-day graduate-level engineering geology fieldclass based at two operating open-cast mines is presented. The trip is structured to develop the students' awareness of the first priority of such workplaces, health and safety. The students then follow a mini "Cook's Tour" led by mine staff, around the open-cast mines, recording geological features, and are prompted to consider engineering hazards relating to the interaction of geology and operations. Students then log core in a mine core shed, observe and record stratigraphy and significant features such as defects and strength variability. Post-fieldtrip, the students analyse borehole geophysical logs, and undertake kinematic analysis and limit equilibrium modelling of highwall stability, incorporating this into an assessed report. Comparisons with Bowen Basin opencast and underground coal mines are encouraged, via provision of industry datasets. Opportunities, and challenges to future expansion of such fieldtrips are also discussed.

1 INTRODUCTION

This paper, which includes photographs and examples of student assessments, describes a field trip that forms the key component in the teaching of Engineering Geology to postgraduate students at The University of Auckland, New Zealand. The field trip has been developed over the past decade and the intention of this paper is to share both the experience gained during this time and also provide some photographs of some of the interesting features during the fieldtrip, along with some examples of some of the work that the students are expected to produce. The purpose of the one-day field course, part of the Earthsci 771 Advanced Engineering Geology paper, is to introduce postgraduate Engineering Geology students to the importance and purpose of site investigation in a mining context, as well as some of the typical issues in open-cut coal mines such as high wall stability, haul road stability, and associated hydrogeological issues. Students receive very little other exposure to mining operations in their studies, and visiting any work sites such as operating mines presents health and safety challenges that are beyond those typically encountered during a standard geological mapping fieldtrip, which would often be in a farmland area. Indeed, at operating worksites, appropriate PPE and inductions can present issues, while issues of accessibility, inclusivity and equity are also important considerations (e.g. Gilley et al., 2015).

Critical to the above is developing the ability of students to identify hazards and to use their geological observations and insights to make predictive judgements about short- and long-term risks to various engineering scenarios within the open-cut coal mine environment. The students visit two operating open-cut coals mines in the Waikato Coal Fields region of New Zealand's North Island (Figure 1), with both mines owned by Bathurst Resources, who are thanked for their support.

2 MINE ENGINEERING GEOLOGY TEACHING: THE BACKGROUND

2.1 NEW ZEALAND

In the late 19th and early 20th centuries, mining education was deemed very important to New Zealand's prosperity. Indeed, mining was traditionally taught at several universities in New Zealand a century ago, including the Auckland School of Mines and the Otago School of Mines (established 1878) in Dunedin. In addition, perhaps the most famous mining education institution was the Thames School of Mines, at the southwest end of Coromandel. Established in 1885, the Thames School of Mines existed until 1954. At its peak, this was the largest mining school in New Zealand, and for almost 70 years it specialised in practical scientific and industry-focused education.

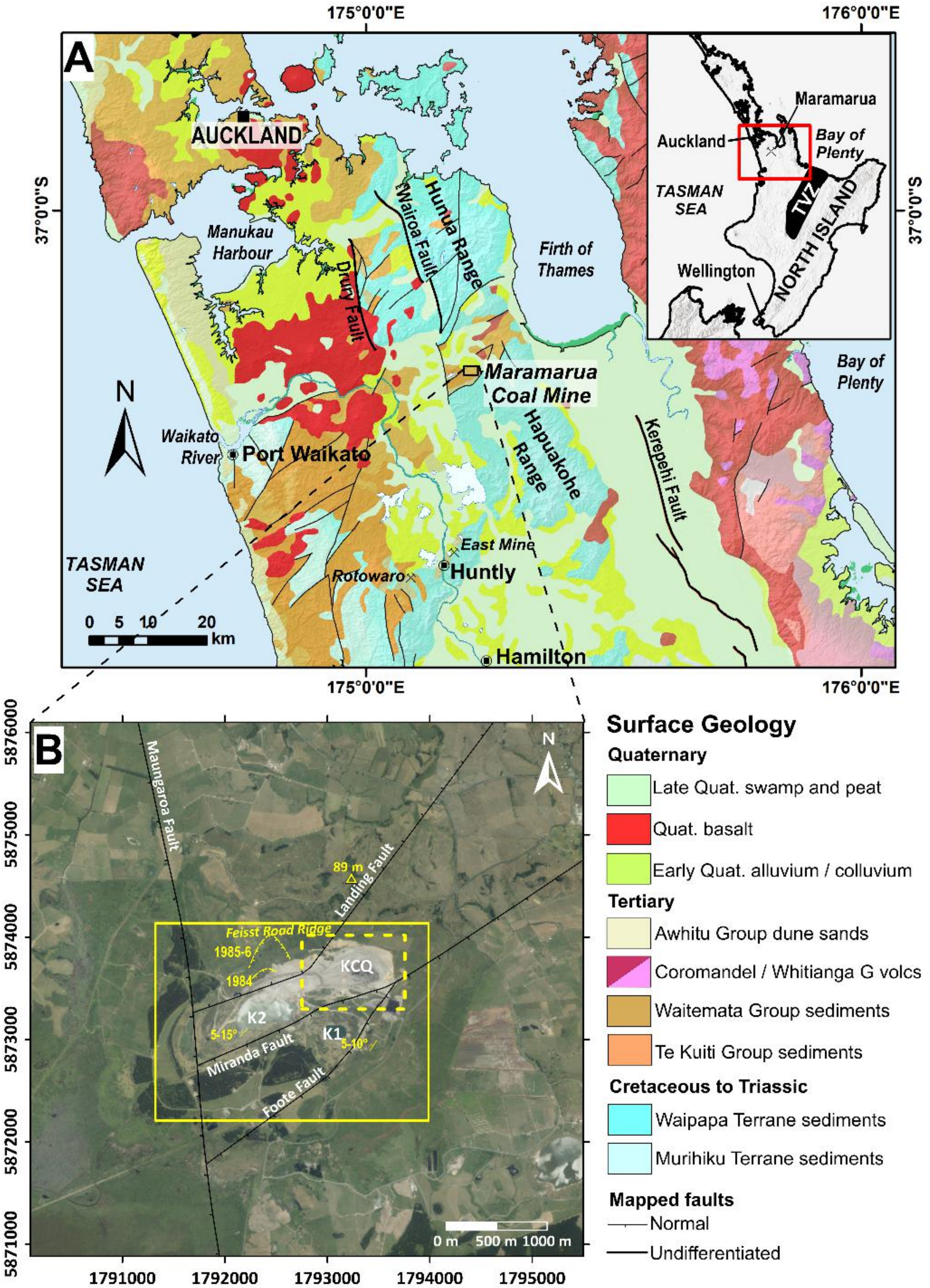

Figure 1: Location of the Waikato Coal Field and Maramarua and Rotowaro open-cut mines, with a blown-up aerial image of Maramarua as an example

Since then, however, mining education in New Zealand has suffered somewhat, and there are currently no active University mining education departments in the country, unlike Australia. Also, there are no mining-specific tertiary qualifications or papers. The lack of mining education is probably for several reasons, including general apathy in New Zealand, an anti-mining mindset (Brook 2024), long-term issues with student enrolments in STEM subjects generally (Brook, 2023a, b), and timetabling issues that plague most universities that follow the "Melbourne Model" of tertiary study. The lack of mining education is despite BSc Earth Science or Geology being taught at 6 New Zealand universities, and a considerable portion of New Zealand graduates working in mining roles overseas, as well as some at gold and coal mines, in addition to quarries, in New Zealand. In addition, civil engineering is taught at several New Zealand universities, and engineering geology master's degrees are available at the University of Auckland (and will return again soon at Canterbury University).

2.2 AUSTRALIA

Unlike New Zealand, Australia has a prevailing and long-standing tradition of mining education and has world-leading mining departments at Curtin University and the University of New South Wales, among other institutions. This includes courses and qualifications in exploration, "standard" geology, and mine geotechnical engineering etc.

3 MINE ENGINEERING GEOLOGY FIELDTRIP AT UNIVERSITY OF AUCKLAND

3.1 EARTHSCI 771 ADVANCED ENGINEERING GEOLOGY

The one-day mining fieldtrip is part of the Earthsci 771 Advanced Engineering Geology paper. This is a 15-point graduate level paper, and students take 8 x 15-point papers for a full (120 points) year of study. Nominally, a 15-point paper is equivalent to 150 hours of study (including all class contact, assessments and reading). The mine geology field trip and the associated assessments account for 50% of the assessment component for the Earthsci 771 paper. The other assessments components usually include 5 x 10% laboratory (computer modelling and soil and rock lab) assessments.

Most students taking the paper are part of the 18-month 180-point, Master of Engineering Geology programme (Brook et al., 2022, 2023). This master's programme has been taught at the University of Auckland for 7 years. Most of these students will already have studied Engineering Geology at 3rd year level during their BSc Earth Science (during Earthsci 372 Engineering Geology). Other students will take Earthsci 771 as part of their 2-year 240-point Master of Earth Science or Master of Engineering Studies. Occasionally, a student will take Earthsci 771 as part of their Earth Science BSc honors degree, or a PG Diploma in Earth Science. So, the student cohort can be somewhat mixed, but all students will have had some prior knowledge of geotechnical engineering or Earth Science to BSc 3rd year level.

3.2 THE MINE ENGINEERING GEOLOGY FIELDTRIP

The Earthsci 771 1-day mine engineering geology fieldtrip has a pre-fieldtrip component, the fieldtrip itself, and a post-fieldtrip component. All of this culminates into a single report, worth 50% of the grade for Earthsci 771.

3.2.1 Pre-fieldtrip

Pre-fieldtrip, preparation involves a desk study using geological maps, borehole data, and selected site photographs from the two open-cut mines. There is also a small selection of relevant papers published in journal articles that the students can read and review, as well as several papers in AusIMM conference proceedings. However, the number of available publications is much less than is available say, for the Bowen basin, Illawarra or Hunter valley coal fields, for example.

The purpose of the desktop reading and engagement with datasets prior to the fieldtrip is to "prime" the students prior to the site visits at the two mines. It also reinforces to the students the importance of developing a strong understanding of existing information at the start of any project, akin to the Total Geological History concept of Fookes et al. (2000), and important in developing the Engineering Geological Model, EGM (Baynes and Parry, 2024). Indeed, both these publications are provided to students in order to provide broader context, beyond the limits of the Waikato Coal Field.

Students are also briefed about what to expect at the mines, and PPE requirements are discussed. PPE can be provided to all students, although many students have existing PPE available from their workplace (many fulltime postgraduate students are employed at least part-time in the geotechnical industry and will have been in that role from the 3rd year of their BSc onwards).

Knowledge of the geology of the area underpins the fieldtrip. The coal seams (Figure 2) that are mined are within the late Eocene-early Oligocene Waikato Coal Measures (WCM), the oldest units of the Te Kuiti Group. The WCM are the basal formation of the predominantly transgressive Te Kuiti Group, unconformably overlying an undulating erosion surface cut into deeply-weathered Mesozoic basement and grading up into shallow marine formations. The Quaternary Tauranga Group sediments (mainly pumiceous sediments) unconformably overly the Rotowaro Siltstone of the Te Kuiti Group in the area. BSc Earth Science students will have previously encountered the Te Kuiti Group in the field before at 2nd year level (e.g. Bevan et al., 2022).

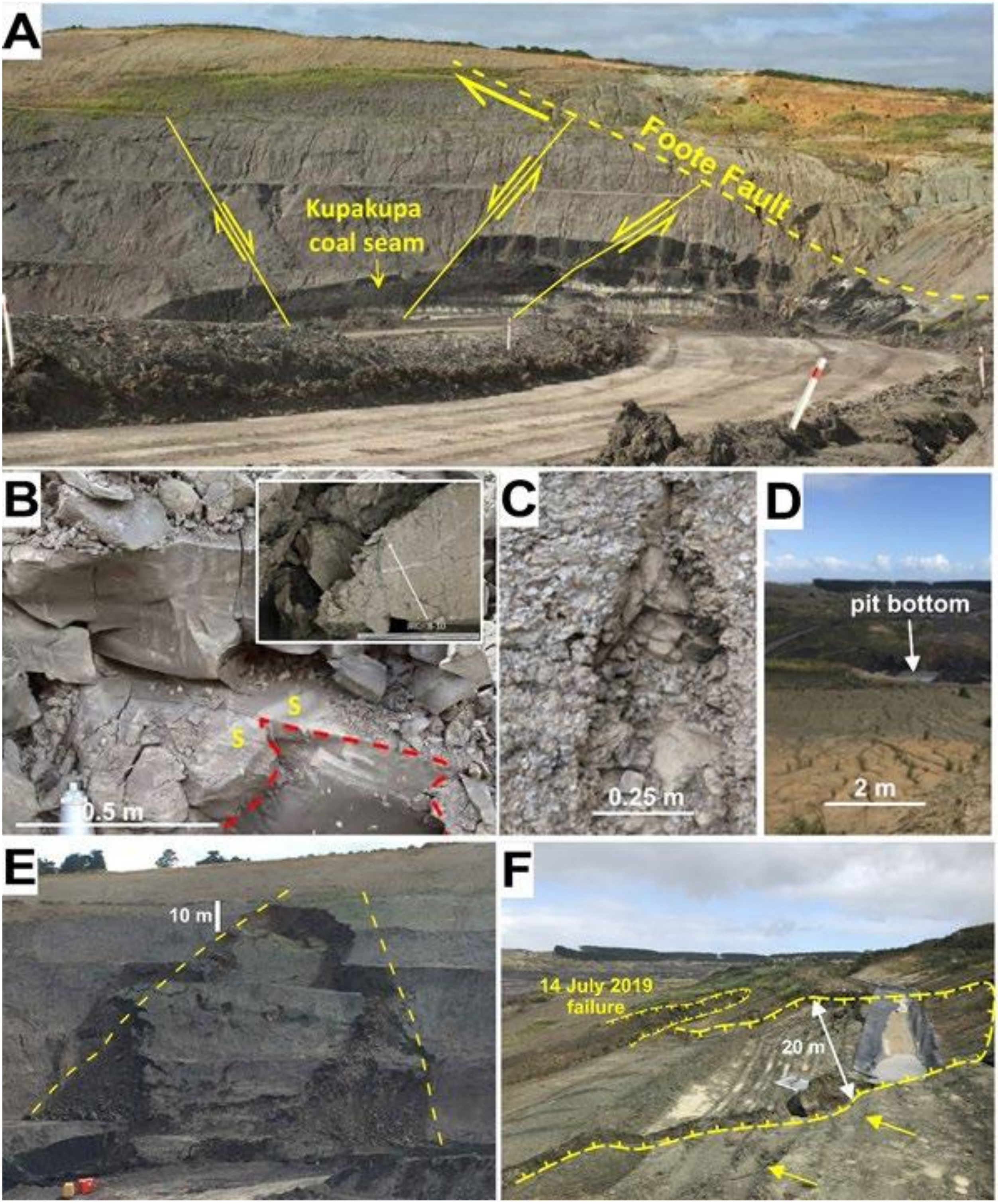

Figure 2: Engineering geology and slope issues at Maramarua mine: (A) Foote Fault and associated minor faults affecting the Kupakupa Seam; (B) smoothed shear surface (S); (C) slaking of Waikato Coal Measures; (D) weak Tauranga Group soils incised by surface runoff; (E) pit wall wedge failure; (F) rotational slump on pit wall

3.2.2 The fieldtrip day

Two mines are visited as part of the one-day fieldtrip. The first is Maramarua mine, which is 1-hour drive southeast of Auckland (Figure 1). The first part of the visit is a site induction with mining staff, and this reinforces that the absolute priority is health and safety. A technical services manager, or occasionally the site senior executive (SSE), provides an introduction in the office block, and in the boardroom, provides insights into the geology, any geotechnical issues, with TV screens showing real-time footage from the CCTV cameras operating around the mine, as a backdrop. This generates questions and discussion, and indeed the enhancement of fieldwork learning in tertiary education using visual technologies is well established (Welsh et al., 2013). The second part of the visit to Maramarua mine is a site walkover with mine staff (Figure 2). This is partly what is referred to in geoscience fieldtrip academic literature as a "Cook's Tour" (Fuller and France, 2015). These are observation-based fieldtrip components, named after the 19th century English travel agent, Thomas Cook. Some typical features they will encounter at Maramarua mine are shown in Figure 2. The floor of the pit is below sea level, so the students get to understand the importance of groundwater control.

Experiential learning activities are also important in geoscience and engineering disciplines (e.g., Fuller et al., 2010). At Maramarua mine, the students will continue their observations in the field, augmenting the desktop study, and make sketches including large-scale geomorphology, structural geology and geotechnical problems, and small-scale sedimentary features, and structural fabric. In terms of experiential activities, they make supporting measurements that can include structural orientations of bedding and joints, rock strength data from Schmidt hammer tests (Figure 2B), and assessments of the Tauranga Group soil profiles (which fail as slumps and flows) using a handheld penetrometer and a shear vane.

After Maramarua mine, the students travel by minibus to Rotowaro mine for the afternoon (Figure 3). At Rotowaro mine, following induction, the students visit the Rotowaro mine pit floor via light 4-wheel drive light vehicles (LV's). The students disembark the LV's and get to understand groundwater issues at the pit, as well as highwall stability. The legacy effects of near-surface former mine workings from the early 20th century near the surface is also evident (Figure 4). The students also consider what ground investigation approaches (invasive and non-invasive) might be appropriate to determine the existence of near-surface abandoned mines with reference to the New Zealand Ground Investigation Specification (NZGIS, 2017) and Brook (2019), and highwall monitoring technology such as InSAR (e.g. Cook et al., 2023).

Figure 3: Briefing from Bathurst resources staff regarding geotechnical issues at Rotowaro mine

Figure 4: Group of students at Rotowaro mine inspecting groundwater issues

Other activities at Rotowaro mine include engineering geological logging of core in a mine core shed. The students apply the New Zealand Geotechnical Society Guidelines (2005) to describe and characterise the properties of core in the core shed (Figure 4). For some of the civil engineering students, this may the first time they will have encountered rock core in the whole of their university studies, so it is potentially an important stepping-stone in their career development.

Application of the NZGS (2005) guidelines is important because it is utilised by contractors throughout the New Zealand civil engineering sector as well. The NZGS (2005) guidelines includes a 38-page that underpins the diagnostic 2-page fieldsheet. Thus, whether the students end up in the mining or civil sectors, this core logging aspect of the fieldtrip is important. The Australian equivalent to the NZGS (2005) would broadly be AS1726-2017.

3.2.3 Post-fieldtrip

After the field-day, the students have three weeks to compile a report, which is assessed and corresponds to 50% of the course mark for Earthsci 771. The report includes these elements: (1) desktop study information; (2) observations and data carried during the field-day; (3) highwall stability analysis; (4) rock UCS calculations; (5) rock mass characterisation.

The stability analysis that the students undertake is first of all a kinematic analysis in Dips software. Following this, the students will progress to modelling in Swedge for example, as wedge failures and bi-wedge failures are common in the Waikato Coal Measures. The more advanced students will also have read around the subject matter, and will also discuss some broader context such as non-daylighting wedge failures in their reporting. Students will also undertake modelling in Slide2 and RS2, to calculate representative Factor of Safety (FoS) and Strength Reduction factor (SRF) values. Some example values that have been produced by students are in Table 1, using a range of scenarios.

Figure 4: Logging Te Kuiti Group rock core in the core shed at Rotowaro mine using the NZGS (2005) guidelines

Table 1: Selected LEM and FEM stability modelling Factor of safety (FoS) and critical strength reduction factors (SRF) for the pit walls modelled by the students

Model scenario	RS2 Critical SRF	SLIDE2 FoS
Baseline with perched groundwater table within Te Kuiti Group	1.41	1.40
Baseline with semi-saturated groundwater conditions	1.31	1.34
Bedding-plane shears and fault gouge as individual units; semi-saturated groundwater conditions	1.14	1.17
Bedding-plane shears and fault gouge as individual units; saturated groundwater conditions	1.09	1.05

The students are also provided with geophysical logs from the mines and from these, apply the original McNally (1987) sonic to UCS curve from to estimate the UCS of the Waikato Coal Measures encountered. The final part for the students in their reports is to use the core shed descriptions and characterisation, alongside the UCS logs, to consider potential roof stability issues if the coal was extracted underground in a bord-and-pillar operation (as has previously occurred in nearby Huntly East Mine), using rock mass rating (RMR) and the coal mine roof rating (CMRR; e.g., Brook et al., 2020).

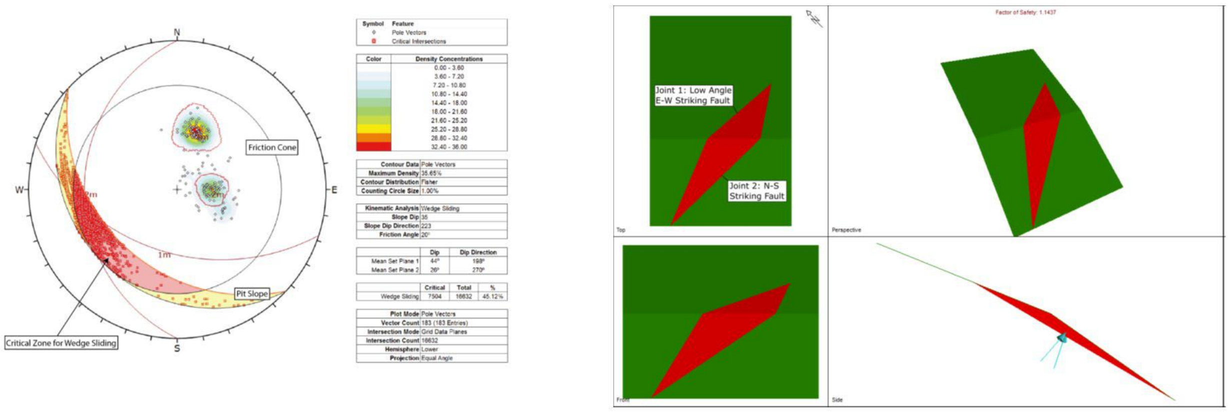

Figure 5: Post-field trip example slope stability modelling in Rocscience software: (left) kinematic analysis, right SWedge

4 THE BROADER LEARNING CONTEXT

4.1 Student reports

An important aspect of this Earthsci 771 course is that students understand the broader context of their work. The learning outcomes have varied to a minor level year-on-year, depending on exactly what access arrangements are available at the mines. Nevertheless, students always need to consider, how do the weak Eocene Waikato Coal measures compare with the much older, stronger rocks of the Australian Permian coal measures? What would this mean for highwall dimensions and overall stability differences? What are the key hydrogeological differences between extraction of the New Zealand weak rock coals and the Australian coals (e.g. Brook et al., 2016). These are important concepts, because a significant proportion of New Zealand graduates will end up working in Australian mines at some point in their career.

Thus, encouraging the students to consult the broader literature, and understand key differences between New Zealand and Australian coal measures and their respective prevailing geotechnical problems, is important. The best students will have fully contextualised their results with reference to Australian literature. Furthermore, the very best students will have also drawn parallels (and contrasts) with the management of slope stability and groundwater issues in the New Zealand civil engineering sector.

4.2 Master of Engineering Geology (MEG) at the University of Auckland

Most students who take Earthsci 771 will be enrolled in the Master of Engineering Geology (MEG). The MEG is an NZQA Level 9 programme, delivered (full-time) as either a 180-point (18 month) degree for those entering with a BSc (i.e. NZQA Level 7) or 120-point (12 month) degree for those entering with BSc Honors (or equivalent NZQA Level 8 qualification). Both the 120-point and 180-point degrees can also be taken part-time over longer durations.

The MEG programme officially is a cross-Faculty programme, led from the Faculty of Science's School of Environment, but also includes to a lesser extent at present, the Faculty of Engineering. MEG students tend to be either (1) continuing students who have undertaken a BSc Earth Science / Geology at Auckland or another domestic university, (2) international students wanting to upskill and also migrate to Australasia, and (3) returning, more mature students who have an existing degree, but wish to formalize their development with an engineering geology qualification. The motivation of the latter cohort is often to facilitate Membership, or Chartered Membership (PEngGeol) status with Engineering New Zealand. Also, graduates wishing to become a Chartered Geologist (CGeol) with the Geological Society of London, will generally need a masters-level qualification such as the MEG and a minimum 3-years of CPD.

It's important to note that there is a major emphasis on experiential learning within the MEG degree (i.e. learning-by doing; Kolb, 1984), and this has included field trips at a range of sites across Auckland and the Waikato. Note that Kolb's (1984) 4-stage cyclic experiential learning model describes two ways of grasping knowledge (1) concrete experiences and (2) abstract conceptualization. The other two modes, (3) reflective observation and (4) active experimentation, help learners transform their experience into knowledge. Each of these stages acts as a foundation for the next stage, and experiential learning exercises, such as field trips (and laboratory exercises) are a common pedagogical practice in geoscience curriculums globally (Whitmeyer et al., 2009) and in New Zealand (Fuller et al., 2010).

4.3 Competency Areas and the MEG curriculum

The key aspects of what constitute the most important aspects of engineering geology to include in university curricula have been debated for over 80 years (e.g. Terzaghi, 1961), and this continues to evolve. The core papers of the MEG curriculum do not follow all of the body of knowledge (BOK) for Professional Engineering Geologists (PEngGeol), as reported in this publication in *New Zealand Geomechanics* in 2020 (PEngGeol BOKS, 2020). Indeed, that BOK defines 98 separate core capabilities across 14 project "phases". However, the core papers of the MEG (Figure 6) do meet some of the IAEG Joint Technical Committee 3 (JTC3) proposed competency profile for engineering geology education (Turner and Rengers, 2010), that addresses both technical and professional competencies.

ASCE Category	Competency Area	Bloom's (1956) Taxonomy Level of Achievement					
		1 Knowledge	2 Comprehension	3 Application	4 Analysis	5 Synthesis	6 Evaluation
Foundational	Math	772	772	772			
	Statistics	771,772	771,772	771,772			
	Basic Science	770,771,772	770,771,772	770,771,772	770,771,772		
	Geoscience	770,771,772	770,771,772	770,771,772	770,771,772	770,771,772	770,771,772
Technical - Engineering Science	Statics						
	Mechanics of Materials						
	Fluid Mechanics	772					
	Soil Mechanics	771,772	771,772	771,772			
	Rock Mechanics	771	771	771			
Technical - Engineering Design	Numerical Modelling	771,772					
	Engineering Geology	770,771	770,771	770,771	770,771	770,771	770,771
	Hydrogeology	772	772	772	772	772	772
	Site Investigation	770,771,772	770,771,772	770,771,772	771,772	771,772	771,772
	Foundations	771	770	770			
	Underground Construction	771					
Professional	Communication	794	794	794			
	Public Policy						
	Business / Public Admin.						
	Globalisation						
	Leadership						
	Teamwork						
	Attitudes						
	Lifelong Learning						
	Professional Ethics	794	794	794			

Figure 6: Conceptual competency profile for engineering geologists based on the ASCE competency profile, as proposed by JTC3 (modified from Turner and Rengers, 2010), with Professional ASCE Competency Areas (CA's). Achieved by university = grey, and via work experience = black. MEG "core" paper numbers have been tentatively superimposed on the table (770 Engineering Geological Mapping; 771 Advanced Engineering Geology; 772 Hydrogeology). Professional CA's are covered to varying extents in the 4th "core" management-style paper. The thesis (794) covers some Professional CAs, and other CAs, depending on the topic

According to Villeneuve et al. (2015), the JTC3 was a committee of the International Society for Rock Mechanics (ISRM), the International Association of Engineering Geologists (IAEG) and the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE). The JTC3 proposed a competency profile for engineering geology education that addresses both technical and professional competencies (Figure 6), according to Bloom's Taxonomy of Learning (Bloom et al., 1956).

Note that Bloom's (1956) Taxonomy of Learning had by 2015 already been revised by Anderson and Krathwohl (2001), to reflect how learning is an active process and not a passive one. Nevertheless, Bloom's (1956) Taxonomy is a hierarchical model of cognitive skills in education, which categorizes learning objectives into six levels, from simpler to more complex: remembering, understanding, applying, analysing, evaluating, and creating. This framework aids educators in creating comprehensive learning goals and assessments.

The ASCE Competency Areas (CAs) are shown in Figure 6 (modified from Turner and Rengers, 2010). Grey cells are what should be achieved by university studies, while black cells are what should be achieved in the workplace, according to Turner and Rengers (2010). In addition, MEG "core" paper numbers have been tentatively superimposed on the table (770 Engineering Geological Mapping; 771 Advanced Engineering Geology; 772 Hydrogeology), as well as the paper code for the 90-point thesis (794).

There are several points about these ASCE CAs in the context of the MEG degree that are worth noting. First, the attempt to map the MEG core papers to ASCE CAs is undertaken with a note of caution. This is because for some CAs, a core paper may only just be "dipping" into the respective ASCE CA, and the Bloom (1956) Taxonomy Level Achievement (1-6) may have been "achieved" only briefly as part of an assignment, rather than in a sustained manner over a full, 12-week semester. Second, knowledge and comprehension of the Rock Mechanics and Soil Mechanics CAs is implicit in two (Earthsci 771, Earthsci 772) of the core papers (Figure 6), but this actually extends beyond the ASCE-required Taxonomy Level, into "Application" (via practical exercises in this case). Third, at present, the CAs of Underground Construction and Foundations are lacking from the MEG core papers.

Fourth, a broad range of "Professional" CAs are generally lacking within three of the MEG core papers, with the exception of "Professional Ethics" and "Communication". The former is achieved approximately probably as far as Bloom's (1956) Level 3 (Application), as students need to compile undertake and quite a lengthy field form and critical review of what their thesis research will include, and who they will be interacting with (outside organisations, landowners, Māori etc). The "Communication" is achieved to a similar Bloom Taxonomy Level (3 – Application), via the compulsory research seminar all master's students must give, toward the end of their studies. The fourth MEG core paper, chosen from a list of project management-style papers, does potentially achieve some of the Professional ASCE categories, but this would vary, very much on the precise choice of paper.

5 CONCLUDING REMARKS

This article has provided an outline of the Earthsci 771 Advanced Engineering Geology one-day field trip that focused on mine engineering geology. After desktop study, the students visited two opencut coal mines in the Waikato Coal Field of New Zealand's North Island. The make observations and measurements and characterise and describe the rock masses. Post-field trip, the then undertake data modelling including highwall stability modelling using Rocscience software (Dips, Slide2, RS2 etc). The students are encouraged to envisage roof stability issues if the coal measures were to be extracted in an underground operation. Students also have to explore the broader context of mine engineering geology, with specific reference to Australian conditions, dominated by older, Permian coal measures which are significantly stronger than Eocene/Oligocene age Waikato Coal Measures. In summary, graduate engineering geologists (Paul, 2024) learn experientially in the workplace after graduation (e.g. Packer et al., 2024), and may be offered numerous on-the-job continued professional develop (CPD) training opportunities in their workplace. However, this should not preclude university academics from developing useful work-integrated learning (WIL) experiences, albeit within the prevailing staffing, budgeting, timetabling and technical constraints, typical of universities.

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