



Department for the  
**Economy**  
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**GSNI** Geological  
Survey of  
Northern  
Ireland  
Celebrating 70 years: 1947–2017

# 70th Anniversary Science Review





# Foreword

by Marie Cowan, GSNI Director

Minerals and other natural resources are essential to support a competitive, regionally balanced economy and a sustainable quality of life for everyone. It is vital there is a sufficient supply of raw and recycled materials for manufacturing, construction, power generation, transportation and agri-food. In the UK, trade in minerals and mineral-based products makes up over 20 per cent of the total, with exports of £66 billion and imports of £85 billion in 2014.

Subsurface mining in Northern Ireland dates back to 1700 and for planning purposes minerals fall into three distinct groups.

Aggregates such as hard rock, sand and gravel are needed for the construction of homes and roads. Industrial minerals including salt and potash are used by manufacturing and agri-food industries, and new technologies are heavily reliant on high-value metals such as gold. Energy minerals include coal, peat, lignite and oil and gas.

The construction sector is worth £2.5 billion to the NI economy with 12 000 firms providing 60 000 jobs. Sixty tons of aggregates are required for an average house and ten thousand tons of aggregate, three thousand tons of asphalt and 2000 m<sup>3</sup> of concrete are required

for one kilometre of a 6-metre-wide single carriageway.

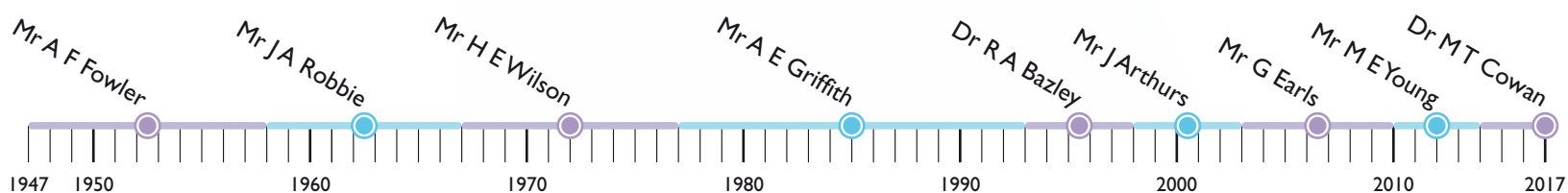
Minerals are valuable, finite resources that can only be extracted where they occur; this poses a challenge for society as the demand for minerals requires long-term, strategic, minerals planning and safeguarding to be balanced with environmental protection, monitoring and management.

The Geological Survey of Northern Ireland (GSNI), an office of the Department for the Economy, generates and provides information, data, research and expertise on mineral resources

and advises on associated planning considerations to support the economy and protect the environment.

This year the GSNI celebrates 70 years of public service since first opening its offices in 1947. This special publication marks this milestone by encapsulating how GSNI scientists provide this service and its impact for Northern Ireland's economy, infrastructure, environment, tourism, health and education in the past three financial years ending 2016/17.

Marie Cowan, Director, Geological Survey of Northern Ireland (GSNI), Belfast





# Foreword

by John Ludden CBE, BGS Executive Director

The BGS has been surveying the UK's geology since 1835; our current role is still very similar to that when we were established during the industrial revolution. Today we advance understanding of the structure, properties and processes of the solid earth system through interdisciplinary surveys, monitoring and research for the benefit of society.

We identify the UK's resources and investigate whether they can be utilised sustainably in the national interest. To do this we map, measure, observe and model the rocks and superficial deposits from a depth of several kilometres all the way to the surface. Providing data, knowledge and information on natural resources means that we identify the extent of the resources, provide estimates on their volume, assess whether they can be extracted

without damaging the natural environment and provide evidence on how competing underground activities may need to be managed to ensure safety.

The BGS also leads geoscience research of strategic importance to government; undertaking this work requires close association with all stakeholders involved in natural resource development including central and local government, regulators, industry and other research institutes.

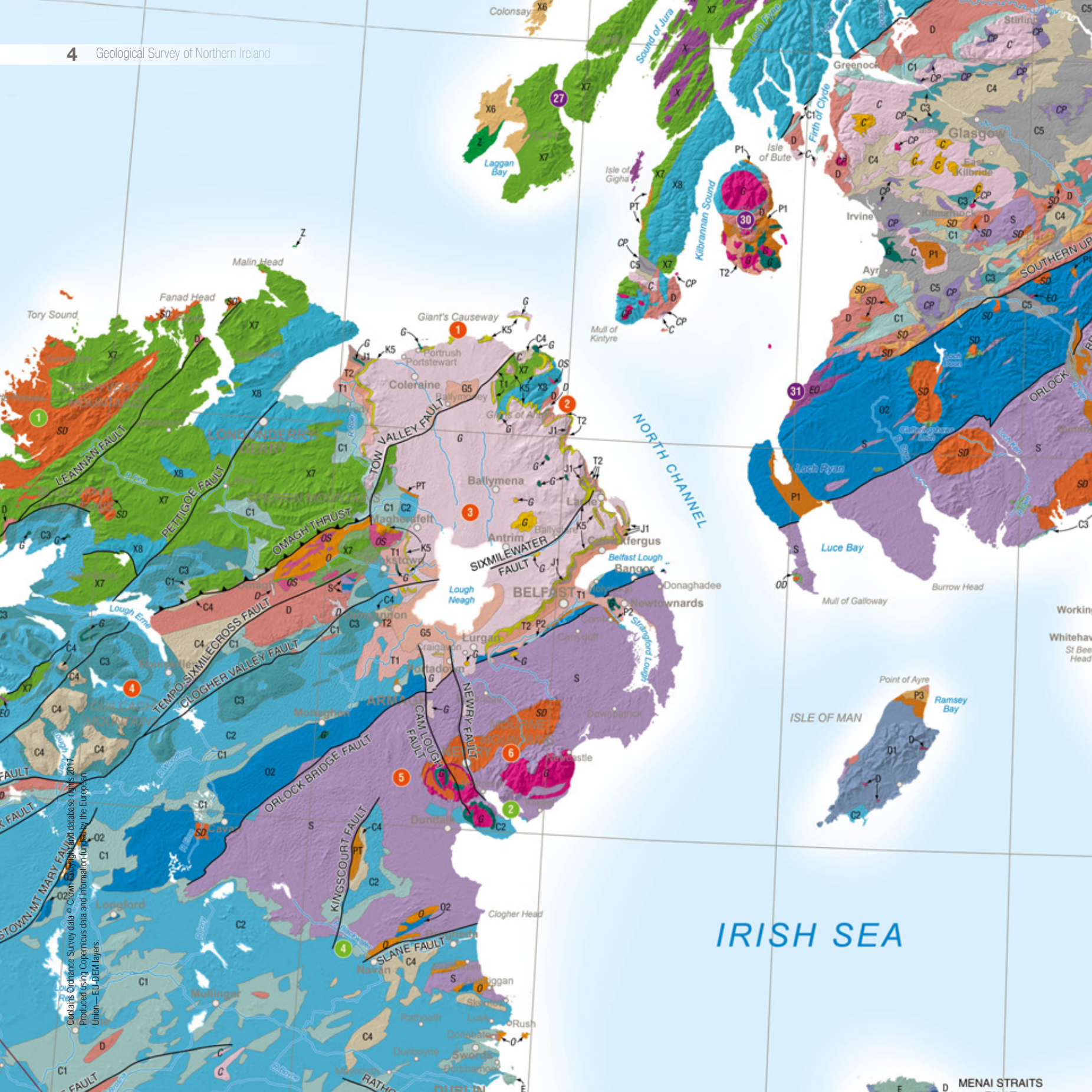
We have offices in all four devolved regions of the UK, however the GSNI in Belfast is unique because it is an office of government and its staff are government officials. This places BGS scientists central to evidence-based policy making and stakeholder consultation. The GSNI is attuned to both the Northern Ireland Executive's

Programme for Government and Industrial Strategy.

This year the GSNI celebrates 70 years of providing this public service to Northern Ireland and this publication reflects on the last three years. In particular it focuses on work for the Department for the Economy (DfE), the Northern Ireland Environment agency (NIEA) and councils, and its joint research with universities and other organisations. Highlights include Northern Ireland being placed in the global top ten for its policy perception index in relation to mineral exploration in the 2016 Fraser Institute Survey of 2700 companies, and the GSNI's invited representation on UNESCO's first Global Geopark Council. This reflects its expertise and commitment to geodiversity and geotourism at home and on the international stage.

The BGS, together with the GSNI, have been collaborating with Geological Survey Ireland formally since 2007 when the three surveys signed a Memorandum of Understanding to work together on geoscience research in areas of mutual national interest. I am delighted with our most recent award-winning collaboration: the newly published 1:1 250 000 scale geological map of the UK and Ireland. In 2016, our joint book with the Royal Irish Academy entitled *Unearthed: Impacts of the Tellus Surveys of the North of Ireland* published 30 papers with 28 authors and was launched at Parliament Buildings in Stormont. Six papers alone were published by GSNI's Chief Geologist and current Visiting Research Professor at Queen's University Belfast.

John Ludden, Executive Director, British Geological Survey (BGS), Nottingham, UK



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# Introduction

The Geological Survey of Northern Ireland (GSNI) is an office of the Department for the Economy (DfE) in Northern Ireland (NI) staffed by scientists of the British Geological Survey (BGS) who provide research services to help develop NI's economy and protect its environment.

Our GSNI scientists provide data, information and advice to support the legislative responsibilities and strategic priorities of DfE, other NI government departments and agencies, Northern Ireland Environment Agency (NIEA), Invest NI and council authorities.

We are based at Dundonald House in Belfast on the Stormont Estate, where we run an enquiry service and shop. We also manage a core store and sample repository at Mallusk.

We collaborate on research projects with the BGS, Geological Survey Ireland (GSI) and over 35 universities worldwide. Our primary datasets are available on Open Data NI and Spatial NI. We

also hold information on geology, engineering geology, minerals, borehole data and site records, mines, quarries and pits, airborne geophysics, soils and water geochemistry.

The GSNI is an entirely outward-facing organisation so we actively engage all sectors of society including central and local government, industry, academia, community organisations, non-governmental organisations (NGOs), schools and the general public. Our primary client is the DfE and key partners are Invest NI; Land and Property Services; Northern Ireland Environment Agency; Marble Arch Caves UNESCO Global Geopark; Quarry Products Association NI; Queen's

University Belfast; Royal Irish Academy; W5; Ulster Museum, and UNESCO.

We are unique within the BGS as we are a government office within the DfE and our scientists are officials of government. We are exclusively well placed to advise and inform policymakers on a range of issues including the supply of energy and raw materials. The GSNI contributes to, and advises the DfE Minerals and Petroleum Branch on, responses to DfE private and press offices and Northern Ireland Assembly business. In the last three financial years we answered 75 Assembly questions for written answer (AQWs) with topics ranging from sand and gravel resources in Lough Neagh to defining the difference between conventional and unconventional oil and gas exploration. In the same reporting periods, we answered 217 environmental information requests (EIRs) that arose from areas of public concern to individuals and NGOs.

### Informing planning policy and decisions

We also act on behalf of the DfE as a statutory consultee on planning issues in Northern Ireland, providing geoscience information and advice on all aspects of planning and development.

In April 2015, the responsibility for planning decisions transferred from the NI Planning Service to 11 newly created 'super-councils'. We embarked upon a two-year-long programme of engagement with CEOs, chief planners and council officials to raise awareness of our data and expertise, as well as providing guidance and advice on the likely risks and opportunities for planning in each area.

In the last three financial years, we have responded to 100 planning consultations that varied from wind-farm applications to quarry extensions, and advised on a range of potential impacts including abandoned mines, compressible ground and hydrogeology. We also responded to two pre-preferred option papers (POP) and seven POPs to date to inform the local development plan process which will determine the next 15 years of strategic development for each council area.



## DfE ministerial and NI Assembly correspondence

Type of response	Number of responses
Ministerial briefings & meetings	25
Assembly question for written answer (AQWs)	75
Ministerial correspondence	22
Official correspondence	139
Environmental information requests (EIRs) & Freedom of Information (FOI) requests	217
Environmental Protection Agency (EPA) unconventional gas exploration and extraction (UGEE) joint research programme	25
Oil and Gas Authority (OGA) Unconventional Hydrocarbons Regulators' Group	26
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# Developing the economy

The GSNI supports Northern Ireland's economic development and job creation by providing information, advice and support for a range of industries. These include aggregates or construction materials, valuable minerals, oil and gas, underground energy storage, groundwater and raw materials for the manufacturing and agricultural sectors.

Courtesy ISME ©Christopher Heaney Photography

## Valuable minerals

Northern Ireland has a mining industry that dates back to the 1700s. This early industry was focused on targeting base metals and coal. The legacy of that time has left mining heritage across the country. Since the mid 20th century the primary high-value material produced has been salt, with reserves that are still good for decades to come. In the latter 20th century and into the new millennium, the focus of interest has switched to gold. Between 2007 and 2012, NI boasted the only operating gold mine on the island of Ireland at Cavanacaw. Currently, the Curraghinalt deposit, ranked top ten by grade, has brought us to the global stage. We are the most prospective location for

the yellow metal in Britain and Ireland.

Roughly one quarter of the country is currently under licence for exploration for high-value minerals. The potential has still not been fully established and companies are continuing to invest time and resources evaluating the prospect of further gold, base metal, platinum group metal and diamond deposits located within the borders of NI.

## Sustainability: planning policy

Minerals are essential to support sustainable economic growth and quality of life, and their responsible exploitation is supported by government. The minerals sector provides





*Underground at the Curraghinalt gold deposit. Courtesy Dalradian Gold.*

materials for construction and local infrastructure development, and is a valued employer, particularly in rural areas. It can also support technological innovation by supplying the critical metals essential for new communication and energy technologies.

As mineral resources are finite and are not distributed evenly, knowledge about their whereabouts is needed to help make effective and sustainable planning and policy decisions that consider the needs of future generations.

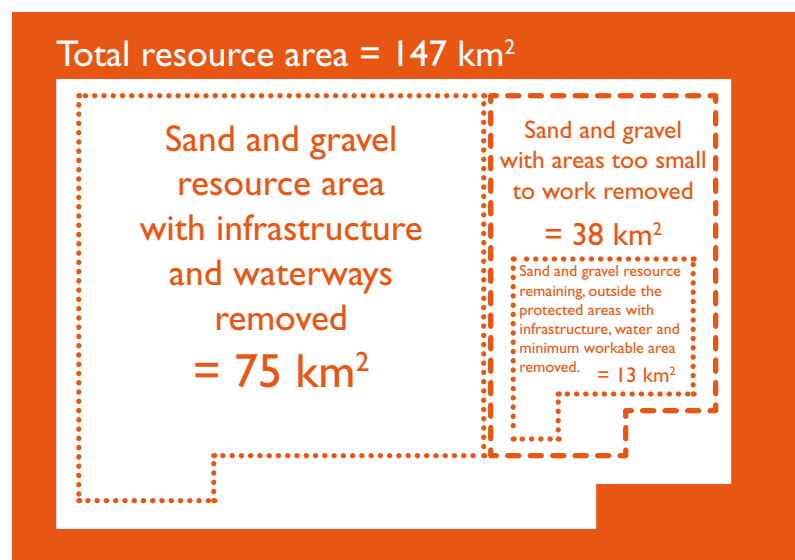
The Department for the Economy (DfE) and the GSNI provide support as consultees on both planning policy and specific

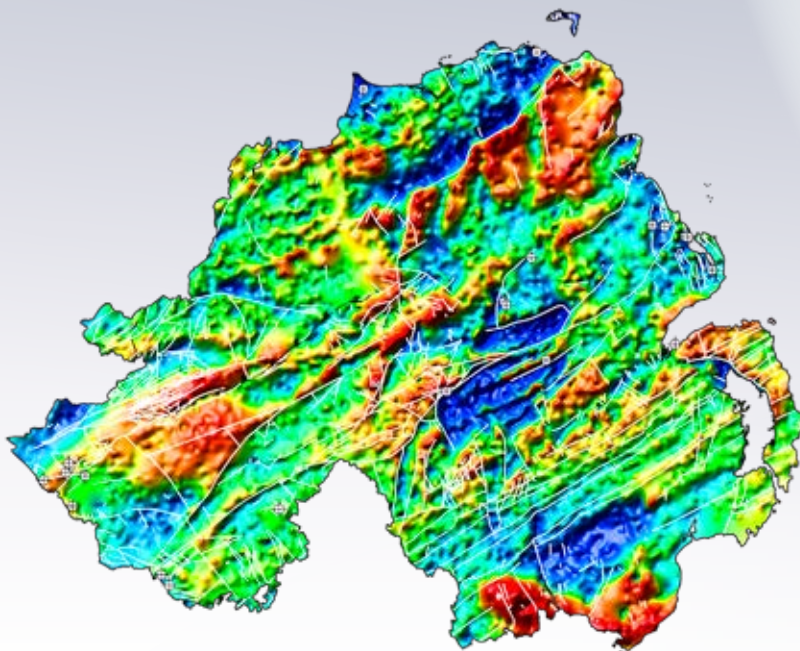
planning applications. In planning policy, the DfE and the GSNI have been engaging with local councils on the formulation of their local development plans (LDPs). We use our professional expertise and draw upon information sources such as the mineral resource maps of NI to help planners develop evidence-based LDPs. DfE and GSNI staff have provided detailed written input at various stages of the LDP process and made presentations to individual councils and the Principal Planners' Group. Although the significance and distribution of mineral resources have been the main focus, our geologists have also suggested that councils consider the potential sustainable use of low carbon geothermal energy and

groundwater resources in their LDPs.

The DfE and the GSNI are currently working with councils

on the adoption of 'mineral safeguarding areas' to ensure surface development does not jeopardise future exploitation of valuable mineral resources.

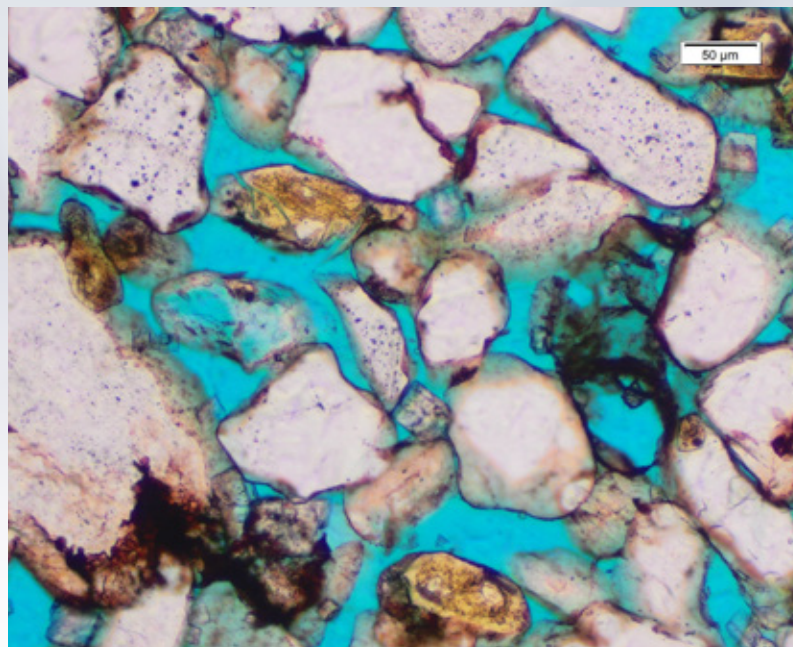




Gravity map of Northern Ireland. ©Crown copyright and database rights MOU577.3.

### Basin analysis and energy potential

The most prospective areas for hydrocarbon and geothermal energy resources lie in the concealed sedimentary basins across Northern Ireland. Good quality reservoir rocks have been identified in sandstones of Carboniferous, Permian and Triassic age. Hydrocarbon prospectivity is enhanced by the presence of source rocks, suitable trap structures and good quality seals. Indications of oil and gas have been found in all three sedimentary basins, which are buried underneath basaltic rocks. A total of eighteen exploration wells have been drilled in Northern Ireland, three for geothermal and fifteen for hydrocarbons, but it still



Photomicrograph of sandstone from the Larne No. 2 Borehole.

remains a relatively under-explored region.

We hold data collected by exploration companies, such as seismic data; well completion reports; wireline log data; thin sections; cores, and cuttings samples. Together they form an extensive source of information about the subsurface geology of NI. Our scientists also carry out their own research using these data, combined with outcrop and borehole sample analyses, to work out the geological history and the distribution, nature and resource potential of the rocks in the sedimentary basins. Other potential energy resources, such as coal-bed methane, shale gas and mine water geothermal energy, have

an as yet unknown potential within NI.

### Energy storage

As Northern Ireland makes the transition to a low carbon economy it faces a number of energy challenges. It has abundant wind energy resources but these are intermittent and there are seasonal, diurnal and hourly mismatches between the demand for electricity and the supply from wind farms, leading to inefficiencies in the electricity system. As a result Northern Ireland relies on the import of oil and gas to manage its energy needs. Energy storage can play an important part in tackling both these problems, firstly by reducing the mismatch between supply and demand and,



*Islandmagee well site. Courtesy of Islandmage Storage Limited.*

secondly, by providing strategic supplies of natural gas on the island.

GSI staff have worked with BGS colleagues to highlight the potential for geological storage of energy in NI. In the Larne area of County Antrim, Triassic and Permian salt beds are thick enough and occur at sufficient depth for the construction of large storage caverns by controlled leaching. The Triassic salt beds vary in thickness over short distances whereas the deeper Permian salt consists of one unit that has a more consistent thickness but is more restricted in its subsurface occurrence.

Seismic surveys and deep boreholes have shown that

the Permian salt beneath the northern parts of Larne Lough and Islandmagee should be suitable for creating storage caverns for natural gas or compressed air energy storage. Feasibility studies have been carried out for energy storage projects in this area and the European Commission has recognised the importance of such facilities to the development of a resilient energy infrastructure on the island.

We have liaised with companies from the early stages of their exploration programmes and continue to carry out seismic mapping to improve our understanding of the distribution of the salt beds. There may also be potential in geological

environments beneath NI for the storage of other materials, such as hydrogen, that may be fundamental to our future energy systems.

# Research, data and innovation

One of the GSNI's core roles is to acquire, maintain, analyse and interpret a vast array of geoscience information that supports and informs decision making. Data, research and innovation underpin all of our work and support all of our key science outputs.

## **Unearthed: impacts of the Tellus survey**

The year 2016 saw the publication of *Unearthed: impacts of the Tellus surveys of the north of Ireland* by the Royal Irish Academy. It tells how an unparalleled combined land and air survey carried out between 2004 and 2013 has unearthed valuable natural resources, refined our understanding of the agri-environment and has identified naturally occurring hazards.

*Unearthed* draws together important findings of the largest collaborative cross-border programme of geoscience surveys ever undertaken on the island of Ireland. Some £12 million of government and EU funding has been invested in high-resolution,

airborne geophysical and ground geochemical sampling surveys of Northern Ireland and the six northern counties of the Republic of Ireland.

In 30 peer-reviewed chapters, scientists from the BGS, the GSNI, Geological Survey Ireland (GSI) and many universities, present the results of the Tellus and Tellus Border surveys. From the discovery of precious, industrial and critical metals to geothermal energy potential and from naturally occurring heavy metals in soils to groundwater quality in various ecosystems, the breadth and depth of the results is extraordinary.

## **GSI short calls**

The GSNI works in close collaboration with a number of



Launching Tellus Unearthed in October 2016.

institutions and organisations from across the UK and the Republic of Ireland. In 2015, we were fortunate to be the recipient of three geoscience research short-call grants from the GSI, part of a suite of research projects that included both public and private sector applicants. They covered topics such as minerals and mining, groundwater, marine mapping, geotourism, geophysics, geochemistry, earth observation and coastal and terrestrial landslides.

The three projects that we delivered were as follows:

- All-Ireland Quaternary map: using data from GSI, the GSNI and the BRITICE project,

we produced an all-Ireland Quaternary map at a scale of 1:500 000, which is now available as a seamless digital dataset.

- All-Ireland karst features dataset: this project extended the GSI karst features dataset north to produce an all-Ireland dataset so that the full extent of Irish karst can be properly visualised and appreciated.
- Geochemical anomaly detection, spatial analysis for improved use of geochemical data: this project compared two mathematical methods for improved use of geochemical data to facilitate novel use of Tellus data for mineral exploration and resources assessment.

### Bedrock geology map

The GSNI, together with the BGS and GSI produced an award-winning, small-scale geological map of the United Kingdom and Ireland. The map incorporates the latest geological and topographical data to provide an overview of the geology of Northern Ireland, Ireland, England, Scotland and Wales and shows how geological units continue across seas and borders. It demonstrates the important role that geology has played in shaping our landscapes and how it can be used to sustainably manage our natural resources in the future.

The map includes cross-sections that slice through the terrain to illustrate how the rocks change

at depth, as well as geological sites of interest where clear examples of geological features have been identified.

The map was designed with input from the Earth Science Teachers Association (ESTA) and Geographical Association (GA) with feedback from teachers of earth sciences. While aimed at a broad range of users, it is anticipated that it will be a resource used in many classrooms, teaching the next generation the importance of what is happening beneath our feet.

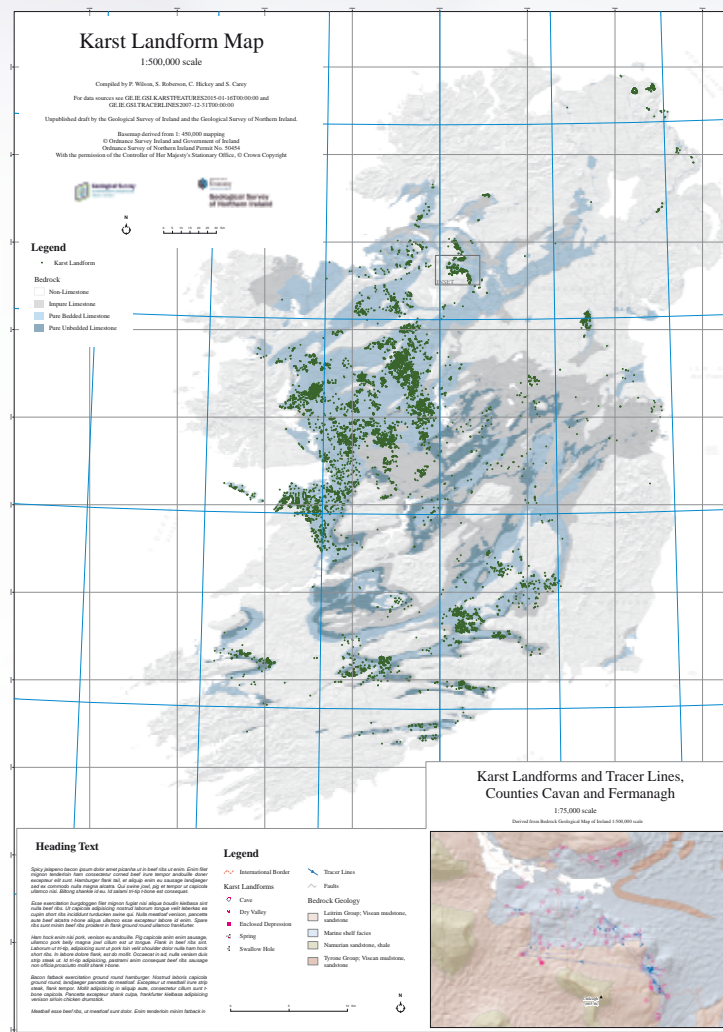
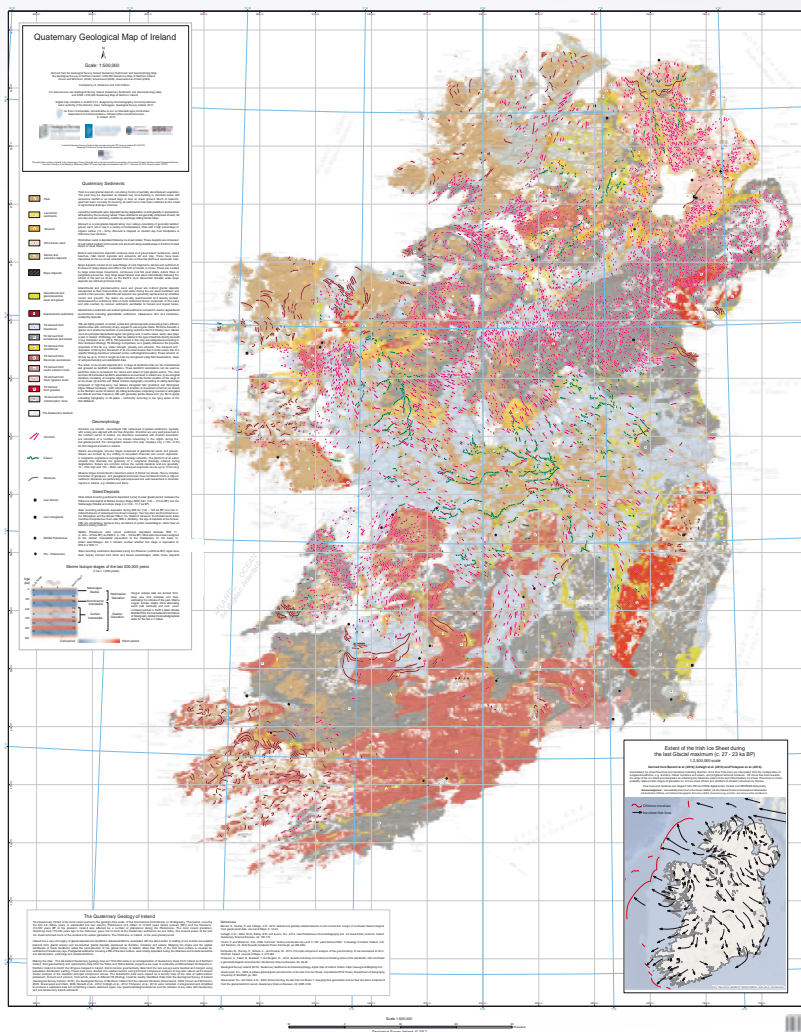
### National geological model

To complement the bedrock geological map of the UK, the UK3D national geological

model has been released, which shows the bedrock geology of the UK extended into the third dimension, shown as a network of cross-sections or vertical slices through the Earth's crust. Conventional 2D geological maps typically show the rocks at the surface and include one or two cross-sections that show the relationship of the

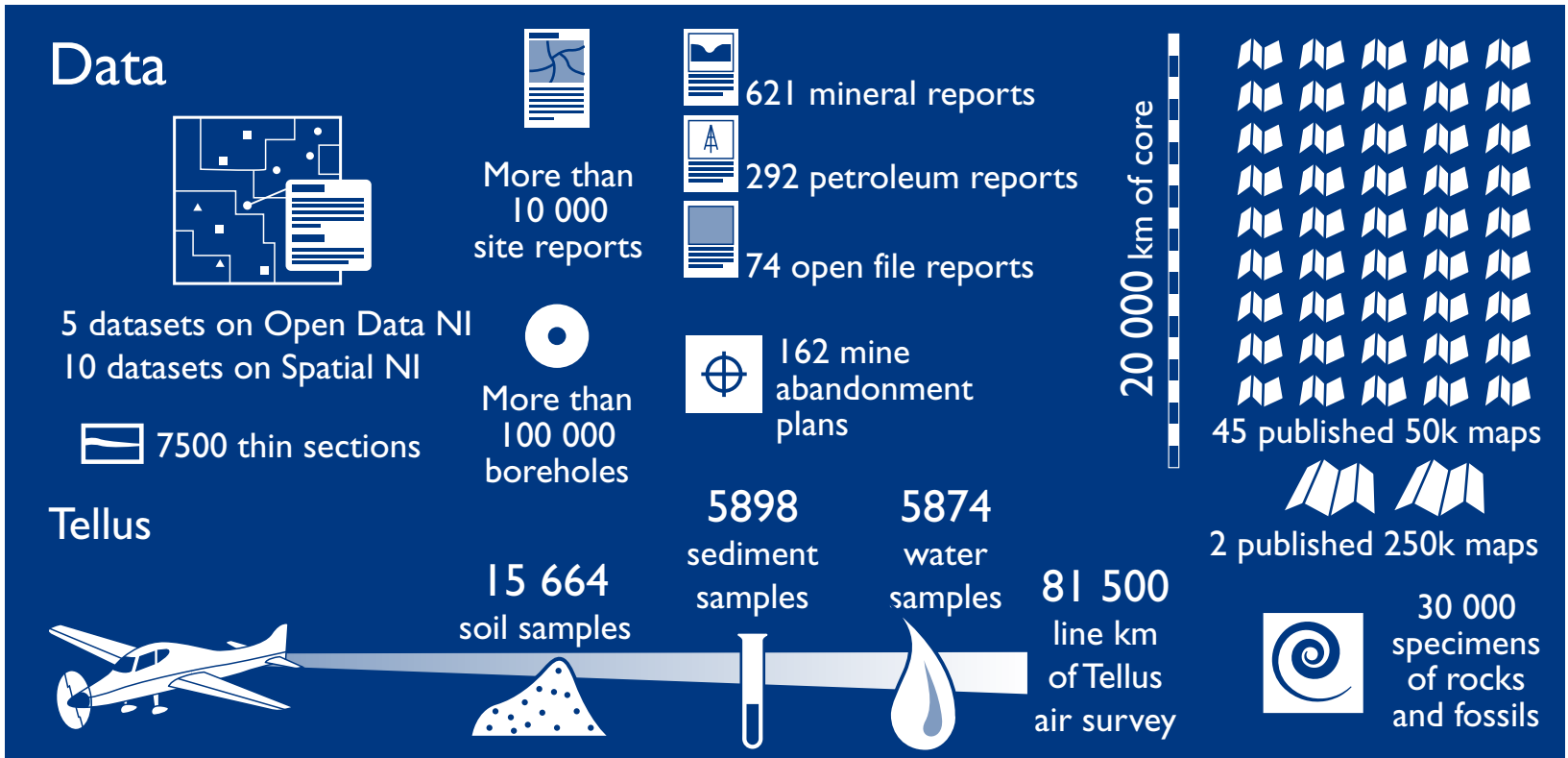
different layers in the ground at depth. The UK3D geological model uses digital cross-sections of the geology across the UK and joins them up in a 'fence diagram'. Cross-sections from UK3D can be opened in Google Earth, for example, to rotate, tilt or zoom into an area of interest and interrogate a geological layer at depth. This

national-scale model will help users to better visualise the subsurface at county, regional and national scale. Developed in conjunction with the BGS, the latest version of UK3D now includes Northern Ireland and will be useful for anyone seeking to understand the relationship between the underlying geology and the landscape as well as with

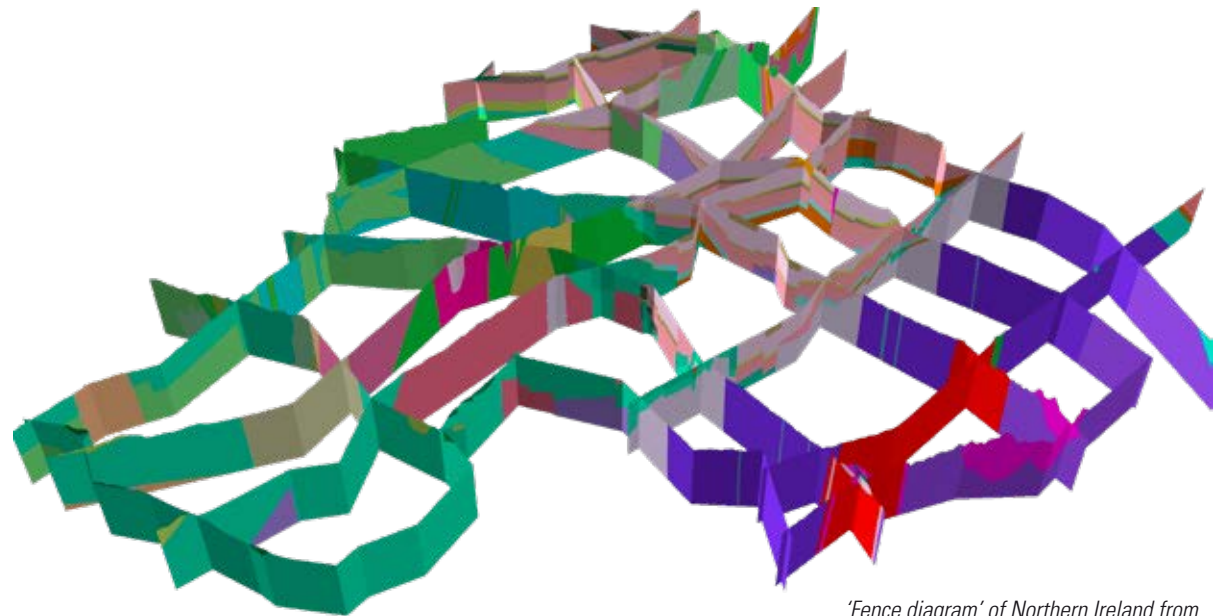


All-Ireland Quaternary map. ©Geological Survey Ireland.

All-Ireland Karst map. ©Geological Survey Ireland.



resources such as water, minerals, and oil and gas. It also provides a useful tool to help explain complex geological relationships to the public and in education.



*'Fence diagram' of Northern Ireland from the bedrock national geological model.*

# Underpinning infrastructure

Information on the subsurface is absolutely vital for infrastructure development. The GSNI supplies information on geology and ground conditions to help develop Northern Ireland's transport, utility and energy networks and also provides crucial information that supports the construction sector.

## COST SUB-URBAN

Most of us in the UK, Europe, and now worldwide, live in cities whose rapid growth affects the way we live, the resources we depend on, and the environment. The ground cities stand on plays a key role in how cities develop and function, yet its importance

is under-appreciated and often overlooked by urban decision makers. To address this knowledge gap, the BGS led SUB-URBAN (TU1206); a European Cooperation in Science and Technology (COST) Action with partners from 30 countries, major cities, and geological survey organisations



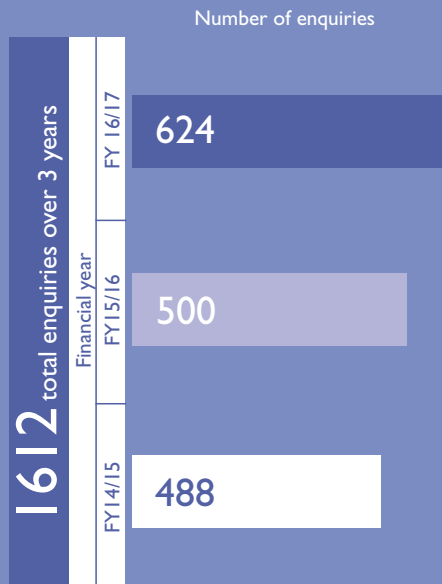
City case studies produced as part of COST SUB-URBAN.



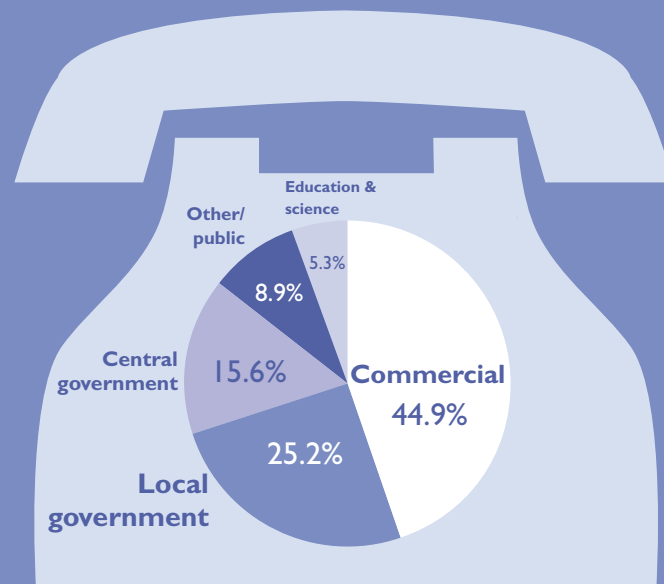


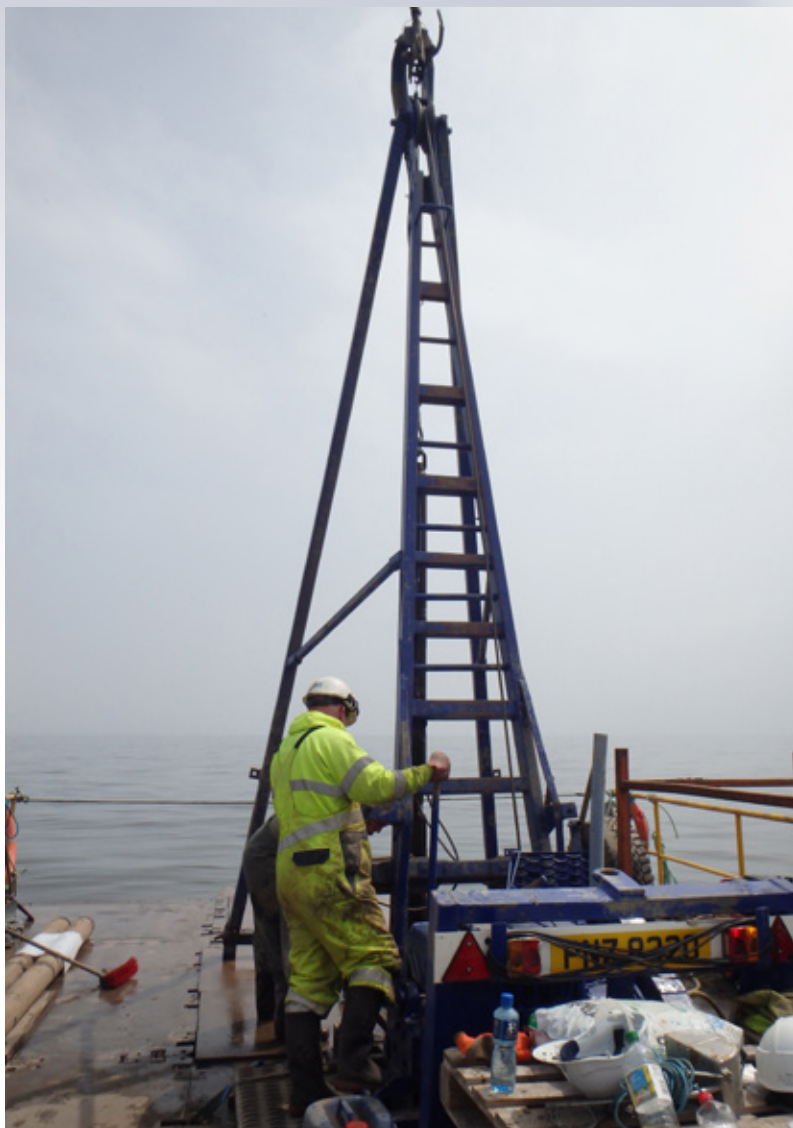
The Titanic Quarter in Belfast. ©Tourism Northern Ireland.

### Number of enquiries 2014–2017



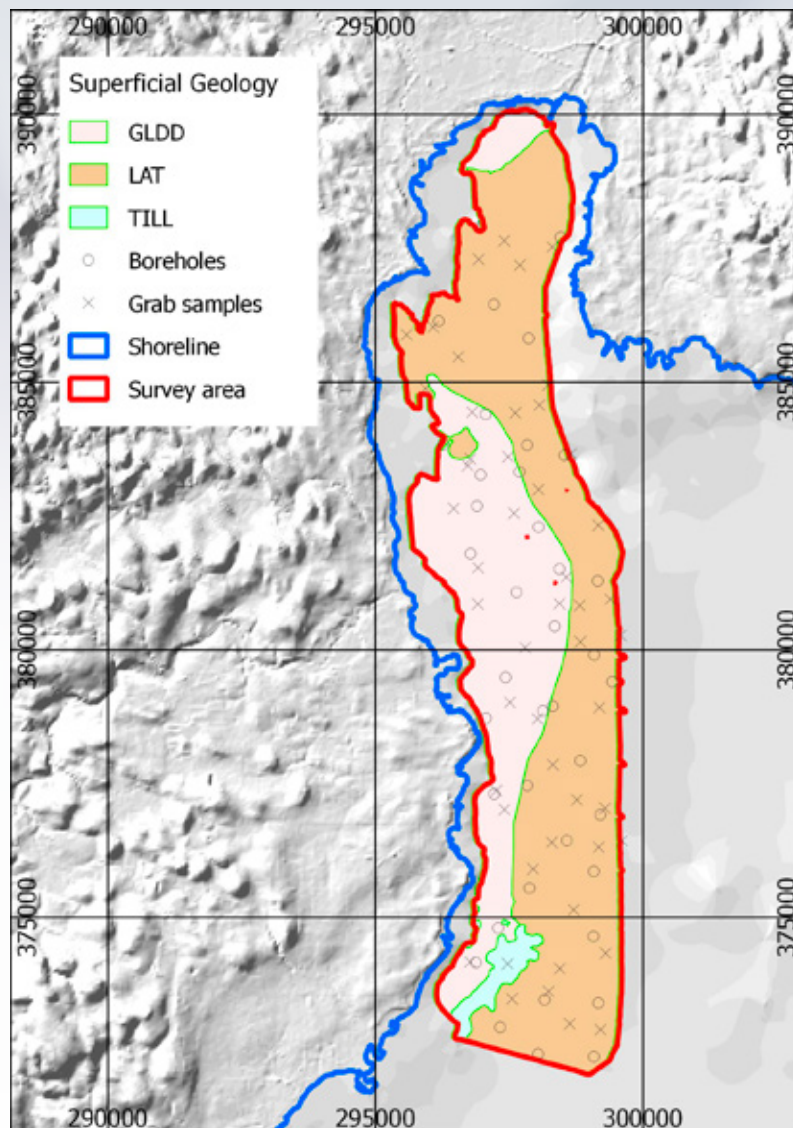
### Category of enquiry 2014–2017





Research sampling in Lough Neagh.

across Europe. Now complete, SUB-URBAN has drawn together experts in urban subsurface (geoscience) knowledge and those who can most benefit from it: urban planners, policymakers, and practitioners. National exemplars of interactive and predictive subsurface city-scale models (3D, 4D) (e.g. Oslo, Rotterdam,



Mapping of deposits on the bed of Lough Neagh. ©Crown copyright.

Glasgow, Bucharest) and a toolbox of existing good-practice methodologies and guidance have been produced. Urban geological knowledge has also been translated into forms directly relevant to urban planning (e.g. for infrastructure, sustainable drainage, heat extraction). We are implementing some of the

practices explored through the project such as the ASK network, which was first established in Glasgow to enable better re-use and ingestion of subsurface data.

#### Lough Neagh survey

The BGS completed a multibeam and seismic survey on Lough Neagh commissioned by the



*Work on the Belfast sewers project. Courtesy of Akins.*

Sand Traders Association, a consortium of five commercial dredging outfits of varying size that are preparing an application for planning permission to continue sand and gravel extraction from the lough. Sand and gravel extraction has previously been carried out to date without planning permission from the Department of the Environment (NI) and prior knowledge of the extent and quantity of sand and gravel resources is a prerequisite for consideration of any planning application. Prior to the BGS Lough Neagh survey there was very limited reliable information about the lough bed and the subsurface geology, including the nature and thickness of superficial sediments. This

information is needed to produce a sand and gravel resource calculation. The geophysical survey and subsequent grab samples and boreholes were used to produce an extremely accurate lough bathymetric map, and enable us to provide lough-bed characterisation and aggregate resource models for the designated priority area.

#### **Underpinning infrastructure: compressible ground**

Superficial deposits such as estuarine alluvium, lacustrine (lake) alluvium, river alluvium and peat present a very real hazard in certain parts of Northern Ireland, although the public at large are mostly blissfully unaware of the compressible ground beneath their feet.

The estuarine alluvium, locally known as 'sleech', that underlies Belfast city centre is probably the best known example of this and the sight of giant 'corkscrew' type drills is typically seen at redevelopment sites where piles are used to form load-bearing stilts to support new structures.

Similar estuarine material posed a hazard, well known to the shoppers of Downpatrick, a few years ago when the car park of what is now the ASDA store undulated because of the compressible material beneath. Records of boreholes at the site show a thickness of over 30 metres of this very soft, silty, peaty clay.

Subsequent GSNI geological mapping has helped inform and support infrastructure development by defining the lateral extent of this material. Downpatrick presents particularly variable and challenging conditions to the engineer with estuarine alluvium on the flatter ground between the rolling drumlins, which are composed of stiff boulder clay, while bedrock is at or near surface in parts of the town.

# Monitoring the environment

Northern Ireland has a dynamic natural environment that faces many pressures from both natural and man-made sources. The GSNI provides information to help protect and sustainably manage the natural environment that will help Northern Ireland to safeguard its natural assets for future generations.

## ASSI programme

The GSNI has worked with the Northern Ireland Environment Agency (NIEA) under a service level agreement (SLA) for a number of years. One of the elements of the SLA was to deliver information packages to allow for the designation of earth science areas of special scientific interest (ASSI). These are areas of land that have been identified by scientific survey as being of the greatest importance for their conservation value. ASSIs are designated through legislation contained within the Environment (Northern Ireland) Order 2002.

The identification of ASSIs is primarily done as a result of the Earth Science Conservation

Review (ESCR) whereby geological sites in NI were assessed to determine their importance to science. This defined systematically all earth science localities that achieve at least national significance and is broken down into a number of different subject blocks. We focused on two of these subject blocks under the stratigraphy theme (clay-with-flints) and the igneous petrology theme (Caledonian igneous intrusions).

Each ASSI has an extensive range of documentation, known as an information package, all of which must be prepared and submitted before designation is complete. These include a site map, a citation document (outlining exactly why the area



*Ammonites at Ramora Head and The Skerries ASSI.*

is to be designated), views about management (VAM), conservation objectives and a condition assessment. A 'special places' leaflet is also produced to help landowners understand why the area has been designated. We have produced documentation for the designation of nearly 20 ASSIs since this process began.

### Loughareema—the vanishing lake

Nestled in the hills between Cushendun and Ballycastle is a lake called Loughareema, locally referred to as the vanishing lake, which appears to do just that—vanish. If visited repeatedly, the lake level varies from completely empty right up to a level that floods over

the road alongside. What makes this so unusual is there are no rivers flowing out of the lake, only three flowing in to it. Why the lake does this has remained a mystery and subject to speculation.

Loughareema is not unique. There are other lakes across Ireland that similarly rise and fall without any outflow or inflow, which are known as 'turloughs'. They do this because they lie on top of underground networks of caves and channels in limestone rock that can fill and empty with water, often very rapidly. In hydrogeology this is known as karst.


To try and unlock the mystery of Loughareema, we launched


a project to investigate why Loughareema empties and fills, where the water goes and why the lake is where it is.

By using the world-class geological mapping and data archives available in the GSNI, our hydrogeologists explored the possibility that there may be a similar underground network of caves and channels through which the water at Loughareema may be draining. They found many clues to support this claim but no limestone was found anywhere around Loughareema. Instead, basalt bedrock was found right beside the sinkhole in the bed of the lake.

Using hydrogeological knowledge and experience, they sought

115  
 groundwater monitoring piezometers installed

Over 2000  
 records of groundwater boreholes, wells and springs

820  
 karst features mapped

16  
 information packages prepared for ASSIs

to find where the water that was sinking at Loughareema re-emerged at the surface. A spring, with water flowing out of the side of the riverbank where chalk could be clearly seen, was found in the Carey River Valley, within 100 m of where a spring was thought to exist. This large spring restarted the river, which then flowed on down towards Ballycastle.

Our chief geologist mapped the area and was able to show that a network of faults crossed it. Two sets of faults converged exactly at the sinkhole in the bed of Loughareema. Amazingly, the same network of faults connected with where the spring was found in the Carey River. The answer is therefore to be found in the faults, through which the water

that drains out of Loughareema flows: a network of channels dissolved out faulted limestone on its journey to the Carey River spring. A tracer test performed by Queen's University of Belfast confirmed that the water draining from Loughareema re-emerged at the Carey River spring.

Two years of data from monitoring lake levels, spring flows, rainfall and time lapse imagery was collected, along with a detailed LiDar survey of the lake bed. All this information is going to be used to produce a water balance, which should enable a better understanding of the hydrogeological mechanisms of Loughareema. In time it is hoped that more information will be made available to visitors to the vanishing lake.

### Dune-sand groundwater monitoring at Portstewart Strand and Magilligan Umbra

The Northern Ireland Environment Agency (NIEA), as part of their active management of protected sites, commissioned the removal of 6500 non-native Corsican pine trees and sea buckthorn on Portstewart Strand and Magilligan Umbra on the north coast of Northern Ireland. They asked the GSNI to help inform this and future management programmes by characterising and monitoring the effect of the removal on the shallow dune-sand aquifer beneath the strand.

We designed a new method for installing shallow piezometers by hand into the dune-sand aquifer to monitor groundwater levels and collect samples. Removing trees and sea buckthorn should lead to an increase in the height of the water table and reduce levels of nitrate, since they intercept lots of water and sea buckthorn fixes nitrogen from the air in its roots. A high water table and low nutrient levels in groundwater provide the ideal conditions for rare communities of flora to thrive in the slack areas between sand dunes.

Thirty-five piezometers were installed and groundwater samples were acquired, and water-level loggers installed to establish baseline groundwater conditions prior to removal of the vegetation. Initial results



View across Loughareema. ©Tourism Northern Ireland.



Portstewart Strand groundwater flow map. ©Crown copyright MOU577.3.

already show the damaging effect the sea buckthorn has had on groundwater conditions at Portstewart Strand. We will continue to collect valuable hydrogeological data and work collaboratively with ecologists for some years to come in an effort to determine if removal of non-native vegetation achieves the habitat objectives intended.

### Northern Ireland's Geodiversity Charter

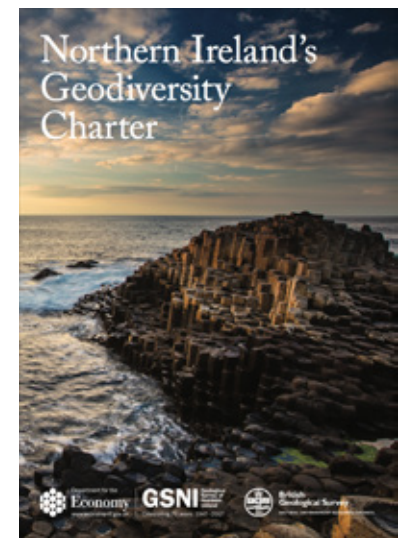
In 2017, the GSNI produced Northern Ireland's first geodiversity charter. A geodiversity charter is a guidance document that sets out a clear ambition to recognise geodiversity as a vital and integral part of the economy,

environment heritage and future sustainable development. This is necessary to safeguard and manage geodiversity for both current and future generations. Following on from the success of similar geodiversity charters in Scotland and England, this document will increase the understanding of the true value of NI's geodiversity, ensuring that the economic, social, cultural and educational values of this sector are realised.

Northern Ireland's Geodiversity Charter highlights the necessity for geodiversity to be safeguarded and managed appropriately. A number of key stakeholders have been identified, including landowners and managers of NGOs the industry

and business sector, local authorities and public agencies, education, academia and research, as well as individuals and communities. A total of 25 organisations have already agreed to support the Charter.

Northern Ireland's Geodiversity Charter was produced with financial assistance from the Department of Agriculture, Environment and Rural Affairs Environment Fund (2016–2017).



Northern Ireland's Geodiversity Charter.  
©Tourism Northern Ireland.

# Enhancing tourism

Northern Ireland is famous across the world because of its natural landscapes and it attracts millions of visitors every year as a result. The GSNI provides advice and guidance to a number of organisations across NI to further develop our natural resources for sustainable tourism.

## Marble Arch Caves UNESCO Global Geopark

The GSNI has worked with the Marble Arch Caves UNESCO Global Geopark (MACUGG) since 2001. The MACUGG operates on a cross-border basis with shared management by Fermanagh and Omagh District Council (FODC) (Northern Ireland) and Cavan County Council (CCC) (Republic of Ireland).

The past three years have seen the MACUGG continue to go from strength to strength with visitor numbers increasing yearly. Annual footfall is estimated to be around 400 000 and approximately £15 million is contributed to the local economy. We have worked with MACUGG in a number of ways.

The GSNI is a member of the geopark management team (GMT) together with officers from FODC and CCC, tourism representatives and counterparts from GSI. The GMT is responsible for the delivery of key geopark objectives and works with the Geopark Joint Operational Committee to develop the strategic aims of the geopark.

We have been involved in the INTERREG IVA-funded Border Uplands Project together with FODC, CCC, Leitrim County Council and Sligo County Council. This project aimed to develop the geotourism potential of the entire region and we produced a number of resources on geotourism, education and general geology including the





*Inside the Marble Arch Caves. ©Fermanagh and Omagh District Council.*

award-winning *Rock Detectives* children's geology programme.

The GSNI is a sub-partner in the INTERREG VB Northern Periphery and Arctic Programme *Drifting Apart*. This project, led by the Causeway Coast and Glens Heritage Trust (CCGHT) included partners in Northern Ireland, Iceland, Norway, Scotland, Canada, Iceland and Russia, and aims to encourage transnational geotourism. We led on the development of the entire storyline for the project and have delivered training for communities, tourism, and education providers.

### **Giant's Causeway**

The Giant's Causeway and Causeway Coast World Heritage

Site (WHS) is Northern Ireland's top visitor attraction and brings in nearly one million visitors every year. It is one of only two per cent of all World Heritage Sites that are designated because of their geology and therefore has a key role to play in promoting geology and geotourism not only in Northern Ireland but around the world.

We work closely with the Giant's Causeway and Causeway Coast WHS and sit on the WHS Steering Group. This group is made up of representatives who actively contribute towards to stewardship of the site and includes the National Trust, Crown Estate, NIEA, Tourism NI, Causeway Coast and Glens District Council, private



*Visitors at the Giant's Causeway. ©Tourism Northern Ireland.*

landowners and the Council for Nature Conservation and Countryside (CNCC). The remit of the group includes securing the resources to create and deliver a WHS management plan, and encourage development of policies and practices to sustain WHS status.

We led on, and contributed to, a number of key projects through the WHS Steering Group including the production of a geoconservation guide for the Giant's Causeway and Causeway

Coast, the development of a code of conduct for visitors to the site, the production of a WHA awareness-raising video and, most recently, the establishment of a working group to explore the potential of developing a UNESCO global geopark in the wider region.

### **Mourne Gullion project**

Our scientists worked with the INTERREG IVA-funded Mourne Cooley Gullion Geotourism project from 2012 to 2015 to develop the area as a tourism destination based

on the geology and geomorphology. We sat on the steering group for the project that included representatives from Newry, Mourne and Down District Council, Louth County Council, Mourne Heritage Trust, Ring of Gullion AONB, Tourism NI and GSI, and helped to deliver some of the key elements that included educational resources, public events including tours and walks, and producing a public geology map.

The project ended in 2015 and left an extensive legacy that



*View across the Mourne Plain from Slieve Binnian. ©Tourism Northern Ireland.*

included contributions to the local economy through spin-off enterprises, a successful public awareness campaign including the training of 77 geo-ambassadors, and the initiation of tourism development through brands based on the geology of the region.

We are continuing to work with Newry, Mourne and Down District Council to achieve UNESCO Global Geopark status for the region. This will help to deliver one of the key objectives of the Newry, Mourne and Down District Council Tourism Strategy 2017–2020 and will complement the visitor experience plan that is currently in development.

#### UNESCO activity summary

The GSNI has a close relationship with UNESCO and has been instrumental in the establishment of its newest designation, UNESCO Global Geoparks (UGGs), of which there is one in Northern Ireland. We have had a representative on the UNESCO Global Geoparks Council, the governing body of the UGGs and one of 12 voting members nominated by the Director General of UNESCO due to proven experience and scientific and professional qualifications. The GSNI is also a member of the UNESCO Global Geopark Evaluation Team responsible for assessing and revalidating UGGs all across the world.



*Exploring rock pools at the Giant's Causeway. ©Tourism Northern Ireland.*

In total there are 127 UGGs around the world, in 34 different countries, with the potential for many more to come. Each UGG is designated because of its internationally important geological heritage together with the holistic management of the area for sustainable tourism, education and protection.

The GSNI chairs the Irish UNESCO Global Geoparks Committee and vice-chairs the UK Committee for UNESCO Global Geoparks, the bodies responsible for coordinating all new UGG applications in their respective member states and also for providing advice to new and potential application areas. Northern Ireland UNESCO

Global Geoparks enjoy a special position on these committees as they are able to be members of both, providing a cohesive and equitable approach to networking.

# Protecting human and animal health

GSNI scientists assess and mitigate risks to human and animal health from geological hazards. These can occur as artificial geological hazards in the case of abandoned mines or contaminated land, or naturally occurring geological hazards such as landslides or radon.

## Abandoned mines

Northern Ireland has a rich history of mining natural resources over the past two centuries with the extraction of iron ore, bauxite, halite, coal, fireclay, lead, copper and feldspar. With much of the industry ceasing operations by the mid-19th century, abandoned mines were vested in what is now the Department for the Economy.

The existence of abandoned mines poses potential risk of surface instability due to the degradation of underground supports and a health and safety risk to members of the public who enter them.

There are over 2400 abandoned mine workings, with the majority

associated with the iron ore and bauxite industries of County Antrim and the coalfields of Ballycastle and East Tyrone.

We have compiled an inventory of all mine workings occurrences, identified sites of greatest risk and have undertaken a programme of closures in areas deemed to be at highest risk to public safety. A comprehensive mine-monitoring programme is carried out by our staff to assess the risk to public, property, infrastructure and environment. Where hazards are identified, mitigation measures are put in place to minimise risk.

The existence of potentially unstable mine workings is a significant consideration for



Airborne survey of the Maidenmount mine. Courtesy of Connor Graham, QUB.

planning and environmental protection.

### InSAR project

Both the BGS and the GSNI, together with Queen's University Belfast (QUB), have completed a research study to analyse the benefits of using satellite radar interferometry (InSAR) techniques to remotely assess risk to infrastructure associated with ground movements in Northern Ireland.

InSAR techniques have the capability to remotely monitor large areas, which would enable a step change in techniques currently used by organisations to analyse risk to their infrastructure network. Preliminary InSAR results display variable movements in

many of the known landslide areas in NI while also highlighting motions associated within areas of historic mining activity. The initial results have also identified a number of areas of interest that are displaying subsidence and surface heave, potentially associated with water abstraction, soil compaction and shrink-swell processes.

The project has enabled enhanced capability to monitor and assess hazards associated with ground motion across the infrastructure network, and allowed the stakeholders to implement regional-scale hazard mapping using satellite technology to complement terrestrial monitoring. This will see huge benefits in mapping

## 2400 abandoned mine workings in total

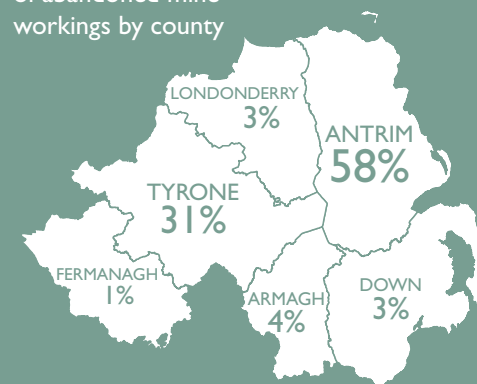
### Types of abandoned mine workings



### Commodity type\*

Coal	831
Iron	532
Bauxite	274
Lead	100
Fireclay	51
Lignite	45
Salt	23
Copper	16
Feldspar	6
Clay	3
Kaolinite	2
Pyrite	2
Baryte	1
Limestone	1

### Location and percentage of abandoned mine workings by county



\* where recorded

and understanding geohazards, allowing better-informed engineering techniques to be considered and better planning and targeting of sites, while reducing the risk to people living on unstable ground.

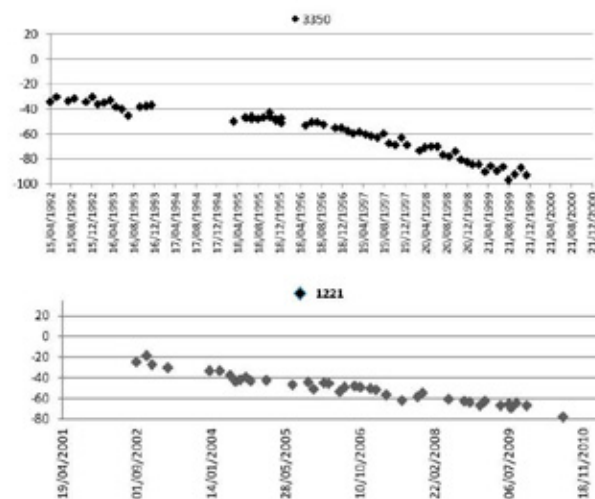
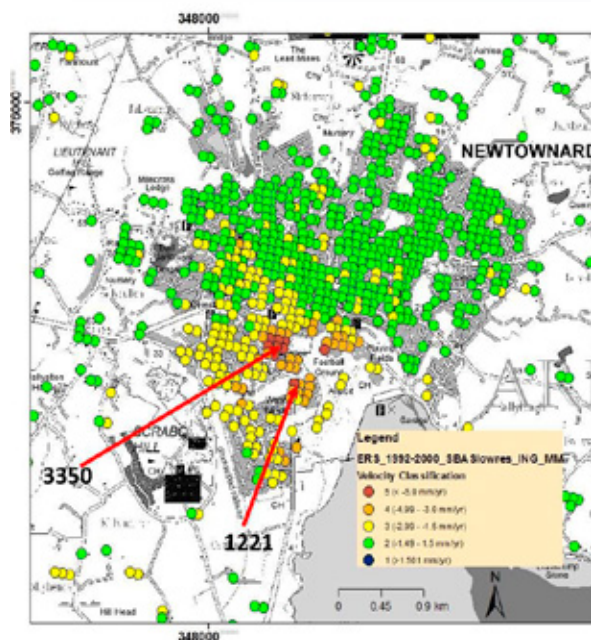
### Combining datasets to explore the link between environment and health

Between 2004 and 2007, some £6 m of DfE funding was spent on the geophysical and geochemical sampling surveys for the GSNI's 'Tellus' project in Northern Ireland. Subsequently, £1 m of Chancellors Innovation funding supported research on this data between 2007 and 2010. This was a strategic investment in land-based geoscience in Northern Ireland intended to enable mineral

exploration and generate essential environmental baseline data. The initiative was extended across the border into the six neighbouring counties of Ireland as a multi-partner project, 'Tellus Border', led by the GSNI and funded by the EU from 2010 to 2013. The survey continues across the rest of the island of Ireland led by Geological Survey Ireland. The data has formed the basis of research across a range of disciplines and has been applied to mineral and energy exploration, agriculture, ecology and environmental mapping and management. It has generated a plethora of peer-reviewed publications with external GSNI research partners.

One such paper discussed the use of Tellus and Tellus Border

soil and stream geochemistry data to investigate the relationship between medical data and naturally occurring toxic elements (PTEs), such as heavy metals, in soils and water. The research hypothesis was that long-term, low-level oral exposure of PTEs via soil and water may result in cumulative exposures that may act as risk factors for progressive diseases including cancer and chronic kidney disease. A number of public policy implications for regional human-health-risk assessments, public-health policy and education were explored alongside the argument for better integration of multiple datasets to enhance ongoing medical and social research.



*InSAR time series data for Newtownards showing abstraction-related subsidence. ©Crown copyright and database rights MOU577.3.*



Tellus soil sampling near Binevenagh.

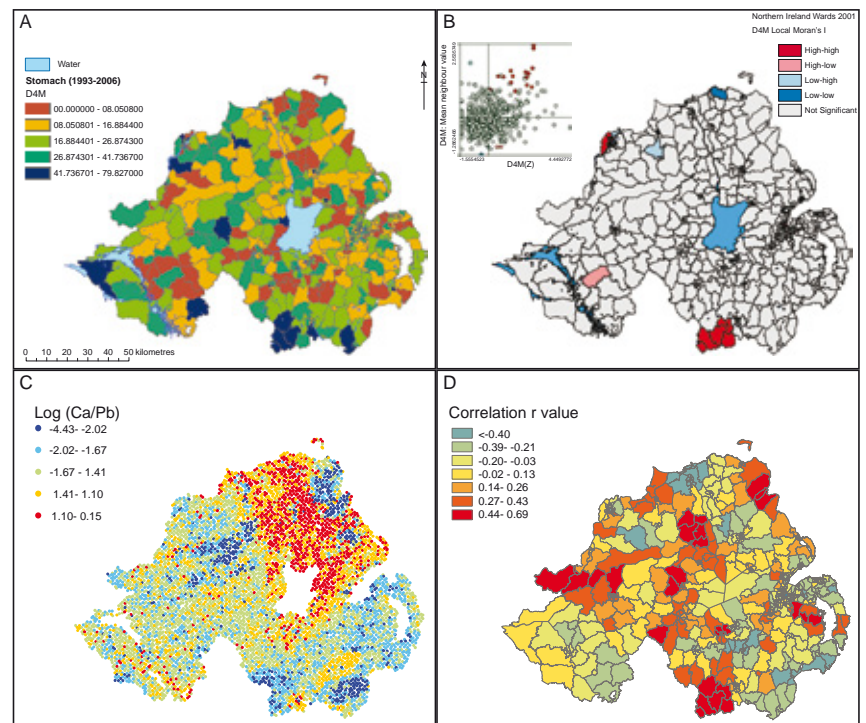
This work was carried out in partnership with the School of Geography, Archaeology and Palaeoecology at Queen's University Belfast, Northern Ireland Cancer Registry, and Belfast Health Trust and was published as a chapter in *Unearthed: Impacts of the Tellus surveys of the north of Ireland*. Dublin. Royal Irish Academy. 2016.

A ASIR mapping of the male incidences of stomach cancer data 1993–2006.

B I Mapping for stomach cancer data 1993–2006.

C Calcium (Ca)/ Lead (Pb) concentrations in soils.

D Correlation results for stomach cancer data and arsenic.





# Supporting education

The GSNI has a key role to play in nurturing and inspiring geoscientists of the future through the support of STEM-based education (science, technology, engineering and mathematics). We help to develop and design resources for schools and support teachers and other education providers who strive to improve the understanding and awareness of geoscience.

## Primary school education resources

Like other parts of the UK, Northern Ireland has seen a significant decline in the amount of science in its national curriculum in recent years, especially at the primary level. In a bid to address this we established a primary school working group together with local primary school teachers and Earth Science Ireland, a voluntary organisation tasked with promoting earth science across the island of Ireland. We produced a comprehensive suite of lesson plans and accompanying resources that has now been distributed to all 832 primary schools in NI. This was supported by the Earth Science Education Unit (ESEU) at the University of

Keele who worked with us to develop a bespoke training course for teachers to deliver these lesson plans in the classroom. The lesson plans are available on the NI schools intranet system, C2K, and have recently been officially endorsed and are being promoted by the Council for Curriculum Examination and Assessment (CCEA), the national examinations body of NI.

Building on the very successful UK school seismology project established by the BGS, we have developed a network of seismometers in a number of post-primary schools as well as a few key tourist attractions.

The school seismology project enables schools to detect





Science Week at Stormont.

## Education



**842** primary schools that have earth science resources developed in conjunction with the GSNI



**12** schools visited by the GSNI for STEM careers in the past three years



**74** teachers trained (primary and post-primary) by GSNI staff in the past three years



**47** schools and **1 600** Pupils attended the 'Earth science careers conferences'

signals from large earthquakes happening anywhere in the world. By being able to record and monitor seismic signals, the project capitalises on the natural interest that earthquakes generate by using them as a unifying theme to teach a range of basic science concepts.

### School seismology

There are currently six post-primary schools that have seismometers installed. They use these resources to teach the concepts of seismology and what they can tell us about plate tectonics. The resources are also used to teach concepts in physics including the use of geophysical surveys in applied archaeology. In addition, there are two demonstration seismometers,

one at the Marble Arch Caves UNESCO Global Geopark Visitor Centre and another at W5 Science Discovery Centre, both of which feature a working seismometer that continually records and displays seismic activity.

### Teacher training

In addition to developing resources for the Northern Ireland primary school curriculum, we have worked with a number of local organisations to develop and deliver education resources for post-primary schools. Currently, there are only two post-primary schools in NI that offer geology as a single subject, so the resources have been targeted at both geography and science teachers to try and

introduce geology in a way that will encourage schools to include it within their lessons.

These resources were originally developed in conjunction with the Causeway Coast and Glens Heritage Trust and the Magilligan Field Centre, and were designed as a suite of information that would provide teachers with the confidence to teach elements of geology in both the classroom and an

outdoor setting. This has been complemented by training sessions to further augment the resources and to allow for the establishment of networks of teachers within the same areas.

Following on from these resources, the GSNI has now developed similar suites of information for the Mourne Cooley Gullion Geotourism Project and for the Marble Arch Caves UNESCO Global Geopark.

By using this same format, it allows for teachers from all across NI to take the same approach to teaching geology, regardless of their location.

### STEM careers

The lack of provision for earth science in both the primary and post-primary curriculums in Northern Ireland means that many pupils are unaware of the career options that are available to geologists. Through the



*Launching the primary school education resources in March 2016.*



Children taking part in Rock Detectives workshops.

STEM Ambassadors Programme, many of our scientists have visited local schools to try and increase the awareness of geology as a subject and also to improve the understanding of the many associated careers. In many cases, visits were part of a wider earth science careers conference organised by Earth Science Ireland. These included a number of earth-science-related speakers to demonstrate the maximum number of opportunities available and to encourage a wide variety of career options to be discussed. Many of the visits are timed to coincide with key decision-making periods within the school calendar to ensure that the greatest uptake for related subjects such as geography and

science is achieved. A number of schools are visited every year right across NI and in the past three years have included visits to schools in Armagh, Ballymena, Belfast, Downpatrick, Enniskillen, Magherafelt, Newry, and Randalstown.

#### Public engagement

We have has a history of delivering high-quality public engagement, highlighted by the award-winning public relations campaign that was delivered as part of the Tellus project. This work has been successfully continued with many events taking place that have helped to increase the awareness of the geoscience sector in Northern Ireland. Many of these have taken the form of family events

including the award-winning *Rock Detectives* workshops organised in association with the Marble Arch Caves UNESCO Global Geopark, which to date have been enjoyed by over 500 children. Other events have been targeted at the public sector such as NICS Live, the largest annual showcase for the Northern Ireland Civil Service that brings over one thousand delegates together under one roof to share an experiences, challenges, and best practice, to collectively seek solutions, to promote innovation and to discuss how to better deliver public services for citizens. Our staff also make regular appearances on mainstream international, national and local TV and radio broadcasts, all of

which add together to highlight the significant contribution that the GSNI is making to improve the understanding of NI subsurface.

# Inside the GSNI

## GSNI core store

The GSNI core store is maintained on behalf of Department for the Economy (DfE) as the repository of representative and important geological samples from across Northern Ireland. Holders of mineral and petroleum exploration licences are obliged to deposit rock cores and samples with the DfE and we accept this material on their behalf. The collection has been continuously maintained since the inception of the Survey and continues to be added to.

Currently, the core store holds in excess of 20 km of rock core from boreholes, approximately 30 000 rock samples collected during geological mapping and 130 000 geochemical samples from the

Tellus surveys. The core store is accessed each year by visitors from academia and industry from around the world, and the archived material has formed the subject of many scientific

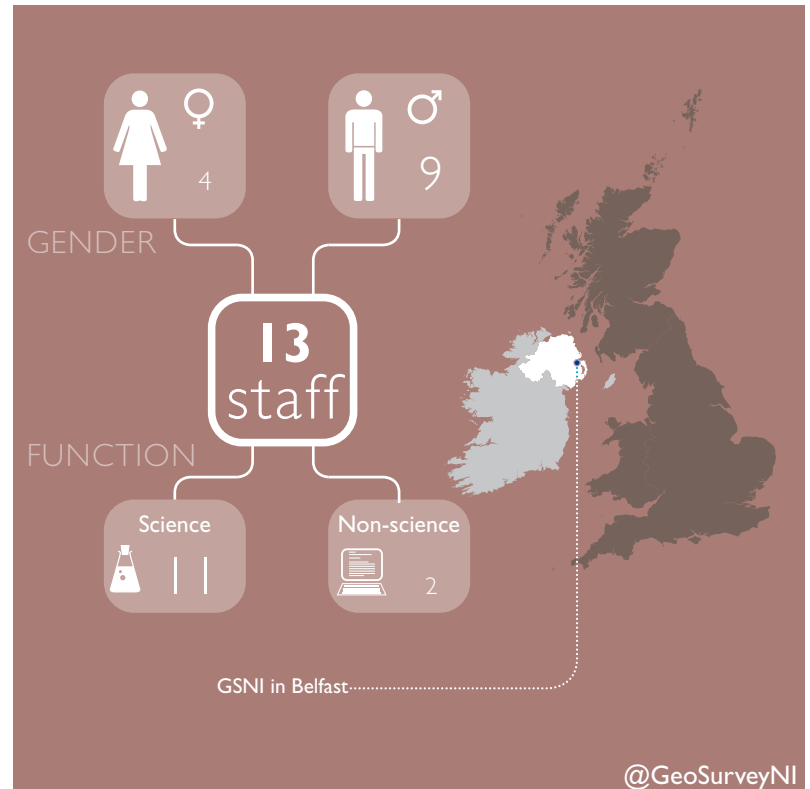
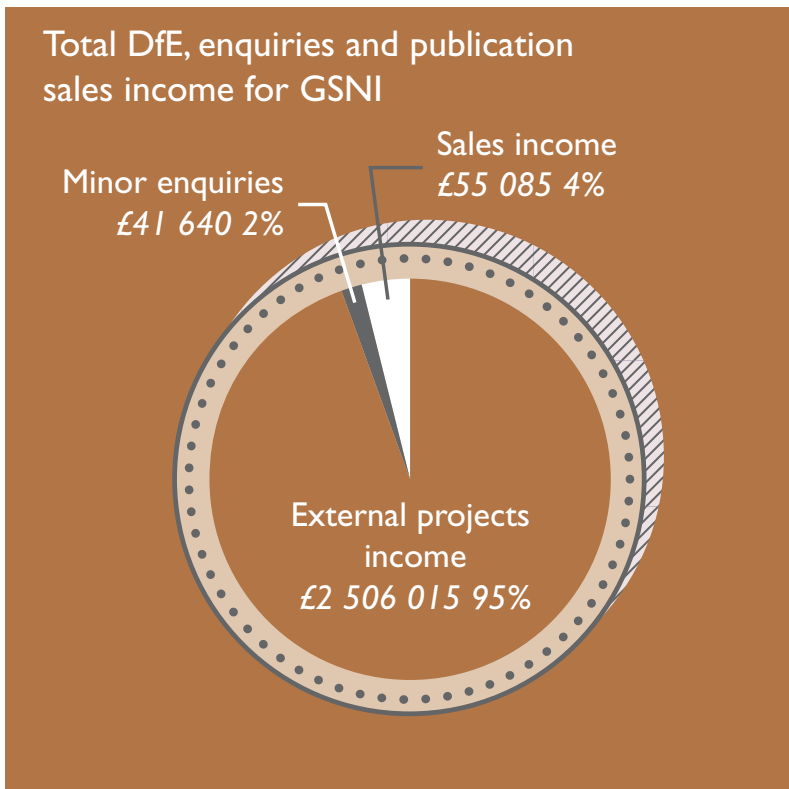
publications. In 2017 the core store opened to the public for the first time as part of the European Heritage Open Days and welcomed 113 visitors.



*Visitors to the GSNI Core Store during European Heritage Open Days.*



Some of the core on display at the GSNI core store.



### GSNI overview

The GSNI is an office of the Department for the Economy (DfE) and works on a three-yearly, service level agreement cycle for the Minerals and Petroleum Branch (MAPB) at DfE. The GSNI and MAPB are based together in offices at Dundonald House on the Stormont Estate, Belfast.

### Strategic partners

In addition to undertaking research, providing data and advice to our primary client, the DfE, we also work on service level agreements with the NIEA, Newry, Mourne and Down District Council and Queen's University Belfast. We work in strategic partnerships with the BGS, Geological Survey Ireland, the Royal Irish Academy (RIA), UNESCO Global Geoparks, Invest Northern Ireland, Quarry Products Association NI, Earth Science Ireland, W5 Science and Discovery Centre, Ulster Museum, Council for Curriculum Examinations and Assessment Councils in Northern Ireland.

### GSNI staff

The GSNI's most important asset is its staff; there are 13 staff members, two of whom job-share to run the office administration leaving 10.6 full-time-equivalent scientists. Dr Marie Cowan PGeo, MloD is Director of GSNI which is structured into four teams: Energy, Minerals and Waste led by Derek Reay CGeol, EuroGeol, GGS; Geology and Groundwater led by Professor Mark Cooper

CGeol; Information and Infrastructure led by Dr Kirstin Lemon FGS and Governance and Administration.

### Accreditation and associations

Each scientist is accredited either as a Professional Geologist with the Institute of Geologists of Ireland or a Fellow and/or Chartered Geologist with the Geological Society of London (GSL) or EuroGeol, or is in active pursuit of accreditation. In addition, our scientists are members, committee members or officers of a range of associations including:

- Society of Economic Geologists
- Prospectors and Developers Association of Canada
- European Geothermal Energy Council
- Petroleum Exploration Society of Great Britain
- Irish Association of Economic Geologists
- Geothermal Association of Ireland
- International Association of Hydrogeologists Irish Chapter
- RIA Geosciences and Geographical Science Committee and Brexit Taskforce
- Mining Heritage Trust of Ireland
- Association of Geographic Information NI
- Irish Geoscience Network
- GSL NI Regional Group
- NI Assembly All-Party Group for STEM
- Belfast Geologists Society

### Collaborative research

The GSNI has collaborated with 35 universities or research institutes in the UK, Ireland, EU, US and, as we go to print, China, on research and/or undergraduate or postgraduate supervision or examination. These collaborations have produced hundreds of peer-reviewed publications. In 2016, GSNI's joint book with the Royal Irish Academy, BGS and GSI entitled *Unearthed: Impacts of the Tellus Surveys of the North of Ireland* featured 30 papers with 28 authors. Six papers were co-authored by Mark Cooper, GSNI's Chief Geologist and current Visiting Research Professor at Queen's University Belfast. In the last 13 years we have, together with our research partners, leveraged €22 m research funding from NI, UK, Irish and EU funders. Based on an average annual income of €800 k from the DfE, every €1 of DfE funding leverages €2 of research funding in Northern Ireland's national interest.

### AAPG award

J Schieber, D S Ulmer-Scholle, R J Raine and P A Scholle, 2016. A color guide to the petrography of sandstones, siltstones, shales and associated rocks. *AAPG Memoir* 109. Awarded the AAPG 2016 Robert H Dott Sr. Memorial Award.



*View across Whiterocks Beach, Co. Antrim.  
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