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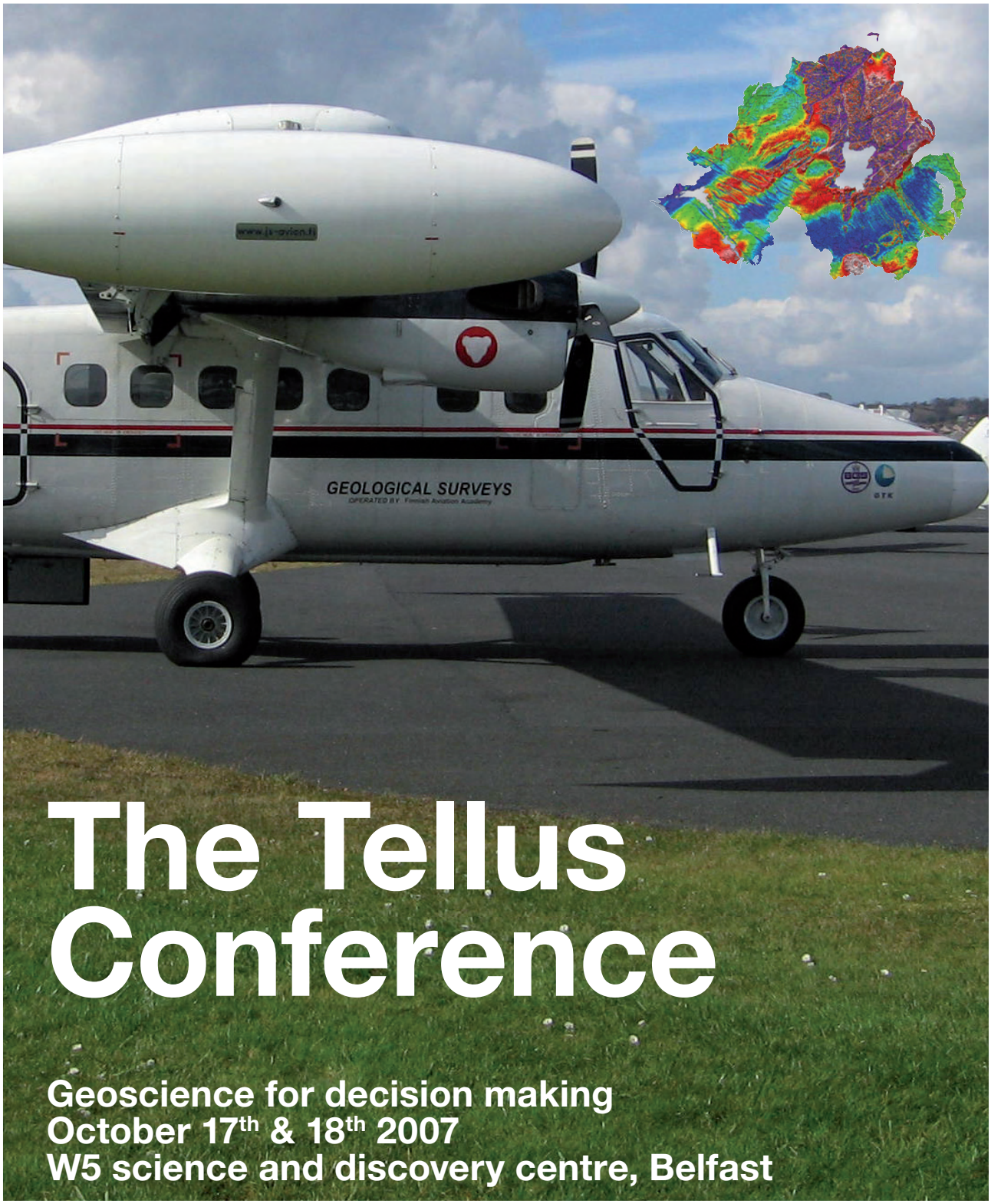
Geological Survey of Northern Ireland



The Tellus Conference

Geoscience for decision making
October 17th & 18th 2007
W5 science and discovery centre, Belfast

TELLUS

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Building Sustainable Prosperity

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Contents

Welcome

Welcome to the Tellus Project Conference and to the W5 science and discovery centre. W5, which aims to demonstrate the wonders of the natural world and the contribution of science to society and the economy, is a fitting venue in which to discuss the Tellus Project.

Over these two days initial results of one of the most focused geoscientific mapping projects ever undertaken in Europe will be presented. The project has produced new geochemical and geophysical information that extends and deepens our knowledge of the geology, soils, natural resources and environment of Northern Ireland. This information can help support the exploration and development of our natural resources, can inform land-use planning and can provide a country-wide baseline of environmental geochemistry.

The British Geological Survey (BGS), in partnership with the Geological Survey of Finland, flew a low-level airborne geophysical survey over Northern Ireland in 2005–6. The results provide new insights into geology, particularly where bedrock is obscured by glacial cover and peat. Delineation of faults, dykes and the major volcanic complexes has been greatly improved. These data contribute significantly to mineral exploration and the definition of natural and anthropogenic hazards.

On the ground, GSNI and BGS teams collected some 31 000 soil, stream-sediment and stream-water samples for analysis. The geochemical results provide a new and consistent baseline standard for some 60 elements and compounds across rural Northern Ireland and also in the main metropolitan centres. The extensive range of new geochemical maps of soils and streams provides a standard against which to monitor change and a means of identifying depleted or potentially toxic levels of key elements or compounds.

The improved mapping has prompted renewed interest in mineral prospecting, and new licenses have been issued as a result. More than half of Northern Ireland is now under mineral prospecting licence or licence application. The project also recognises the important place of the quarry industry in Northern Ireland — a vital source of aggregates for the UK — and GSNI are pleased to have collaborated with the Quarry Products Association (NI) and W5 in mounting a new exhibit about the extractive industries.

Tellus data represent a major resource for industry, regulatory authorities and environmental organizations and provide contextual, baseline geoscience information for managing development sustainably. The project has stimulated academic research into a range of applied geological, environmental and land-use issues and data have been disseminated amongst research groups in Northern Ireland, in GB and as far afield as USA and Canada.

GSNI acknowledge the encouragement and assistance of the British Geological Survey, Geological Survey of Ireland and the United States Geological Survey in the development of a project dealing with the resources and environment. We also acknowledge the support of the Department of Enterprise, Trade and Investment, The Rural Development Programme for Building Sustainable Prosperity, and the Environment and Heritage Service.

We wish you a useful two days here at the Tellus Project Conference and we look forward to your contribution.

EurGeol Garth Earls
Director, GSNI

Wednesday 17th October 2007

0815–0915 Registration and coffee (Level 4)

0915–1040 **Opening (Lecture Theatre)**
Welcome
EurGeol Garth Earls
The Natural Environment Research Council and natural resources
Prof. John Ludden
Earth - the Power of the Planet
Dr Iain Stewart

1040–1110 Coffee and tea (Level 4)

1110–1300 **Session 1: The Tellus surveys and results (Lecture Theatre)**
Chair: Noel Cornick, Assistant Secretary, Department of Enterprise, Trade and Investment

A national geoscience framework for the 21st century
Dr Mick Lee
The Tellus airborne geophysical survey and results
Mike Young
The Tellus geochemical programme — survey and results
Dr Dermot Smyth
Sustainable management of our natural resources
EurGeol Garth Earls

1300–1400 Lunch (Level 4)

1400–1530 **Session 2: Soils, the environment and health (Lecture Theatre)**
Chair: Dr Peadar McArdle, Director, Geological Survey of Ireland

Soils and their environmental significance
Dr Crawford Jordan & Dr Barry Rawlins
Soil geochemistry and impacts on human health
Dr Andrew Tye
The influence of geochemistry on animal health in Northern Ireland
Helen Broadwith
The geochemistry of soils in Greater Belfast
Dr Rory Doherty

1530–1600 Coffee and tea (Level 4)

Wednesday 17th October 2007

1600–1645 **Break-out workshops**
1. Minerals in Northern Ireland: implications of the Tellus results
2. Soils and waters: impacts on human and animal health

1645–1715 Discussion

1715–1830 Poster viewing (Level 4)

The Tellus Conference Reception and Dinner

1830–1930 **Reception and viewing of GSNI/QPA exhibit (Level 2)**
During the reception you are invited to visit the newly inaugurated display, on Level 2, about the quarry industry and its importance to the Northern Ireland economy. This display has been organised jointly by GSNI and the Quarry Products Association Northern Ireland.

1930–2200 **Conference Dinner (Level 2 atrium)**
The guest of honour will be Professor Sir Keith O'Nions FRS, Director General, Science and Innovation in the Department for Innovation, Universities and Skills. Sir Keith was previously Chief Scientific Adviser at MOD from January 2000 to July 2004 and Director General, Science and Innovation and Chief Scientific Adviser in DTI from 2004 onwards.

He attended the University of Nottingham, gained a PhD in Earth Sciences from the University of Alberta and became a Postdoctoral Fellow at the University of Oslo.

From 1971 to 1975 he was Demonstrator and then Lecturer in Geochemistry at the University of Oxford. He became Professor of Geology at Columbia University in 1975, Royal Society Research Professor at Cambridge from 1979 and Head of Earth Sciences at Oxford in 1999.

Keith O'Nions has enjoyed extensive participation in a broad range of academic and technological committees. He became a Fellow of the American Geophysical Union in 1979, and a Member of the Norwegian Academy of Science and Letters in 1980. He is a Fellow of the Royal Society (1983), Honorary Fellow of Indian Academy of Sciences (1998), Fellow Indian National Science Academy (2001), Honorary Fellow Royal Academy of Engineering (2005). He has received Honorary doctorates from a number of Universities.

He has been the chairman, or a member, of a number of Research Council committees over the last 25 years and a member of the Council of Science and Technology from 1998–2000. He was Trustee and Chairman of the Natural History Museum from 1996 to 2005. He received a Knighthood for services to Earth Sciences in the 1999 Queen's Birthday Honours.

Thursday 18th October 2007

0815–0900 Coffee and tea (Level4)

0900–1040 **Session 3: Monitoring man-made influences (Lecture Theatre)**
Chair: Dr Andrew McCormick, Permanent Secretary, Department of Health, Social Services and Public Safety

Surface and groundwater quality — meeting new standards
Dr Silke Hartmann
Human impacts on ground and surface waters
Dr Ulrich Ofterdinger
Pilot environmental airborne geophysical surveys in Ireland
Dr EibhlÍn Doyle
New mapping of natural and man-made radioactivity
Cathy Scheib
Site-investigation and landfill characterisation by airborne geophysics
Dr David Beamish

1040–1110 Coffee and tea (Level4)

1110–1230 **Session 4: Natural resources and sustainable development (Lecture Theatre)**
Chair: Dr Denis Peach, Chief Scientist, British Geological Survey

Quarrying — a major rural industry in Northern Ireland
Andrew Bloodworth
Assessing our untapped energy resources
EurGeol Derek Reay
The scope for carbon capture and storage in Northern Ireland
Michelle Bentham
Information delivery and licensing of GSNI and Tellus data
Mark Patton

1230–1345 Lunch (Level4)

1345–1430 **Break-out workshops**
3. Energy and geology: new perspectives for Northern Ireland
4. Geoscience mapping of urban areas and contaminated sites

1430–1530 Discussion and close

THE NATURAL ENVIRONMENT RESEARCH COUNCIL AND NATURAL RESOURCES

PROF JOHN LUDDEN, EXECUTIVE DIRECTOR BRITISH GEOLOGICAL SURVEY

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John Ludden was appointed Executive Director of BGS in 2006. He graduated in Environmental Sciences at the University of Lancaster and earned a doctorate in Igneous Petrology from the University of Manchester. In 1976 he moved to the USA and Canada where he worked at the Lamont Doherty Earth Institute of Columbia University and with Woods Hole Oceanographic Institution in the USA and was Professor of Geochemistry at the Université de Montréal in Canada. He moved to France in 1994 and served as director of the CNRS - CRPG Centre de Recherche Pétrographiques et Petrographiques and the in Fédération de Recherche « Eau-Sol-Terre » in Nancy, France, where he also taught Early Earth Processes at the French National School of Geology (ENSG-Nancy).

His fields of research include crustal evolution, mafic magmatism through time, and early Earth processes. He has been the lead participant in the Ocean Drilling Programme projects and was the leader of the Precambrian geology part of the Canadian Lithoprobe project which associated the National Environment Research Council, the Geological Survey of Canada and industry. He is author of about 150 published articles in fields ranging from geochemical models of Earth's evolution to high-resolution geophysics applied to mining regions. John is currently President of the European Geosciences Union and the International association of Geochemistry (IAGC).

KEYNOTE
EARTH - THE POWER OF THE PLANET

DR IAIN STEWART

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Iain Stewart is well known as the presenter of the popular and successful BBC TV series 'Journeys from the Centre of the Earth' and 'Journeys into the Ring of Fire'. His next series, 'Earth: the Biography' will be screened in November.

Iain is Senior Lecturer in Geodynamics, School of Earth, Ocean and Environmental Sciences in the Department of Geology at the University of Plymouth. He graduated in Geology and Geography from Strathclyde University in Glasgow and received his PhD from Bristol University for research on the geology of earthquakes in Greece and Turkey. After finishing his PhD in 1990, Iain lectured in geology at Brunel University and in 2002 was appointed Honorary Research Fellow at Glasgow University.

His main research interests are in the broad area of Earth hazards and natural disasters, particularly in terms of identifying past major earthquakes, tsunamis and volcanic eruptions in the Mediterranean region.

A NATIONAL GEOSCIENCE FRAMEWORK FOR THE 21ST CENTURY

DR MICK LEE

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The Tellus Project will underpin sustainable management of the environment, responsible economic development and research into natural and human-induced processes in the shallow geosphere for the next fifty years, and will place Northern Ireland at the forefront of integrated environmental science.

Provision of a national 'framework' of baseline geoscientific data is one of the prime responsibilities of a Geological Survey organisation. Until recently this was often limited to geological maps, low/medium resolution geophysical surveys and variable geochemical coverage. Digital geological data were almost non-existent and the geophysical/geochemical surveys were aimed at understanding the geological structure and resource potential at a regional rather than local scale. This level of information was designed to meet the needs of the mid/late 20th century but is no longer adequate for today's challenges in relation to environmental regulations and issues such as aquifer vulnerability, sustainable land use management, responsible resource development and climate change. Users across the spectrum of government, environmental agencies and industry need a consistent (three-dimensional) geological framework and much more detailed information on the geo-environmental properties of the surface and shallow subsurface. This is a major challenge requiring: migration from analogue/2D to digital/3D geology; comprehensive coverage of multi-element geochemical data (soils, stream sediments and stream waters); and a new generation of high-resolution airborne geophysical surveys (magnetic, radiometric and electro-magnetic). The migration to digital/3D geology is beginning to gather pace but provision of comprehensive geochemical data and modern airborne geophysical surveys is very patchy in many countries. Northern Ireland is a notable exception — DETI's vision in funding the Tellus geochemical and airborne geophysical surveys has provided two key components of the 'next generation' geoscience framework. This will underpin sustainable management of the environment, responsible economic development and research into natural and human-induced processes in the shallow geosphere for the next fifty years, and will place Northern Ireland at the forefront of integrated environmental science.

Mick Lee is Director of Geology and Resources and a member of the BGS Board and Executive Committee (since 2000). He joined BGS as a geophysicist in 1972 and has worked in the UK and overseas on a diverse range of projects including regional geophysical surveys, crustal modelling, geothermal exploration, nuclear waste disposal and structural studies for hydrocarbons exploration. Prior to his current appointment he was manager of the BGS Regional Geophysics Group (1991–2000). As Director of Geology and Resources, Dr Lee is responsible for six multi-disciplinary survey and research programmes to define the surface and sub-surface geology and geo-environmental characteristics of the UK (onshore and offshore) and provide information to underpin sustainable development of the nation's mineral and hydrocarbon resources. The work programme also extends into Europe and world-wide through collaborative international research projects and commissioned contracts.

THE TELLUS AIRBORNE GEOPHYSICAL SURVEY AND RESULTS

MIKE YOUNG

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The Tellus airborne survey has generated high resolution imagery of the surface and subsurface that will promote the exploration and development of mineral resources and provide key data for monitoring the environment.

The survey, flown in 2005/6, was the first regional geophysical survey of Northern Ireland since 1959 and was flown by the Joint Airborne-geoscience Capability (JAC), a partnership of BGS and the Geological Survey of Finland (GTK). The survey was flown 56 m above the ground over rural areas and 244 m over villages and urban areas. Survey lines were spaced 200 m apart. Thanks to this closely spaced sampling, and to the great improvement in instrumental sensitivity since the previous survey, very high resolution images of the magnetic field, electrical conductivity and terrestrial gamma radiation have been produced.

These three methods aid geological mapping by provide complementary information on different rock and soil types and provide new insights into Northern Ireland's geology, particularly where bedrock is obscured by glacial cover and peat. Delineation of faults, dykes and the major volcanic complexes has been greatly improved. Prominent magnetic anomalies include those of the Antrim Lava Group, the swarms of Palaeogene dykes, and the Palaeogene intrusions of south Co. Down. The electrical conductivity image reflects petrological differences between the principal geological formations, areas of increased salinity, expressions of major fault zones, certain industrial effects and signatures of landfills. These electrical data contribute significantly to characterising the natural and anthropogenic properties of the near-surface. Variations in gamma-ray emissions characterise near-surface rocks and soils. Prominent gamma-ray anomalies include those of the intrusive rocks of the Mourne Mountain Complex and parts of the ancient metamorphic rocks in Counties Tyrone and Londonderry. These data are improving the prediction of radon risk and provide a baseline representation of current terrestrial radiation levels.

Mike Young has been manager of the Tellus Project at GSNI since 2004. He graduated in physics from Bristol University and in geophysics from Imperial College. In the 70s he worked on mineral exploration programmes in North and Central America, southern Africa and Iran, before starting the geophysics department of the consulting company Robert Research International in 1979. Over the next 12 years Mike promoted and directed airborne and ground geophysical exploration and mapping projects in 20 countries. From 1991 to 2003 he managed development projects in the water sector in the Sultanate of Oman and in South America. His special interest is the use of geophysics in mineral and groundwater exploration and development, particularly in arid environments.

THE TELLUS GEOCHEMICAL PROGRAMME — SURVEY AND RESULTS

DR DERMOT SMYTH

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Following the Tellus surveys, Northern Ireland is more comprehensively surveyed with geochemical methods than any region of Europe. The surveys have revealed important anomalies associated with precious metal mineralisation and defined areas with depleted or elevated levels of key trace elements.

The Tellus Project conducted three geochemical surveys over the land surface of Northern Ireland between 2004 and 2006:

- Rural soils: sampled at 20 and 50 cm depths on a regular grid at one site per 2 km^2.
- Urban soils: sampled at 20 and 50 cm depths on a regular grid at four sites per km^2.
- Streams sediments and waters: sampled from 1st and 2nd order streams at an average of one site per 2 km^2.

Some 31,000 soil and stream samples were collected from 12,900 sites, including those sampled in 1994–1996 by BGS. Samples were analysed for 60 elements and inorganic compounds. 25% of the urban samples were analysed for a range of semi-volatile organic carbons.

Results of environmental interest include maps of the distribution of nickel, chromium and other metals in soils. The maps show naturally elevated concentrations of these elements over the Antrim Lava Group. The distribution of essential trace elements such as zinc and selenium identifies areas where soils are relatively depleted for agricultural purposes. Elevated anthropogenic levels of some elements, notably tin and lead are associated with urban centres.

Prominent anomalies of precious and base metals were recorded, not only those associated with the known areas of mesothermal quartz vein gold in Co. Tyrone and Co. Armagh, but elsewhere in Co. Down and Co. Antrim. Elevated values for platinum group elements were recorded, notably in stream sediments and soils over the Antrim Lava Group. Elevated concentrations of base metals also occur in soils and streams on the Antrim Lava Group. High nickel values are also associated with dykes in Co. Fermanagh and a major dyke swarm in Co. Down.

Dermot Smyth has a B.Sc. (Hons) degree in Geology from Queen's University, Belfast, a MSc in Petroleum Geology from University College Dublin and a PhD in exploration and environmental geochemistry, also from Queen's. Prior to joining GSNI in 2004 he was employed by BHP-Billiton in prospecting for platinum group elements, and as a consultant to local government and the insurance industry in Northern Ireland. His research interests include exploration and environmental geochemistry and contaminated land investigation using geochemistry and biogeochemistry; orthomagmatic PGE-Cu-Ni deposits; and lode gold mineralization.

SUSTAINABLE MANAGEMENT OF OUR NATURAL RESOURCES

EURGEOL GARTH EARLS

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Mineral extraction is essential to maintain living standards. Exploration and sustainable development of resources, and associated environmental monitoring, require modern, multi-parameter geoscience data. Tellus provides this baseline data for Northern Ireland.

The common perception is that extractive industries represent a challenge to the environment both as sources of pollution and as eyesores on the landscape. The paradox is that very few people want to live next to a mine or quarry yet they accept many of the life benefits that extractive industry provides.

Predictions of world population growth suggest a 50% increase to nine billion by 2050. If demand from developing countries continues to increase then one forecast suggests that, in the next 50 years, we need to extract five times the amount of metal that has been mined to date. Recycling has a part to play but it cannot meet rising demand. Consequently we have no option but to continue mining.

Given this scenario we need to rethink our attitude to the extractive industries. Mines and quarries are now planned with closure in mind and essentially represent transitional land uses. Longer-term views need to be taken regarding our natural resource industries — what presently may be regarded as scar on the landscape in 50 years could represent a site of amenity value to our children.

The concept of sustainable development of minerals goes past the paradox of finite resources and leaves social and industrial skills that can be developed in both new and traditional markets.

The Tellus data provides part of an environmental baseline against which to measure change, while allowing the opportunity for new resources to be defined. It is only through knowing what might be under our feet that we can plan sustainably and responsibly for the future.

Before becoming Director of GSNI in 2002, Garth worked in the exploration and mining industry for 23 years. He was part of the team that discovered gold in Northern Ireland in the 1980s and has also worked in the Cononish gold mine in Scotland. He then became a partner in the CSA Group, one of Europe's leading geological consultancies, where he worked on a global basis for companies searching for gold and base metals. He has taught Professional Practice in geology courses to universities and in recent years he has developed projects relating to landscape tourism and the public understanding of science. Garth is the Chair of the Geosciences Committee of the Royal Irish Academy.

SOILS AND THEIR ENVIRONMENTAL SIGNIFICANCE

DR CRAWFORD JORDAN[1] AND DR BARRY RAWLINS[2]

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Northern Ireland's soils vary widely in composition. Tellus data help to define these variations and identify zones deficient or replete in nutrients. Tellus surveys have mapped soil organic carbon, thus contributing to a statutory requirement to audit variations in soil carbon.

This presentation will describe the distribution of soil types in Northern Ireland, their physical (including hydrological) and chemical characteristics and their environmental significance. In particular, changes in soil pH, phosphorus (P) and organic carbon (SOC) over the 10-year period 1995–2005 will be discussed.

There have been two recent, comprehensive surveys of soils in Northern Ireland which fulfil different objectives. The first full survey of Northern Ireland soils was carried out by staff from the Department of Agriculture and Rural Development (DARD) over the period 1988–1997. During this survey, soils were systematically sampled, described, analysed and classified into soil series, after which soil maps at 1:50,000 scale were created in both paper and digital formats. The survey identified 308 distinctively different soil series developed from 97 soil parent materials.

The later Tellus survey focused on geochemical properties, but also included the measurement of SOC. Regional governments have a statutory requirement to estimate accurately the size and any change in SOC stocks. By combining the Tellus soil survey data with those from the airborne radiometric survey the uncertainty in the estimation of SOC content can be significantly reduced. Quantitative relationships will be demonstrated between: i) the major and some trace element geochemical parameters, and ii) the radiometric survey elements (K, Th and U) and parent materials across the region.

Crawford Jordan has been a Project Leader in DARD's Science Service since 1981 and, subsequently, in the Agri-Food and Biosciences Institute (AFBI), a non-departmental government body sponsored by DARD. His research interests revolve around the impact of agriculture on the environment and how GIS techniques can be used to aid the quantification and mapping of nutrient losses from land to water and to identify areas at risk from pollution including heavy metals, nitrate and phosphorus. He is responsible for all AFBI soil monitoring activities and his team have carried out a number of countrywide soil surveys in recent years, the latest in January–March 2005.

Barry Rawlins manages the soil properties and processes project at BGS. His research interests include: the factors which control the distribution of potentially harmful elements in the soil and wider environment; the use of airborne radiometric survey data to map soil properties; the processes which influence the properties and fate of black carbon or char – a potential long-term sink for soil carbon; the use of large soil archives; and databases in forensic investigations and forensic geology.

SOIL GEOCHEMISTRY AND IMPACTS ON HUMAN HEALTH

DR ANDREW TYE

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Some soils related to certain parent materials or those that have been contaminated through anthropogenic activity, have properties that could be detrimental to human health. The Tellus project has demonstrated the importance of high resolution baseline soil geochemistry maps in recognising where potential impacts on human health may occur.

The presentation will briefly review the major human health impacts associated with soil geochemistry. Soils, via food, provide humans with much of their essential mineral nutrition. However, some soils related to certain parent materials or those that have been contaminated through anthropogenic activity, have properties that could be detrimental to human health. Exposure to these properties over a lifetime could be contributory in the number and types of illnesses found in the general population as average life expectancy increases. It could also be a factor in the increasing number of allergy sufferers. Hence more research is needed into the possible contribution that soil properties may have on human health. The major pathways from the soil to the human receptor include (a) particle ingestion, (b) soil gases and radioactivity and (c) soil chemistry including the uptake of elements by plants and the filtering of water. Examples from both the G-BASE geochemical survey of mainland UK and the Tellus project will be used to demonstrate the importance of high resolution baseline soil geochemistry maps in recognising where potential impacts on human health may occur. In addition, Physiologically Based Extraction techniques (PBET) will be examined to assess their suitability in examining the bio-accessibility of elements such as Ni that are enriched in soils derived from basalt rocks in Northern Ireland.

Andrew Tye was awarded his PhD in soil fertility and plant nutrition at the University of Wolverhampton in 1996. He was a Post Doctoral Research Fellow at the University of Nottingham from 1997 to 2003. The first 4 years were spent developing isotopic dilution techniques for evaluating the labile pool of metals in contaminated soils, developing empirical models of free ion activity of heavy metals in soil pore waters and their subsequent up-take by plants. Later he worked on Spitsbergen using stable isotope techniques to examine nitrogen biogeochemistry on tundra ecosystems. Andrew moved to BGS in December 2003. His current research interests include weathering studies and soil/regolith formation, the use of 3D models of the near surface environment in process orientated research as well as the mobility of heavy metals in contaminated peat soils in peri-urban environments.

THE INFLUENCE OF GEOCHEMISTRY ON ANIMAL HEALTH IN NORTHERN IRELAND

HELEN BROADWITH

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The Tellus geochemistry maps provide a valuable database for farmers, animal nutritionists and veterinary practitioners on potential mineral deficiencies or toxicities in soils.

Trace elements and minerals play an important part in animal health and nutrition including functioning as components of enzymes or co-factors in biochemical reactions. Poor health, clinical disease or death may occur if minerals and trace elements are present in either insufficient or excess amounts in the diet. Trace elements and minerals may also interact with each other in complex biochemical reactions. For example, high levels of molybdenum in the diet can result in insufficient copper being available to an animal, which may then show signs of copper deficiency.

The level of minerals and trace elements in the soil will determine the levels present in the pasture or crops grown in that area. Most cattle and sheep in Northern Ireland are farmed on pasture and grass forms the basis of their diet. Without supplementation the level of trace elements in the animal is determined by the amount of grass they ingest.

The maps produced by the Tellus project provide a valuable resource which determines the total amount of mineral present in the soil. Interpretation of these maps, in conjunction with local knowledge of mineral deficiencies and toxicities in a particular area, may provide a valuable database for farmers, animal nutritionists and veterinary practitioners. An important development would be to assess bioavailability of certain compounds as well as total levels in the soil.

Helen Broadwith graduated as a veterinary surgeon from the University of Glasgow. She worked in Lancashire as a mixed practice vet before moving to Northern Ireland. In 2004 she took up a post as a Veterinary Research Officer in the Disease Surveillance and Investigation Branch of the Veterinary Sciences Division, Agri-Food and Biosciences Institute. In this role Helen provides a clinical pathology service to practising veterinary surgeons in Northern Ireland as well as providing information and data for disease surveillance which is used by DARD.

THE GEOCHEMISTRY OF SOILS IN GREATER BELFAST

DR RORY DOHERTY

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The Tellus project has produced the first Belfast-wide survey of inorganic and organic chemical constituents in the soil. High levels of nickel and chromium in soils arise from naturally high levels in local rocks but Belfast suffers less from pollution of other heavy metals than other industrial cities of the UK. Sporadic elevated levels of certain organic contaminants in soils are ascribed to combustion of domestic and vehicle fuel.

The Tellus Project made two base line soil sampling surveys across the Greater Belfast area. Sampling densities and coverage are greater than other recent soil surveys in UK cities. Inorganic (metals) and organic (hydrocarbon) sampling strategies give an insight into the effect of geological features and human activities on soil quality. The organic sampling strategy analysed for Persistent Organic Pollutants (POPs) that include Polyaromatic Hydrocarbons (PAHs), Polychlorinated Biphenyls (PCBs) Phenols and Phthalates. Preliminary analysis of PAH data in Belfast soils indicates that the distribution has not been from point sources (such as an individual industry directly polluting the soil). The use of environmental forensic techniques which compare ratios of individual PAHs would suggest that they originate from combustion sources (domestic fuels). The Tellus geochemical baseline provides a vehicle for the fulfilment of EU Soil Thematic Strategy, placing Northern Ireland in the forefront of urban soils management in Europe.

Rory Doherty joined the School of Planning Architecture and Civil Engineering at QUB as a lecturer in Environmental Engineering in 2005. His introduction to contaminated land was as an engineer on bioremediation projects using his MSc in Biogeochemistry from University of Newcastle upon Tyne. He completed his PhD in 2002 modelling groundwater contamination at a gasworks site. He was also technical manager for a contaminated land remediation company and during this time was an industrial board member of the QUESTOR Centre at QUB. Rory also worked as a research fellow at the Environmental Engineering Research Centre on the award winning SEREBAR and Portadown PRB groundwater remediation projects.

SURFACE AND GROUNDWATER QUALITY — MEETING NEW STANDARDS

DR SILKE HARTMANN

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Tellus data will contribute to Northern Ireland's compliance with new EU directives on the management of water resources and to our understanding of the links between surface water and groundwater.

The EC Water Framework Directive (WFD) and Groundwater 'daughter' Directive demand a fundamental reappraisal of how we assess, manage and protect the water environment. A key objective is to encourage a holistic approach, which recognises the continuum between groundwater, surface waters and dependent ecosystems.

A more systematic approach is now being taken in considering the pressure-pathway-receptor concept, which requires better definition of the effects of superficial and bedrock geology on the movement of water and pollutants. Geophysical data collected by Tellus allows an improved understanding of the pathway between surface land-use and groundwater within underlying aquifers. Tellus results and imagery improve the mapping and definition of geological features such as faults and dyke intrusions that influence groundwater flow patterns.

The intent of the WFD is that all water bodies should attain 'good status' by 2015. In defining good status in a consistent manner, new water quality 'standards' or targets are being adopted and existing standards reviewed. In considering what standards should be set, where monitoring of waters should take place and how data should be interpreted, an understanding of the natural baseline chemistry is required. Tellus stream water data help define the natural background chemistry and assist in identifying suitable locations for monitoring.

Silke Hartmann took a combined Primary-Masters-Degree in geophysics at Leipzig University in Germany. She carried out her final 12-month project in Namibia with the Department of Water Affairs. Silke holds a PhD in hydrogeology from the University of Leeds, where she studied groundwater flow and transport processes of the confined chalk aquifer in East Yorkshire. Since joining GSNI in 2005 Silke has worked on various projects for the Environment and Heritage Service, including the establishment of the Water Framework Directive groundwater monitoring network for Northern Ireland. She recently completed a pilot 1:50,000 groundwater vulnerability map and is also involved in the assessment of contaminated land and the effects of landfills.

HUMAN IMPACTS ON GROUND AND SURFACE WATERS

DR ULRICH OFTERDINGER

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Tellus data provide a valuable resource in the assessment of the impacts of different types of land-use and help define the extent of diffuse and point-source contaminants on the ground surface which may contaminate groundwater. Tellus data also yield additional data for the assessment of wetland characteristics, such as thickness of peat cover.

The assessment of anthropogenic impacts on the environment is subject to a series of current and forthcoming EU framework directives concerning the management and protection of waters, soils, wastes and ecology. These require a comprehensive assessment of qualitative and quantitative impacts on the environment and the implementation of scientifically based management programmes in order to preserve environmental quality status.

The complementary datasets collected within the Tellus Programme provide a valuable resource in the assessment of the impacts of different types of land use on groundwater and surface waters and will help target research activities. Airborne geophysical data as well as soil geochemistry may be employed to assess the nature of potential diffuse and point source impacts on the environment. Pedological data collected during the Tellus Project provides a database of background compound concentrations in soil on which the imprint of anthropogenic impacts may be identified. With regard to the assessment of relevant receptors, Tellus data may furthermore yield additional data for the assessment of wetland characteristics, such as thickness of peat cover.

The comprehensive data sets provided through the Tellus Programme will form an integral part in assessing the governing processes for environmental impact in Northern Ireland and a successful template for an all-island approach as envisaged originally in the RESI Initiative, supplementing established and forthcoming monitoring programmes.

Ulrich Ofterdinger joined the Environmental Engineering Group at Queen's University Belfast as Lecturer in 2005. Previously, as Senior Hydrogeologist, Ulrich worked with URS Ireland Ltd., Dublin on a series of environmental projects for an international client base. Prior to working with URS, Ulrich worked on groundwater hydraulics in fractured bedrock, numerical modelling and contaminated land remedial technologies during his research at ETH, Switzerland and at Queen's University. A qualified Hydrogeologist (Dr.sci.nat) with a first degree in Geology, his main areas of expertise include catchment hydrogeology, isotope hydrology, quantitative risk assessment, remedial design and supervision, hydraulic testing and numerical modelling. He has particular interest in environmental liability legislation and his experience also includes GIS, geophysical investigations and site investigation of organic and inorganic contamination at a variety of industrial sites.

PILOT ENVIRONMENTAL AIRBORNE GEOPHYSICAL SURVEYS IN IRELAND

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The Geological Survey of Ireland made three successful pilot airborne geophysical surveys in 2006 to test the application of this method as a tool for environmental management. GSI hopes to extend these surveys over the whole of the Republic of Ireland.

In June 2006, the Geological Survey of Ireland (GSI) commissioned pilot high resolution airborne geophysical surveys over three selected areas in Ireland:

- Part of Cavan-Monaghan-Leitrim,
- Castleisland area,
- Silvermines area.

The three areas posed different challenges and the different complementary geophysical systems on board assisted in improving our understanding of the issues in each of the three areas. The high resolution data reveal numerous features of interest and demonstrate the diverse usefulness of such a dataset for Ireland.

Detailed structural geological information provided by the survey in Cavan-Monaghan-Leitrim supports existing work by GSI on a groundwater protection scheme. This survey extended the coverage of the Tellus airborne survey into the Republic of Ireland. The Castleisland area has recorded elevated radon levels in buildings and was surveyed to provide more detail on the bedrock geology and to identify geological units and or structures that may have potential for radon. Analysis of the data is being carried out in conjunction with the Radiological Protection Institute of Ireland. The Silvermines area is a former base metal mining area and was surveyed to support ongoing rehabilitation programmes.

The GSI contracted the Joint Airborne-geoscience Capability (JAC) to make the survey, with the aircraft and systems used by the Tellus survey and with similar specifications. The work was accompanied by a substantial public relations campaign managed by Aurum Exploration Ltd.

Eibhlín has a BSc in geology from UCD, an MSc in geology from Acadia University in Canada and a PhD in geology also from UCD. Eibhlín has worked in the minerals industry in both exploration and development. She was the geologist responsible for the discovery of the Galmoy orebody while at Conroy Petroleum and Natural Resources in 1986. She became exploration manager for BHP in Ireland in 1995. Eibhlín joined the Geological Survey of Ireland in 1999 where she worked in the Minerals Programme on Industrial Minerals Projects. She was involved in the successful Irish National Seabed Survey. In 2006 she was promoted to Principal Geologist for the Marine Geology and Geophysics Programme and later assumed responsibility for the Minerals and Groundwater Programmes as well as becoming manager for airborne surveys.

NEW MAPPING OF NATURAL AND MAN-MADE RADIOACTIVITY

CATHY SCHEIB

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The Tellus airborne survey has resulted in the most detailed map of terrestrial radioactivity of any region in the UK. These data aid geological and soil mapping, improve our estimation of in-house radon risk, and define the extent of caesium deposition remaining from the 1986 Chernobyl accident.

Airborne gamma-ray spectrometry, flown as part of the Tellus geophysical survey of Northern Ireland, provided detailed information on natural and man-made radioactivity relating to: bedrock and superficial geology; soil and landscape; human activity such as wastes associated with power generation, mineral extraction and landfills; and the distribution of ^{137}Cs from atmospheric weapons tests and the Chernobyl accident.

The natural radioactivity from potassium, thorium and uranium reflect major solid geological subdivisions and the effects of overlying superficial deposits and soil. Low natural radioactivity levels resulting from peat cover are very clear, as are higher zones where glacial tills are derived from areas of relatively radioactive geology.

Patterns seen in the Tellus data for ^{137}Cs are consistent with wet deposition caused by bands of rain intercepting the Chernobyl plume. Comparison of the ^{137}Cs data with a land-use classification showed that salt marsh areas, forests, natural grassland, pastures and similar classes exhibited higher average ^{137}Cs values although the values fall within the expected range for the UK.

These radiometric data have been used for geological and soil mapping, exploration for uranium and gold, radon potential mapping, environmental studies and for establishing a terrestrial radiation baseline for comparison with future measurements.

Cathy Scheib holds a joint honours primary degree in geology and environmental chemistry from the University of Glasgow. Following this she completed a research masters (MSc) focusing on radio-nuclides in the urban environment at the Scottish Universities Environmental Research Centre (SUERC). Her major research focus is environmental radioactivity and she has worked in this area during the past six years with BGS, both in the UK and overseas. Airborne, ground-based and laboratory gamma spectrometry data acquisition, processing and interpretation remain her main areas of interest as well as radon potential mapping. She provides training for World Bank and European funded projects in these areas and has presented to international audiences on the geological aspects of radon risk mapping.

SITE-INVESTIGATION AND LANDFILL CHARACTERISATION BY AIRBORNE GEOPHYSICS

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Analysis of selected results suggests that Tellus airborne methods can in some cases detect the geophysical signatures of landfill sites. These may be due to the contents of the landfill or to polluted water draining underground from the site.

The Tellus airborne geophysical survey was designed to provide national scale coverage of Northern Ireland using a line separation interval of 200 m. The magnetic and electromagnetic (EM) conductivity models, in particular, provide some spectacular new information on geological formations and their attributes at both regional and local scales. In addition, within the data sets, a multitude of localised responses (anomalies) are observed. Many of these are non-geological and relate to the impacts of human activity on the environment. Using the Tellus EM data as the primary data lead, the manner in which site-scale investigations may be carried out is considered. The pitfalls — including the sampling interval, variations in flying height and the impact of noise — must all be managed correctly, especially when we move from observational data to detailed subsurface models. A series of site-investigation scale studies (typically no more than 3x3 km in extent) are considered. The studies relate to a variety of localised sources of material concentrations that include refuse tips, sewage works, industrial sites, quarries and landfills. Such studies and the gained understanding are a necessary prerequisite to making wider practical use of the data. In the UK and wider context, the Tellus geophysical results represent a new form of high resolution and extensive assessment of the near-surface. The conductivity models, in particular, present us with a new type of information on rock/fluid properties and their environmental significance.

Dr. David Beamish (BA, PhD) has been with the British Geological Survey for some 30 years. His first 13 years were spent working in Geomagnetism, largely undertaking solid-earth geophysical investigations and developing the magnetotelluric method. This was followed by a move to the Keyworth office to specialise in the development and application of a variety of electromagnetic geophysical methods to BGS programmes of work in the UK and overseas. He has contributed over 100 external papers to journals and over 125 internal reports. He is currently Head of Airborne Geophysics and coordinates the Joint Airborne-geoscience Capability that acquired the Tellus data.

QUARRYING — A MAJOR RURAL INDUSTRY IN NORTHERN IRELAND

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Northern Ireland is an important source of aggregates for the whole of UK and contributes significantly to the economy of Northern Ireland. Airborne geophysical mapping of the surface and near-surface helps to define the extent of deposits and maps new potential sources. Geochemical surveys provide baseline data for environmental impact assessments.

In 2005, the Northern Ireland quarry products industry produced almost 26 million tonnes of aggregate from 160 quarries. This represented over 11% of total UK aggregate production. Products from the industry in Northern Ireland are worth around £700 million per annum, literally underpinning a construction sector which constitutes about 12% of the province's GDP. Northern Ireland is also a major exporter of premium quality crushed rock aggregate — material which mostly goes to provide skid-resistant road surfacing on roads in England. As elsewhere in the UK, the industry is an important job provider in rural areas where other employment opportunities may be scarce.

Through their role in construction, primary aggregates such as crushed rock and sand and gravel, together with secondary materials recycled from demolition waste and road maintenance, are vital in sustaining the economic development of Northern Ireland. Although both active and former quarry sites make a considerable positive contribution to local biodiversity, negative environmental impacts are inevitable, particularly those resulting from road transport of bulk materials.

As part of an integrated range of initiatives to improve the sustainability of the aggregates sector, Tellus data have the potential to assist industry and regulators enhance the economic benefit and minimise the negative environmental impact of aggregate production and transport.

Tellus EM data can potentially be used for rapid reconnaissance of concealed sand and gravel bodies within glacial deposits in the east of the province, although this will require investment in geological control and processing. Tellus geochemical data will provide excellent baseline information for environment impact assessments associated with proposed quarry development and restoration, as well as that which may be required to fulfil the requirements of European legislation such as the Mine Waste Directive.

Andrew Bloodworth is Head of Science for Minerals in BGS and is responsible for about 35 staff working on a variety of projects related to the sustainable development of metallic and non-metallic economic minerals in the UK and overseas. His own interests are in the geology of industrial and construction materials, as well as in spatial planning and regulatory issues associated with minerals extraction. In addition to his considerable experience of the UK minerals sector, he has also worked in a number of countries across the developing world and was formerly the Mining Advisor to the UK Department for International Development.

ASSESSING OUR UNTAPPED ENERGY RESOURCES

EURGEOL DEREK REAY

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The improved geological mapping resulting from the Tellus surveys contributes to the search for hydrocarbon and geothermal energy resources.

Northern Ireland relies on imported gas and oil to meet most of the energy needs of its economy and, despite the increasing use of renewable energy, this situation is unlikely to change significantly in the near future. The search for indigenous oil and gas has the potential to yield valuable reserves that would both boost the economy and help to maintain the security of Northern Ireland's energy supplies.

Gas has been discovered, but not yet in commercial quantities, in Carboniferous rocks in Counties Fermanagh, Cavan and Leitrim. The sedimentary basins concealed beneath the Antrim Plateau may also contain accumulations of oil and gas, but the thick cover basalt lava obscures the underlying geological structure. The high-resolution Tellus aeromagnetic data can provide new insights into the geological structure and development history of the prospective sedimentary basins. Structural trends and faults mapped at surface can be recognised on the Tellus data and extended into areas where surface outcrops are poor. Depth-to-basement estimates may also be derived from the aeromagnetic data, and then integrated with well, seismic and gravity information to produce improved geological models.

Geothermal energy stored in rocks deep below the land surface could provide a significant low-carbon sustainable resource for the generation of electricity and heat. Tellus radiometric data identifies near-surface rocks with relatively high radiogenic heat production. Similar rocks, buried at depths of 3 to 5 kilometres, may provide geothermal heat energy suitable for power generation.

Derek Reay has over 25 years experience with the British Geological Survey. His early career was spent in Edinburgh where he worked on the regional geophysical and geological surveys of the UK Continental Shelf, before producing hydrocarbon prospectivity evaluations for the Department of Energy. Since moving to the Geological Survey of Northern Ireland Derek has been active in geological mapping, and introduced IT and database systems into the office. He provides technical advice on petroleum licensing and exploration to the Department of Enterprise, Trade and Investment, and has interests in the development of geothermal energy.

THE SCOPE FOR CARBON CAPTURE AND STORAGE IN NORTHERN IRELAND

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Sites in Northern Ireland may be appropriate for the long-term storage of carbon dioxide. High quality lithological and structural information provided by GSNI and Tellus will be vital to their assessment.

Rising greenhouse gas emissions create a potentially huge threat to the environment, human populations and global economies. A major greenhouse gas is carbon dioxide, which contributes approximately two-thirds of the worlds greenhouse gases emitted by human activities. As a result of governmental policy, commitments have been made to reduce CO_2 emissions by 60% by 2050.

In the UK, the power generation sector accounts for approximately one-third of total CO_2 emissions. This CO_2 could potentially be captured at the power plant, transported by pipeline, injected into the subsurface and stored in a suitable geological storage site. This is known as carbon capture and storage (CCS).

A storage site may be required to store the CO_2 for tens or hundreds of thousands of years and it needs to be chosen very carefully on the basis of its geological characteristics. The main criteria are a reservoir rock with good porosity and permeability, coupled with a cap rock (seal) to prevent the CO_2 from escaping. The site should be a sufficient deep (usually 800 m below the ground surface) for the CO_2 to be in its dense (supercritical) phase so that it occupies less volume. The site must also be large enough to store the required volumes of CO_2. These parameters can be found in several geological settings:

- Oil and gas fields
- Saline aquifers
- Coal seams
- Natural and man-made caverns

In Northern Ireland there are several sedimentary basins that may exhibit the necessary criteria for geological storage of CO_2, including the Larne, Rathlin, Lough Neagh, North Channel and Portpatrick Basins.

Michelle Bentham graduated from Leeds University (BSc, Earth Sciences) and Royal Holloway (MSc, Basin Evolution and Dynamics). Since joining BGS in 2000 she has been working on the geological storage of carbon dioxide, focusing on site selection and storage capacity estimates. She was BGS project manager of the Green Energy from coal and GeoCapacity project. She is a researcher on several EU and UK funded projects and for the UK carbon and capture consortium. She is currently involved in undertaking an assessment of the potential to store CO_2 in the geological formations of all of Ireland as part of the 'Assessment of the all-Island potential for geological storage of Carbon Dioxide in Ireland' project.

INFORMATION DELIVERY AND LICENSING OF GSNI AND TELLUS DATA

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The Geological Survey of Northern Ireland holds a wealth of information relevant to any organisation concerned with the surface or subsurface of Northern Ireland, its resources, rocks, soils and drainage systems. These data are readily available to all and include digital geology, information on mine workings, borehole and hydrogeological results, mineral and hydrocarbon exploration data, and various datasets from the Tellus Project.

Tellus data can be provided as whole country coverage or as subsets for specific areas. Geochemical analyses of individual sampling sites of soils, stream sediments and stream waters are available as ASCII text or Excel spreadsheet. 1:250 000 scale printed maps are available for common elements and compounds. Airborne data are available in Geosoft grid or database formats, or as ASCII text line data. 1:250 000 scale printed maps of the airborne results and several common data-transformations are also available.

The current delivery mechanisms are via optical disk or e-mail for smaller datasets. Hardcopy data are provided where appropriate. Selected datasets will be available online in the future.

GSNI data, including Tellus data, are available under a standard licence arrangement modelled on the BGS licensing scheme. Nominal fees are charged to commercial users of Tellus data, which are a small fraction of the data acquisition and processing costs. Data are made available free of charge to academic researchers pursuing projects which accord with the goals of the Tellus Project.

Mark Patton graduated from the University of Liverpool (BSc (Hons), Geology) and the University of Birmingham (MSc, Applied Geophysics). He spent four years working in oilfield services as a data manager for multinational exploration and production companies before moving into software development and support. He worked in this role supporting the systems used by the Northern Ireland Planning Service before joining GSNI in 2004 as data manager for the Tellus Project.

POSTER PRESENTATIONS

LOCATION: LEVEL 4

Tellus data

Regional interpretation of Tellus geophysical imagery
Mike Young

Prominent features of Tellus geochemical data
Dermot Smyth

Natural resources

Metallic mineral potential of Northern Ireland: new insights from prospectivity analysis using Tellus data.
Gus Gunn

Geothermal resource prospectivity in Northern Ireland
Adrian Walker

Tellus information in areas with hydrocarbon potential
Adrian Walker

Quaternary investigations, including sand & gravel, using the Tellus EM data.
Dave Beamish

Environment, agriculture and health

Airborne radiometric survey data and a DTM as co-variates for regional scale mapping of organic carbon
Barry Rawlins

Geochemical considerations in planning the use of sewage sludge in agriculture
Crawford Jordan

Pilot study of the application of Tellus airborne radiometric and soil geochemical data for radon mapping
Don Appleton

High-resolution ^{137}Cs data over Northern Ireland: understanding ^{137}Cs deposition
Cathy Scheib

Iodine and iodine deficiency disorder in Northern Ireland
Chris Johnson

Nutrients in stream waters
Louise Ander

Fluoride in stream waters
Louise Ander

Isotope and geochemical analysis of Tellus waters applied to measuring nutrient cycling
Hannah Corcoran

Landfill investigations using the Tellus EM data
David Beamish

Potential for mapping the variation of peat thickness with airborne gamma-ray spectrometry
Chris van Dam

Historical chronologies of sedimentation and heavy metal contamination in Strangford Lough, Northern Ireland
James Strong and Matthew Service

Regional geological mapping and interpretation

Structure and zonation of late Caledonian Newry Igneous Complex: geophysical update from Tellus
Mark Cooper and Ian Meighan

Comparison of the stream sediment geochemistry of the Down-Longford Terrain with the Southern Uplands of Scotland
Neil Breward and Phil Stone

Cenozoic pull-apart basins in the British Isles
Martyn Quinn

A preliminary assessment of the use of natural radioactivity data from the Tellus airborne survey
Dave Jones

Radioactivity through the Ages: the Mourne Mountains
Alastair Ruffell

Geostatistics

Geostatistics applied to data integration of multi-source geophysical and geochemical data from the Tellus Project
Jenny McKinley

Computing average variograms from imagery to guide soil sampling
Ruth Kerry

Monte Carlo analysis of soil characteristics and sampling theory parameters for optimisation of environmental sampling programs
David Hiroz

Education

Geoscience education and outreach — the Tellus contribution
Marie Cowan

Characterisation of poorly producing aquifers — the Griffiths Geoscience Award
Ulrich Ofterdinger

Collaborative research between Queen's University and the Tellus Project
Jenny McKinley

NOTES

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