Training and education of engineering geologists for the new urban challenges in applied geosciences

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Abstract: The University of Portsmouth, UK, has offered applied geoscience degree courses for nearly 40 years. These programmes started initially with degrees in Engineering Geology and Geotechnics which were complemented by an Applied Environmental Geoscience programme and, more recently, with BSc (Hons) Geological Hazards, together with an applied postgraduate Masters portfolio. During this period the focus of these applied courses has changed drastically. In the very early years the taught component included many aspects of the mining industry, primarily focusing on coal and progressing on to deep mining in Africa, with both industries being the key exit point for many of the graduates. As these mining industries waned or recruited more local graduates consulting and contracting civil engineering became the more dominant employer with careers in ground engineering and construction reflecting the new nature of the taught programmes.

Latterly, the nature of the courses has again changed to reflect the changing nature of the industry and employment needs, driven mainly by the urban regeneration agendas and the increasing importance of the understanding of risk and hazard. Employment now for graduates is very much in the brownfield site / contaminated land sectors of the industry within the urban environment.

This paper will review the education and training of engineering geologists at Portsmouth and will describe the more recent aspects of these programmes as they relate to the urban geosciences. The paper will outline the course units in contaminated land, its assessment, investigation and reclamation, together with the more risk-based approach adopted in modern geotechnical practice.

Résumé: L'université de Portsmouth, UK, a offert des cours appliqués de degré de geoscience pendant presque 40 années. Ces programmes ont commencé au commencement par les degrés dans la géologie et le Geotechnics de technologie qui ont été complétés par un programme environnemental appliqué de Geoscience et, plus récemment, avec des risques géologiques de BSC (Hons), ainsi qu'une brochure universitaire supérieure appliquée de maîtres. Pendant cette période le centre de ces cours appliqués a changé rigoureusement. En années très premières le composant enseigné a inclus beaucoup d'aspects de l'industrie minière, se concentrant principalement sur le charbon et progressant dessus à l'exploitation en grande profondeur en Afrique, avec les deux industries étant le point principal de sortie pour plusieurs des diplômés. Pendant que ces industries minières s'affaiblissaient ou recrutaient des diplômés plus locaux la consultation et contracter du génie civil sont allés bien à l'employeur plus dominant avec des carrières dans la technologie au sol et la construction reflétant la nouvelle nature des programmes enseignés. Récemment, la nature des cours a encore changé pour refléter la nature changeante des besoins d'industrie et d'emploi, conduite principalement par les ordres du jour urbains de régénération et l'importance croissante de la compréhension du risque et du risque. L'emploi maintenant pour des diplômés est infiniment dans l'emplacement de brownfield/secteurs souillés de terre de l'industrie dans l'environnement urbain. Cet article passera en revue l'éducation et la formation des géologues de technologie à Portsmouth et décrira les aspects plus récents de ces programmes comme ils se relient aux geosciences urbains. Le papier décrira les unités de cours dans la terre souillée, son évaluation, la recherche et la récupération, ainsi que l'approche risque-basée adoptée dans la pratique géotechnique moderne.

Keywords: Education and Training, Engineering Geology, Geological Hazards, Geotechnical Engineering, Urban Geosciences.

INTRODUCTION

The University of Portsmouth, UK, has offered applied geoscience degree courses for nearly 40 years. These programmes started initially with degrees in Engineering Geology and Geotechnics which were complemented by an Applied Environmental Geoscience programme and, more recently, with BSc (Hons) Geological Hazards, together with an applied postgraduate Masters portfolio. During this period the focus of these applied courses has changed drastically. In the very early years the taught component included many aspects of the mining industry, primarily focusing on coal and progressing on to deep mining in Africa, with both industries being the key exit point for many of the graduates. As these mining industries waned or recruited more local graduates consulting and contracting civil engineering became the more dominant employer with careers in ground engineering and construction reflecting the new nature of the taught programmes.

Latterly, the nature of the courses has again changed to reflect the changing nature of the industry and employment needs, driven mainly by the urban regeneration agendas and the increasing importance of the understanding of risk and hazard. Employment now for graduates is very much in the brownfield site / contaminated land sectors of the industry within the urban environment.

The courses cover areas including ground investigation, site characterisation, contaminated land, the geotechnical aspects of civil engineering and environmental science, tunnelling and underground excavation and the minerals extractive industries. Topics such as site and ground investigation, soil and rock mechanics, landslides and slope stability assessment, hydrogeology (the role of water in geological processes) and geological hazards form a core component of the curriculum.

Students enrolling on these applied programmes come from varied backgrounds, often from science-based A levels, but not always so. Many succeed on this and other degree programmes through starting with a science or engineering-based foundation course.

Fieldwork is a strong feature of the degrees with a number of residential courses both in the UK and overseas, where students gain hands-on experience of a variety of applied geological techniques and geological terrains.

Graduates from the course have found themselves involved in work as diverse as major site investigations for international projects, undertaking geohazard appraisals of old mine workings, coastal engineering works, flood alleviation, dam site investigation, tunnelling and slope stability assessments. Some have acted as expert witnesses in support of legal proceedings arising from claims for unforeseen ground conditions. With nearly 40 years of experience under its belt, this course has developed an enviable international reputation and graduates are employed world-wide, with many now occupying senior positions within the industry.

These courses are fully accredited by the Geological Society, the UK national learned and professional body for the Geosciences. This enables graduates to achieve Chartered Geologist status after a period of work experience.

APPLIED GEOSCIENCE PROGRAMME COURSE PORTFOLIO

A total of five specific degree pathways are currently offered within the Applied Geoscience course portfolio:

- BEng (Hons) Engineering Geology and Geotechnics
- BSc (Hons) Geological Hazards
- MSc Ground Investigation and Assessment
- MSc Contaminated Land
- MSc Geohazard Assessment

Sadly the third undergraduate pathway, BSc (Hons) Applied Environmental Geoscience, was closed this year due to lack of undergraduate interest despite a continuing strong demand from industry for graduates from this course.

UNDERGRADUATE CURRICULUM AND COURSE STRUCTURE

The courses are structured to develop transferable skills such as meeting deadlines, organising and prioritising work, self-reliance, team skills, self motivation, report writing, numeracy, IT literacy and communications skills. Teaching is via traditional lectures in both large and small groups as well as self-learning. Tutorials, seminars and laboratory-based practical sessions cover the more practical aspects of disciplines. The courses are delivered via a modularized credit-rated unit system taught over two twelve teaching week semesters. Each year of undergraduate study comprises of 120 credits broken down into a variety of 10 and 20 credit units with a 30 credit project in Level 3. Each 10 credit of study nominally represents 100 hours of study of which 30 hours involve direct student contact.

Wherever possible, problem-solving experience is gained by working on real data from schemes such as the Jubilee Line Extension or from sites visited as part of the fieldwork programme for mapping and data collection purposes. Report writing and the art of making presentations to peers are incorporated into the assessment of some units, and an active Industrial Advisory group contributes speakers, projects and ideas.

The fieldwork programme is a major element of the degree and comprises some 75 to 80 days of mostly residential visits spread over the three years of the programmes. During the first two years this work has a strong techniques emphasis and aims to provide the observational, recording, synthesising and problem-solving skills required of a modern engineering geologist. Areas such as the Isle of Wight, Dorset, Kent, Spain and France (including Normandy, Provence, the Massif Central and the French Alps) are currently visited.

The final year project dissertation involves a period of independent field study and many students use this as an opportunity to be adventurous and travel abroad. Students have arranged projects in locations as diverse as Florida, France, Canada, Australia, Hong Kong and Taiwan, with a group recently returning from the Cascades Volcanic range in the USA.

The course culminates in a study tour of engineering geology-related sites, which aims to integrate the various strands of the course and provide an insight into current industrial practice. The current tour is scheduled to include the Central Alps, Provence and the Massif Central regions of France.

Year 1

A firm grounding in geology is provided by units that cover the principles of geology, rock forming minerals, igneous, metamorphic and sedimentary rocks, structural geology, geomorphology and terrain studies. Observation and practical skills are given a strong emphasis in both laboratory and field studies throughout the first year. Students are also given practical training and experience in geological mapping techniques prior to the start of the second year. Currently this involves a two-week field trip to an area just outside of Madrid in Spain.

The current syllabus for Level 1 Engineering Geology and Geotechnics is outlined below:

- Planet Earth
- Geoscience Toolbox
- Sedimentology
- Igneous and Metamorphic Petrology
- Quantitative Methods
- Geomaterial Science
- Terrain Studies
- Geological Data Analysis
- Geological Hazards and Engineering Geology

Year 2

In the second year geological studies become increasingly applied. Engineering applications of structural geology, petrology, sedimentary processes, more applied geomorphology and stratigraphy, and the effects of climate are developed. Two units examine the engineering properties and behaviour of rocks and soils, whilst site investigation techniques such as geophysics and drilling methods are also introduced. Computer applications in engineering geology and the study of hydrogeology complete a very practical year, complimented by an extensive, hands-on, residential fieldwork programme.

The current syllabus for Level 2 Engineering Geology and Geotechnics is outlined below:

- Geotechnics
- Rock Mechanics
- Ground Investigation Methods
- Engineering Stratigraphy
- Hydrology and Hydrogeology
- Geotextiles and Ground Improvement
- Structural and Lithological Analysis
- Flood Hazard Analysis and Assessment
- Professional Skills for Applied Geoscientists

Year 3

In the final year studies are devoted entirely to engineering geology with advanced coverage of soil and rock engineering, ground investigation, contaminated land, risk assessment and analysis, landslides and slope stability, remote sensing and GIS. Practical experience is provided through a variety of real engineering geology problems, site visits and an independent project dissertation. The course concludes with the two week study tour of sites of engineering geological and geohazard interest in France.

The current syllabus for Level 3 Engineering Geology and Geotechnics is outlined below:

- Applications in Rock Engineering
- Applications in Soil and Foundation Engineering
- Landslides and Slope Stability
- Contaminated Land
- Risk Analysis and Assessment
- Remote Sensing and GIS
- Engineering Geology Study Tour
- Engineering Geology Project

FIELDWORK PROGRAMME

The fieldwork programme is a major element of the degree courses and comprises some 75 to 80 days spread over the three years of the undergraduate degrees. The emphasis in the first two years is strongly towards providing the observational, recording, synthesising and problem-solving skills required of a modern applied geologist. Areas such as the Isle of Wight, Dorset, SW England, the Malvern and Cotswold Hills, Kent, North Norfolk in the UK along with Normandy in France and a mapping area just outside of Madrid in Spain are currently visited.

Level 1 Introductory Geology Fieldwork

The first year programme is based around a series of introductory field courses that introduce the students to the basic field principles of observation & description. Students develop their interpretive skills in the field with a variety of 1 day trips.

Figure 1. Students on a Level 1 introductory geology field course on the Isle of Wight.

Level 2 Techniques-Based Fieldwork

In the second year the fieldwork becomes much more 'technique' based with the students being taught a variety of applied geological field skills that would be required by a practising engineering geologist. Table 1 outlines the current Level 2 fieldwork programme.

Table 1. Level 2 Undergraduate Techniques-Based Fieldwork Programme

Locality	**Techniques Practised**
Madrid, Spain	At the end of the first year students embark on a 2 week trip to just outside Madrid where they are taught how to cerate a geological map along with other aspects of basic field geology.
North Norfolk	A trip studying the glacial geology & geomorphology of a former ice-sheet margin. Activities include geomorphological mapping, landslide hazard assessment, coastal geohazards and glacial sediment logging.
Bath	Work looking at aspects of periglacial geology around Bath as well as a trip underground to a bath stone mine at Westwood.
Malvern Hills	Development of rock mass assessment techniques. Students undertake a number of exercises aimed at characterizing a rock mass in terms of its strength and engineering behaviour.
Cotswold Hills	Geomorphological mapping techniques are introduced on the Cotswold escarpment just outside of the village of Broadway.
North Devon	More aspects of geological field skills are developed in this trip to North Devon where spectacular examples of structural geology in action can be seen. Students develop structural geological assessment techniques and palaeoenvironmental analysis and reconstruction.
Villerville, Normandy, France	While staying in the pretty French port of Honfleur the students undertake a more advanced geomorphological mapping & geohazard assessment exercise, fine tuning their field techniques before embarking on their summer field data collection for their final year projects.

Figure 2. Students being taught and practising rock mass assessment techniques in the Malvern Hills.

Level 3

A variety of more specialised trips are undertaken in Level 3 that are directly linked to a specific taught unit. For example a rock slope stability exercise is undertaken on the Isle of Wight and a landslide geohazard trip completed in Kent where classic British sites such as the A21 Sevenoaks Bypass, Folkestone Warren and Warden Point on the Isle of Sheppey are studied. The course culminates in the final year with a study tour of engineering geological sites that integrates the various strands of the course and provides an overview of the diversity of engineering geological problems in a variety of terrains. The study tour takes place in southern and central France where volcanic, earthquake, landslide and other hazardous terrains are examined along with visits to dam sites, tunnels, slope stabilisation schemes and sites of significant geohazards requiring engineering geological solutions for their mitigation and management.

Figure 3. Students on the final year study tour in the French Alps visiting the Super Sauze landslide.

THE FINAL YEAR PROJECT

The final year project dissertation involves a significant period of independent field study. Many students use this as an opportunity to be adventurous and to travel abroad. Projects have taken place in areas where the School has direct experience and contacts, such as the Western USA, Sicily, Taiwan, New Zealand, Brazil and the French Alps. The Final Year Project is a 30 credit point unit which can account for 25% of the final degree award.

Applied Geoscience Postgraduate msc conversion courses

The School of Earth and Environmental Sciences at Portsmouth also delivers a range of full time and part time MSc courses in Applied Earth Sciences. These include:

- MSc Contaminated Land
- MSc Geohazard Assessment
- MSc Ground Investigation and Assessment

The MSc Contaminated Land course has been designed to provide the relevant training and knowledge required to enable students to tackle the increasingly important problem of contaminated land. The course is focused towards the continuing expansion of employment opportunities in the subject area.

MSc Geohazard Assessment aims to train earth scientists and engineers in state-of-the-art techniques for the identification and assessment of geological hazards. Such training will enable graduates to pursue careers in UK or overseas dealing with risk assessments of hazards such as earthquakes, volcanoes and landslides. The course was designed to meet the criteria for hazard reduction and mitigation put forward as part of the International Decade for Natural Disaster Reduction.

MSc Ground Investigation and Assessment has been designed to enable candidates to switch their area of speciality and upgrade undergraduate geoscience studies and provide a sound background and training in engineering geology for a subsequent career in the ground investigation and geotechnical industry.

Figure 4. The Folkestone Warren landslide complex visited as part of the Level 3 Landslide Geohazards field course.

THE NEW URBAN CHALLENGES AND THE UNDERGRADUATE CURRICULUM

As has been previously stated the early days of the Engineering Geology and Geotechnics programme at Portsmouth saw much teaching emphasis placed on the key employment opportunities for graduates at that time, namely the UK coal mining industry and deep mining in South Africa. With the demise of the British coal mining sector and the recruitment of more local graduates in the Developing World the applied geological programmes at Portsmouth have evolved and have taken up the challenge presented by the urban regeneration agenda and the move towards more environmental sustainability and risk-based engineering design. New courses have been introduced that

have taken the increasingly important area of Brownfield site redevelopment and the role that the engineering geologist plays in that process. Units addressing all aspects of contaminated land are now a key part of the curriculum. Table 2 outlines the current learning aims, outcomes and syllabus for this particular taught course.

Table 2. Course Aims, Outcomes and Syllabus for Level 3 Contaminated Land unit.

AIMS • To provide an overview of the key geoscience and environmental issues associated with contaminated land and brownfield site redevelopment • To detail the investigation, reporting and interpretation of contaminated land and contaminated sites, within the new legalistic framework of assessment • To outline the significant geotechnical and geoenvironmental factors associated with the landfilling of waste and in the engineering design of landfill sites • To consider other waste and contamination reclamation and remediation solutions and technologies, within the new waste management hierarchy • To introduce the significant legal issues concerning contaminated land and the environment
LEARNING OUTCOMES • Categorise contaminated land within a geoscience and geoenvironmental framework • Design and plan a contaminated land desk study and ground investigation and evaluate the results • Predict the occurrence and nature of contaminated land within the new legal framework • Propose management, mitigation, reclamation and remediation methodologies for contaminated sites • Design or appraise a landfill site
SYLLABUS OUTLINE Contaminated land: Introduction, context and definitions including government policy, social, political and economic context, planning law and redevelopment background. Registers, environmental protection acts and bills. Health and safety requirements. Site characterisation and desk studies, both environmental and geotechnical. Risk – based contaminated land assessment. Codes of practice and environmental standards. Site investigation techniques, geophysical assessment, use of remotely sensed data. Specialist sampling and testing methods. Laboratory testing, contaminant determination and trigger value assessment. Background to and the use of CLEA. Interpretation and modelling of results: environmental, legal, political and social implications. Organic contaminants, NAPL's, POPS, linkage to groundwater contamination. Made ground: Geotechnical and chemical aspects. Monitoring and instrumentation. Ground improvement, remediation and control, ground improvement design. Landfill: Introduction and background. Waste management and waste hierarchy. Landfill types. Site suitability. Geotechnical design. Codes of practice. Use of liners and membranes. Site management and monitoring. Leachate and gas monitoring and control. Restoration and after-care. Innovative treatment technologies

Increasingly the engineering geologist is becoming more involved in hazard and risk assessment utilising the key hybrid knowledge-base that they posses. Their ability to undertake both qualitative and quantitative risk assessments ensures that engineering geologists are core members of any *geoteam* (Brunsden 2002). Units have been introduced which address this hazard and risk agenda, for example Risk Analysis and Assessment. Table 3 outlines the current learning aims, outcomes and syllabus for this particular taught course.

Table 3. Course Aims, Outcomes and Syllabus for Level 3 Risk Analysis and Assessment unit.

AIMS • To describe the notion of hazard, risk and vulnerability. • To develop the basic statistical and probabilistic concepts and techniques necessary for the quantitative analysis and assessment of risk in a geological context. • To carry out risk assessments of a variety of geological hazards.
LEARNING OUTCOMES • Outline a mathematical basis for risk analysis and assessment. • Describe hazard and risk, its analysis and interpretation in a geological context. • Undertake geoscience risk analyses and hazard assessments.
SYLLABUS OUTLINE Combinations, elementary probability theory, Bayes' theorem. Probability distributions – binomial, normal, negative binomial, Poisson, exponential – and their relationships and use. Basis of stochastic modelling. Basic concepts of risk and hazard. The analysis, assessment and management of risk and hazard. The risk management framework. Concepts of uncertainty, likelihood and probability. Deterministic and stochastic methods of risk and hazard assessment. Concepts of a probabilistic assessment. Decision analysis. Use of logic trees, fault trees, event trees, influence diagrams and interaction matrices. Risk modelling. Monte Carlo methods. Simulation and Scenario modelling. Sensitivity of hazard and risk assessments. Data completeness. Data error, accuracy and inherent variability. Geotechnical and geological risk and hazard assessment. Probabilistic slope stability assessment. Landslide hazard, Seismic hazard, volcanic hazard, assessment and analysis.

These units compliment the traditional ground engineering material that still forms the backbone of the Engineering Geology and Geotechnics degree pathway.

Figure 5. Students completing their road geohazard assessment project on the French Engineering Geology Study Tour.

SUMMARY

The University of Portsmouth has run applied geology and in particular engineering geology and geotechnics degree programmes for over 40 years, During that time the emphasis of the programmes has changed from training graduates for the coal and deep mining industries to the more recent challenges of the urban environment presented by aspects of urban regeneration and Brownfield site redevelopment as well as the greater use of risk-based approaches and assessment methods in ground engineering. This paper has presented a précis of the taught material and fieldwork programme that now addresses these new challenges.

Acknowledgements: All of the staff of the University of Portsmouth past and present who have contributed to the development and driving forward of the engineering geology programmes at Portsmouth are duly acknowledged for their contributions. Special reference is made to Bill Hodges who sadly passed away this year and who made an outstanding contribution to the soil mechanics teaching in the early days of the degree.

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