Geophysics Education in the UK

A Review

by

The British Geophysical Association

A Joint Association of:

The Royal Astronomical Society, Burlington House, Piccadilly, London W1J 0BQ, UK

And

The Geological Society, Burlington House, Piccadilly, London W1J 0BQ, UK.

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Lord Browne's Foreword to the GSL / RAS Review of Geophysics Education

The continued supply of energy is fundamental to the progress of mankind. And technology is absolutely fundamental to the continued supply of energy. The modern energy business is firmly underpinned by sound science and engineering, and is developing and applying advanced technology to solve some of the world's most challenging problems.

At no time in our history has the question of energy security been more important. The solutions to this question demand innovative technological solutions. This is particularly true in the oil and gas exploration and production business, where we seek out and develop sources of oil and gas. This activity relies on the key disciplines of petroleum engineering and petroleum geoscience to enable the industry to carry out this essential role, yet scientists and engineers with these skills are becoming scarcer each year.

This joint review of geophysics education by the Geological Society of London and the Royal Astronomical Society is both timely and comprehensive. It makes clear recommendations that, if implemented, will help ensure a healthy supply of geophysics graduates able to satisfy the short, medium and long-term requirements of industry. These are vitally important issues for BP, for the energy industry in general, and for the nation.

The Lord Browne of Madingley

Group Chief Executive, BP plc

Preface by the Presidents of the Royal Astronomical Society and the Geological Society of London.

Geophysics is a broad subject at the meeting point of many of the major sciences - physics, astronomy, planetary science, geology, environmental science, oceanography, and meteorology. Geophysical observations are fundamental to our understanding of the earth and how it works and modern geology is largely based on such observations.

Our two societies have promoted world-wide discussion and dissemination of knowledge in the subject since the beginning of the 19^{th} century. The Royal Astronomical Society held meetings on the earth's gravitational and magnetic fields, earthquakes, and the earth's interior. Complementary and joint discussions subsequently took place at the Geological Society, which celebrates its two hundredth birthday in 2007 with a programme of many themes in which geophysics is central.

Modern geophysical methodologies allow us to investigate the subsurface and explore for raw materials and energy. Additionally, geophysics is an essential tool in the safe storage of radioactive waste, monitoring nuclear test-ban treaties, natural hazard assessment and mitigation, the sequestration of carbon dioxide from the atmosphere and the characterisation and protection of the world's water resources. It is the only way in which we can investigate and learn about the Earth's deep structures and processes. Thus, as Lord Browne emphasises in his foreword, a healthy supply of geophysicists is vital for the future of the nation. In the last few decades the UK's universities have done a remarkable job in providing varied geophysics first-degree courses. It is matter of great concern that these are declining due to the lack of entrants with the necessary physics and mathematics. It is a serious situation that the BGA, a joint association of our two societies, needed to investigate. Emeritus Professor Aftab Khan, one of the initiators of geophysics degrees in the country, assembled a committee of geophysicists with widely different interests to carry out an enquiry into the state of geophysics education in the UK. This report and its recommendation is the result; and as geophysicists ourselves, we commend it to you.

Kathryn A. Whaler, President, Royal Astronomical Society

Peter Styles, President, Geological Society of London.

Executive summary & recommendations

Geophysics is fundamental to the needs of society. It is essential in exploring for energy, water, and mineral resources; monitoring environmental impact and change; assessing natural and man-made hazards; in subsurface investigations for engineering and archaeology; and in forensic science.

The growing demands of industry and government service are facing a severe shortage of trained UK graduates with geophysics skills. For example, by 2030, despite efforts to develop alternative sources, nearly 2/3 of the world's energy will still be coming from oil and gas requiring many geophysicists to explore for the 50% increase in supply required by that time. However the population in the industry is aging while the numbers of students entering university to read geophysical science are falling and courses are being discontinued. If current rates of decline continue there will be no geophysics undergraduates by 2030. The problem is global.

> ***'Filling vacant geophysicist positions is the single most difficult recruitment task at present'***
>
> *Major international geophysical contractor*

This review has been undertaken to:

- Assess the present state of geophysics education in the UK
- Identify the problems that need to be addressed
- Make recommendations that will ensure a healthy crop of geophysics graduates able to satisfy the short-term national requirement, and train the next generation in the longer term.

Widespread national concern is being expressed over declining numbers of students doing school and university courses in the physical sciences. Geophysics can help to counteract this by virtue of being able to attract young people in large numbers because of its stimulating mix of Earth science, computing, physics and discovery.

> ***'We need to make sure that more physics and mathematics students are aware of what geophysics is all about.'***
>
> *EAGE President*

Recommendations

There is a need to increase the awareness of geophysics in schools by including more geophysical topics in the A-Level physics curriculum.

The BGA should have a close association with the Institute of Physics (IoP) and so have access to the facilities, organizational structure and visibility that the IoP provides at all levels (schools, higher education, industry and government).

Our parent learned societies should work with industry to increase the promotion of geophysics as a career in schools and universities.

There is an urgent need to develop geophysics courses for physics teachers through activities like those of the Earth Science Education Unit of the University of Keele, the Earth Sciences Teachers Association, the Teacher Scientist Network at the Norwich Research Park, and the seismology in schools projects.

Web sites like *scentra* and the Science Council's *Careers from Science* should highlight information on geophysics and the careers it offers.

A Geophysics Promotion Officer should be appointed, for two years at least, to facilitate these new activities.

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The Report

What is geophysics?

Geophysics is the application of physics to the study of the Earth. This report focuses on the solid Earth but the subject extends to the oceans, atmosphere, and near-Earth space.

Worldwide geophysical observations of the properties and behaviour of the Earth made in laboratories and observatories, from ships, aircraft, satellites, and in boreholes, have led to a revolution in our understanding of the physics of the Earth's interior, how it works, its hazards and their mitigation. Technological and computing advances have increased our ability to make refined investigations of geological structure and physical properties beneath the surface at depths ranging from the centre of the Earth to those required for the exploration for the oil, gas, geothermal energy, water, and other raw materials essential for human survival; environmental monitoring; civil engineering; the disposal of CO_2 and nuclear waste; military activity; the location of archaeological remains; and forensic science including the monitoring of test-ban treaties.

The skills base in the UK, developed through university degrees in geophysics since the 1960s and 70s, has significantly contributed to the wealth of the nation (through exploration and exploitation of natural resources) as well as to national environmental concerns, safety, and security. Development of programmes that will impart geophysical knowledge and skills to the next

> ***'With the emphasis on the planet today, youngsters must understand that geophysics is at the centre of the issues of climate change, natural disasters and also the future of energy resources, where we are desperately struggling to find more geophysicists.'*** President EAGE

Education in geophysics

Geophysics education provides the intellectual, practical and mathematical skills of classical physics, integrated with the observational, field and interpretational skills of geology.

Degrees in geophysics provide a rigorous training in physical science and the key technical skills required for research and industry. They also offer a sophisticated range of computing skills, as well as all the necessary modern requirements of university courses (team-working, presentation and other transferable skills).

In the UK, most geophysics degrees today are primarily concerned with the solid Earth but all include fluid dynamics in the Earth's mantle and core and some include the oceans, atmospheres and surrounding space. This review is concerned with those which have become available in university departments of Geology, Earth and Ocean Sciences in the last few decades during which the science has emerged as a powerful educational subject in its own right.

Programmes provided

Up to the 1950s in the UK, specialist geophysics education was acquired by a few through PhD programmes. We then had the emergence of five Research Council-funded vocational MSc courses, four in Earth Sciences departments and one in a Physics department, for candidates with first degrees in geology, physics, or related subjects. These serve as conversion courses for graduates from other disciplines and also provide advanced training in geophysics to meet the demands of industry. In the last decade we have also seen the emergence, in a few universities, of the 1-year MRes (Master of Research) degree aimed at providing the skills required for research in government, industry or universities. A PhD before employment often follows the MRes.

The major development came in the 1960s and 70s when about a dozen broadly based BSc degrees in geophysics were developed in earth science, geology, physics and ocean science departments, usually for candidates with A-levels in physics and mathematics. By the close of the 20th Century a few new geophysics degrees had started and a number of programmes had closed. At present there are only seven university departments offering geophysics BSc degree programmes (Fig. 1).

Figure 1. Provision of geophysics education in the UK. Filled stars indicate current undergraduate geophysics degree programmes; hollow stars are closed geophysics degree programmes; filled squares are current geophysics MSc courses; hollow squares are closed MSc programmes; filled circles are university departments that include permanent geophysics staff, but do not teach a geophysics course; hollow diamonds are universities (that responded to the survey) that teach an element of geophysics within archaeology departments.

Geophysics is also necessary at an introductory level and is often offered as an advanced optional module in geology, earth and ocean science, archaeology and sometimes in physics and civil engineering courses.

Careers

The main employers of geophysicists are in the industries concerned with oil and gas, minerals, water, environmental monitoring and archaeology. Increasingly sophisticated geophysical methodologies will be needed as resources become scarcer and targets more elusive.

There will be a growing demand for well-educated geophysicists in the future. We shall want to know more about hazards like earthquakes, volcanoes, tsunamis, and about the Earth's structure and history. Monitoring and implementation of nuclear arms control, nuclear waste disposal, CO_2 release and sequestration, and the environment, will call for increasing sophistication in the methodology. There will be a continuing need for broadly based researchers in universities, public sector and industry. Dealing with the effects of climate change on our way of life requires the predictive skills provided by a geophysics education. Geophysics graduates are also well suited to the wide range of non-geophysical careers in which numerical skills are required.

Major concerns

The major concerns leading to this review include:

(a) Employers in Government and major companies based in the UK have identified the filling of geophysics vacancies as their most difficult recruitment task. They foresee that demand will go on rising.

(b) Despite growing employer demand, the number of students reading for first degrees in geophysics is now about half of that 20 years ago (Fig. 2) although the total number of students entering the university system has risen. Only about half of this decline can be attributed to the fall in numbers of students entering with A-levels in physics and mathematics (Fig. 3), subjects normally required for entry at 18. Because of falling demand from students, excellent geophysics courses are being discontinued by universities on economic grounds, leading to reductions in the variety of courses available and in the research base.

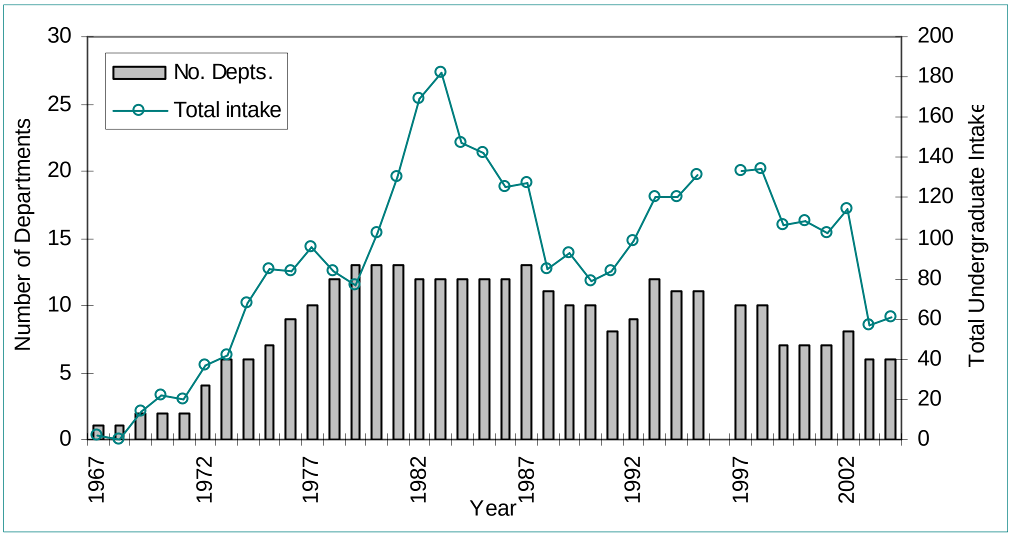

Figure 2. Undergraduate intake and number of departments offering geophysics. (Data from 1999 to present day based on responses to this survey and may be incomplete. Pre-1999 data from BGA archives.)

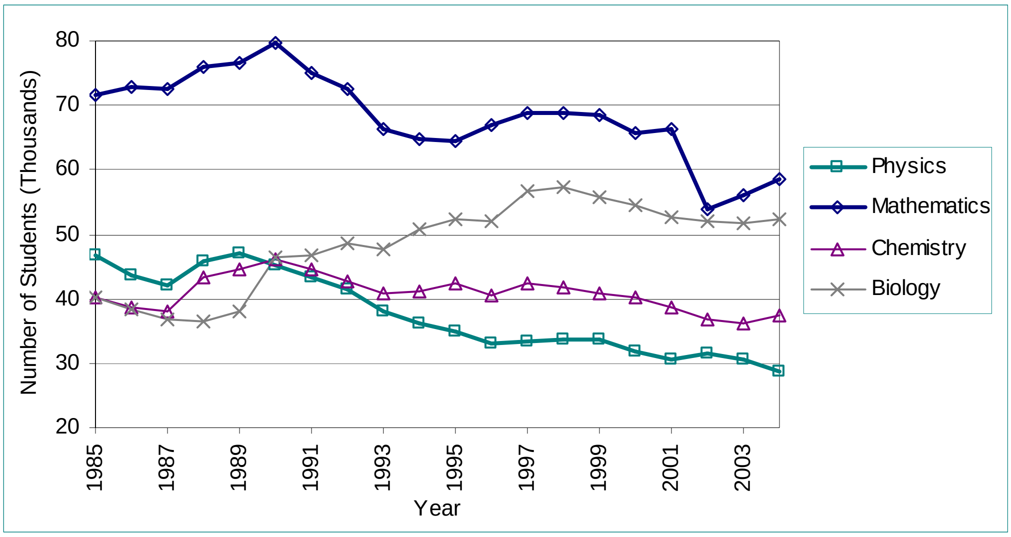

Figure 3. Entries to A-level examinations 1985-2004 (Source AQA).

(c) The number of MSc courses in geophysics has been reduced from five to one following withdrawal of Research Council and university support. This reduction has been directly associated with a fall in the overall numbers of geophysics Masters graduates entering exploration and environmental careers. The resulting decline in the academic and industrial skills base is depriving the UK of much-needed expertise.

The BGA Review

This alarming decline called for a wide-ranging review of UK geophysics education. The British Geophysical Association (BGA), a joint association of the Royal Astronomical Society (RAS) and the Geological Society of London (GSL -Appendix 1), initiated the review under the Chairmanship of Professor Aftab Khan (University of Leicester) in September 2004 (Appendix 2). The Review was focused initially on departments with geophysics degrees. It was also asked to identify why more school-leavers are not coming into geophysics, and to determine the effect of the falling numbers of geophysics graduates on UK industry.

The review was set up to cover issues like

- UCAS statistics and trends in these sciences.
- The training of teachers in geophysics.
- The provision of geophysics in secondary education.
- A survey of university provision in undergraduate and Masters courses.
- The use of geophysics as a way to create transferable skills for the science base.

- Government, industry and academic need for geophysics graduates.
- The promotion of geophysics as a means of attracting young people into the physical sciences.
- Accreditation of geophysics courses.
- The role of the RAS, The Geological Society of London, the BGA and other organisations in the promotion of education in these sciences.

Information was sought by direct contact, letter and on-line questionnaire from:

- University departments with geophysics degrees, as well as all departments of geology, physics, archaeology, and engineering which taught some aspect of geophysics.
- Present and past students who were undertaking or had completed a geophysics degree.
- Employers in the oil, mining, water, and environmental management industries, and in the public sector.

Articles advertising the Review and its interim findings, together with an Open Discussion meeting held at the Geological Society of London on 22 April 2005 (Appendix 3) have solicited further information.

Survey findings

Commentaries on the returns from universities, employers, and students are summarised in Appendices 4, 5 and 6.

Responses from the universities and students alike indicated that lack of exposure to geophysics in schools is the major contributing factor to poor recruitment to university degree programmes. The geophysics content of GCSE and A-level geography and science courses was examined, to see how it would be possible to address the lack of awareness of geophysics as an educational and career option. The results of this analysis are included in Appendix 7.

Students of geophysics, 40% of whom are currently female, have an average A-level grade of B in physics, mathematics and any additional post-16 qualifications. They are motivated primarily by scientific curiosity and almost without exception said they were stimulated by their degree courses (Fig. 4). They believe the shortage of applicants is due to lack of awareness in schools and the perceived difficulty of the subject.

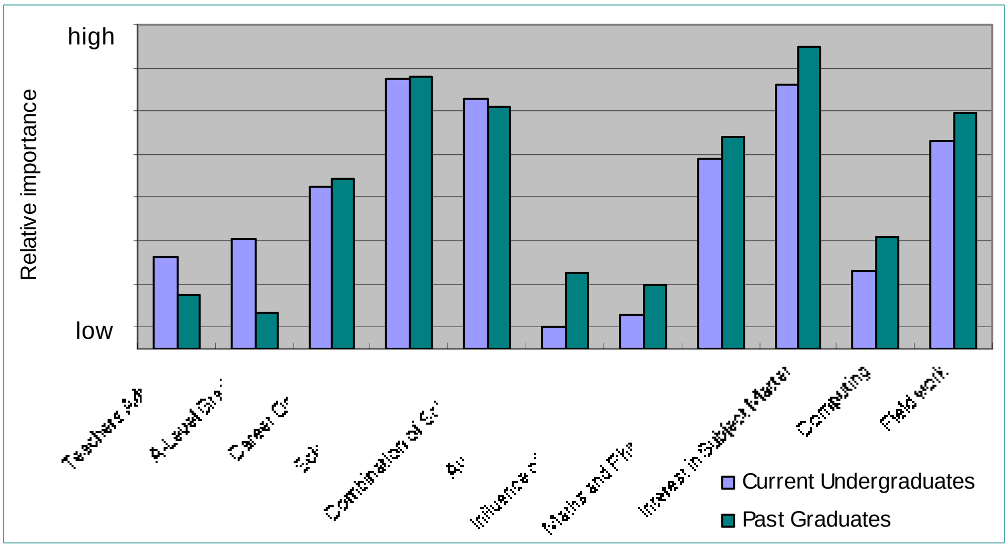

Figure 4. Relative influence of factors on the choice to study geophysics.

While there is some qualitative coverage in geography, geophysical topics are not included in the physics A-level syllabus, the most appropriate place to describe the physics of the Earth. The oil industry was the most common employer of graduates, followed by IT, private geophysical service companies, the public sector, the environment, mining, teaching and research (Fig. 5).

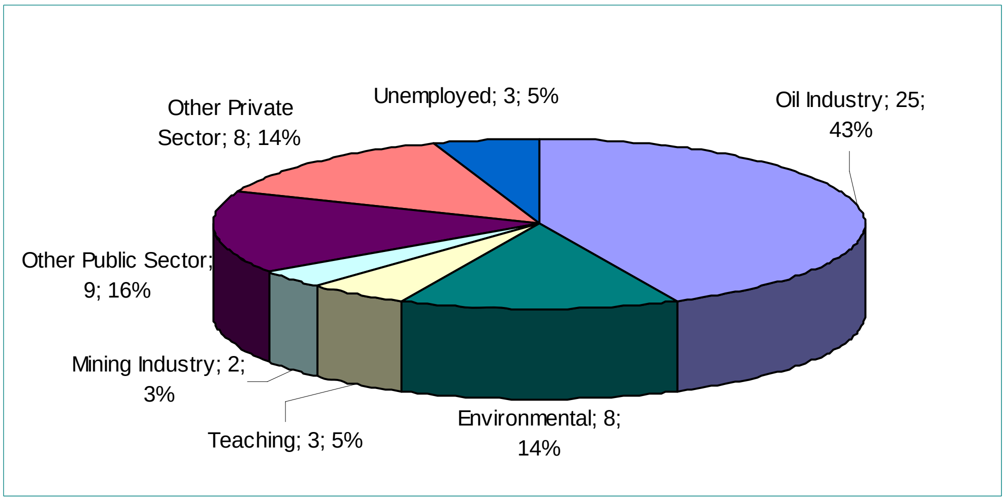

Figure 5. Area of employment of past geophysics graduates. The data labels give the category, number of responses and the percentage this represents

Geophysics was seen as being an ideal university education with its mix of physical Earth science, computing, mathematics and fieldwork (Fig.6)

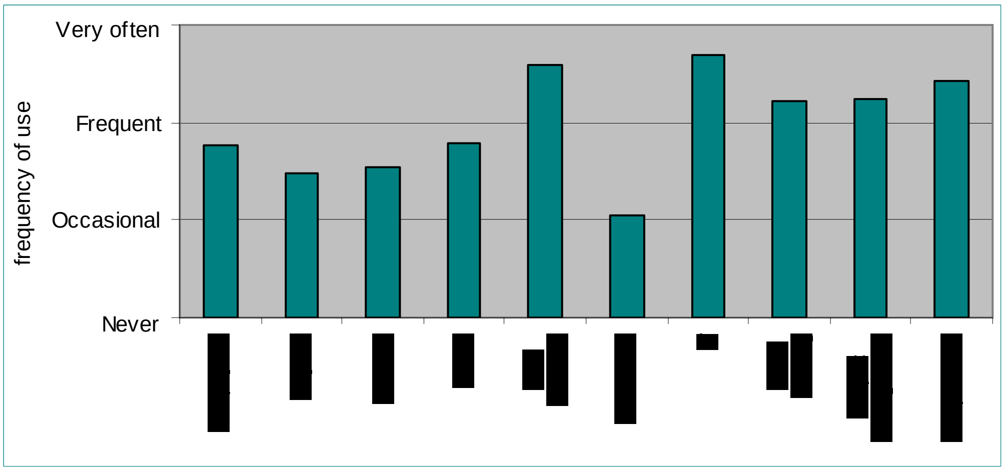

Figure 6. Use of skills acquired during degree.

Over half the **employer responses** came from the big oil and related companies, 70% being multinationals that may employ a few hundred geophysicists, over half of whom may come from the UK. The remaining responses came from the environmental, equipment, educational and research sectors.

The responses strongly emphasised the need for high quality geophysicists, and pointed out the difficulties in recruiting such UK graduates. The "taught MSc" was the best-known and most desired qualification, and the major employers bemoaned their reduction to only one. The more broadly based BSc is also highly favoured by some. The MSci and the MRes degrees were not well understood. The most desired skills were: theoretical and practical geophysics with geology and IT (Fig. 7). Overall, there was concern about the growing shortfall in the supply of well-trained geophysicists at a time when the demand is increasing.

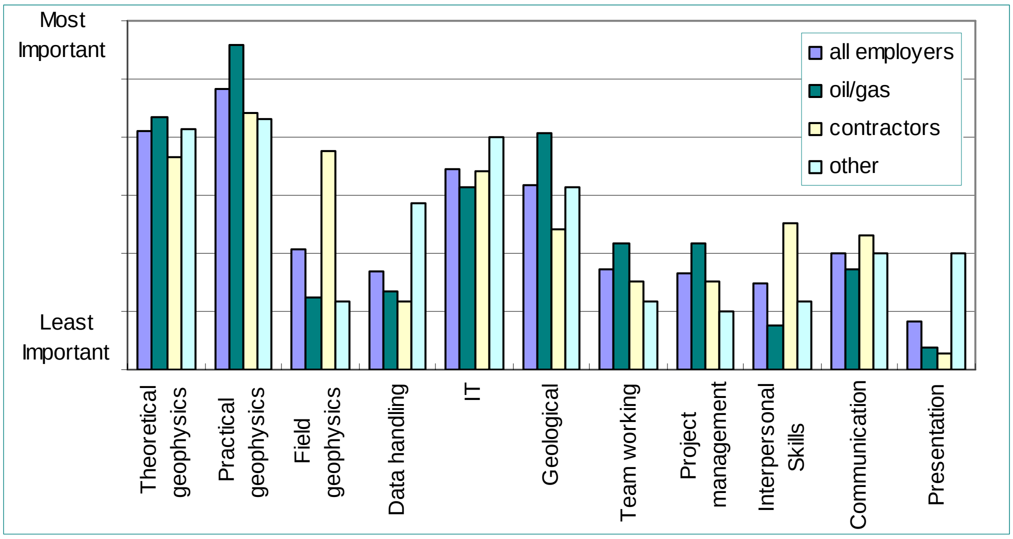

Figure 7. Skills desired by employers.

Companies in the non-oil sector (mining, engineering, environmental, and archaeology) were smaller and favoured the more broadly based BSc followed by up to five years of on-the-job specialised training. The subject is not well understood by some clients to whom accreditation is therefore important. Graduates with quantitative Earth science skills, for which a geophysics degree is an ideal education and training, are essential for this commercial sector. At a time when environmental concerns are increasing daily, the need for such graduates is even more urgent. There is also a vital need for university collaboration in research (for which individual small companies lack facilities and resources) to enhance the methodological base, which was generally seen as being fragile at present.

In order to provide the necessary skills base and to ensure that such research collaboration takes place, the numbers of geophysics graduates has to increase for the long-term viability of such applied geophysics research in the university sector.

Numerate Earth science graduates are also needed in vital public sector organisations like the British Geological Survey (BGS) with a wide range of thematic programmes, all requiring geophysicists for a plethora of geophysical projects as well as, for example, 3D-imaging, visualisation, and GIS. Graduates with BSc, MSc and PhD degrees all have roles. There is again, a perceived shortage of such graduates trained with the necessary quantitative and computational skills, which geophysics degrees can provide.

Universities bemoaned the lack of awareness in schools of HE provision in this major area of science, despite recent media exposure through Earth science TV programmes, archaeology TV programmes, web casts and other outlets, as well as geohazards such as earthquakes, volcanoes, and tsunamis. Universities' own efforts to increase awareness through outreach programmes are limited by manpower resources, and they generally only link with local schools.

The MSc courses have been a major safety net for those students who discovered the subject while at university, reading for first degrees in physics, computing, mathematics, engineering and other fundamental scientific disciplines, but the numbers applying have been decreasing rapidly. This is partly due to the discontinuation of 80% of the geophysics MSc courses over the last 15 years, but also because of graduate debt, exacerbated by the better quality undergraduates being encouraged to complete four-year MSci programmes in their own undergraduate disciplines.

Recommendations

In the light of these findings we recommend that:

1. The British Geophysical Association, Royal Astronomical Society and The Geological Society of London should (using this review) present to Government and schools curriculum agencies the case for increasing awareness of geophysics in schools. This should be achieved by including Geophysics in the A-Level physics curriculum, in order that (a) adequate numbers of geophysics graduates are produced to satisfy national commercial and governmental requirements in energy, mineral resource exploration and production, and in environmental management and (b) the interest factor of the physics syllabus may be enhanced thus encouraging more young people to read physics.

2. Geophysics should become a component part (Subject Group) of the Institute of Physics, and so enjoy access to the facilities, organizational structure and visibility that the IoP provides to all levels of those interested in the science (schools, higher education, industry and government).

3. The BGA, RAS and GSL should directly work with industry (e.g. through the PESGB, the IMMM) to increase the promotion of geophysics as a career in schools and universities, to provide increased numbers of graduates with the necessary skills that industry needs.

4. That BGA and GSL should offer help in developing geophysics courses for teachers such as the Earth Science Education Unit at Keele University and the Earth Sciences Teachers Association.

5. The BGA should co-ordinate the Geophysics component of the Science Council's Careers from Science website, which should highlight information on careers in Geophysics.

6. These activities will require the appointment of a Geophysics promotion officer for the BGA.

Conclusions

Action is needed now to address a simultaneous increase in demand for qualified geophysicists and a rapid decline in recruitment to geophysics programmes. Our strongest recommendation is that geophysics must be included into the physics A-level syllabus to add to the interest and encourage more students to read physics, as well as to increase awareness of geophysics as a career.

That more physics is not already taught through the medium of Earth science is surprising, given that "the most commonly cited reason for the lack of participation in physics is the perceived lack of relevance of the subject, either in the students' aspirations or to the world at large"[2]. Geophysical examples of natural phenomena are the most engaging way to demonstrate basic physical principles. Using earthquakes and tsunamis to demonstrate aspects of wave propagation, the geomagnetic field to examine electricity and magnetism, the Earth as a gravitational body in the solar system, are but a few obvious topics that might be considered. The recent installation of seismographs in some UK schools to record real data that can be shared on-line with schools worldwide has generated considerable excitement among the young and has attracted much media attention following the 2004 Boxing Day Indian Ocean Tsunami, the October 2005 earthquake in South Asia, and the 11 December 2005 explosion at the Buncefield Oil Depot, Hemel Hempstead.

These recommendations would require a considerable initial effort that would be best coordinated by the BGA and the Education Committees of the Royal Astronomical and Geological Societies. These Societies should consider seeking funds from industry and government for the immediate appointment of a Geophysics Promotion Officer, for two years in the first instance, to promote linkages between schools, industry and relevant university departments throughout the country.

Acknowledgements

The Committee would like to thank the BGA and its parent societies, the RAS and GSL for sponsoring this Review. Tajinder Panesor of the Institute of Physics provided much helpful advice and kindly updated some of the data used in the Institute's Physics education review of 2001[1]. Special thanks are due to Dr Richard Mobbs, Head of Learning Technology at the Computer Centre in the University of Leicester for designing the on-line questionnaires and collating the responses; and to Dr Annabel Kelly for organising the data and helping with the report. Cynthia Kat provided much useful advice on linking with schools. Ruth Pollington designed the cover for the review. The committee is grateful to all the individuals in universities and industry, and to the students who took the time to respond to the letters of enquiry and on-line questionnaires.

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Appendices

Appendix 1 – Geophysics and the Learned Societies

Geophysical knowledge is disseminated through learned societies and their publications. The oldest and most prestigious society is the Royal Society of London founded in 1660. In the UK, the Royal Astronomical Society (RAS), founded in 1820, has always had strong interests in geophysical matters and publishes one of the world's leading international journals, the Geophysical Journal International. The Geological Society of London (GSL), which will be celebrating its bicentenary in 2007, represents professional and academic scientists. In particular it offers chartered status to individuals and accreditation of geoscience courses including geophysics courses, as contributing to an individual's progress to that status.

The RAS and the GSL are the parent societies of the British Geophysical Association (BGA), the national association for geophysics which provides links to other national and international geophysical societies and nominates the UK representatives to the IASPEI, IAG, and IAGA, constituent associations of the IUGS, the International Union of Geological Sciences, which represents about 250,000 Earth scientists in 117 countries. The BGA has specialist groups to promote and co-ordinate research in these areas as well as in Environmental and Industrial Geophysics (EIGG), and in Education. EIGG is concerned with shallow geophysical investigations, normally to depths to about 500m that are important in hydrogeology, engineering, archaeology, forensic science, environmental investigations, mineral exploration, hazard assessment, and geological mapping. The Education group of the BGA aims to promote awareness in schools and colleges and the teaching, learning and career development of geophysicists in the UK. It is responsible for this review.

Appendix 2 – The Steering Committee

Because of the wide scope of geophysics, it was decided to form a steering committee with membership from the Societies, universities with different geophysics specialities, schools, and a variety of employers to guide the review. The membership was as follows.

- Prof Aftab Khan, Emeritus Professor of Geophysics, ex-Geophysics Course Director and Dean of Science, University of Leicester
- Prof Peter Maguire, University of Leicester, President of the BGA (2003-2006)
- Dr Christine Thomas, University of Liverpool, Education Secretary of BGA

- Prof David Sanderson, Imperial College, Chair GSL Education Working Party
- Dr Roger Clark, Coordinator Geophysics Degree Courses, University of Leeds.
- Prof John Mc Closkey, Geophysicist, Head of School of Environmental Sciences, University of Ulster.
- Dr John Reynolds, Managing Director, Reynolds Geosciences, (Small Business Awards winner).
- Dr David Bamford, Former Head of Exploration, BP
- Dr W. Henry, Processing Manager, CGG
- Dr Nigel Cassidy, University of Keele, Sec EIGG Group of BGA
- Dr Jane Stimpson, Geophysicist, Physics Teacher and examiner, Westonbirt School, Gloucestershire.
- Mr Stewart Bullen, Combined Sciences graduate, Physics Teacher, Hailey Hall School, Hertfordshire.
- Dr Roger Scrutton, ex-Head of Department of Geology and Geophysics, University of Edinburgh, RAS Education Committee, BGA President 2006-.
- Dr Russ Evans, BGS, recent Managing Editor of Geophysical Journal International.

Appendix 3 – The Open Discussion Meeting of April 22 2005

Because of the broad nature of the educational and employment issues involved it was important to consult widely so submissions were invited from anyone with an interest in the subject by advertisements in the house journals of the societies, the professional bodies, and on the internet. An open all-day meeting to present and discuss the initial findings was held at the Geological Society on April 22 2005. Invitations were sent to staff and students from all UK Universities where the subject is taught, relevant people in the public sector, the NERC, the societies, and all those who responded to the enquiry, including employers and former students.

There were presentations from members of the Steering committee as follows:

- Professor Peter Maguire : Introduction
- Emeritus Professor Aftab Khan: Summary of the findings so far.
- Dr Roger Clark Geophysics as an Education: The University Provision
- Stewart Bullen; Geophysics in Schools
- Dr W. Henry: Geophysical Education for the oil industry
- Dr John Reynolds: Geophysical requirements in Mining, the Environment, Archaeology, and Engineering
- Dr Russ Evans: Geophysics for the Public Sector.

The main part of the meeting was concerned with a discussion of the issues involved. Reports of the meeting were published in Astronomy and Geophysics[4], the Geoscientist[6], and the Newsletter of the Petroleum Exploration Society of Great Britain[5] with an invitation to those who had not responded to the enquiry, or wished to add to their response, to do so. Subsequently, in response to requests from the Editors who became aware of the meeting, versions of the report were published in Science and Parliament[3] and Teaching Earth Sciences[7].

Appendix 4 – Survey Findings (university courses)

MSc Courses

In the 1950's we saw the emergence of vocational taught MSc's in geophysics and at its peak in the 1980's there were five. One of these was in a Physics department but only ran for a short time and was discontinued before the period covered by this review. The others were Earth Science departments with an optimum of 10-12 students. The aim was mainly to provide specialist training in applied geophysics from data acquisition to interpretation on depth scales ranging from a few kilometres appropriate for exploration for raw materials to shallow investigations up to a few tens of metres needed in engineering, environmental management and archaeology. UK students were primarily dependent on studentships provided by the NERC but over the years the numbers supported by industry increased to about one third of the total. The courses ran for a full 12 months, with formal teaching for the three terms followed by supervised field and project work in the summer. They were highly successful in meeting the demands of industry but very demanding in manpower. In recent years, due to the changes in the nature of university funding, the reduction in studentships, and the fall in student numbers, most courses have been discontinued so that now there is only one which has an intake of about 25, about half of whom are from overseas. As part of the review, letters of enquiry were sent to the departments asking about themselves, and their experiences with running the courses over the last 10 years or to the time of closure. Offshore geophysics is also included in departments that do oceanography.

The normal entry requirement for the Geophysics MSc is a relevant first or second-class science degree and mathematics to A-level or beyond. This was usually achieved with most UK acceptances having an upper second class degree or better in geology or physics. Lower qualifications were sometimes accepted from those with industrial experience. There has always been a healthy female participation rate, which has increased from zero at their inception to nearly 50% now. There were occasional candidates for conversion from PhD graduates in other subject areas. The experiences with application numbers varied and were affected by course closures elsewhere, the fall in the numbers of NERC studentships available, the emergence of the 4-year undergraduate degree in England and Wales and increases in applications from Europe and other overseas countries. There was a small effect when the geophysics BSc's were introduced but the MSc remained important for those physicists and numerical geologists who only found out about geophysics while at university. Some geophysics BSc graduates found it beneficial to do an MSc as well, in preference to the MSci. In all courses there was a continuing decline in the number of good home applications, particularly from physics graduates who had already done a 4-year undergraduate degree.

The departments running geophysics MSc courses varied in size from 10 to over 30 staff including 4 or more active geophysicists, with research funding and PhD students, technicians, a good equipment base and some industrial software. Within these departments there were sometimes other geological MSc and BSc courses e.g. hydrogeology, engineering, structural geology, in which geophysics was an important component. The areas of academic strengths in departments varied with the research interests of the staff but all the courses included the main applied geophysical methods and emphasised seismic reflection, the prime method in the oil industry, sometimes with the addition of petroleum geology and reservoir engineering. The shallow investigation methodology was usually included and used on the field courses that often provided the data for summer projects. Sometimes the general core content was supported by additional advanced options in either petroleum or environmental geophysics. Options became necessary, as it is no longer possible to fit the whole range of the subject into a one-year course. The training had to add geology for physicists and physics/maths for geologists. Non-applied and pure geophysics were also now included to cater for requirements in the public sector such as national surveys and institutions, and as a base for research degrees.

In all the MSc degrees there has been some involvement of the extractive and contractual industries that provide scholarships, lectures, seminars, projects with supervision, placements, visits in the field and for recruitment. Senior staff from employers often act as external examiners and provide vital feed back on training and course content.

Departments have had to make drastic adjustments to changes in student demand and the nature of university and research council funding in the last decade or so. Three of the four courses were closed, as they were not viable without NERC funding. The remaining course has over 20 students - an unhealthily large number at this level for a single department. This course has not been numerically affected by changes in the system but there are serious worries about the continuing decline in the mathematical base of the UK entrants.

The departments themselves had recognised the need to improve their publicity and broaden their links with industry and contractors as well as with schools but lacked the time to do so. There is a view that geophysics needs to be introduced at age 14 to stimulate students to continue doing mathematics.

Accreditation of degrees was not regarded as being of great importance in the oil industry but affiliation with the SEG was useful to the students. Accreditation is important in non-oil applied geophysics.

BSc/MSci Courses

The MSc degrees demonstrated not only the need for geophysics graduates but also the problems of producing them in a 1-year course from a mixture of graduates whose first degrees were either geology or physics with little common content. The new ways of looking at the Earth, which emerged in the 60's and 70's, were largely due to advances in geophysics. It was axiomatic that geophysics should be central to future degrees in geology/Earth sciences. Undergraduate geophysics degree courses naturally emerged in which students with A-levels in physics and mathematics were taught geology with appropriate classical physics and mathematics integrated into geophysics in a logical way towards the frontier of knowledge in the new geology.
Figure 2 shows that during the last two decades undergraduate geophysics degrees became available in 14 Universities, primarily in departments of geology or Earth sciences. Two of these were in departments that also did MSc courses. At present, BSc degrees in geophysics are only available in 7 universities and the total intake has fallen to less than one half of the peak value. It was this worrying decline that prompted this review.
University departments which offered geophysics degrees were asked to provide information about their departments, their specialities and courses, field work, student numbers and quality, how they responded to student demand and changes in the nature of university funding, links with industry and schools, the effects of the RAE and the QAA, and the importance of accreditation.

Over the years departments have worked quite hard to increase the numbers of students without modifying the quality and content of their well thought-out and stimulating courses. But the shortages of qualified applicants and changes in the university funding system meant that some courses became uneconomical and have been discontinued. Most of the current courses are now in fairly large, broadly based departments or schools including subjects like oceanography and environmental sciences. The departments are fairly large with over 20 staff including an average of 5 geophysicists, matching numbers of researchers, and with an annual first year intake averaging over 100. All of the geophysics courses included geophysical and non-geophysical fieldwork. The academic strengths of these departments were quite varied including global and exploration seismology (including marine data-acquisition), gravity, magnetism, terrestrial electricity and electromagnetism, lithosphere dynamics, tectonics, hazards and shallow geophysics. The diversity of expertise in the departments ensures that graduates suitable for a wide range of employers are able to be provided nationally.

Response to changing demands

Departments have been responding to changes in demand by changing the structure of their courses in positive and imaginative ways to build on research strengths. In one university students are drawn from geology as well as physics departments. As departments merge into bigger units, options in the subject are available to a wider range of students. The introductions of "year-abroad" options have been successful in attracting a higher quality of students. Staff appreciate the need to increase schools outreach activity locally and develop attractive websites for wider appeal but their activities are uneven because of location and the time and effort involved. Most departments are forced to dilute the scientific content of their courses to match the weakening mathematical base, to add some in-house teaching of mathematics. One of the attractions of geophysics is that it offers the opportunity to do physics in an attractive way away from conventional laboratories. But departments are having to reduce the amount of field work they offer because of the cost.

Range of skills needed and taught

Most departments cover the range of skills required by employers in industry, academe, teaching, and non-geophysical jobs through the broadly based courses including geology, physics, maths, computing and associated field work, seminars, reports, independent projects and practicals. Care is taken when designing modules to ensure that a range of transferable skills is acquired. Attention is also paid to research skills, safety, first aid, and time management. In some of the broadly based schools, modules in oceanography and meteorology are offered.

4-year courses

Most of the departments which have the 4-year undergraduate degree found it beneficial as they attract better students able to benefit from the additional year especially when a year overseas is offered. The major benefit is the opportunity to build on the geophysics done in the third year and do more extended projects, often using large industrial data sets and software. However, it is not clear that the 4-year undergraduate degrees are well understood by employers.

Student feed-back on the courses is generally very positive despite the relatively heavy and demanding workload required. The workload doing a broad based, integrated science, with laboratory work sometimes seems unfair compared with subjects without practicals. The problem is compounded when vacation fieldwork is added. An increasing number of students now need to undertake some paid employment in the vacations and departments have had to reduce the vacation fieldwork commitments for this reason as well as minimising the cost for the students and departments. The appreciation of the students is confirmed by the responses from the past graduates in the on-line survey.

Departments are unanimous in stating that the solution to the numbers problem is to make students in schools more aware of geophysics by including it in A-level physics, which ideally should be taught by physicists. A major Scottish think tank on the school-university transition has urged a major school curriculum review to include more on the relevance of science to society. Although geophysics gets media exposure through natural disasters and popular science TV programmes it is not getting into schools. The need to get the subject into schools is recognised but it is time consuming and universities can only do this locally in a small way. The departments predict that introducing geophysics in schools would help to reduce the downward trend in the numbers of students doing A-level physics and maths. The need to have more qualified maths and physics teachers in schools is again emphasised by university teachers. Universities recognise the need to work together to increase awareness in schools.

Links with industry

All departments have links of some kind with industry or research establishments. Formal links include the appointment of external senior experts as Honorary Visiting Professors or Senior Fellows. Departments sometimes have Advisory Boards in which industrialists advise on aspects of the degree programme. Research links also provide contacts, visits and contracts from which students benefit. Most of the links are less formal. Some have Knowledge Transfer Partnerships in which students get summer placements working on appropriate industrial projects. These sometimes lead to projects forming part of the degree requirement e.g. shallow geophysics field work or on commercial data acquired in exploration programmes. Such projects usually involve a supervisor from the organisation with exchange visits and meetings. Students get a good insight into the workings and requirements of industry and benefit from having access to state of the art facilities and the use of specialised libraries. Company experts sometimes contribute more formally through participation in seminars and lecture programmes.

Interdepartmental links

Departments link with other relevant departments in their university for courses in physics, mathematics and computing. Particular problems occur with mathematics in which the attainment on entry is low, even with the requirement of post-16 qualifications in mathematics, and special courses have to be put on by the departments. Some universities have a broad degree structure which allows students to do advanced options in other subjects including mathematics and languages. The converse applies in some broad degree schemes which allow students from other departments (physics, mathematics, engineering, geography, archaeology) to do geophysics modules. This is often the first contact such students have with the subject and it can lead to further study, e.g. in a taught masters course or a research degree.

From the perspective of the universities, geophysics degrees are expensive and demanding in staff time because of the small numbers of students. From the departmental perspective, the broad base of the degrees means small numbers of staff have to cover a very wide-ranging subject. Time consuming requirements imposed by the QAA, and other quality assurance initiatives seriously reduce the effort which can be put into the teaching. Departments have to work within the guidelines but the QAA is generally perceived to produce a lot of pain for very little gain. The rigorous auditing procedures restrict the quality and innovation which students expect. The RAE and the resulting pressures to publish add to the stress and make life very difficult and unhealthy for the staff because of the long hours required.

Courses are accredited by the Geological Society of London and/or the Institute of Physics. There are mixed feelings about the importance of accreditation in geophysics. It seems to be important for some students and their parents. It also seems to be important to employers in small-scale, shallow geophysics. The survey of employers shows that it not regarded as important in the oil related industries or in the public sector, perhaps because of the shortage of geophysicists.

Geophysics in Other Courses

The small numbers of students on geophysics degree courses compared to the far larger numbers on physics, archaeology, environmental science and general Earth science/geology degree courses means that many undergraduate students are only exposed to geophysics as optional or introductory modules within other degree programmes. For some students this introduction to the subject inspires a change in career direction or further study in geophysics, e.g. a taught Masters or PhD. Therefore, the provision of geophysics within departments that do not offer a full degree course is highly important to the health and development of the geophysics community.

Questionnaires were sent to all the physics, mathematics, geology, archaeology and Earth/environmental science departments in the UK, with the aim of determining the quantity of geophysics taught and the range and enthusiasm of students exposed to the subject.

The survey responses indicate that the majority of geophysics taught in this way is to students on archaeology or Earth science degree courses. In several British universities there is a research base in geophysics within Earth Science departments or schools including environmental and oceanographic sciences with several specialist geophysics staff providing geophysics modules to students studying general Earth science degree programmes, some of whom go on to geophysical careers in research or industry. In archaeology, the emphasis is on appropriate small-scale geophysics including data acquisition in the field, data processing and presentation.

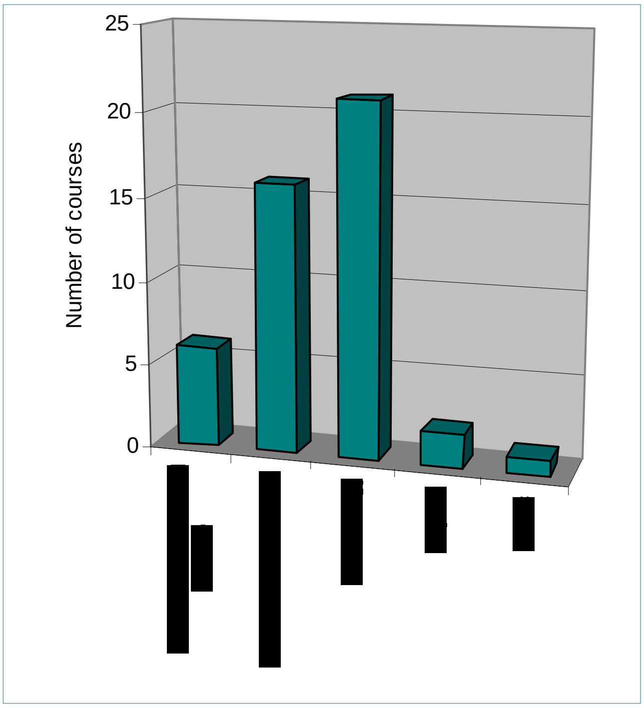

Figure 8. The number of degree courses in different university departments offering an element of geophysics.

In physics departments, a small amount of geophysics is often included within planetary physics and provided by earth science departments. The departments indicate that the students that are exposed to geophysics as a minor component of their degrees generally find it an exciting and lively subject and stimulate some students to continue the subject at the MSc level.

Appendix 5 – Survey Findings (Employers)

Geophysics graduates are employed in a wide range of industries. Their subject-specific training and skills are desired by the engineering, petroleum and extractive industries and by governmental and research establishments, while their general training in physical sciences and good numeric skills make them highly employable in general graduate positions. In order to assess the future need for geophysics graduates and to determine whether the geophysical education currently provided is fulfilling the requirements of industry, a survey of employers was conducted.

Companies and organisations employing geophysicists were contacted and asked about their requirements for qualified geophysicists at graduate and post-graduate level, for the skills they desired in employees and for general comments on recruitment and the quantity and quality of geophysics education in the UK.

Nature of Activity

The employer responses to the questionnaire are dominated by companies involved in the oil and gas industry (including consultants) and geophysical contractors. A breakdown is given in Figure 9.

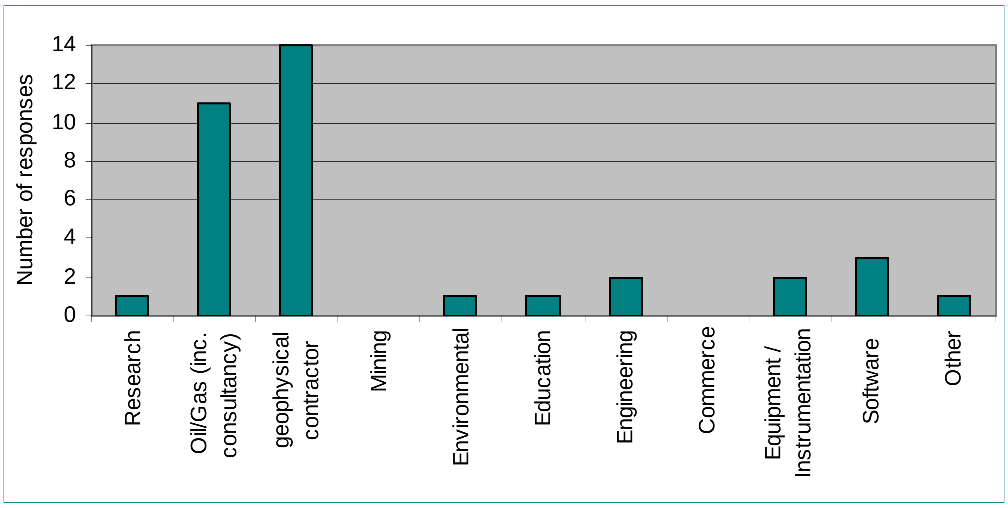

Figure 9. Employer responses by nature of business.

Preferred Entry Qualifications

The most desirable qualification for employees varies depending on the nature of the business. As shown in Figure 10 the geophysical contractors are the most likely companies to employ staff directly from a BSc course whereas the petroleum industry and the other employers generally prefer post-graduate qualifications. In general, the most desirable employees are those with the vocational post-graduate MSc. The comparatively new 4-year undergraduate MSci is still poorly understood by some employers.

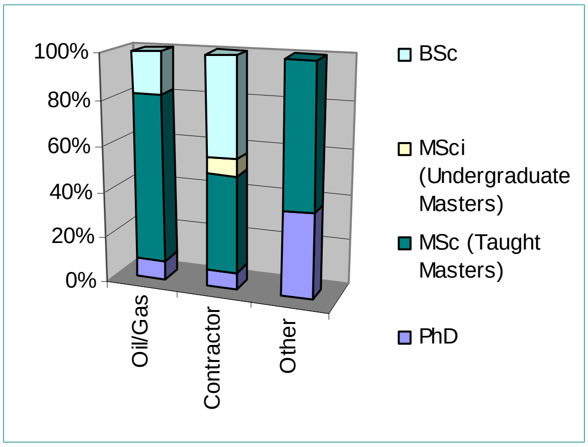

Figure 10. Employers' first choice of qualification.

There is a widespread concern about the falling number of geophysics graduates and, in particular, the decline in the number of MSc courses and graduates. The quality of the graduates and especially the MSc graduates is widely praised, but the limited number of geophysicists leaving university is a major concern as it limits the number of skilled potential employees. This is a common concern across all employers irrespective of the primary nature of their business.

Desired Skills

The employers' opinions of the most desirable skills differ notably from the graduates' opinions as to the skills that they use the most frequently. The employers' generally rate good practical and theoretical geophysics as the most desirable skills (compare to Figure 20):

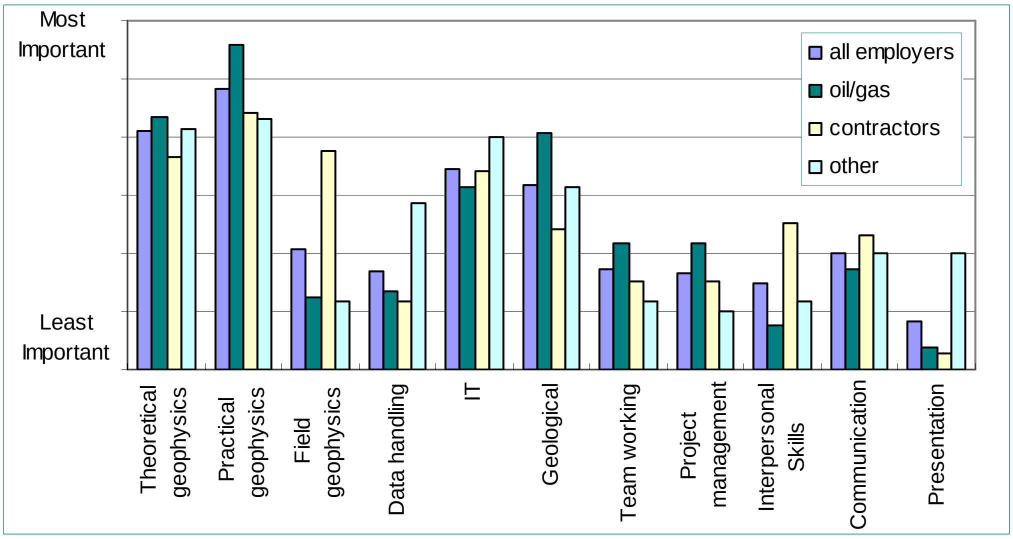

Figure 11. Skills desired by employers.

Some employers point out that even with a specialist geophysical education new recruits take several years of professional training and experience to become profitable to the company, but a relevant post-graduate qualification can significantly reduce this time. Experience in using industry software packages and modern equipment was cited as being highly desirable in graduates.

Companies generally anticipate an increasing need for graduate geophysicists over both the short- and longer-term. As many companies are already experiencing problems with finding adequate numbers of graduate geophysicists they are worried by the small and decreasing number of geophysics graduates and MSc courses. Even recruiting from overseas to fill geophysics positions is difficult as the shortage is worldwide. The growing demand is led by the need to increase the global oil supply by 50% in 2030 and the aging of the present work force.

Some of the comments received were as follows:

"Filling vacant geophysicist positions is the single most difficult recruitment task at present - there are not enough good ones around!"

"While we anticipate increasing recruitment requirements in the next few years, the supply of suitable candidates seems to be decreasing. We are now actively looking at candidates with physics and mathematics degrees to fill the gap, and are also increasingly recruiting overseas."

"Good field geophysicists are VERY thin on the ground"

"Obvious shortage of geophysics candidates."

"Limited recruitment carried out during the past 10 years. Major recruitment drive planned for 2005 / 2006. Positions will be based initially in Norway, candidates will primarily come from Europe."

"We are very aware that the pool of geophysics and physics graduates coming out of UK universities is diminishing"

"Too few good quality applicants from universities in the UK"

"Given the oil industry G&G demographics there will be a greater need for graduates in the next 5 years and onwards"

"The geoscientists workforce is aging"

"Geophysicists with 1st degrees in Geology, Physics or Maths most desirable"

"One of the key issues today is awareness in schools. We need to make sure that more physics and mathematics students are aware of what geophysics is all about. With the emphasis on the planet today, youngsters must understand that geophysics is at the centre of the issues of climate change, natural disasters and also the future of energy resources, where we are desperately struggling to find more geophysicists. It is even harder to find geophysicists than to find geologists or reservoir engineers!"

Appendix 6 – Survey Findings (Students)

Current and past undergraduates were asked about their post-16 qualifications and in particular about their grades in physics, mathematics, the subjects normally required for entry. They were asked how they became aware of geophysics and why they chose to read it at university. Their opinions were sought on why their contemporaries did not elect to read geophysics. Current undergraduates were asked to rate (on a scale of 1-5) various aspects of the courses they did or were doing at the university and on whether they thought that the physics and mathematics they did at school were adequate for the physics, maths, geophysics and computing components of their degree courses. They were also asked about their career aspirations. Past graduates were also asked about their post-graduate experiences including the nature of their employment, salary, and the relevance of the various skills acquired at university to their current employment. The findings from these questionnaires are summarised below.

Gender and ethnicity

Of the response to the questionnaires, female students constitute approximately 40% of current undergraduates and 20% of past graduate students:

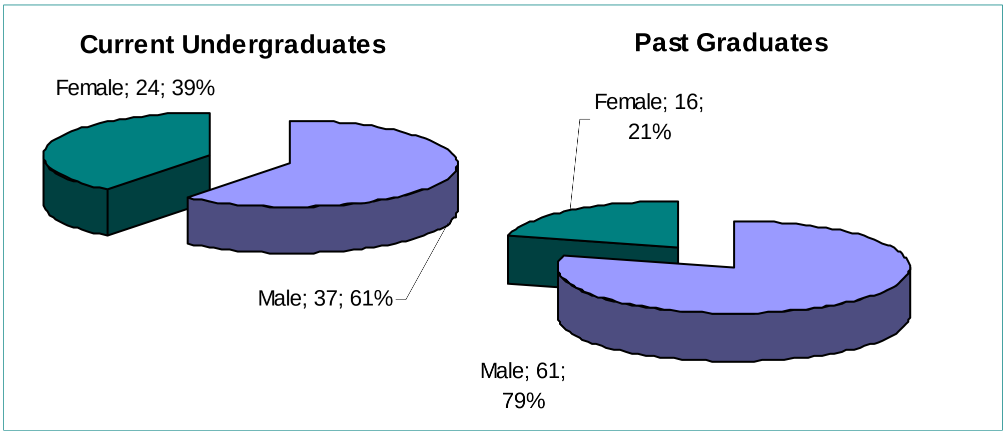

Figure 12. Gender distribution of undergraduates. The data labels give the category, number of responses and the percentage this represents.

The overwhelming majority of past and present undergraduates are of white British ethnic origin, with other ethnic groups comprising only 11% of past and present students:

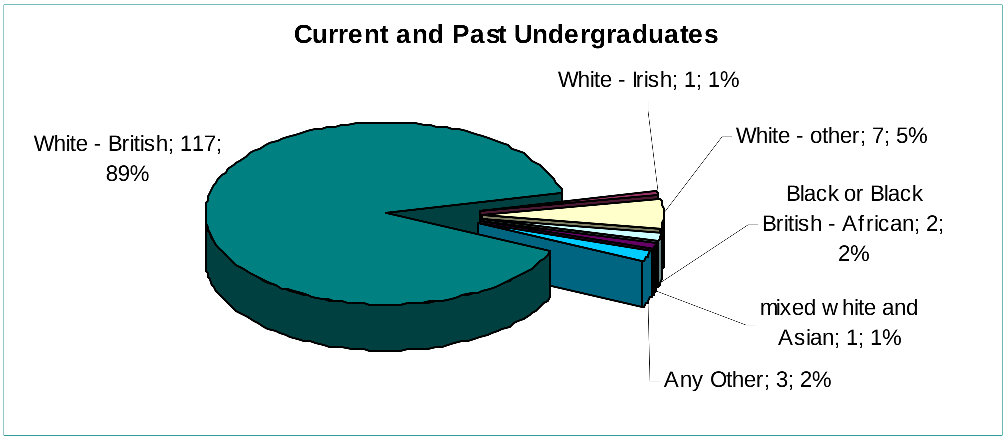

Figure 13. Student ethnic distribution. The data labels give the category, number of responses and the percentage this represents

The cause for this poor diversity in ethnic distribution was not revealed by this survey.

Post-16 qualifications

Post-16 qualifications in mathematics and physics are required as standard for UK degree courses in geophysics. The subjects studied for additional post-16 qualifications vary widely, but chemistry, geography and geology are the most popular subjects:

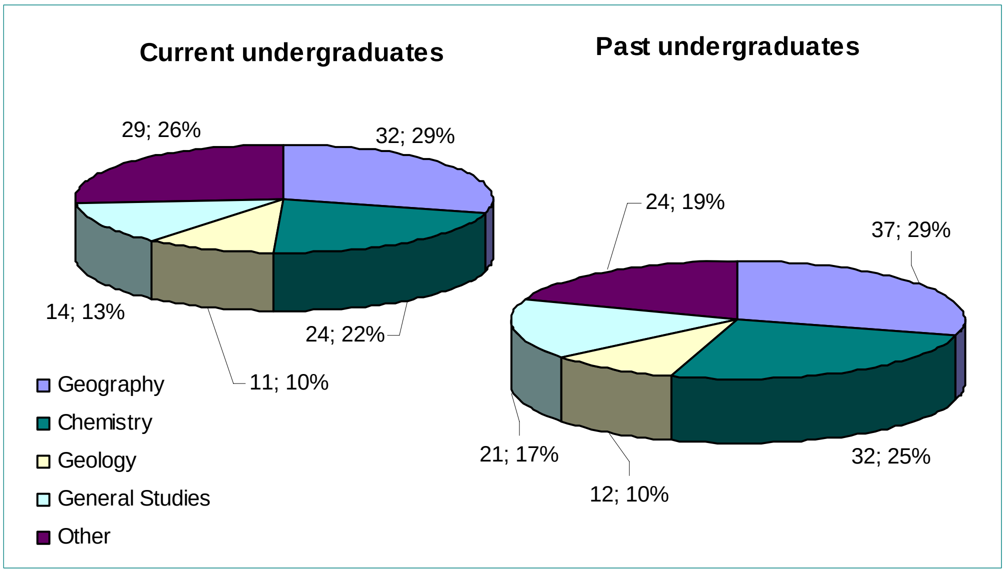

Figure 14. Post-16 qualifications in addition to maths and physics. The data labels give the category, number of responses and the percentage this represents

The broad background and high standard of geophysics students is exemplified in the grades achieved in post-16 qualifications, with an average grade of B achieved in all subjects studied (except for the current students who average an 'A' in geology):

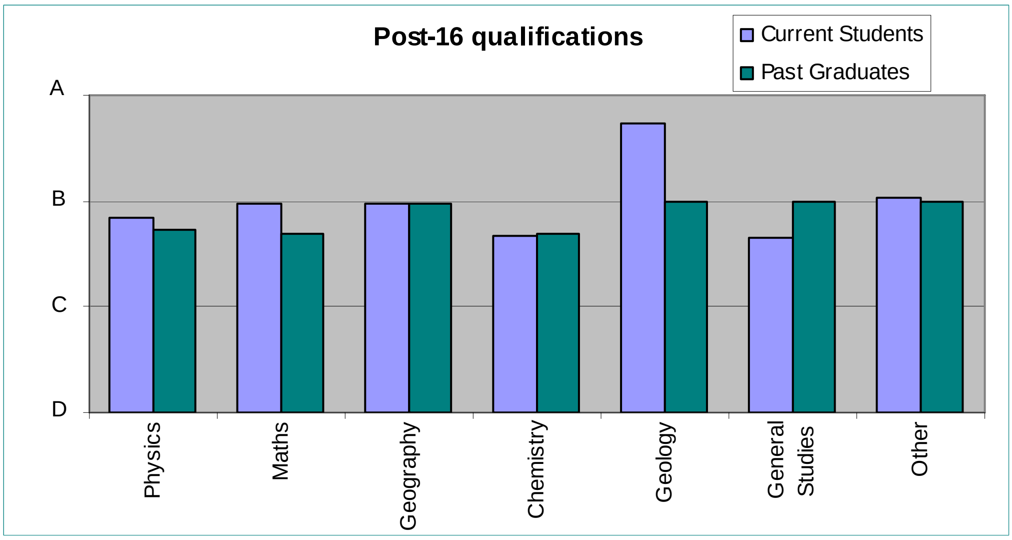

Figure 15. Average grade in post-16 qualifications for current and past undergraduates.

Route into geophysics

The current and past undergraduates were asked for the reasons they choose a geophysics degree. The survey results indicate that the route into geophysics is dominated by a general interest in the subject matter and the attraction of a broadly based subject, with fieldwork, the maths and physics content of the courses and the career options also rating highly:

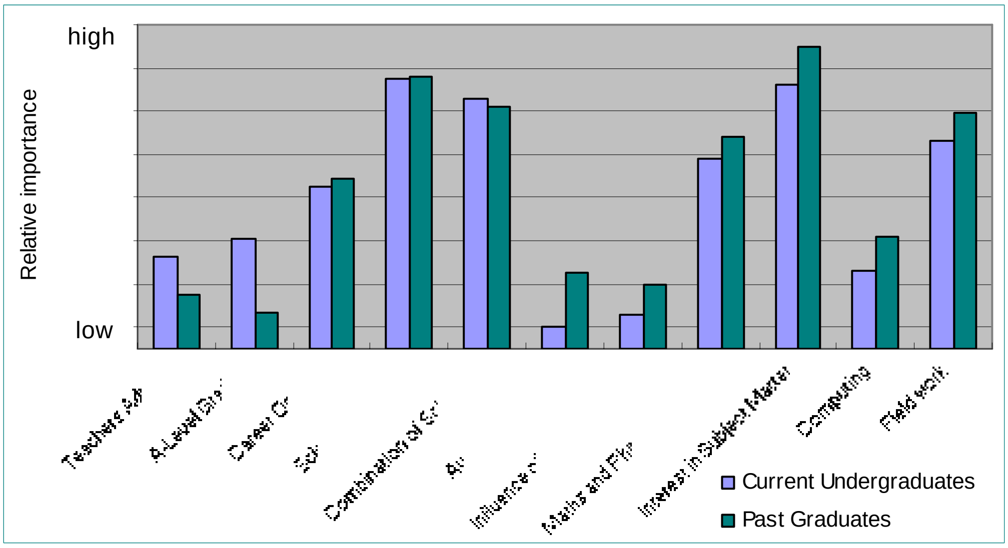

Figure 16. Relative influence of factors on the choice to study geophysics.

Career aspirations

The first choice careers for current geophysics undergraduates' are industry (30%), further training (21%), research (17%), and other (32%)

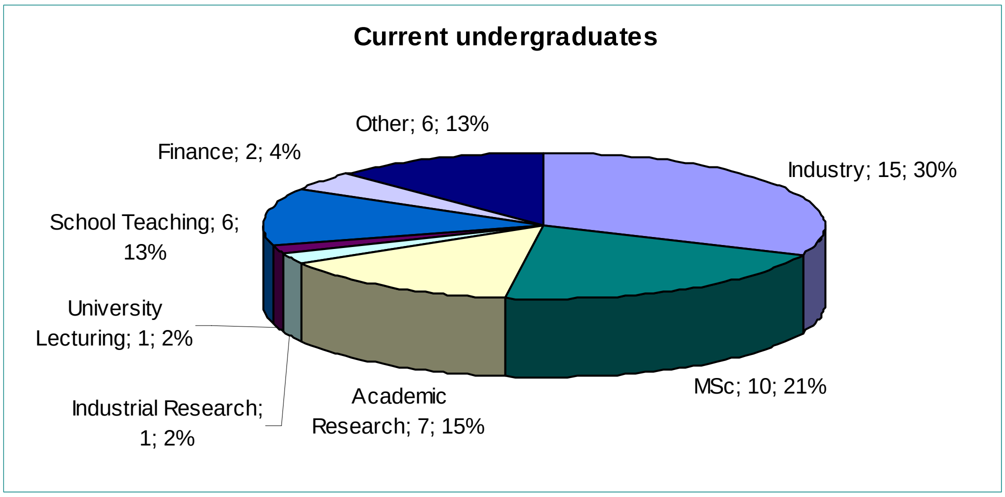

Figure 17. First choice careers for current undergraduates. The data labels give the category, number of responses and the percentage this represents

Employment

The past graduates who responded to the questionnaires are employed in a range of industries, but the results are dominated by the oil industry; however, as the survey was distributed though university departments and Earth science publications the results may be biased towards those graduates who have taken career paths related to Earth science, with those that have left the subject more likely to be unaware of the questionnaire than those who have remained in the field.

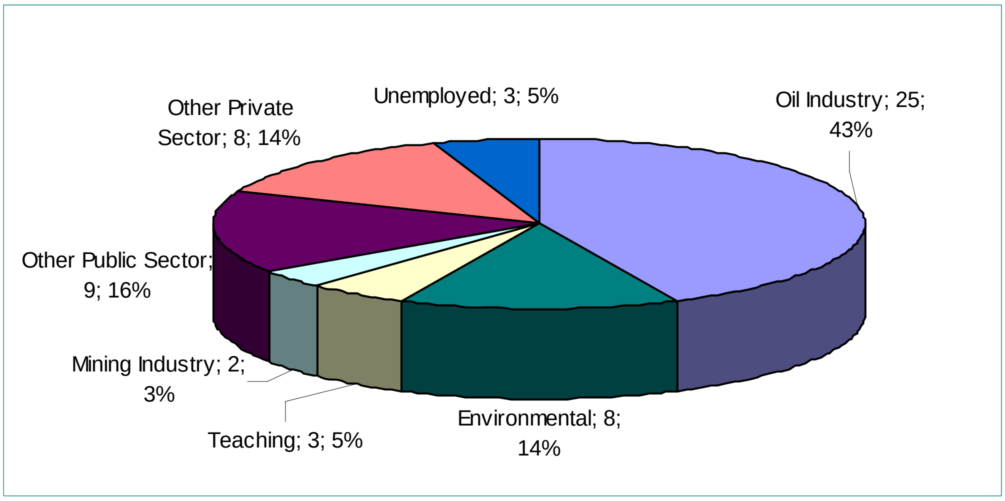

Figure 18. Area of employment of past geophysics graduates. The data labels give the category, number of responses and the percentage this represents

The data on salaries of past graduates is limited by the relatively small number of responses and the uneven age distribution of those who completed the questionnaires:

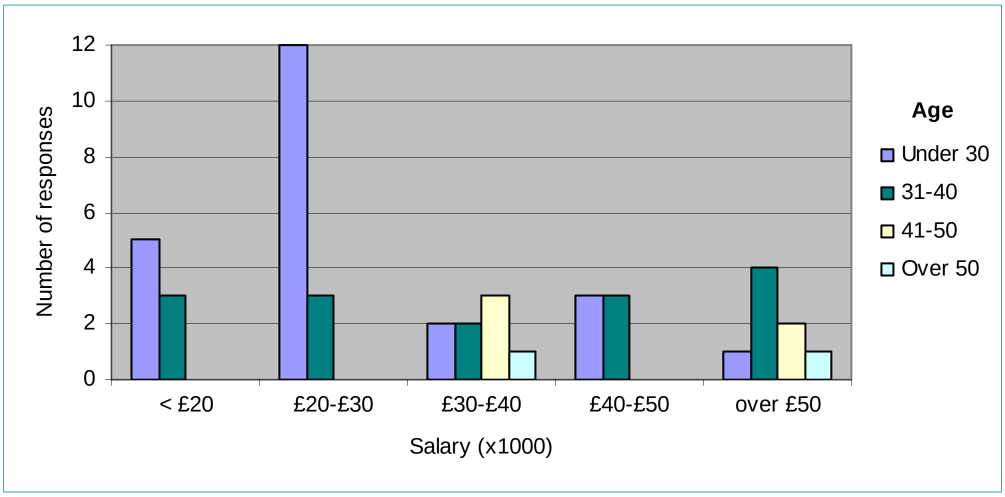

Figure 19. Age-related salary distribution of responders to the questionnaire.

Of the skills acquired during their degree, the past graduates indicated that the soft skills such as data handling and IT skills were used the most frequently, with laboratory skill and subject specific skills used relatively infrequently:

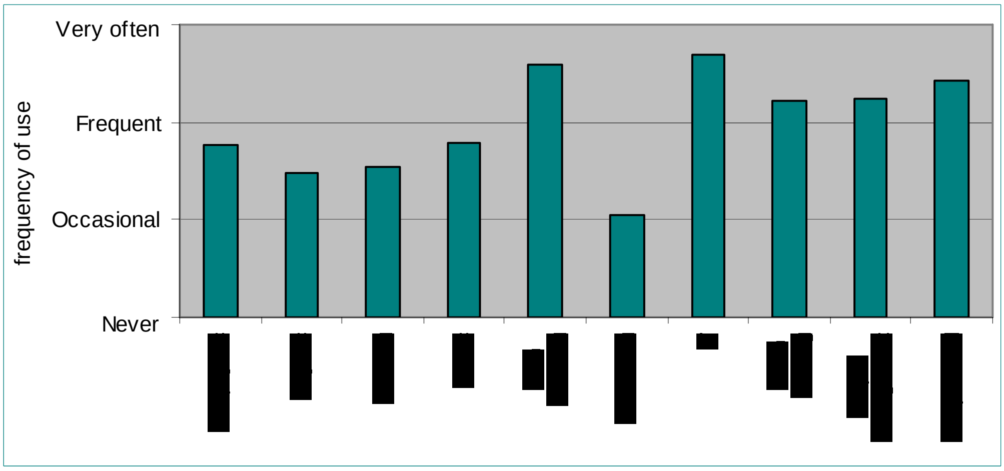

Figure 20. Use of skills acquired during degree.

Appendix 7 – Survey Findings (Schools)

The following tables indicate topics covered in the A-level and GCSE syllabi for geology, geography and physics. At GCSE level there is considerable coverage of geophysical topics within science and physics. At the more in-depth A-level standard, many of these topics are moved from the physics syllabus to the geography syllabus. The most complete introduction to geophysical topics is through geology A-level courses; however, only relatively small numbers of students study geology at this level. Therefore, the most common introduction to geophysics, at A-level standard, is through geography courses.

Table 1. Elements of geophysics in A-level Physics syllabi.

Topic	A-Level Physics					
	AQA GCE ASA Physics A	AQA GCE ASA Physics B	Edexcel Advanced GCE in Physics	Edex Advanced GCE in Physics (Salters Horners)	OCR ASA Level GCE Physics A	OCR ASA Level GCE Physics B (Advancing Physics)
Specification Number	6451	6456	9540	9552	7883	7888
Earthquake waves can reveal the earth's internal structure						
Description of Earth's structure, crust, mantle, core, inner core						
Inference about nature of the mantle from density of Earth						
Nature of P and S waves						
Relative speed of P and S waves						
Ability of waves to penetrate						
Speed increases with depth						
Direction change occurs at boundaries (refraction)						
Interpretation of seismic wave paths						
Evidence for tectonic plates, fossil, lithological						
Tectonic movement and rock cycle						
Tectonic processes and mountain						
Tectonic plates driven by convection						
Earthquakes and volcanoes at plate boundaries						
Focus and epicentre						
Difficulty in predicting earthquakes						
Nature of tectonic boundaries						
Sea floor spreading and magnetic						
Movement of magnetic poles evidence tectonics						
Mention 'seismographs' or						
Seismograms indicate the speed of						
History of Wegener's theory						
Buiding design related to earthquakes				x		
Detection of earthquake waves				x		
Measurement/monitoring of						
Richter Scale						
Management of the earthquake hazard						
Tsunami activity						
Number examined in Summer 2004	5353	2469	6263	2075	1507	1592

Table 2. Elements of geophysics in A-level Geography syllabi.

	A-Level Geography					
Topic	AQA GCE ASAGeography A	AQA GCE ASAGeography B	Edex Advanced GCE in Geography A	Edex Advanced GCE in Geography B	OCR ASA Level GCE Geography A	OCR ASA Level GCE Geography B
Specification Number	*6031*	*6036*	*1312*	*1313*	*7832*	*7833*
Earthquake waves can reveal the earth's internal structure						
Description of Earth's structure, crust, mantle, core, inner core						
Inference about nature of the mantle from density of Earth						
Nature of P and S waves	x					
Relative speed of P and S waves						
Ability of waves to penetrate						
Speed increases with depth						
Direction change occurs at boundaries (refraction)						
Interpretation of seismic wave paths						
Evidence for tectonic plates, fossil, lithological	x	x				
Tectonic movement and rock cycle						
Tectonic processes and mountain	x	x				
Tectonic plates driven by convection						
Earthquakes and volcanoes at plate boundaries	x				x	x
Focus and epicentre	x					
Difficulty in predicting earthquakes						
Nature of tectonic boundaries	x	x			x	
Sea floor spreading and magnetic		x				
Movement of magnetic poles evidence tectonics						
Mention 'seismographs' or						
Seismograms indicate the speed of						
History of Wegener's theory	x					
Buiding design related to earthquakes						
Detection of earthquake waves						
Measurement/monitoring of						
Richter Scale	x					
Management of the earthquake hazard	x			x	x	x
Tsunami activity	x				x	x
Number examined in Summer 2004	*5567*	*4232*	*13271*	*10960*	*4942*	*513*

Table 3. Elements of geophysics in A-level Geology syllabi.

	A-Level Geology	
Topic	WJEC Geology	OCR Geology
Specification Number	*450*	*7884*
Earthquake waves can reveal the earth's internal structure	x	x
Description of Earth's structure, crust, mantle, core, inner core	x	x
Inference about nature of the mantle from density of Earth	x	x
Nature of P and S waves	x	x
Relative speed of P and S waves	x	x
Ability of waves to penetrate		
Speed increases with depth	x	x
Direction change occurs at boundaries (refraction)	x	x
Interpretation of seismic wave paths	x	x
Evidence for tectonic plates, fossil, lithological	x	x
Tectonic movement and rock cycle	x	x
Tectonic processes and mountain building	x	x
Tectonic plates driven by convection	x	
Earthquakes and volcanoes at plate boundaries	x	x
Focus and epicentre	x	x
Difficulty in predicting earthquakes	x	x
Nature of tectonic boundaries	x	x
Sea floor spreading and magnetic	x	x
Movement of magnetic poles evidence tectonics	x	x
Mention 'seismographs' or 'seismometer'	x	x
Seismograms indicate the speed of waves	x	x
History of Wegener's theory		
Buiding design related to earthquakes	x	
Detection of earthquake waves mentioned	x	x
Measurement/monitoring of earthquakes	x	x
Richter Scale	x	x
Management of the earthquake hazard	x	x
Tsunami activity	x	x
Number examined in Summer 2004	*883*	*842*

Table 4. Elements of geophysics in GCSE Physics syllabi.

Topic	GCSE Physics: AQA GCSE Physics A (Modular)	AQA GCSE Physics B	Edexcel GCSE in Physics A	Edexcel GCSE in Physics B	OCR GCSE Physics
Specification Number	*3453*	*3451*	*1540*	*1549*	*1982*
Earthquake waves can reveal the earth's internal structure	x	x	x	x	x
Description of Earth's structure, crust, mantle, core, inner core	x	x			
Inference about nature of the mantle from density of Earth	x	x			
Nature of P and S waves	x	x			x
Relative speed of P and S waves	x	x			x
Ability of waves to penetrate	x	x	x	x	x
Speed increases with depth	x	x			
Direction change occurs at boundaries (refraction)	x	x			
Interpretation of seismic wave paths	x	x			
Evidence for tectonic plates, fossil, lithological	x	x			
Tectonic movement and rock cycle			x	x	x
Tectonic processes and mountain					
Tectonic plates driven by convection	x	x			x
Earthquakes and volcanoes at plate boundaries	x	x			
Focus and epicentre					
Difficulty in predicting earthquakes	x	x			
Nature of tectonic boundaries	x	x	x	x	
Sea floor spreading and magnetic	x	x			
Movement of magnetic poles evidence tectonics					
Mention 'seismographs' or	x	x			x
Seismograms indicate the speed of					x
History of Wegener's theory	x	x			
Buiding design related to earthquakes					
Detection of earthquake waves					
Measurement/monitoring of					
Richter Scale					
Management of the earthquake hazard					
Tsunami activity					
Number examined in Summer 2004	*8077*	*17545*			*10245*

Table 5. Elements of geophysics in GCSE Science syllabi.

	GCSE Science						
Topic	AQA Double Award Coordinated	AQA Double Award Modular	Edexcel GCSE in Science Double Award A	Edexcel GCSE in Science Double Award B (Modular)	OCR GCSE Science Double Award A	OCR GCSE Science Double Award B	OCR GCSE Science Double Award C (Salters)
Specification Number	*3462*	*3468*	*1522*	*1536*	*1983*	*1977*	*1974*
Earthquake waves can reveal the earth's internal structure	x	x	x	x	x		x
Description of Earth's structure, crust, mantle, core, inner core	x	x					x
Inference about nature of the mantle from density of Earth							
Nature of P and S waves	x	x			x		x
Relative speed of P and S waves	x	x			x		
Ability of waves to penetrate	x	x			x		
Speed increases with depth	x	x					
Direction change occurs at boundaries (refraction)							
Interpretation of seismic wave paths	x	x					
Evidence for tectonic plates, fossil, lithological	x	x					x
Tectonic movement and rock cycle	x	x	x	x	x		x
Tectonic processes and mountain							
Tectonic plates driven by convection	x	x			x		
Earthquakes and volcanoes at plate boundaries	x	x	x	x			x
Focus and epicentre							
Difficulty in predicting earthquakes							
Nature of tectonic boundaries	x	x	x	x	x		
Sea floor spreading and magnetic	x	x					x
Movement of magnetic poles evidence tectonics							x
Mention 'seismographs' or	x	x			x		x
Seismograms indicate the speed of					x		
History of Wegener's theory	x	x					
Buiding design related to earthquakes							
Detection of earthquake waves							
Measurement/monitoring of							
Richter Scale							
Management of the earthquake hazard							
Tsunami activity							
Number examined in Summer 2004	*77741*	*220122*	*17364*	*74772*	*23194*	*76824*	*14506*

Table 6. Elements of geophysics in GSCE Geography syllabi.

	GCSE Geography							
Topic	AQA GCSEGeography A	AQA GCSEGeography B	AQA GCSEGeography C	Edex GCSE in Geography A	Edex GCSE in Geography B	OCR GCSE Geography A	OCR GCSE Geography B (Avery Hill)	OCR GCSE Geography C (Bristol Project)
Specification Number	*3031*	*3032*	*3033*	*1312*	*1313*	*1986*	*1987*	*1988*
Earthquake waves can reveal the earth's internal structure								
Description of Earth's structure, crust, mantle, core, inner core								
Inference about nature of the mantle from density of Earth								
Nature of P and S waves								
Relative speed of P and S waves								
Ability of waves to penetrate								
Speed increases with depth								
Direction change occurs at boundaries (refraction)								
Interpretation of seismic wave paths								
Evidence for tectonic plates, fossil, lithological	x							
Tectonic movement and rock cycle								
Tectonic processes and mountain	x		x	x				
Tectonic plates driven by convection								
Earthquakes and volcanoes at plate boundaries	x		x	x	x	x		x
Focus and epicentre	x							
Difficulty in predicting earthquakes								
Nature of tectonic boundaries				x	x	x		
Sea floor spreading and magnetic								
Movement of magnetic poles evidence tectonics								
Mention 'seismographs' or								
Seismograms indicate the speed of								
History of Wegener's theory								
Buiding design related to earthquakes								
Detection of earthquake waves								
Measurement/monitoring of	x							x
Richter Scale								
Management of the earthquake hazard	x		x	x	x	x		x
Tsunami activity								
Number examined in Summer 2004	*66660*	*9996*	*15879*	*13271*	*10960*	*25788*	*41501*	*23942*

Table 7. Elements of geophysics in GSCE Geology.

	GCSE Geology
Topic	WJEC
Specification Number	
Earthquake waves can reveal the earth's internal structure	x
Description of Earth's structure, crust, mantle, core, inner core	x
Inference about nature of the mantle from density of Earth	
Nature of P and S waves	x
Relative speed of P and S waves	x
Ability of waves to penetrate	
Speed increases with depth	
Direction change occurs at boundaries (refraction)	
Interpretation of seismic wave paths	
Evidence for tectonic plates, fossil, lithological	x
Tectonic movement and rock cycle	
Tectonic processes and mountain	x
Tectonic plates driven by convection	
Earthquakes and volcanoes at plate boundaries	x
Focus and epicentre	x
Difficulty in predicting earthquakes	
Nature of tectonic boundaries	x
Sea floor spreading and magnetic	
Movement of magnetic poles evidence tectonics	
Mention 'seismographs' or	x
Seismograms indicate the speed of	
History of Wegener's theory	
Buiding design related to earthquakes	
Detection of earthquake waves	x
Measurement/monitoring of	x
Richter Scale	x
Management of the earthquake hazard	x
Tsunami activity	
Number examined in Summer 2004	*709*

GCSE Student Numbers

The numbers of students taking GSCEs in subjects containing an introduction to geophysics topics, or training in the core skills required to study geophysics at a higher level are given in the figure below. Since the early 1990s there has been a continual growth in the popularity of Double Award Science at the expense of the single subjects.

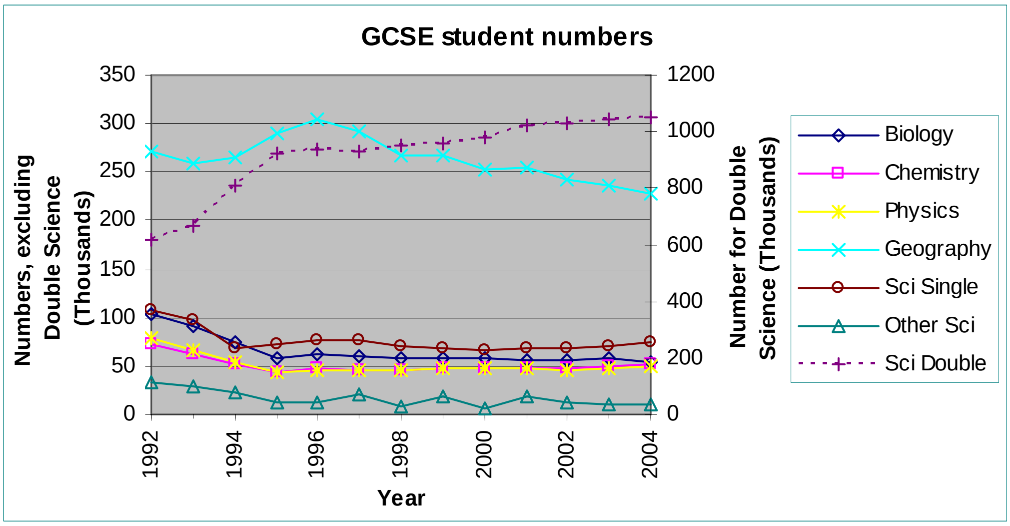

Figure 21. GCSE student numbers for selected subjects. Source: QCA and the Joint Council for General Qualifications

A-level Student Numbers

A-level entries into Physics and Geography have shown a steady decrease through the 1990s and early 2000s, with physics more than halving in entries and geography reducing by approximately 40%. Conversely, for the limited data available, geology appears to have maintained a stable, if relatively small, intake.

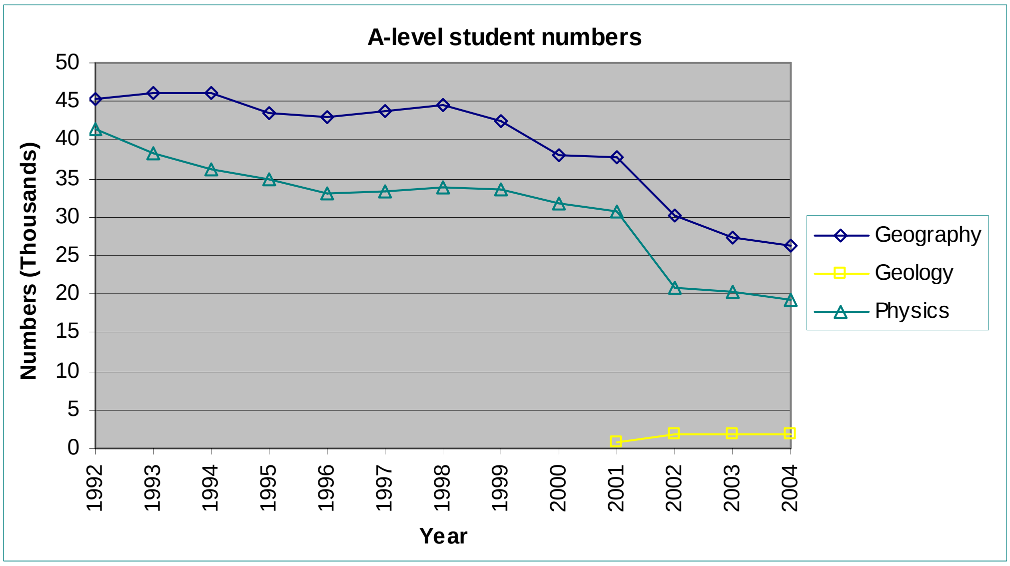

Figure 22. QCA A-level entries for Geography, Geology and Physics (pre-2000 Geology data is subsumed into 'other science' and entry numbers are unavailable).

Appendix 8 – Acronyms

AAPG American Association of Petroleum Geologists
AQA Assessment and Qualification Alliance
CHUGD Committee of Heads of University Geology Departments
CTBT Comprehensive Test Ban Treaty
DfES Department for Education and Science
DTI Department for Trade and Industry
EAGE European Association of Geoscientists and Engineers
EIGG Environmental and Industrial Geophysics
ESTA Earth Sciences Teacher's Association
ESEU Earth Science Education Unit (University of Keele)
GSL Geological Society of London
GTTR Graduate Teacher Training Registry
HEFCE Higher Education Funding Council for England
HESA Higher Education Statistics Agency
IAG International Association for Geodesy
IAGA International Association for Geomagnetism and Aeronomy
IASPEI International Association for Seismology and the Earth's Interior
IUGS International Union of Geological Sciences
IMMM Institute of Materials, Minerals and Mining
IoP Institute of Physics
LEA Local Education authority
NERC Natural Environment Research Council
ONS Office for National Statistics
QAA Quality Assurance Authority
RAE Research Assessment Exercise
RAS Royal Astronomical Society
SEAF Scottish Earth Science Forum
SEG Society of Exploration Geophysicists
SET Science, Engineering and Technology
SETNET Science, Engineering, Technology and Mathematics Network
SQA Scottish Qualification Authority
STEM Science, Technology, Engineering and Mathematics
UAS Undergraduate Ambassador Scheme
UCAS Universities and Colleges Admissions Service
UNESCO United Nations Educational, Scientific and Cultural Organisation