GEOSCIENCE:

Gaining Ground

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Geological Survey of Ireland (GSI)
Beggars Bush
Haddington Road
Dublin 4

Phone:	+353 1 678 2000
Reception:	+353 1 678 2880
Lo-call:	1890 44 99 00
Fax:	+353 1 668 1782
e-mail:	gsisales@gsi.ie
Websites:	www.gsi.ie
	www.eurogeosurveys.org
	www.planetearth.ie

CONTENTS

SUMMARY

This study defines the contribution made by the geoscience sector to the Irish economy. Its activity has an enormous impact on the quality and standard of living, and as such is an essential element of economic policy and spatial planning. Ireland has a small, but flourishing, open economy, with a Gross National Product (GNP) of €149.1 billion for a population of 4.17 million in 2006. The geosciences have been a significant contributor to the success of the Irish economy.

The total direct value added to the Irish economy by the geoscience sector in 2006 was €3.3 billion, representing 2.24% of GNP. In addition, the geoscience sector made a substantial indirect contribution to GNP, because of the low import content of its inputs, and the combined direct and indirect contributions of the sector to the 2006 economy was €4.24 billion (or 3% of GNP).

As a relatively capital-intensive sector of the economy, the employment share of geoscience is much lower than its share of value added: in 2006 the geoscience sector employed over 30,000 people, or 1.4% of total Irish employment. Salaries among geoscience professionals tend to lie in the mid to upper range for science and engineering salaries in UK and Ireland. The sector makes a valuable contribution to balanced regional development because it provides attractively paid work in rurally-based enterprises.

The majority of private geoscience businesses reported strong growth trends over the past five years and anticipated continued growth in 2008. There is an underlying stability in the sector driven by regulatory requirements under international, EU and Irish legislation. However the current slowdown in the construction sector may have a negative impact on many aspects of the sector.

Third level institutions in Ireland and Northern Ireland receive approximately €7.9m per annum in funding for geoscience research. In 2007, geoscience received a funding boost under the National Geoscience Programme and the Marine Research Programme of the National Development Plan (2007-2013). However funds provided to geoscience by the key national funding mechanisms, Programme for Research in Third Level Institutions (PRTLI) and Science Foundation Ireland (SFI), amounts to no more than 5% of their budgets. This reflects the relatively low societal value placed on geoscience research in Ireland at present.

An international comparison of spending on public sector geoscience (based on geological survey organisations) indicated that Ireland's spending on its geological survey, at US$1.03 per capita, is similar to that of Great Britain, but is less than 10% that of Finland. Basic geoscientific research and knowledge is close to a pure public good and the private sector will not compensate for any deficiencies in public spending in this area. Adequately supported geoscience services and research are essential to meet challenges such as the supply of natural resources, the mitigation of climate change and the need for balanced environmental and socio-economic development.

INTRODUCTION

Ireland has a small, but flourishing, open economy, with a Gross National Product (GNP) of €149.1 billion for a population of 4.17 million in 2006. Geoscience has been a significant contributor to Irish economic success. Its activity has an enormous impact on the quality and standard of living, and as such is an essential element of economic policy, spatial planning and environmental regulation. The National Geoscience Programme (NGP), 2007-2013, published last year by the Royal Irish Academy and the Geological Survey of Ireland, estimated that geoscience-based industry contributes more than €2 billion annually to the Irish economy, derived largely from mine production of zinc and lead, quarrying of aggregates for construction, gypsum for plasterboard, as well as dimension stone and natural gas production. This value estimate is generally regarded as conservative.The geoscience sector operates across a range of production (quarrying, mining, mineral processing and fabrication) and service-style (exploration, geological, geo-engineering, geophysical, laboratory, hydrogeological, energy and environmental) disciplines, as well as providing the basis for many crafts and landscape-based tourism.

Many people working within a geoscience discipline in Ireland would not readily identify themselves as linked to geoscience. Similarly, many consumers would be unaware that many everyday products are derived from geoscientific activity, such as houses and roads (from aggregates, cement and concrete blocks), cars (from iron and other metal ores) and household goods (from clay and silica minerals). Thus the challenge is to quantify the value of such deeply embedded economic activities, which are largely lost behind other more clearly defined economic sectors.

In economic terms, 'Geoscience' is somewhat imprecise as an activity and has not yet become accepted as a defined sector by statisticians in Irish and international statistical offices. A conservative approach to its definition has been adopted here and only those sectors of the Central Statistics Office's (CSO) NACE Rev 1.1 classification of economic sectors with a recognisable geoscientific dependence have been included (Table 1). The CSO Input-Output Tables can provide not only the *direct* contribution of the geoscience sector to national output, but also its *indirect* contribution through the inputs from other sectors of the economy. This recognises that all components of the economy are interlinked. However, for reasons of age (2000), coverage and structure of the data, it was decided not to rely wholly on Input-Output analysis in arriving at the indirect contribution. Other CSO surveys were also examined, principally, the Census of Industrial Production, the Annual Census of Services and the PRODCOM series. With the exception of PRODCOM, which was available for 2005, the other two series were only available for 2004.

In addition a distinction has been made between "core" activities where there are higher geoscience inputs, and "non-core" activities which have lesser inputs. Given the diverse nature of geoscience activity, two distinct methods were employed in this study: a top-down disaggregation of national published data, as described above, and a bottom-up estimate from surveys of geoscience practitioners measured at the level of individual businesses, agencies and institutions. Both methods facilitated the estimation of sectoral value and impact, as well as potential multiplier effects. The bottom-up method produced additional qualitative data and trends in the geoscience market. Using a triangulation method, the various results were combined so that realistic results were achieved.

A survey of participants in the geoscience sector, which supplemented the information publicly available in the 2006 accounts of relevant public companies, such as Bord Na Móna and Bord Gáis Eireann, had three elements. The first was a questionnaire sent to a broad range of practitioners in the geoscience sector, seeking information on employee numbers and the costs and gross value added of the firm (for 2006). Secondly, in-depth interviews with key participants tested the quantitative results emerging from the questionnaire survey and also provided qualitative direction as to emerging trends in geoscience. Thirdly, desk and web-based research was conducted to source printed reports, company returns to the Companies Registration Office (CRO), the CSO and the UK Office for National Statistics, as well as a range of websites for company, academic and international data.

The total number of questionnaires distributed to private industry respondents was 51, with an 84% response rate, while 10 of 14 academics replied (71% response), 5 of 7 statutory agencies and authorities (71%) and there was 100% response from 7 geological surveys contacted (including GSI).

The Geological Survey of Ireland (GSI) commissioned this study to characterise the value, both direct and indirect, to the economy of the full range of production, processing, services, research and education across the geoscience sub-sectors. The study demonstrates that the impact of the geoscience sector in Ireland in its totality is considerably larger than has previously been recognised. This report is an edited version of the following full study: The CSA Group with Jerome Casey and Co. Ltd. (2007). Economic study of the impact of the geoscience sector in Ireland. (48 pages).

Table 1. Core and non-core geoscience activities

CORE ACTIVITIES
Mining/mineral exploration
Petroleum exploration/production
Extraction of construction materials
Extraction of peat
Geoscience consultancies
Engineering/geotechnical consultancies
Laboratories
Drilling companies
Public sector geoscience
Academic research

NON-CORE ACTIVITIES
Manufacture of construction materials
Distribution of natural gas
Geoscience contribution to local authorities
Landscape tourism
Arts and crafts

Based on the Central Statistics Office's NACE Rev1.1 classification

PROFILE OF THE GEOSCIENCE SECTOR IN IRELAND

Based on the approach outlined above, this study has estimated that the total direct value added to the Irish economy by the geoscience sector in 2006 was €3.3 billion, representing 2.24% of Gross National Product (GNP). In addition, the geoscience sector made a substantial indirect contribution to GNP, because of the low import content of its inputs, and the combined direct and indirect contributions of the sector to the 2006 economy was €4.24 billion (or 3% of GNP).

As a relatively capital-intensive sector of the economy, the employment share of geoscience is much lower than its share of value added: in 2006 the geoscience sector employed over 30,000 people, or 1.4% of total Irish employment. The turnover, gross value added (GVA) and employment of the geoscience sector are summarized in Table 2.

The GVA is defined as gross domestic sales less gross industrial costs, that is, the value added by both labour and capital. The sum of GVA for all sectors (after adjusting for taxes, subsidies and external income) is the GNP. GNP is considered to be the total value of all final goods and services produced within a country in a particular year, plus income earned by its citizens (including income of those located abroad), minus income of non-residents located in that country.

Mining/ Mineral Exploration

There are currently three operating base metal (zinc-lead) mines in Ireland at Navan (Tara Boliden), Lisheen (Anglo American) and Galmoy (Lundin Mining). For Navan, turnover for 2004 was reported at €121.5m, with a Gross Value Added (GVA) calculated at €93.6m based on CSO multipliers. Figures for Lisheen 2006 outputs and turnover were reported globally through corporate Anglo American returns, but a conservative turnover of €100m, with GVA of €77m, has been calculated for this study. Galmoy mine had a turnover of €95m for 2006, with an estimated value added of €65m. Total gross value added for mining in Ireland was calculated at €235.6m, based on an aggregate turnover of €316.5m.

Mining is no longer a labour-intensive activity but it provides well paid employment. Total direct geoscience jobs reported by mining companies were 1,250 for 2006, with average salaries in the range of €53-63,000 per annum, significantly above the industrial average.

With the recent boom in base metal and gold prices, significant activity was reported by Prospecting Licence (PL) holders in Ireland in 2006. Total direct expenditure for all PLs was €6.9m, which reflected an increase of 52% over 2005 exploration expenditures. Total direct expenditure on mine exploratory drilling for base metals, proximal to the Navan, Lisheen and Galmoy operating mines was €3.3m in 2006, similar to that carried out in 2005. Total value added for all exploration activity is calculated at €6.5m, based on a turnover of €10.2m. It is calculated that up to 100 geoscience jobs are created through such activity.

Data for mineral exploration and state mining facilities were obtained from questionnaires, Companies Registration Office (CRO) annual company returns and from Exploration & Mining Division of DCENR. GVA was usually derived from turnover less gross industrial costs: where data gaps existed, turnover/GVA multipliers were adopted from various CSO sources.

A number of Irish-based exploration companies operate almost exclusively outside of Ireland such as Ormonde Mining, Kenmare Resources and Navan Resources with most (over 90%) expenditures incurred outside of the state and only limited value addition in-state. Although they do not contribute a quantified value to the sector, they provide valuable experience for geoscientists and ensure that a significant skills base remains available to it in Ireland.

While the mining industry in Ireland is not labour intensive, it contributes to balanced regional development as the currently operating mines are rurally located in Counties Meath, Tipperary and Kilkenny with a significant distributed spend in those rural economies. All mineral exploration work is rurally based, with a small corps of highly-skilled and semi-skilled operators.

Table 2. Summary of Geoscience Economic Activity in Ireland 2006

Geoscience Economic Activity	Turnover (attributable to Geoscience)	Jobs (attributable to Geoscience)	Gross Value Added
CORE	**€million**	**Nº**	**€million**
Energy, Mining and Quarrying Extraction			
Mining	316.5	1250	235.6
Mineral Exploration	10.2	100	6.5
Petroleum Production/ Exploration	695.1	690	476.8
Extraction of Construction Materials	1039.0	5,900	554.6
Extraction of Peat	164.1	950	76.6
Private Sector Geoscience Services			
Drilling Companies	113.0	1100	57.6
Geoscience Consultancies	33.5	230	16.4
Engineering/ Geotechnical companies	31.0	550	16.1
Laboratories	5.8	100	3.6
Public Sector Geoscience Services			
Public Sector geoscience activity	11.2	120	6.7
Academic Research	7.9	120	6.0
CORE Sub-Total	**2427.3**	**11,110**	**1456.5**
NONCORE			
Manufacturing of Construction Materials	1389.0	8540	833.4
Geoscience contribution to local authorities	1033.0	7650	436.0
Distribution of natural gas	867.0	670	311.9
Landscape Tourism	399.0	3080	263.3
Arts & Crafts	65.9	650	39.5
NON-CORE Sub-Total	3753.9	20590	1883.9
TOTAL	**6181.2**	**31,700**	**3340.4**
As % Ireland (2006) GNP			**2.24%**

Petroleum Production/ Exploration

In 2006 the only hydrocarbon production was from the Kinsale Head Gas Field by Marathon Oil Ireland Limited. There is some preparatory work ongoing on the Corrib Gas Field which is expected to start production in 2009. More than thirty companies hold offshore petroleum exploration licences and are involved in geological evaluation of potential exploration targets offshore Ireland. Five of these companies have offices with staff based in Ireland. Tullow Oil is an example of a company that employs geoscientists, some of which are based in Dublin, but it does not have exploration or production in Ireland.

For the Kinsale Head Gas Field the value of gas sales was calculated based on known production rates and the relevant marker price in Great Britain. The estimated value of gas sales for 2006 is almost €200m. The gas storage facility at SW Kinsale generates some additional revenue. With investment costs long since written off, the operating costs of gas storage and production is unlikely to have exceeded €20m; thus the GVA for the natural gas sector is estimated at €180m.

The value of business related to the Corrib Gas Field is based on construction activity in 2006. During the construction phase the direct effect of the Corrib project on national and regional value added is the gross labour cost incurred by Shell on the project. GVA is estimated at €295m for 2006.

With respect to the oil exploration activities of companies with offices in Ireland annual reports and financial returns were obtained from the Companies Registration Office. The GVA is based on the turnover, operating expenditure and numbers employed. The multipliers adopted by the CSO in their Input-Output model of the economy were also used to constrain the GVA figures. The GVA for this group is conservatively estimated at €1.6m.

The overall turnover for petroleum production and exploration is €695.1m and its GVA is estimated as €476.8m.

Extraction of Construction Materials

Construction materials add by far the most geoscience value to the economy and have an enormous impact, particularly in rural areas where many quarries are situated. The volume and value of a range of key construction materials, which have undergone rapid expansion in the recent construction boom, are summarised in Table 3.

The aggregates estimate took account of CSO, Irish Concrete Federation (ICF) and GSI estimates, the calculated usage from cement and explosives data, and a comparison with Northern Ireland. The ICF considered that about 67% of material came from rock quarries and 33% from sand and gravel pits. Rock quarries had an estimated output of 84-94 million tonnes in 2006. Grossing this up by the ICF's factor of 0.67 gives a total range of extracted tonnage of 125 – 140m tonnes for 2006. The mid-point of this range gives a final figure of 133m tonnes of material. The turnover of the core activity of construction minerals extraction is €1039m which equates to a GVA of € 554.6m.

A conservative estimate of geoscience-related jobs in this sub-sector is 5,900, most of which are located in rural areas, with consequent significant socio-economic impact and contribution to balanced spatial planning.

Table 3. Volume and value of Ireland's construction materials in 2006

Product	Volume (million tonnes)	Value (€ million)
Extraction		
Aggregate, stone, sand and gravel	133	896
Manufacturing		
Readymixed concrete	8.9	580
Concrete Blocks	541	281
Precast		336
Other incl. asphalt, mortar		192
Total		**2,285**

Extraction of Peat

Bord na Móna is the key state agency for peat production (90%), while a further 10% is extracted by horticultural companies. In combination, the two combined activities accounted for turnover of €164.1 and gross value added of €76.6m, with at least 953 jobs in Bord na Móna attributable to geoscience.

Drilling Companies

Drilling companies are operating across the full range of geoscience disciplines, whereas a decade ago, much of the drilling would have concentrated in the minerals and construction sectors. More recently there has been significant growth in geotechnical, water well and more recently geothermal drilling. Water well drilling is a major business in Ireland with about five major dedicated drilling companies, and some tens of one-man operations. It was reported that while the volume of work was growing, margins were decreasing due to strong competition. It is estimated that 7,500 water wells are completed each year generally with depths of about 50m. In total, the drilling (including water, geotechnical and mineral) sector conservatively accounts for turnover of €113m with an estimated GVA of €57.6m. This is likely to be an underestimate.

Geoscience Consultancies

Fourteen consultancy firms with a significant core geoscience component were identified. A further thirty individual geoscience consultants were identified. The consultancies work across a range of geoscience sub-disciplines: mineral exploration, energy, construction, water, waste, geotechnical engineering, environment, public sector and others, reflecting the full gamut of the geoscience disciplines. The turnover for the consultancy sector in 2006 was estimated at €33.5m. The GVA for this group is conservatively estimated at €16.4m. The firms employ (conservatively) 226 specialised geoscientists and are among the main employers of geoscience graduates from universities and institutes of technology. All consultancies reported strong growth over the past five years, with anticipated growth of 5-20% range in 2008.

As well as questionnaire-sourced data, Annual Reports and financial reports were obtained from the Companies Registration Office. GVA was calculated based on turnover, operating

expenditures and numbers employed. The CSO multipliers from the Input-Output tables were used to constrain the GVA figures.

Engineering/Geotechnical Companies

Ten engineering firms with a strong geotechnical component were identified. The estimated turnover for 2006 in this sector is over €310m. It was assumed that only 10% of the turnover (€31.0m) related to geoscience activity. A conservative GVA for the sector for 2006 is estimated at €16.1m. Information on turnover was obtained from a recent review of the ground investigation industry in Ireland by the Geotechnical Society. The information was collected by issuing a questionnaire to seven ground investigation contractors. These figures were cross checked by reference to the 2006 annual reports and financial returns for a number of large companies that did not participate in the original survey.

Laboratories

Three laboratories that are known to work actively in the geoscience sector were contacted. One lab works 100% in the minerals/ mining sector, including a significant amount of overseas work, while the other two work across a range of sub-sectors, including water (65%), waste (10%) and environmental (20%) sectors. All laboratories showed strong growth in the past five years, particularly in 2006-7 and are optimistic about continued growth. Total turnover of these laboratories was €5.8m, with an added value of €3.6m, based on CSO multipliers.

Public Sector Geoscience Activity

Public sector geoscience activity resides primarily in the Geological Survey of Ireland (GSI), the Petroleum Affairs Division (PAD) and Exploration and Mining Division (EMD) of the Department of Communications, Energy and Natural Resources (DCENR), who are the key actors of the state in gathering and providing information (GSI, PAD), as well as regulation (EMD, PAD) of geoscience economic activities in the minerals and petroleum fields. Geoscience is considered to be the core activity of these agencies.

Additionally, a level of public geoscience activity is carried out by the Marine Institute (MI), Sustainable Energy Ireland (SEI), Environmental Protection Agency (EPA), Teagasc and Ordnance Survey Ireland (OSi). It is difficult to ascertain the exact geoscience contribution of these agencies, but a conservative estimate and multiplier have been allocated. OSi map sales have not been included as a geoscience activity, although arguably they could be added to the overall figure.

Overall, core public sector geoscience turnover was calculated at €11.2million (Table 4.a), with value added of €6.7million. These figures do not include the research budgets which are included under ‘Academic Research’ (see Table 4.b). Chapter 4 contains additional discussion of public sector geoscience activity.

Table 4. Geoscience funding (1999-2007)

	€ million
GSI	45.00
EPA	14.48
Met Eireann	8.79
Marine Institute	8.00
Other	1.60
TOTAL (7years)	**78.05**
TOTAL PER ANNUM	**11.20**
Note: ***In Northern Ireland:GSNI (TELLUS)-€3.06million***	

Public sector services and research (Ireland)

	€ million
NUIG	21.36
UCD	10.26
UCC	3.34
TCD	1.41
NUIM	1.00
UL	0.27
QUB	13.28
UU	1.00
IT *	2.00
DIAS	1.18
Other	0.50
TOTAL (7 years)	**55.60**
TOTAL PER ANNUM	**7.9**
Institutes of Technology (aggregate figure)	

Academic research (Ireland and Northern Ireland)

Academic Research

Geoscience research in geology, geochemistry, geophysics, meteorology, physical geography and aspects of climate change, resides primarily in the universities, the Dublin Institute for Advanced Studies (DIAS) and the Institutes of Technology. The GSI, Marine Institute, Sustainable Energy Ireland, Environmental Protection Agency, Met Eireann, Teagasc and other public sector agencies are significant funders of third level academic research.

As academic research is funded multi-annually generally, it is exceedingly difficult to devise an accurate spend per annum, but pure geoscience research for Ireland and Northern Ireland is estimated to be worth €7.9m per annum (Table 4, b). This has a calculated gross added value of €6.0m based on a CSO multiplier. For further discussion of geoscience research fields and funding sources, see Chapter 3.

Manufacturing of Construction Materials

Manufacturing of construction materials is the single largest contributor to geoscience value added in the economy. The gross value added of this non-core geoscience activity is €833.4.

Geoscience Contribution to Local Authorities

Geoscience contributes substantially to public sector investment in construction projects, road transportation, water supply and environmental protection. The estimate of expenditure by local authorities on activities with geoscience input was approached in two ways.

Several county council engineering departments were interviewed to understand the level of geoscience input in different areas of activity. Very few county councils employ geologists directly. County council engineers use geological data obtained from the GSI and where appropriate use geological consultants to interpret the data. The GSI also contributes significantly to groundwater protection schemes for local authorities. The expenditure and budgets of selected county councils were reviewed for 2005 and 2006. The percentage contribution of geosciences to road

expenditure is small, as low as 5% based on the ground investigation that would be required for road widening/construction. The geoscience contribution to the water services is higher, up to 15% based on the amount of input required on water purification, aquifer vulnerability, water well drilling, interpretation of pump tests, groundwater studies and hydrogeology reports. The geoscience contribution to the environmental expenditure (mainly waste) is small, maybe 2%, and relates only to landfill selection and remediation studies where required.

The second approach was to take the local authority current expenditure by programme group derived from Department of Environment and Local Government publications and website.

The turnover attributable to the three combined geoscience sub-sectors in 2006 was estimated at €55.8m (Roads), €177m (Water) and €18m (Environment), which combined with geo-related public investment in construction projects (bridges, tunnels, etc) brings the total estimate to €1,033m, while GVA was estimated for 2006 at €436m. Approximately 7,650 jobs are attributable to geoscience activities in this non-core public sector activity.

Distribution of Natural Gas

Bord Gáis is the major distributor of natural gas in the state, a direct product of geoscience productive activity. It was estimated that €867m of its turnover is attributable to geoscience. With 98% of Bord Gáis' assets devoted to geoscience, 98% of Bord Gais gross value added was attributed to geoscience. This amounted to €311.9m. More than 670 jobs can be attributed to non-core geoscience activity at Bord Gáis.

Landscape Tourism

Landscape tourism is a growing market, with record numbers over the past decade visiting areas of spectacular landscapes and seascapes such as the Cliffs of Moher, Aillwee Caves, the Giant's Causeway, the Burren, the Copper Coast and Marble Arch Geoparks, as well as engaging in "landscape tourism" activities such as hillwalking and cycling. Overseas tourism in Ireland generated a record €4.3 billion in 2006, representing 8.5% growth on 2005, most of it derived from UK, Europe and USA. Walking and cycling tourism revenues in Ireland and Northern Ireland amounted to €309.3m and €65.1m respectively in 2006 (413,000 and 132,000 visitors respectively).

If we consider the numbers who visit key geo-tourism sites, then at least 900,000 visitors in Ireland and 500,000 in Northern Ireland are directly attributable to 'geoscience' landscape tourism. If their average spend for a five day visit is €496 (Tourism Ireland 2006 data), then at least one night, or €100, is attributable to geoscience. This is worth €90m in Ireland and €50m in Northern Ireland.

Thus in Ireland walking and cycling bring revenues of €309m per annum, where at least 900,000 visitors to geo-scenic sites generate €90m, for a total turnover of €399m, with GVA of €263.3m. If Northern Ireland data is included, total landscape tourism revenue is €374m to the all-island economy, with an estimated GVA of €339.5m.

Arts & Crafts

As part of the evaluation of the contribution of geoscience to the arts sector in Ireland, a number of practising artists was consulted about the materials used in their products. Of 1301 craft workers registered with the Craft Council of Ireland (www.ccoi.ie), approximately half (646 artists - 49.7%)

are working in geo-derived materials such as stone, clay, glass, gold and silver, with the bulk of 'geo'-artists working in ceramics/ pottery (41%).

Although Irish pottery clays are locally suitable, consultations with individual artists reveal that most of these 'geo'-materials are imported. For stone workers, the cost of local stone has increased exponentially with building materials in Ireland over the past decade, out of reach for most individual artists. This has meant that many stone sculptors are moving to other media. Stonemasons and mortuary stoneworks are not included in this section of the analysis as their work is picked up readily in the mainstream CSO stone production data.

Given that about 50% of the CCOI membership utilise 'geo-sourced' materials, the value of geoscience attributable to direct and indirect sales of domestic crafts in 2005 is estimated at €65.9 million, or 50% of the total domestic direct and indirect sales (€131.7 million), with GVA of €39.5m.

Economic Trends in Geoscience

Consultees reported significant growth in turnover over the past 2-5 years of between 5-20% in all sub-areas of geoscience activity (especially hydrogeology, mineral production and services such as drilling and laboratories).

It is likely that the current slowdown in the construction sector will have a negative impact on quarrying and manufacturing of construction materials, but the extent of this effect remains to be seen in the coming years. Overall sentiment in the sector is positive with consultees anticipating growth in turnover of up to 10% in 2008. Much of the business activity in geosciences is driven by regulatory requirements in the fields of water, soils, waste, environment and natural resources management.

The IGI graduate geologist survey (2005) indicated an average salary of €20-30,000 for 57% of graduates, with 21% reporting a salary of €30-40,000. These are on a par or slightly higher than British graduate scientist salaries as reported in a recent issue of New Scientist (October 2007). 31 private sector responses in this study were not confined to early-career geoscientists and showed an average salary of €50,900. The indications are that public sector salaries are not lower. It seems that Irish professional geoscience salaries lie within the mid-upper range for science and engineering salaries in UK and Ireland.

There are some labour shortages reported within sub-sectors, notably in geology, hydrogeology and geotechnical engineering, with the international minerals boom attracting many graduates to Australia and Canada.

There are considerable deficiencies in post-graduate geoscience training opportunities in Ireland, with courses in key fields such as hydrogeology and geotechnical engineering unavailable on the island. Thus many graduates choose to pursue further studies overseas, many of whom do not come back, a poor return on taxpayers investment in education. The Dublin Institute of Advanced Studies has recently implemented the Irish Geoscience Graduate Programme, funded under the Griffith Geoscience Research Awards, which may go some way towards harnessing the skills of geoscience graduates to addressing Ireland's challenges in a meaningful way.

ACADEMIC TRAINING AND RESEARCH

The nature and level of training, research and services in the third level sector in Ireland and Northern Ireland were reviewed as part of the study. Information was requested from each university and Institute of Technology in relation to numbers of academics, senior researchers and geo-related graduates. Additionally, information on relevant research programmes and budgets was sought.

The study has concluded that an average of 60 geologists graduate each year from Trinity College Dublin (TCD), University College Dublin (UCD), National University of Ireland Galway (NUIG) and University College Cork (UCC). This figure is supported by the 2005 report (from the Institute of Geologists of Ireland) that about 300 graduates (58% female) graduated from those same universities over the five-year period 1999-2003 with geology as a final year subject. In addition, about 130 geo-graduates per annum are produced by other colleges and institutes of technology in Ireland and Northern Ireland, of which about 50 are “pure” geology graduates. Approximately 67 academic teaching staff are dedicated to geoscience in third level institutes and universities in Ireland and Northern Ireland.

Additionally, NUIG offers adult evening diplomas in Gemmology (15 students every two years) and Geology (9 per annum). UCC also offers Open University modules for adult students. Six universities (Table 4.b) offer Geography (Quaternary Studies, GIS, Climate, Coastal processes etc) as a major subject: TCD, UCD, UCC, University of Limerick (UL), National University of Ireland Maynooth (NUIM) and Queens University Belfast (QUB). A number of universities offer Environmental Sciences, but with specialised geo-related modules in Geophysics, Landscape, Coastal, Quaternary and Freshwater, such as the University of Ulster at Coleraine (UU).

The Sligo Institute of Technology (IT Sligo) offers basic geoscience-related training (up to 10% of courses) as part of their applied Environmental, Archaeological, Marine and Climate programmes. The percentage related to geoscience is difficult to calculate. Athlone IT (AIT) offers a B. Eng. in Quarry Management, while it has discontinued the once-successful Mineral Sciences course due to lack of exploration demand in the late 1990s. Dundalk Institute of Technology (DKIT) offers courses in Environmental Engineering and through its Centre for Renewable Energies, offers an MSc in Renewable Energies, with a strong emphasis on geothermal energy. Dublin Institute of Technology (Bolton Street) has a Department of Construction Management and Technology, but is not specifically geo-focused. No data were received for graduate numbers of these courses, other than IT Sligo, which has about 29 graduates with geo-related training each year.

The 2005 survey by the Institute of Geologists of Ireland (IGI) indicates that while almost 1100 geology graduates qualified over the previous 30 years, only 300 were still practising in Ireland and Northern Ireland. Considerable numbers of geoscientists left the discipline over this period or else are working abroad. Prior to the 1990s most geoscience graduates worked in the minerals and petroleum sectors while since then they have worked in other sectors (environment, water supply, geotechnics) in increasing numbers.

When participants in the 2005 IGI survey were asked which university courses were most useful to them in their career, field mapping scored very highly, a basic skill for geoscientific observation. Other subjects included computer applications, hydrogeology, engineering geology, petroleum

geology and environmental management systems. Many graduates considered in hindsight that additional tuition in subjects such as these would have been most helpful. Indeed these topics largely reflect the current employment market demands. Because of the lack of modules in GIS, environmental geoscience, earth science and geophysics, most graduates are obliged to undertake these as postgraduate courses, usually research-based and often in the UK. There is a challenge here to the Irish universities to develop appropriate post-graduate courses to meet this demand. The Irish Geoscience Graduate Programme, currently being developed by the Dublin Institute for Advanced Studies, will be one response.

Geoscience research is largely concentrated in defined research groups within third level institutions. Currently, the four largest universities have between them 29 dedicated geo-research groups, in geology, hydrogeology, geophysics, geochemistry, isotope geochemistry, volcanics, structural fault analysis, marine and petroleum geology, geofluids and magmatics. Researchers have attracted multi-annual funds for collaborative applied research in areas such as petroleum, landscape evolution, energy, climate change and magmatic processes. Additionally, research teams channel geo-research through environmental themes such as coastal and freshwater research and climate change.

As part of the preparation for the National Geoscience Programme (NGP), the Royal Irish Academy's Geosciences Committee (RIAGC) commenced a compilation in 2006 of the levels of third level geoscience research funding in Ireland and Northern Ireland. This study presents updated amounts for such research (Table 4.b). Relevant research funding in meteorology, largely disbursed by Met Eireann, has been included. Most of the funding released under the NDP Geoscience (as Griffiths Awards) and Marine (as Beaufort Awards) Programmes will be disbursed to the third level sector to address the core research requirements in meeting Ireland's strategic research objectives.

A total figure for geoscience research funding for any given year is difficult to extract from the data, given that budgets are multi-annual with different start and finish points. There are also some acknowledged gaps in the available data. However, best efforts reveal that in total, Irish third level geoscience research has received at least €55.6 million over seven years, averaging €7.9 million per annum. Using the CSO Input-Output tables to extract Gross Value Added, it is estimated that third level geoscience research sector contributes (conservatively) €6.0 million to the economy per annum in Ireland.

What is notable is that geoscience receives a relatively low proportion of funding available from key state science funding mechanisms such as the Programme of Research in Third Level Institutes (PRTLI) and Science Foundation Ireland (SFI), reflecting the relatively low societal value placed on geoscience research to date in Ireland.

PUBLIC SECTOR GEOSCIENCE

The National Geoscience Programme highlighted the need for research in the fields of geothermal energy; hydrocarbon potential offshore; carbon storage in geological formations; quality & quantity of groundwater resources; impacts of climate change; assessment of inshore marine resources; monitoring networks for geo-hazards such as tsunamis, landslides and radon; and databasing of our aggregate resources to ensure effective and spatial planning. €33 million has been allocated to address these focal areas including the INFOMAR programme.

GSI, as the national geological agency, has the mission to provide geoscience information, services and research to meet Ireland's changing needs. Through its programmes it supports economic development, environmental protection, natural resource management, natural heritage and education. Further information on its strategy and achievements is available on www.gsi.ie, through its Annual Reports and related documents. GSI makes its information available free of charge to users and, in order to maximize its usage, has embarked on a project to make data accessible in digital format over the internet; most of its seabed data is already available in this manner. Its information delivery system has been augmented in recent years by new databases. The Irish National Seabed Survey, completed in 1999-2005, was a major survey of Ireland's extensive offshore areas undertaken in conjunction with the Marine Institute. The new INFOMAR programme, jointly managed with the Marine Institute, will complete data acquisition for the nearshore environment. The resulting databases will assist in the sustainable development of Ireland's marine, coastal and estuarine resources.

GSI has already carried out pilot surveys for systematic geophysical and geochemical coverage of landward areas of Ireland. Called the Resource and Environmental Survey of Ireland (RESI), it requires new funding to implement it and would result in integrated databases to support spatial planning, environmental protection and economic development. In collaboration with a range of partners, GSI has commissioned and supported research on a range of current issues, including the remediation of contaminated land and the potential for carbon capture and storage. GSI is also now a significant manager of dedicated third level geoscience research funding through its administration of the Griffith Geoscience Research Awards, launched in 2007, valued at €10m.

GSNI carries out a similar mission for Northern Ireland as the GSI does for Ireland. GSNI has recently completed the TELLUS project, comprising province-wide geophysical and geochemical coverage and providing high quality databases for the development and environmental management of water, mineral and agricultural resources. Both GSI and GSNI, through providing access to significant datasets, have stimulated significant new geoscience research at third level in Ireland and Northern Ireland. It is difficult to compare the relative societal values placed on geosciences by Ireland and Northern Ireland. However, there is generally a greater public awareness of geosciences in Northern Ireland.

The Marine Institute (MI) in its strategy document Sea Change - A Marine Knowledge, Research & Innovation Strategy for Ireland 2007-2013, focused on three research measures, one of which is Industry, aiming to strengthen the competitiveness of existing marine industries and to support activities that add value to their outputs. Offshore Oil & Gas (including Marine Hydrates) Research is a core component of the Industry measure. MI comment that in 2003, gas production generated

€115 million for Irish firms, while Irish companies received €22m of the €350m worth of contracts awarded for the exploration and development of the Corrib Field. Irish-based and Irish-owned companies also supply some niche technologies to a number of key foreign markets. The total Marine Research Programme was allocated €141million under the NDP 2007-13, a percentage of which will support geoscience.

GSI, Teagasc, MI, SEI, EPA and Met Eireann conduct and fund significant research in applied geoscience which mainly focuses on environmental risk assessment and supporting how Ireland meets its commitments under the Nitrates, Soils and Water Framework Directives.

Teagasc has a dedicated soils research team, which aims to provide a complete digital soil information system for Ireland. Other areas of research deal with phosphorus loss, runoff and water pollution, while nutrient export from farming systems is also under research to address Ireland's commitments under the EU Nitrates Directive. This research also provides scenario analysis to examine the impact of national policies in reducing nitrogen emissions to the environment.

Met Eireann has extensive research programmes in climatology and meteorology, largely channeled through the university sector, while the EPA has very large programmes in climate change, water quality and hydrogeology, land use and soils, many of which are tailored to ensure that Ireland will meet its commitments under EU Directives (Water, Soils, Nitrates).

SEI is focused on renewable energies and has funded studies in conjunction with other agencies on Ireland's potential geothermal energy and capacity for carbon capture and storage.

INTERNATIONAL COMPARISON OF GEOSCIENCE CONTRIBUTION

A number of foreign Geological Surveys were consulted to ascertain whether comparative studies on the value of geoscience had been completed in other jurisdictions. Unfortunately, no readily available studies were to hand, although specific studies were completed on the value and cost-benefit analyses of geoscientific maps in the United States. The net present value (NPV) of the benefits of the National Map was estimated at US$2bilion (€1367m) over a 30 year period. Sensitivity analyses were built into the study, but the overall conclusion was that despite significant outlays of up to US$30 million per annum over 15 years, the National Map programme would break even in 14 years.

It became apparent that studies of the overall impact of geoscience on economies are largely provided by advocacy groups, primarily mining interests in resource-dependent countries. The geoscience contribution to such economies is enormous. Metallic minerals in Australia account for 36-40% of exports worth €30-33 billion and between 4.4% (Australian Mining & Exploration Council, 2005) and 8% (Minerals Council of Australia 2006-2007) of Gross Domestic Product (GDP). If petroleum, gas and minerals are combined, then the total value to the Australian economy is €56 billion. In Canada, mining, minerals, milling and energy account for 10% of GDP, worth an estimated €27.5 billion (core activity), while the value of mining and mineral manufacturing has been calculated at €50 billion (non-core activity), with support services worth an additional €4 billion.

Initially, it had been hoped to provide international comparisons of the extent of the geoscience sector in other countries, but this proved impossible. National accounts data was too aggregated by country, and industrial production data suffered (as was the case in Ireland) from large gaps, for confidentiality reasons. It was considered that a comparison of Geological Survey expenditure by country would provide a reasonable approximation of the extent of public policy commitment to the geoscience sector by country (Table 5). It was assumed, a priori, that countries which were rich in natural resources, such as Canada and Australia, might head the list. To remove anomalies due to fluctuating exchange rates, OECD Purchasing Power Parities (PPPs) were used. Spending comparisons were made on a per capita basis, with an acknowledgement of the relative wealth of the eight countries and regions for which information was available.

Geological Surveys in Northern Ireland, Britain, Sweden, Finland, Germany, United States, Canada and Australia were consulted either directly or through web searches (Table 5). Most respondees focused on the value of the services and products which they provided, rather than the broader value of geosciences within the economy. Ireland, which in relative

Table 5. Geological Survey spending per capita in selected countries

Country	Geol. Survey spending per capita (US $)	GDP per capita as % of OECD average
Resource-poor + Moderately-rich countries		
Ireland	**1.03**	**110***
Northern Ireland	0.62	87
Germany	0.87	105
Great Britain	1.02	109
Sweden	2.35	110
Finland	10.96	105

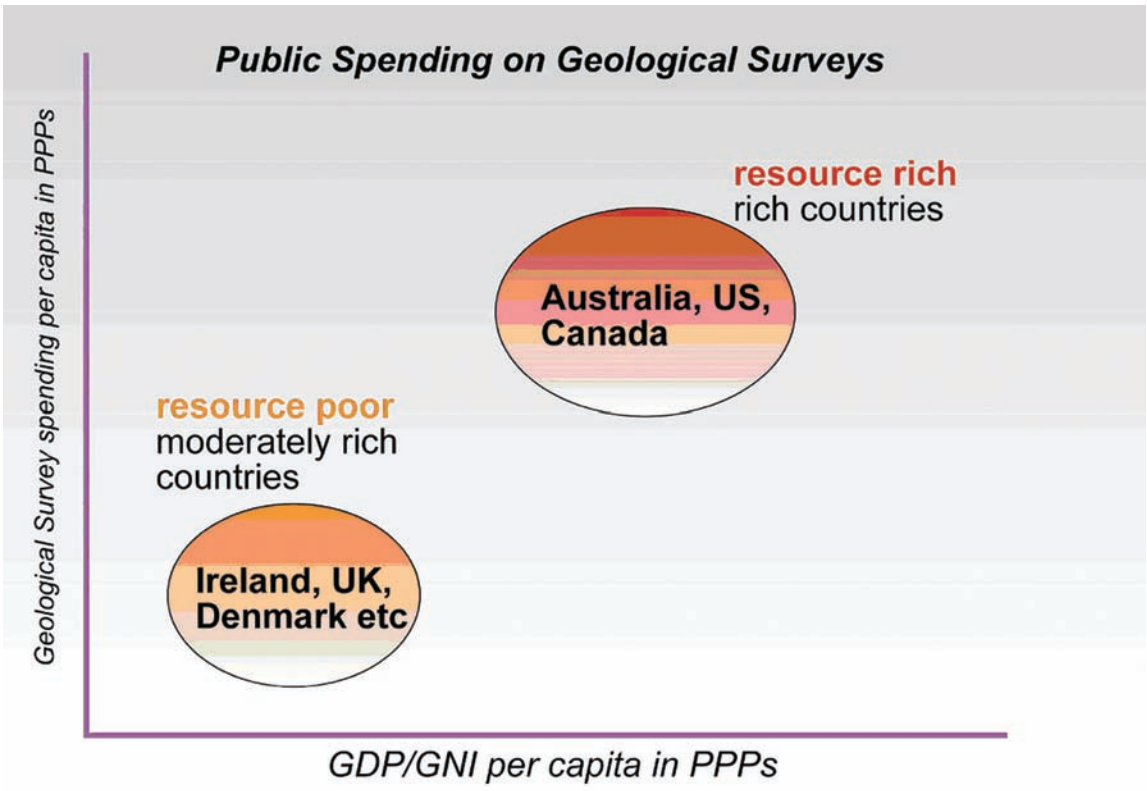
**GNI (Gross National Income)*
used instead of GDP for Ireland because of profit repatriation.

terms is a resource-poor country, but moderately wealthy, spends less per capita on its Geological Survey than Sweden, Finland, Canada, United States or Australia. A UK study estimated that the total value added of UK national output to which the British Geological Survey (BGS) contributed for 2001 lay in the range of £34–61 billion, representing 5%-8% of total UK output (gross value added).

Among economically-wealthy and resource-rich countries such as Australia, Canada and the USA, per capita spending on their respective Geological Surveys (as corrected by an appropriate PPP factor) is 3 to 5 times that of Ireland. This is not unexpected. With a Gross National Income per capita 10% above the OECD average, Ireland was at the top of the grouping of countries entitled Resource-poor + Moderately-rich (Figure 1). Ireland's per capita spending on its geological survey was similar to that of Great Britain but was less than one-half that of Sweden and less than one-tenth that of Finland. Finland and Ireland are two small, peripheral countries of the EU, which share similar mineral resource endowments and successful economies. The disparity in levels of government investment in geoscience between the two countries is only partly explained by the fact that the Finnish government has maintained a commitment to mineral exploration through the GTK (Geological Survey) while Ireland leaves this activity solely to the private sector.

The results of this comparative survey raise questions concerning Ireland's expressed desire to maintain relatively high-value employment against competition from lower-cost economies. It is evident that this requires a stronger focus on improving the knowledge economy which in turn will be dependent on our willingness to invest in science-based education and infrastructure.

Figure 1. Diagram showing Comparative Spending on Geological Surveys



CONCLUSIONS

This study has outlined the contribution made by geoscience to the wider Irish economy. Geoscience activity has an enormous impact on the quality and standard of living, and as such is an essential component of economic policy, spatial planning and sustained research funding. In 2006, Gross Value Added directly in core geoscience activities amounted to €1.4bn and in non-core geoscience activities reached €1.9bn. The total direct value added by the geoscience sector of €3.3bn represented 2.24% of GNP. In addition to the direct contribution of its value added to the economy, the geoscience sector made a substantial indirect contribution to GDP, mainly because of the low import content of its inputs. In 2006, the direct and indirect contribution of geoscience (both core and non-core) to the economy was €4.24bn. This was equivalent to 3.0% of GNP.

Geoscience is one of the more capital-intensive sectors of the economy, so its employment share is much lower than its share of value added. In 2006, geoscience employed over 30,000, or 1.4% of total Irish employment. It makes a valuable contribution to balanced regional development because it provides attractively paid employment in rurally-based enterprises.

The majority of geoscience businesses consulted in the course of the study reported strong growth trends over the past five years, and anticipated positive business growth in 2008. Much of the geoscience services and consultancy demand is driven by regulatory requirements under EU and Irish legislation. However, the current slowdown in the construction sector may have a negative impact on many aspects of geoscience activity.

Third level institutions in Ireland and Northern Ireland receive approximately €7.9 million per annum in research funding. Under the National Development Plan (2007-13), the geosciences received a funding boost under the National Geoscience Programme and the Marine Research Programme. However, less than 5% of the budget of key funding mechanisms such as the Programme of Research in Third Level Institutions (PRTLI) and Science Foundation Ireland is assigned to geoscience.

An international comparison was made of the amounts expended on the Geological Survey service in Ireland and in eight other countries for which data were available. Ireland's spending on its Geological Survey in 2006 of $1.03 per capita equalled that of the UK, but was only one-tenth that of Finland. Basic geoscientific research and knowledge is close to a pure public good and the private sector will not compensate for a deficient public sector in this area. If Ireland is serious about moving up the value chain towards a knowledge-based society, it must lay down stronger foundations in the geoscientific sector, particularly in the areas of research and public services.