The example of the British Geological Survey: past, present and future

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Cover illustration
Extract from BGS 1:50 000 solid geological map Sheet 52 (Thirsk)

This map was prepared using digital techniques

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BRITISH GEOLOGICAL SURVEY

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The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Overseas Development Administration.

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ABSTRACT

The British Geological Survey was established in 1835 with a mandate to geologically map Britain. This example was followed by many other countries over the next 50 years. A pattern was established which saw the work of the geological surveys as an essential public service paid for and used by 'the tax payer'. This enabled most Surveys to take a long-term strategic approach to geoscience. Mapping was (and indeed still is) seen as the primary role of the national geological survey and virtually all surveys had a programme, the aim of which was to complete the geological mapping of the country. Progressively it was realised by the geologist that such an aim was neither achievable nor necessarily desirable. At the same time others questioned why areas were mapped, remapped and remapped again.

Many changes in the way geological surveys work in recent years have resulted from changes in government philosophy with many governments no longer prepared to leave it to surveys to decide what is in the 'public good'. Market-based policies resulted in further changes as the user was expected to pay a progressively larger share of the cost. As a consequence the British Geological Survey has a very different modus operandi to that of the original survey or even the survey of 10 years ago. Much of the funding is now 'soft'; long-term core funding constitutes less than 50 per cent of the budget making it difficult to develop a strategic approach in some areas. Nevertheless the Survey has survived and, indeed, has started to prosper again after some difficult years. Traditional mapping activities now constitute a smaller proportion of the Survey's activities and it is necessary to have a balanced portfolio with a major involvement in activities related to waste disposal, groundwater resources studies, environmental geochemistry, etc, many of which are underpinned by geological mapping. The Survey has strengthened marketing as an activity and now vigorously sells its services to the public and private sectors. To some this is an anathema for a geological survey, but if done in the right way it can result in a significant gain to geoscience.

In the 1830s Britain served as an example to the rest of the world in establishing a national geological survey. The British Geological Survey of the 1990s may not necessarily serve as an example for the future for all countries but it is likely that as economic constraints bite, progressively more countries will have to follow its example.
INTRODUCTION

The importance of mineral resources, coupled with the recognition of the importance of geology as a science in its own right, led to the establishment of geological surveys in virtually all major countries during the 19th century, commencing with the British Geological Survey in 1835. These surveys or equivalent institutions have become firmly established within the public infrastructures of most nations, and although they may vary in breadth of function, their core purpose is essentially the same — to make available comprehensive geological data and knowledge on the national landmass and offshore areas.

This paper will examine the manner in which the geological survey was established in Britain and how this served as an early role model for most of the world’s major geological surveys. Over the years the British Geological Survey has changed in response to the changing needs of society, and scientific and technological advances. The rate of change has never been more marked than in the past 10 years. The paper will examine those more recent changes, outline the nature of the British Geological Survey in 1992 and consider the extent to which the British Geological Survey 1992 model is likely to be applicable to other geological surveys now and in the future.
THE EARLY YEARS

The antecedents of the British Geological Survey lie perhaps first and foremost in the most active period of pioneering mapping of William Smith (Figure 1) extending from about 1790 to 1830. His work in southern Britain as part of the canal-building programme, which was underway at that time, resulted in the production of the first modern geological maps and in the formulation of the stratigraphic principles which underlie them. In 1791, Britain established the Ordnance Survey for the purpose of producing topographic maps of Britain at a scale of one inch to one mile. Flett (1937) reports that from the start the Ordnance Survey was interested in incorporating geological information into their maps where possible and that several of the surveyors did have some geological knowledge. Indeed, Maclauchlan in southwest Wales and Still in southwest England put a considerable amount of effort into producing coloured geological maps. In 1832 the Ordnance Survey appointed its first full time geologist in Ireland. No similar appointment was made in England, although in 1831 Roderick Murchison lobbied for William Smith to be officially appointed as ‘Geological Colourer of Ordnance Maps’. William Smith was 62 years of age at this time and was deemed to be too old for the job (he did, at least, finally receive official recognition for his services to geology in 1832 when he was awarded a government pension of £100 a year)!! At about this same time Henry de la Beche was producing geological maps of western England including, for the first time, comprehensive maps of complete Ordnance Sheets, with a total of 8 sheets being produced in the period 1832–1835. Also at this time, the Geological Society of London was pressing for the setting-up of a geological survey and in responding to a request from the Master General and Board of Ordnance for an opinion on the feasibility of combining geological and geographical surveys, three members of the Society, Charles Lyell, William Buckland and John Playfair, placed particular stress on ‘The great advantages which must accrue from such an undertaking, not only as calculated to promote geological science which alone would be a sufficient objective, but also as a work of great practical utility, bearing on agriculture, mining, road-making, the formation of canals and railroads and other branches of national industry’. (quoted by Bailey, 1952)

In his presidential address, Lyell (1836) discusses the response to the proposal in which ‘The enlightened views of the Board of Ordnance were warmly seconded by the present Chancellor of the Exchequer, and a grant was obtained from the Treasury to defray the additional expenses which may be incurred in colouring geologically the ordnance county maps’.

And so the scene was set for establishing a Geological Survey in 1835 initially as part of the Ordnance Survey, the first of many ‘parent bodies’ for the Survey (Figure 2). Henry de la Beche (Figure 3) was appointed as its first Director, at the age of 39, with a clear mandate to address the practical aspects of geology. His success in pursuing

Figure 1  William Smith (1769–1839).
this quickly became apparent: a particularly good example of this recognition is provided by no less an authority than Senor Sella, the Minister of Finance for the Kingdom of Italy (also a noted crystallographer and mathematician in his spare time) who in 1862 stated: ‘England is without doubt the country where geological maps are prepared with much greater accuracy than in any other land. The singular importance of her mining industries, the spread of the elementary principles of geology, the zeal applied by the geologists charged with these labours, and the precision of the works, have been so accomplished that few undertakings of the British Government have so much contributed to the benefit of the public as the Geological Survey of the United Kingdom.’ What wonderfully perceptive Ministers for Finance they had in those days!

However, questions were being asked, notably how long would it take to complete the mapping of Britain? In his first attempt to respond to this question from the Secretary of the Treasury, de la Beche gave the ingenious answer (4 July 1835) ‘I consider that the Geological Map will keep pace with the Geographical Map and consequently that both Maps will be completed at the same time’. This was not quite good enough for the Treasury and therefore in his further response of 9 July 1835, he is more specific stating ‘It took Mr de la Beche 3 years to complete the Geological Map of Devon - Hence, assuming the same rate of progress for the area (equal to 35 large sheets) which yet remains, it would take Mr de la Beche 21 years to complete that part of the Ordnance Map of England and Wales which is now published, assuming that he worked singly and was unassisted.

If, however, he receives the aid of two or three competent assistants, as has been contemplated, and is enabled to purchase from time to time as occasion may require, a great Map of scattered local information which now exists, Mr de la Beche considers that he could complete the published part of the Ordnance Map in 7 years.

Estimating the rate of progress as above, Mr de la Beche considers that, assuming he receives the necessary aid, the Geological Map of England and Wales may be completed in about 10 years’.

No doubt de la Beche came to regret his reply and certainly it is a question that has bedeviled Directors of Geological Surveys ever since! It is also a matter to which we shall return. Despite these awkward questions, the Survey was highly successful; so successful in fact that it was quickly emulated by many countries including many British colonies, which in turn lead to perhaps the earliest episode of geological head hunting.

Various members (or ‘volunteers’) of the Survey became senior members of a range of colonial surveys including Murray (Director of the Newfoundland Geological Survey) Oldham (Director of the Geological Survey of India), Selwyn (Director of the Geological Survey of New South Wales) and Gould (Government Geologist to Tasmania).

One of the earliest of these emigrants was Logan (Figure 4), one of de la Beche’s associates in the geological

**Figure 3**  Henry De la Beche (1796-1855), first director of the Geological Survey, Department of the Ordnance Survey, UK.

**Figure 4**  William Edmund Logan (1798-1875), first director of the Geological Survey of Canada.
mapping of the South Wales coalfield. William Edmund Logan became interested in geology through his role as a representative of a South Wales company initially involved in trying to extract copper from metallurgical slag and then in coal mining. Through his work he developed considerable skills in geological mapping, first exhibiting his map of part of South Wales in 1837. Flett (1937) reports that 'By this time he had made the acquaintance of de la Beche, who was much impressed by Logan’s maps, and recognised that for accuracy and detail they were ahead of anything that had been produced in England up to that time. When the Geological Survey entered South Wales, Logan very generously placed at their service all the results of his observations and de la Beche welcomed them with enthusiasm. In some of the Sheets that were published in 1845 Logan’s name appears as joint author and he gave very active assistance to de la Beche for several years. Apparently he was never a regular member of the Survey staff but continued to be an enthusiastic amateur who rendered gratuitous assistance. In 1840 Logan visited Canada and published several geological papers containing the results of his geological observations during his travels. In 1842 the Canadian Parliament decided to institute a Geological Survey and Logan was appointed geologist. De la Beche wrote a letter supporting Logan’s application and expressing in the highest terms his appreciation of the accuracy and thoroughness of Logan’s work in South Wales'.

And so Logan became the first director of the Geological Survey of Canada.

By the middle of the nineteenth century, the pattern of geological surveys throughout the world had been established: geological mapping was the primary function of all surveys but with a clear recognition that mapping was undertaken for a variety of practical reasons relating to mining, construction and transport. It became clear that geological mapping was not a short-term enterprise; it was a long-term and continuing undertaking. It was also recognised that good science was needed to underpin the primary role of geological mapping and that such mapping was not just a routine exercise in surveying but was a highly skilled interpretive exercise which also relied on skills such as palaeontology and mineralogy. The Geological Surveys expanded and also began to acquire a much wider range of skills. They began to look and act much more like the Geological Surveys of the twentieth century, and also were seen as essential to the material well-being of a country.

THE NEXT 100 YEARS

Publication of maps at a scale of six inches to one mile commenced in the coalfields of Britain in 1860. In Scotland and Ireland, mapping was done at six-inch scale, but results were published at one inch to one mile. At first the mapping in Scotland was of solid geology only but after a few years authority was given to survey the surficial deposits of 'drift'. In 1872, A C Ramsay became Director-General of the Survey and set a pattern that was to be followed for almost a century of primary mapping on six inch to one mile scale and publication of maps on one inch scale, except in the coalfields where six inch scale maps continued to be published. Gradually explanatory memoirs to accompany the maps began to appear.

The interval from 1880 to the start of World War I was of critical importance to British geology. In 1881 Geikie, the Director-General, was brought under governmental pressure to conclude the Survey. His first priority was to complete the mapping of England and Wales, which was due to be finished by 1884 and, while this was accomplished, most of the field survey had been carried out at the one-inch scale and little effort had been devoted to the explanatory memoirs. The emphasis in the mapping programme changed from detail and accuracy to speed. In Scotland, much of the Midland Valley had been mapped at six-inch scale and work had begun in the Highlands where Peach and Horne, were to make fundamental advances in understanding the geology of the metamorphic rocks of north Britain.

During World War I, the Survey responded to demands for information on mineral resources of the UK by producing a new series of ‘Special Reports on the Mineral Resources of Great Britain’. This was the first serious attempt by the Survey to react quickly to a national need (Wilson, 1985), and perhaps the first occasion when the British and other surveys went to war.

New geologist posts were created including those designated as of District Geologist, Petrographer, Palaeo-ontologist, Curator and Librarian. Legislation was enacted (in 1926) to ensure that the Survey received compulsory notification of all boreholes and shafts over 30 m for minerals. Water supply (including groundwater) reports had first appeared in the late 1800s, but it was not until 1926 that there was formal acknowledgement that work on groundwater should be done by the Geological Survey.

World War II resulted in a greatly enhanced level of interest in groundwater studies because of the need to establish emergency water supplies. More than half the Survey staff became involved in groundwater work and there was disruption of the standard mapping programme. Work was more concerned with raw materials such as iron ore, bauxite, glass sand, feldspar and mica. There was an intensification of work on coal and the first investigations into sources of radioactive materials (Bailey, 1952). Publication of normal Geological Survey memoirs was postponed and only those of special economic significance were published. The first Geological Survey involvement in uranium was in 1941 when a secret request was submitted for a precis on world resources. By 1944 the number of enquiries generated by the new atomic energy field was such that DSIR asked the Director for a full time geological advisor and this position was given to C F Davidson. Davidson’s ‘Special Investigations Unit’ was retained as the authority on radioactive ores and was paid for by the Ministry — the first long-term ‘commissioned research’ in the history of the Survey. This unit advised the Ministry on the discovery and assessment of uranium and thorium ores which could supply the British requirement and, at the request of colonial or dominion governments, to investigate occurrences of these minerals and to undertake analyses of samples submitted by governments, mining companies or prospectors. Close links were developed with countries such as Canada, Australia, South Africa and the United States of America and with organisations engaged in similar work such as the US Geological Survey and the Geological Survey of Canada (Wilson 1985).

THE PROGRESS OF CHANGE

So, for 130 years, apart from periods of international conflict, the pace of change in the Geological Survey was measured and slow. The Survey continued to be structured
for mapping, with the field staff being supported by a small number of palaeontologists, petrographers and chemists, who provided a service to them. Progressively, due to particular needs, Survey staff carried out a range of special investigations in support for the search for minerals, coal, oil, building stone and water but this was generally done either as an adjunct to the field survey, or within it.

In 1965, the Institute of Geological Sciences (IGS) was created by bringing together the Geological Survey and Museum of Practical Geology with the Overseas Geological Surveys in the newly formed Natural Environment Research Council. The effect of this union was dramatic. On the one hand, the Geological Survey was bound by its traditions, constrained in its vision by the scale of its mapping (six inches to the mile) and served by a narrow range of specialists. On the other, the Overseas Geological Survey (OGS) was a multidisciplinary support group, technically and scientifically modern in its approach, and structured to provide support for the colonial geological surveys as well as supply them with their field staff, who worked at all scales from large to reconnaissance. With the OGS came photogeology, isotope geology, applied mineralogy, mineral intelligence, economics and statistics, modern chemical laboratories, new expertise in field geophysics and a new dynamic.

The broadening of the expertise base provided the platform for all subsequent developments. It allowed the IGS to widen its view of its strategic function and, in 1967, to enter new fields such as marine geology and mineral resource evaluation. The stimulus for the move out to sea was the discovery of natural gas fields in the southern North Sea in the early 1960s. Until the formation of IGS the Geological Survey had been funded entirely from what is known as the Science Budget. However, with the addition of the OGS in 1965, which was funded by the Overseas Development Administration, the principle of tapping sources of funds outside the Science Budget was established. In 1967 the IGS persuaded what later became known as the Department of the Environment, to fund a programme to assess UK industrial mineral resources. In the same year, the Survey was paid by the UK Atomic Energy Authority to search for radioactive minerals and subsequently, the Department of Trade and Industry paid for a programme to explore for metallic mineral deposits.

Thus, by 1970, the IGS was organised to carry out long term programmes in support of many sectors of the UK national economy. The Land Survey provided general purpose geological maps; offshore mapping supported seabed and hydrocarbon resource investigations; industrial mineral resource assessments and metalliferous mineral studies specifically supported the mining and bulk mineral extractive industries; the Hydrogeology Unit provided baseline data for the water industry.

In 1973, after the ‘Rothschild Transfer’ (the principle under which funding previously provided through the Science Budget was provided through commissioning departments of state) there was a further broadening in the scope of the Survey’s activities as it took on commissions to carry out more applied projects. Strategic programmes of regional geochemical surveys, geothermal energy, environmental pollution, radioactive waste disposal, evaluation of hydrocarbon resources and environmental geological mapping were supported by departments.

This expansion broadened the expertise base even further and changed, probably irreversibly, the nature of the organisation. Between 1966 and 1974 the total IGS staff doubled to nearly 1000, but the UK field staff increased only from 115 to 128, and has remained around that level since. From being an essentially mapping organisation in 1964 the IGS had become a truly multidisciplinary earth science research institution, still essentially field based, but in which mapping was only one of many parts of its remit.

Prior to 1964, the Geological Survey was organised along essentially authoritarian lines. The District Geologist, who headed the field units, managed his staff directly and with strict discipline. His overall control was complete. Like an orchestra conductor, he would call in each member of his staff at the right time to do his piece of work and then stop. But far reaching changes arose under the influence of the Mineral Reconnaissance Programme. For this required multidisciplinary teams consisting of field mappers, geochimists, geophysicists and mineralogists, who worked together in pursuit of agreed objectives. The establishment of project teams and the bringing together of the different disciplines on equal terms contrasted sharply with the traditional way of the Survey and set a pattern for all future developments. By 1982 multidisciplinary project work had even infiltrated the Land Survey. In 1992, it is the standard method of working.

THE INFLUENCE OF GOVERNMENT POLICY OF THE GEOLOGICAL SURVEY

Of all the influences that have been brought to bear by Government on the evolution of the Geological Survey this century, three stand out as seminal. The first is the 1918 Report of the Machinery of Government Committee, by Viscount Haldane. The second is the 1971 report by Lord Rothschild on ‘The organisation and management of Government R&D’. The third cannot be linked to any internal enquiry of Government, but relates to an ideological shift towards the Market Economy during the 1980s.

In Haldane’s short, deeply analytical report prepared in 1918 in the aftermath of World War I, he recognised three classes of research legitimately carried out by Government: a) research done within Government departments for their own purposes; b) research supervised by departments, but which also met objectives shared by other departments; c) research for general use, which had relevance to the workings of several Departments. Haldane insisted that the last category, which came to be called strategic research, must be developed to its fullest potential, saying, ‘Science ignores departmental as well as geographical boundaries’, and warned about the dangers of departmental parochialism in research. It was Haldane’s view that the Geological Survey carried out research of general use and in 1919, on his recommendation, the Geological Survey and Museum of Practical Geology was transferred from the Board of Education to the recently created Department of Scientific and Industrial Research. For more than half a century, the Geological Survey pursued a policy based on its acknowledged function to provide for national strategic aims.

In 1965, following the first major review of Government science since Haldane, the DSIR was dissolved and five Research Councils were established. Their purpose was, ‘to develop the sciences as such, to maintain a fundamental capacity for research, and to support higher education.’ In essence they were to support basic and fundamental research. The Geological Survey became part of the
Natural Environment Research Council. Though important in relation to recent developments within the Survey, the creation of the research councils was significant at the time only in that it allowed the Geological Survey and the Overseas Geological Surveys to come together within the Institute of Geological Sciences and stimulate a period of unprecedented expansion. Far more important on the conduct of the Survey was the implementation of Rothschild’s recommendations in 1973.

It was already clear by the 1970s that Government was distancing itself from scientific research, with the Government of the day stating, in 1972, that ‘Applied research and development are necessary to achieve many of the Government’s objectives, but they cannot be regarded as forming a distinct function of government. Any attempt to formulate overall objectives for a supposedly collective activity of research and development would lead to confusion’. Rothschild, therefore, reversed the 1918 Haldane report, for he was wholly committed to organising research on departmental lines, funded directly by departments through the customer/contractor relationship. The research was primarily meant to be applied. His concession to the need for some underpinning basic research was to suggest a 10 per cent levy on contracts to cover it (which departments, without exception, refused to pay). Strategic research, which Haldane thought so important, did not feature specifically in the remit of the research councils and had now gone from consideration for other government funding. Funding from the Science Budget was transferred to Government departments with the expectation, though no formal condition, that it would be spent on research. The effect of this change on the Geological Survey was quite fundamental for, despite the huge and vigorous expansion taking place, as early as 1974, the Director, Sir Kingsley Dunham, warned that the domination of the work programme by short-term ad hoc investigations would threaten the scientific health of IGS.

The next year, his successor pointed out that 87 per cent of the Survey budget for 1976/77 was under the direct control of four departments, other than the Department of Education and Science. Much of the work that could be defined as strategic was put into departmental hands. The Department of Energy took 85 per cent of the continental shelf survey; the Department of Trade and Industry took over all mineral intelligence and statistics and the regional geochemical survey; the Land Survey mapping programme came under the control of a consortium of interested departments. Despite the potential difficulties, in fact, expansion continued until 1979, when the staff complement reached just short of 1200. By then, however, the mapping programme, which was all that was left of strategic research under the direct control of the Survey Director, had reduced to about 12 per cent of the total of Institute of Geological Sciences resources in terms of scientific staff. In 1981 the consortium that managed the mapping programme collapsed and in that year there was no Science Budget-funded mapping in Scotland and very little in England and Wales. In an attempt to revive the strategic mapping survey Sir Malcolm Brown, the Director at the time, reformed the remnants of the mapping programme into five major, multidisciplinary regional geological surveys and gave them protected funding for three years, but the funding proved to be inadequate for the task in hand.

The emergence of free market economics in the 1980s following on Rothschild had a profound effect on the Geological Survey as one department after another cut their support, sometimes at short notice and withdrew from funding any long-term programmes. The Council of NERC made it clear that it would not be prepared to replace lost funding with Science Budget and urged the Survey Director to seek replacement funding from non-Government sources. Writing in 1984, the year the Institute of Geological Sciences became the British Geological Survey, the Director stated that ‘BGS is close to a crossroads of crucial importance for its future. The core activity of the Survey, concerned with ongoing surveying and revision of the national inventory of geological information, is seriously behind schedule... many maps and memoirs remain unpublished because of lack of funds’ (Brown, 1991). At this same time the research councils switched resources away from their institutes towards universities and in doing so reduced manpower drastically. By 1985 the year of its sesquicentenary, BGS appeared to be fighting for its survival. At the same time in response to free market economics, departments decided to let contracts for applied scientific research by competitive tender. The Survey now found itself in competition with universities and private sector firms for Government funds to carry out much of its research, including mapping. The traditional distinctions between the Survey, academia and private sector became blurred. Competition probably stimulated new ideas and reduced initial costs but it also resulted in much information on the nation’s geology and mineral resources becoming dispersed; yet no-one, other than the Survey, was equipped for long-term storage of these data, or held a remit to maintain a national inventory. The position of the Geological Survey as a national geoscience data centre, effectively the custodian of the nation’s geological memory, was under severe threat as was its position as an impartial, independent agency, free to provide information to all enquirers.

Under the threat of extinction, the staff of BGS carried out an enquiry early in 1985 and developed the concepts of Core and Responsive programmes to describe the work of the Survey. In its original concept the Core consisted on the long-term, strategic activities without which the Survey would have no distinct identity. The Responsive programme, consisted of essentially applied research, done on commission, and largely short-term, often ad hoc in nature. The ability of the Survey to carry out this Responsive Programme was dependent on the Core: thus the two were interdependent. There was considerable discussion about what should be put into the Core, with consensus agreement that it should comprise programmes of onshore, and offshore geological, geochemical and geophysical surveying, hydrogeological research and the maintenance of a national geoscience data centre.

In 1985, Sir Clifford Butler was commissioned by Government ‘To assess the UK need for geological surveying over the next 5–10 years ...’. His report, published in 1987, accepted the concepts of the Core and Responsive programmes, adding a third, Science Programme in which underpinning basic research could be carried out. In addition, he recommended that the Core Programme should be overseen by a Programme Board made up of individuals from industry and academia with assessors from the Department of State. The Government accepted the recommendations of the Butler report and in November 1988 announced a special fund to support Core activities. This was important recognition by Government that there was indeed a place for Government-funded strategic research. A second funding award, the next year, was made to allow the Survey to develop its capacity to exploit its data holdings and expertise in such a way as to
earn money further to support the Core. In other words, the Survey was expected to pay for part of the Core Programme through its own commercial efforts.

THE PRESENT AND FUTURE BGS

In response to the requirement to increase our level of funding from Government and non-Government sources, the Survey has now been restructured at the divisional level along market sector lines (Figure 5). The programme divisions have particular responsibility for market sectors (corresponding in part to commodities) but at the same time the structure recognises that mapping/surveying is an activity that is pursued by all the programme Divisions. The corporate divisions tend to have fewer staff than the programme divisions and, as implied by the name, BGS-wide responsibilities. All divisions are seen as business units with considerable autonomy to determine how they will reach their agreed financial targets. Many services are now offered on a unit cost basis and there is a great deal of buying and selling of staff time between divisions. Each year a Business Plan is produced which shows how targets will be achieved. One of the fundamental questions examined during reorganisation was whether a commercial arm should be established separate from the Survey. It was decided that this should not be done because of the symbiotic relationship that exists between the core science and the contract work done for Government departments and the private sector. In consequence, management is more complex but it ensures that neither activity becomes marginalised and high quality science, on which the reputation of BGS depends, is carried out across all activities. It also forces management to take account of the needs of an essentially government-funded organisation to remain impartial in its dealings with customers. It is the view of the Survey that a more business-like approach is not only compatible with the management of good scientific research, but can in fact enhance it.

Through these new arrangements the core science funding is used to support a number of strategic programmes in mapping and monitoring. The largest single core activity is onshore geological mapping. A 15-year programme was started in 1990 with the aim of bringing the geological map of Britain to an acceptable modern standard, and making available 1:50 000 scale maps for the whole country. A schedule has been established for the publication of 300 maps sheets in this programme (Figure 6) and mapping is proceeding apace. Full advantage is being taken of the increasingly sophisticated computer technology now available. BGS has developed a digital map production system for 1:10 000 standard maps, with the capacity potentially for proceeding directly to the 1:50 000 scale for publication. The system meets the requirement for printing full geological maps on demand and for the generation of special thematic maps from digital geological databases according to customer needs.

Apart from the flexibility in output that it allows, a digital system such as this allows periodic review and continual updating of maps and the publication of results cost effectively and fairly easily. Thus, as the mapping programme progresses, a programme of continuous revision of maps will take place in parallel for areas where there is a high level of construction activity, mineral extraction and oil exploration. The digital map production system is based on comprehensive and highly sophisticated digital databases which will be used to generate three-dimensional models. This is perhaps the most exciting new development. In the twenty-first century, geological mapping in the highly populated parts of Britain may approach geological monitoring. However, the diverse and intense pressures that will be brought to bear on land for many often conflicting uses will require a highly sophisticated methodology for understanding the three-dimensional geology of the upper kilometre of the crust.

The extent to which other countries pursue the equivalent of a core mapping programme varies. Few, if any, base it on the 1:10 000 scale. For large countries such as Canada or Australia, it is impractical to aim for total national coverage at 1:10 000. Even 1:100 000 may be unrealistic and 1:250 000 commonly becomes the scale of choice for national cover. For many European countries a programme to provide full 1:10 000 coverage would be feasible, but few surveys are pursuing (or contemplating) such a programme of detailed mapping. This is in part a consequence of perceived national need and in part a consequence of tradition. Commonly, mapping is the preserve of the universities. The geologically exciting areas are mapped, and remapped in great detail, whilst other areas may be ignored. The value of having national cover of large-scale geological maps should be examined. It is perhaps significant that Britain, one of the most intensively geologically mapped countries in the world is also one of the world’s major producers of raw materials. As resources become more difficult to find, as land-use conflicts become more intense and as environmental concerns are heightened, so an increasing amount of detail will be required on the geological map. Therefore, it is likely that more European countries may find it necessary to follow the UK’s lead and develop systematic national large-scale mapping programmes, and that they will employ digital methods for geological database building and map generation. The rigour that this will impose may result in a transnational approach to mapping, something which is long overdue in Europe.

Whilst onshore geological mapping is the major part of the BGS core science programme, it is not the only part. Nearly all the British continental shelf has been mapped and offshore mapping remains part of the core programme. Science Budget funds are used both for individual projects and, increasingly, as ‘seed money’ which together with industry support can be used for large mapping projects. One such example is to map the Rockall trough, a relatively unknown part of the UK continental margin.

A major core programme on regional geochemical surveys has been underway for twenty-three years and more than half of Britain has been geochemically mapped. While the initial impetus for this programme was to support the search for mineral deposits, increasingly it has become relevant to questions regarding industrial pollution, land use and human and animal health. This programme involves detailed sampling of stream bed sediments, water and pan concentrates at an approximate spacing of one sample per square kilometre. A total of 35 elements are analysed for each stream sediment sample, five determinations are also made on every water sample with twenty additional analytical values recently added to the suite. Water samples are now collected at the same density as stream sediment samples. Heavy mineral concentrate samples are collected, visually examined and analysed by non-destructive methods where they have potential to aid mineral exploration. Similar, but generally less comprehensive programmes are underway in many countries; for example Canada. In Europe there have been
discussions on a multination approach to geochemistry for a number of years but as yet there is no agreement on the methodology. Indications so far are that the British regional geochemical survey programme is fulfilling its planned purpose and may be a useful model for other countries to follow. In the absence of similar types of survey in other counties we are likely to see regional geochemistry, albeit severely limited in scope, being done by remotely sensed methods, particularly radiometrically. This is an area where Britain does not have a viable programme.

The core Science Budget supports only a very limited amount of hydrogeological and geotechnical mapping in Britain. The absence of a national mapping programme in either field is a major deficiency of the core programme and one which we hope to address in the future.

Geophysics is carried out within the core programme in two parts. Geophysical surveys and interpretations are done in conjunction with the core mapping programmes, while geomagnetic and seismic monitoring programmes are free-standing. Both the land area and continental shelf are covered by modern gravity surveys; on land at better than one station per 2 km². Aeromagnetic survey data, however, dates from the 1960s onshore and more recently offshore. All the potential field data have been digitised and have yet to be fully interpreted, but the limitations of the aeromagnetic data are now known and the need for national cover of high resolution aeromagnetic and VLF or EM surveys is recognised. So far, attempts to raise funds to carry them out have failed. Seismic and magnetic monitoring are funded only in part through the core programme. It can be argued that programmes on seismic hazards should be funded entirely by the national government because of its relevance to the whole community. This is not a view shared by the UK government and increasingly this and geomagnetic monitoring are being funded through industry/government consortia. Under this arrangement a long term strategic programme can be pursued, but at the same time a number of products, tailored to the needs of the members of the consortia are also provided.

Both the core and responsive programmes depend heavily on ready access to comprehensive databases. In a recent survey of BGS dataholdings, 774 databases were identified, of which 265 were digital. Work is presently underway to establish a data architecture that will establish linkages between a large number of these data sets, thus making them more accessible and more usable. Special government funding was provided to help this process. The benefits to the Survey of this investment are two fold: (1) enhancement of the Survey’s programmes (both core and contract) (2) enhanced public access to the databases.

Together, these have the effect of making the core programme more cost effective and bringing in additional income from contracts and data sales (or licensing) in order to enhance the core science. The BGS has a strategic plan for achieving these aims; effective data architecture and the appropriate hardware configurations are an essential part of that plan (Figure 7). It is anticipated that the system will be in place within 18 months.

One of the fundamental issues regarding a data service is whether it should be provided for the public good at little or no cost or whether it should be provided at full cost recovery. This is essentially a political question and, for the present, the UK government has taken the view that BGS should aim for full cost recovery for data and services; the charge should reflect the value of the service or the data to the user, although no attempt is made to cover the cost of data collection, or survey. A change in this philosophy would not cause any profound problems for BGS — provided the loss of income from these activities is made up from government sources.

CONCLUSIONS

The British Geological Survey served as a very important example in the nineteenth century. It is responsible for the ‘traditional’ approach of many of the world’s major surveys, such as the importance placed on geological mapping, the value of multidisciplinary geoscience, the need for a long term strategic approach to many studies and the public funding of those activities. Not surprisingly, the BGS has changed quite drastically during its more than 150 years of existence but the rate of change has been most marked in recent years. Many of the basic tenets have been questioned by those outside the Survey and the view that the Survey knows best what it should be doing is no longer an acceptable dogma. ‘The customer’, whether in the private or the public sector, is now the arbiter of what is required from a Survey and either we adapt or we wither on the vine. Contract science, whether we like it or not, has come to dominate our programme in such a way that if we lost it, it is unlikely that any government would provide public funds to make up for any loss of funds from the private sector. It has also to be acknowledged that contract science has brought with it the discipline of a business-like approach and the need for quality assurance and quality control. However, perhaps the greatest loss would result from the breaking of the strong links that have developed between customers and the Survey leading not only to a loss of data exchange but also a potential loss of relevance and the stimulation of that relevance.
Figure 6  Onshore geological mapping in Great Britain. This map shows the 15 year mapping programme which commenced in 1990.
Figure 7  Information system at the British Geological Survey. This flow chart shows the development stage at the end of 1993 and the present situation is indicated by shading.
The preferred future course for the BGS requires the establishment of the right balance of core and contract science. Just where that balance lies will vary with time as Government and Community priorities change. The Survey must continue to ensure that it is able to respond to these changes.

REFERENCES


