1. The Tellus geoscience surveys of the north of Ireland: context, delivery and impacts

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€15 million of government and EU funding was spent on geophysical and geochemical sampling surveys in the north of Ireland between 2004 and 2013. This was a concerted national investment in the terrestrial earth sciences in Ireland, intended both to stimulate mineral exploration and to generate essential data for environmental management. Here we summarise the background to this work and the surveys that were undertaken. The scientific results have been widely published elsewhere and the purpose of this book is to reflect on the outcomes in terms of the economy, the environment and policy.

The background to the Tellus programme

There is a long history of mineral exploration and development throughout the island of Ireland and the mining industries continue to contribute significantly to the economy. Mining of metallic ores dates from the Bronze Age, and in the 18th and 19th centuries major deposits of base metals were exploited in both Northern Ireland and the Republic of Ireland to supply the Industrial Revolution. Today, the Republic of Ireland is the leading producer of zinc ore in Europe while in Northern Ireland salt, coal, bauxite and gold are currently mined or have been mined in the recent past. Roadstone and other quarry products are important exports from both jurisdictions.

It is well known globally that investments by governments and international development agencies in regional geoscience mapping have been successful in encouraging inward investment in mineral prospecting and development. To stimulate exploration throughout Ireland, both governments began in the late 1990s to plan an integrated project to acquire continuous regional geochemical and airborne geophysical data across the whole island.

Originally named 'The Resource and Environmental Survey of Ireland', or RESI, the project was initially scoped to survey Ireland in one operation. The concept was developed in discussions involving the Northern Ireland Department of Economic Development (now the Department for the Economy), the Geological Survey of Northern Ireland (GSNI), the British Geological Survey (BGS) and the Geological Survey of Ireland (GSI),

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with technical advice also from the US Geological Survey. Detailed scoping and costing studies were made by the geological consultancy CSA Group Ltd of Dublin, both for an all-island project and separately for Northern Ireland. The RESI project proposal was evaluated by environmental economists based at University College Dublin, who estimated a potential cost–benefit of 1:5.

The Tellus Project

As it turned out, the government of Northern Ireland provided the first tranche of funding and the Tellus Project, as it was called, began in May 2004. Contributions to the budget were made subsequently by the Department of Environment and by the 'Building Sustainable Development' scheme of the EU Rural Development Programme, administered by the Department of Agriculture and Rural Development. An interim continuation of the Tellus Project in Northern Ireland was financed jointly by the Department of Enterprise, Trade and Investment (DETI) and the BGS, and further funding for 2009–11 by the Chancellor's Fund for Northern Ireland, to pursue objectives of the Northern Ireland Regional Innovation Strategy Action Plan 2008–11. In these later phases GSNI and BGS together pursued more focused applications of the data, with both mineral exploration and environmental objectives. The data acquired during the Tellus Project, 2004–8 and regional interpretations of the geophysical and geochemical data have been presented previously (Young and Donald, 2013).

The Tellus Border Project

An objective of the Northern Ireland Regional Innovation Strategy was to collaborate with partners in the Republic of Ireland in extending the Tellus Project, in accordance with the original RESI concept. Accordingly GSNI and GSI, with Queen's University Belfast and Dundalk Institute of Technology, successfully applied for a £4 million grant under the INTERREG IVA programme of the European Regional Development Fund to fund the Tellus Border Project. This grant, which ran until the end of 2013, financed continued analysis of the Tellus data in Northern Ireland and further airborne geophysical surveys and ground geochemical sampling programmes of the Border Region of the Republic of Ireland – counties Cavan, Donegal, Leitrim, Louth, Monaghan and Sligo.

The Tellus Border airborne survey was undertaken using the same technical specifications and survey aircraft as the earlier Tellus airborne survey, thus facilitating the merging of the data sets. The new geochemical sampling surveys were undertaken to the same technical protocols as the Tellus Survey, although the budget available did not initially extend to such comprehensive laboratory analysis. Further analysis was later financed by the Department of Communications, Energy and Natural Resources (DCENR). The Tellus Border Project facilitated and funded several research projects by industry and research institutions. Reports describing the data acquisition and processing and the results of research are presented on the project website, www.tellusborder.eu.

Project goals and benefits

The Tellus and Tellus Border Projects shared the same goals, concerned with natural resources development on one hand and environmental management on the other. These were:

- to stimulate mineral exploration and development by acquiring and publishing essential regional geoscience data and maps;
- to generate data sets of the regional geochemistry of soils and streams as a baseline against which to measure environmental change;
- to contribute to sustainable land-use planning decisions by mapping relevant geological conditions;
- to improve human health by detecting and mapping geological conditions that might give rise to hazards such as radon gas, radiation and contaminated land; and
- to contribute to environmental and agricultural management by mapping the concentration of trace elements in soils and steams, some of which data were required in complying with national and EU standards.

The survey programmes

The geophysical and geochemical surveys and their results are described in later chapters of this book but are introduced briefly here.

Airborne geophysical survey

Geophysics is the study of the physical properties of the Earth. Three of these can be measured from an aircraft: the Earth's magnetic field, the electrical conductivity of the upper skin of the earth, and the gamma radiation from rocks and soils at the surface. The intensities of these parameters vary spatially and we can interpret these variations in terms of underlying geological structures. Geophysical methods are particularly useful for mapping areas, as in much of Ireland, where superficial deposits such as glacial till, alluvium or peat obscure the bedrock.

On survey, the aircraft flies along a network of parallel lines, taking readings at close and regular intervals. A global positioning system continuously records the aircraft's position and the aircraft's height is measured accurately with a radar altimeter. Data are recorded digitally and after correction and standardisation are contoured and presented visually as coloured maps and images. The digital data may be processed numerically with a variety of spatial filters and operators to enhance or suppress features or trends.

Geochemistry surveys

Geochemical sampling and analysis of soils, streams and rocks is used routinely in mineral exploration. These data also have wide environmental and agricultural applications in mapping concentrations both of essential nutrients and of potentially harmful elements. A regularly spaced data set acquired to an exacting protocol provides a standard, or baseline, for the current chemical composition of soils, stream sediments and stream waters that may be used to monitor change, both locally and regionally.

Regional geochemical surveys that focused on agricultural applications had previously been made over parts of the region, although at generally wider sampling intervals. The purpose of the Tellus surveys was to undertake more comprehensive and detailed sampling and analysis that would extend the range and detail of previous surveys and provide analyses of a wider range of elements, particularly those relevant for mineral exploration.

Data management and visualisation

Data from both geophysical and geochemical surveys are usually presented in the form of scaled coloured maps or images, as illustrated in the following chapters. The Tellus digital data are freely available from the Geological Surveys and may be downloaded from national data repositories. The data are readily adaptable for use in geographic information systems and other mapping systems. Metadata have been prepared in accordance with the INSPIRE Directive of the EU.

Stakeholder engagement

Good communication with stakeholders was an important and integral objective of both the Tellus and Tellus Border Projects. From the outset it was vital that every measure should be taken to counter any possible negative public perceptions of the survey work, particularly where it might be thought to be infringing privacy and where there was the possibility of frightening livestock by aircraft noise. Accordingly, communications campaigns were designed, with the help of professional advisers, to ensure that the wider public understood the goals and values of the work. County and District Councils were briefed in person by project staff, radio and TV interviews were given, open days were held, farming and other interest groups were visited, and a wide range of media outlets was used to disseminate leaflets, notice and press articles. During the airborne operations telephone hotlines were managed to receive and respond to complaints and enquiries.

The success of both campaigns significantly raised awareness of the government commitment to the application of science for the public good, and both Tellus and Tellus Border communications campaigns were recognised by awards from national public relations professional bodies. Chapter 4 of this volume describes the detail of the Tellus Border communications campaign and the extent to which it reached a wide range of stakeholders.

Results and outcomes

To date some 250 scientific papers and conference presentations and two books have been produced by the two projects or by researchers using project data. Many of these are briefly reviewed in Chapters 2 and 3. The remaining chapters are intended to illustrate the outcomes and impacts of the results on different areas of the economy or policy, rather than the results of research. General assessments of the various outputs and benefits were presented in a series of post-project evaluation reports (BGS, 2012; PAC, 2008, 2014).

Mineral and energy exploration

A tangible impact of the Tellus Project on mineral exploration was the increase in data licensing in Northern Ireland following publication of the first set of data in October 2007. At the beginning of the project only 15% of the land area of Northern Ireland was licensed for exploration; by early 2008, following data release, 70% of the area was licensed by companies from the UK, Canada, Australia and the Republic of Ireland. Increased interest was also of course stimulated by a doubling of the gold price over the same period. The percentage of area licensed has since declined, following relinquishments required by the terms of licensing, but mining companies are still pursuing active exploration and mine development campaigns, notably for gold and precious metals. Similarly, in the Republic of Ireland, almost all land available for licensing has been taken up in the Border Region.

Some impacts of the project on mineral exploration in Ireland are presented in Part 2 of this book. In Chapter 5, Earls reflects on our continued need for mineral products and the challenges facing mining in the context of sustainable development agendas. In Chapter 6, Earls examines the impact of Tellus on the exploration for gold in Ireland and the encouraging potential for further discoveries in the light of the project results. In Chapter 7, Dempster *et al*. discuss the widespread distribution of gold by glacial action and demonstrate how multivariate statistical analysis of the data can help to identify further prospective areas.

The limited supply of 'critical' metals and metalloids, which are vital to many modern technologies, is a current worldwide concern. Based on the Tellus geochemistry, Lusty (Chapter 8) considers the potential for discovering these in the north of Ireland and the possibility of their extraction as a by-product in existing or future mining operations. Several of the critical metals are found in the rocks of the Mourne Mountains, although not in economic quantities, and in Chapter 9 Moore *et al.* investigate their origin in granite bedrock and their dispersion locally in stream sediments.

The Mourne granites are among the most radioactive in the UK and Ireland and may have potential as a source of geothermal energy. Ture *et al.* (Chapter 10) summarise the results of surveys to examine the depth extent and heat potential of the granite. North of the Mournes, the Newry Igneous Complex appears less radioactive but displays distinctive geophysical and geochemical characteristics. Cooper *et al.* (Chapter 11) combine these results with recent age-dating data to derive an innovative model of the intrusion sequence.

In the west, the Tyrone Igneous Complex is currently a focus for exploration, as the new data have greatly improved our understanding of the complex and its potential to host volcanogenic massive sulphide mineralisation. Hollis *et al.* (Chapter 12) describe how using the Tellus data has helped to identify new mineral occurrences and zones for further exploration.

Base metal and gold deposits are hosted by sedimentary rocks in the Monaghan–Armagh mineral belt. Cooper *et al.* (Chapter 13) describe how they used Tellus airborne and ground electromagnetics to improve geological mapping in this historically prospective district.

Anderson *et al.* (Chapter 14) also focus on improving geological mapping and our understanding of tectonic processes. They analyse the major regional faulted structures mapped by the Tellus airborne magnetic data in terms of Cenozoic tectonics of Britain and Ireland, work that has implications for fluid flow in crustal rocks and for hydrocarbon exploration.

Agriculture and ecology

The Tellus geochemical sampling surveys have defined the concentrations of some 57 trace elements and parameters in soils, stream sediments and stream waters. Many trace elements are essential nutrients for arable crops, grassland and livestock. Others are potentially toxic at higher concentrations. The Tellus sampling, at one site per 2 km^2 in Northern Ireland and one per 4 km^2 in the Republic of Ireland, is the most detailed sampling programme undertaken to date in the region and provides core information for agricultural management.

In Part 3, Lark *et al.* (Chapter 15) present a case study showing how geostatistical methods allow us to quantify the uncertainty in mapped soil pH (acidity) and its implications for management of pasture soils, using all the Tellus and Tellus Border data. Such information is vital for farm management, and the authors discuss how it can be communicated understandably. The chapter illustrates the power of geostatistics to extract the maximum information from and quantify the uncertainties of geochemical data.

Two chapters consider how the Tellus data can be used in the management of wetland ecology. McCarthy *et al.* (Chapter 16) have combined Tellus Border soil geochemistry with ecological parameters to inform the development of a framework for wetland assessment. Flynn *et al.* (Chapter 17) consider the hydrogeological characteristics of wetlands and examine how information on soil geochemistry can be used in assessing and protecting against nutrient enrichment.

Environmental management

Tellus geophysical and geochemical data can contribute in various areas of environmental survey and monitoring, as illustrated in Part 4. Several chapters illustrate the benefits of advanced statistical analysis. In Chapter 18, Beamish calculates the levels of terrestrial radioactivity present in the north of Ireland and considers these in terms of current exposure guidelines. Some examples of man-made radioactivity are considered, including the residual effects of the Chernobyl accident of 1986. In Chapter 19, Beamish investigates the extent to which airborne radiometrics may be used to characterise soils and particularly their carbon and water contents, information that is germane to assessing and monitoring the carbon-in-soil inventory. In a third chapter using the radiometric data (Chapter 20), Appleton and Hodgson describe how these data, with the soils' geochemistry, have been used to improve predictions of in-house radon levels.

The geochemistry of soil is widely used for the detailed assessment of potentially contaminated land, at the site scale. Regional Tellus data are used to put site-scale data in context and particularly to define the expected, natural backgrounds of different elements at any location. In the first of several papers that consider the important issue of defining a background or threshold level, McIlwaine *et al.* (Chapter 21) present a method for establishing thresholds for distinguishing geogenic and diffuse anthropogenic contaminant sources, and concentrations generated by point sources, using zinc and iodine as examples. Cave *et al.* (Chapter 22) use multivariate statistics to determine the sources of geochemical inputs in the Tellus Border soils and apply the process to several elements across the survey area. For stream sediments, Palumbo-Roe *et al.* (Chapter 23) assess the backgrounds of metals in data from the Monaghan–Armagh mineral belt, where it is essential to establish relevant thresholds for environmental assessments and for establishing feasible catchment restoration goals. In Chapter 24, Lass-Evans studies local and regional backgrounds in a mixed urban–rural cross-border zone, and identifies elements that exceed or approach environmental benchmarks.

In considering the possible health effects of contaminants in soil, Palmer *et al.* (Chapter 25) investigate oral bioaccessibility of four potentially harmful elements – arsenic, chromium, nickel and lead – information about which is essential in establishing rational environmental benchmarks for land-use planning. McKinley *et al.* (Chapter 26) apply geostatistics to investigate the spatial relationship between certain diseases and levels of potentially harmful elements in soils and water.

Airborne geophysics can in some cases map the spread of leachates from mine sites or landfills in the near-surface and into groundwater. Landfills typically display enhanced electrical conductivity, which can be mapped by geophysical methods. Ofterdinger *et al.* (Chapter 27) describe a case study that examines the airborne anomaly over a landfill and tests methods of ground follow-up. In a groundwater application of airborne techniques Dickson *et al.* (Chapter 28) describe how they used airborne magnetics to map the distribution of intrusive dykes that affect underground water flow in the important Lagan Valley aquifer near Belfast. Incorporating these data improved the reliability of the groundwater model used to estimate sustainable yield.

Carbon-in-soil has been the subject of several previous studies based on Tellus data. Ashton *et al.* (Chapter 29) describe the results of a project that combined further field studies with Tellus data to examine the factors that influence the ability of soil to take up carbon; they found that soil mineralogy and geochemistry play an important role in determining the concentration of soil organic carbon. Ruffell and McKinley (Chapter 30) investigate the extent to which regional databases such as Tellus can provide reliable data for use in forensic applications.

The future of Tellus

Since 2014, the Tellus programme has continued to expand southwards in Ireland under the direction of the GSI, with the objective of completing geophysical and geochemical surveys of 50% of the area of the Republic of Ireland by 2017 (see www.tellus.ie). Contracts for airborne geophysical survey and geochemical sampling and analysis are let regularly and data are released as they become available. Wide participation by the research community is sought and encouraged, notably by commissioning multiple short research projects to work on the questions and challenges posed by the data. The survey of the island is scheduled to finish by 2023, just 25 years after the project was conceived. However, interpretation and analysis of such a volume of high-quality earth science data will continue into the foreseeable future, accompanied, it is hoped, by a stream of economic and environmental benefits.

The Tellus model has now extended to Great Britain, where in 2013/14 the BGS completed 'Tellus South West', a programme of airborne geophysical, LiDAR, geochemical sampling and habitat surveys of Devon and Cornwall, in partnership with the Centre for Ecology and Hydrology, the British Antarctic Survey and the University of Exeter Camborne School of Mines (see www.tellusgb.ac.uk). The results of the several Tellus projects were presented to UK parliamentarians in 2014 (Howard *et al*., 2014) and in 2015, Research Councils UK extended the concept further, launching 'Tellus How', an outreach project designed to embed the experience and value of the surveys into local government, businesses and environmental organisations (see http://gtr.rcuk.ac.uk/projects?ref=NE/M021777/1).

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References

British Geological Survey (BGS), 2012 *Post-project Evaluation of the Tellus2 Project*. Report for Department of Enterprise, Trade and Investment. Belfast.

Howard, A.S., Young, M.E. and Cowan, M.T., 2014 'Valuing and realising our natural capital assets: Tellus all about it', *Science in Parliament*, 71, 3, 28–30. Available at http://nora.nerc.ac.uk/507975/.

PA Consulting Ltd (PAC), 2008 *Post-project Evaluation of the Tellus Project*. Report for Department of Enterprise, Trade and Investment. Belfast.

PA Consulting Ltd (PAC), 2014 *Post-project Evaluation of the Tellus Border Project*. Report for Department of Communications, Energy and Natural Resources. Dublin. Available at http://www.tellusborder.eu/Library.htm.

Young, M.E. and Donald, A.W. (eds), 2013 *A Guide to the Tellus Data*. Belfast. Geological Survey of Northern Ireland. Available at http://nora.nerc.ac.uk/509171/.

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