British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

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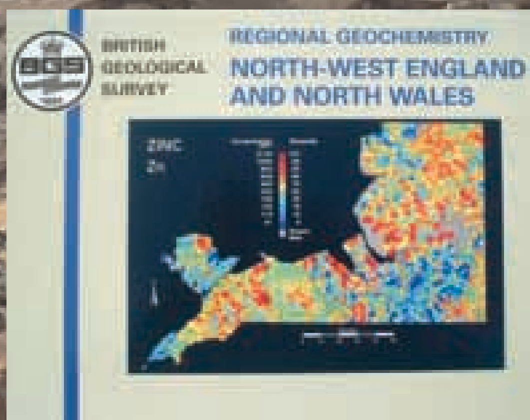
G-BASE Geochemical Baseline Survey of the Environment



SUMMARY

The Geochemical Baseline Survey of the Environment (G-BASE) is one of the British Geological Survey's (BGS) core strategic projects and commenced in the late 1960s at which time it was primarily concerned with mineral exploration. It has now evolved into a multi-media, high resolution geochemical survey producing baseline data relevant to many environmental issues. Demand for high quality geochemical data for the surface environment is driven by legislation such as Part IIa of the Environmental Protection Act and the EU Water Framework Directive.

This on-going geochemical mapping of Great Britain involves the collection of drainage sediment and water samples, and soils at a density of 1–2 samples every square kilometre. By the end of 2003 the project has completed approximately 80% of Britain (excluding Northern Ireland) and southern England remains to be sampled. Drainage samples have been collected from all areas but it is only in recent years that soil sampling has become part of the systematic survey.

Samples are collected during the summer by teams of geoscience/environmental science undergraduates led by experienced BGS geochemists. All chemical analyses are done at the BGS laboratories in Keyworth with x-ray fluorescence spectrometry (XRFS) being the principal analytical method for stream sediments and soils, and inductively coupled plasma (ICP) spectrometry the main method for surface waters.

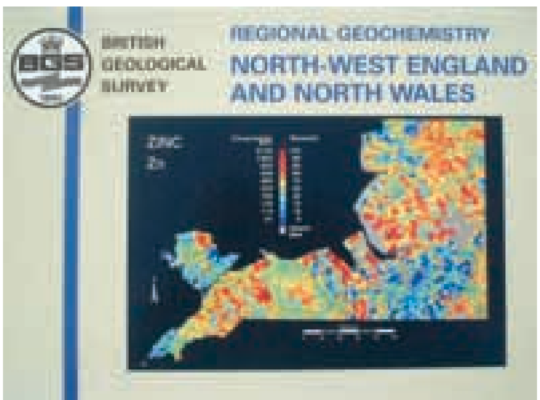
A wide range of uses for the G-BASE sample archive, data and methodologies are described here including:

- environmental assessment
- elementary detectives — contributions to provenancing studies and forensic geology
- mineral exploration
- solving geological problems
- international geochemical mapping projects
- university collaboration
- geochemistry and health
- the urban and rural environment

The G-BASE data are accessible to all BGS staff and NERC researchers subject to IPR restrictions. Users from outside NERC can use the data under licence. Information about the availability of BGS geochemical data can be obtained from the BGS website (www.bgs.ac.uk) using the Geoscience Data Index.

Part of Tamar catchment sampling area.

Liverpool Bay Geochemical Atlas.



Collecting a soil sample by hand auger.

G-BASE: Geochemical Baseline Survey of the Environment

G-BASE Project
BGS Keyworth

Bibliographic reference:

Johnson, C C, and Breward, N. 2004. G-BASE Geochemical Baseline Survey of the Environment British Geological Survey, Keyworth, Commissioned Report, CR/04/016N

The G-BASE project is administered within the Economic Minerals and Geochemical Baseline (EMBG) Programme of the BGS at Keyworth, near Nottingham. It is one of the BGS's strategic surveying activities forming part of the Core Programme supported and funded by the Natural Environment Research Council.

Photographs and diagrams in this report have been provided by Chris Johnson, Louise Ander, Fiona Fordyce, Neil Breward, Robert Lister and Barry Rawlins, and other contributions and comments from the G-BASE project team are gratefully acknowledged.

Cover photograph:
Llyn Llydaw. Looking SW. Ordovician volcanics. Cwm lake feature. Three summits of Lliwedd to the left, Snowdon to the right. BGS © NERC.

Field base 2003, Monk Soham, Suffolk.

Filtering a stream water sample.

Stream sediments drying at field base.

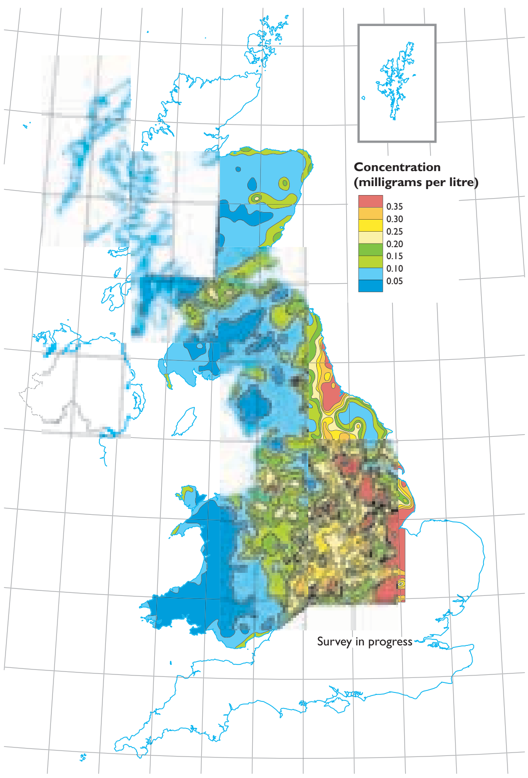
INTRODUCTION

Geochemistry is the study of the distribution and movement of chemical elements within the Earth and at its surface. Applications range from the atomic scale in mineral structures to a global overview of element distributions on a continental scale. As an earth science, geochemistry is used in many specialisations including mineralogy, petrology, economic geology, hydrogeology, volcanology, isotopic dating and medical geology. Geochemists also make significant contributions to the environmental sciences where chemistry is a significant component of 'earth systems science'. The near-surface zone is where the earth meets man and the distribution and migration of chemical elements is of fundamental importance. Geochemical methods can be applied to map and monitor changes in the surface environment whether they be caused through natural (e.g. the weathering of surface rocks) or anthropogenic (human) activity (e.g. agriculture). We rely on the near-surface environment for the majority of our resources and the results of man's activities can lead to an imbalance of the Earth's natural equilibrium.

Where the Earth meets man

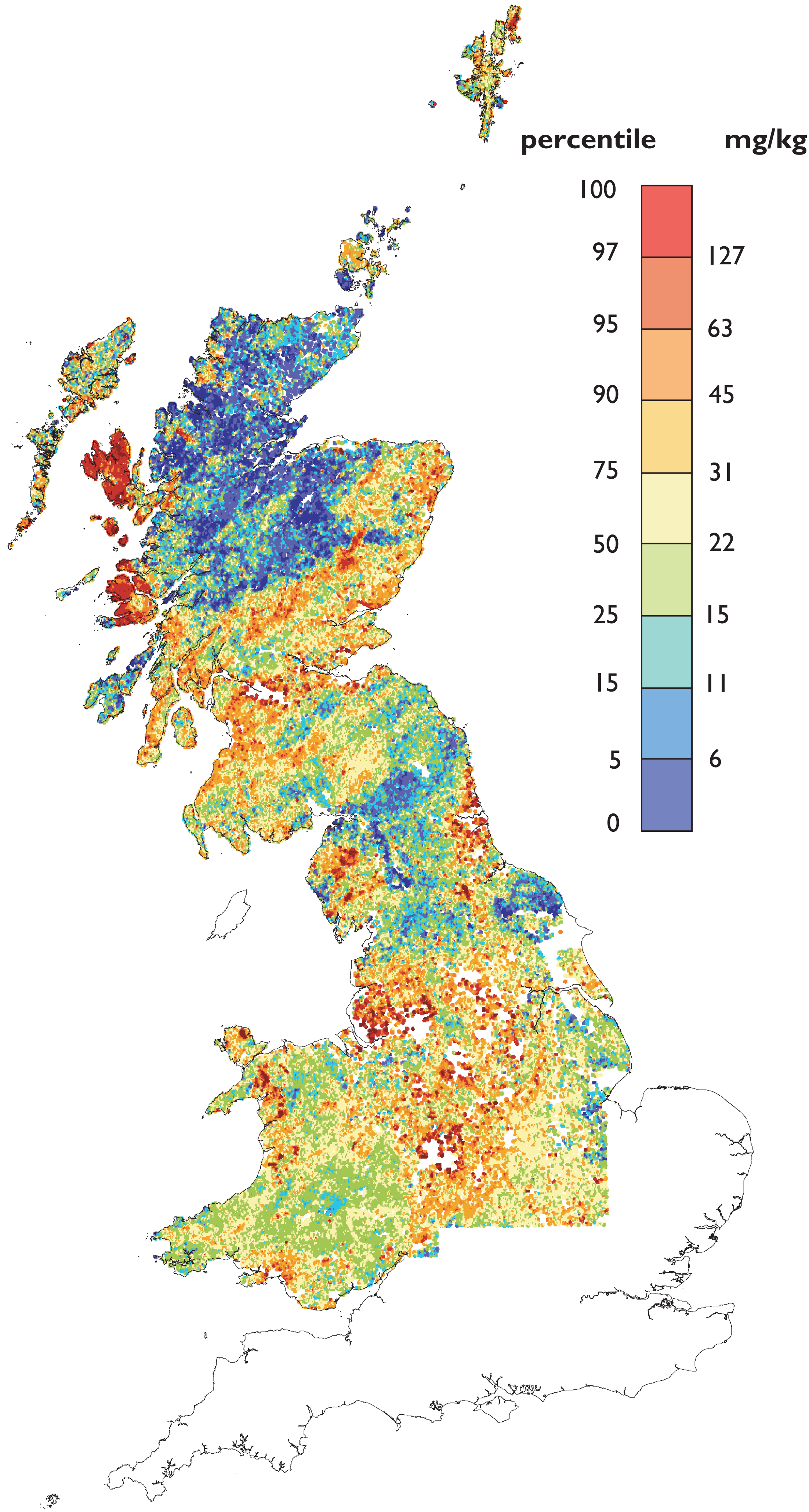
Most of man's activities impact on a zone at the Earth's surface that is only several metres deep. These activities change the soils sediment and water on which the biosphere depends. A geochemical baseline establishes the natural chemical status of the surface environment and enables us to assess and monitor both the impact of natural changes and anthropogenic activity.

We need to have geochemical baseline data in order to understand our environment and measure changes, whether they be natural or man-made. The G-BASE (Geochemical Baseline Survey of the Environment) project is producing geochemical maps of the British surface environment for over 30 chemical elements. The principal method is by the collection and chemical analysis of stream sediments to give an estimate of the elemental concentrations in the drainage catchment upstream from the sampling point. Small streams are used in preference to larger streams or rivers because the origin of the stream sediment is likely to be more localised. The survey is described as 'high-resolution' survey because samples are collected at a high density, averaging one sample every 1½ to 2 square kilometres. In areas where the drainage system is more mature (i.e. mainly large rivers), modified by agriculture or is absent because of limestone or chalk bedrock, soil samples are collected. Indeed soils are a medium with which man has significant interaction and so surface soil collection has become an important part of the geochemical mapping process. The BGS holds data on over twenty British urban environments systematically mapped at four samples every one kilometre square. Recent developments in analytical chemistry also mean that water analyses can now detect a greater range of element variations and a suite of water samples is collected and analysed at every drainage site. A comparison of the water and sediment geochemistries can give important insights in to element mobilities and speciation.



At a national and international level political initiatives resulting in legislation and directives, such as the Environment Protection Act and Water Framework Directive, are driving the demand for geochemical information about the surface environment. Global themes concerned with sustainable development and climate change as discussed in Earth Summits in Kyoto, Rio and Johannesburg require that we understand the geochemistry of the surface environment.

Above: *Fluoride in stream waters.* Opposite: *Copper in stream sediments.*



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GEOCHEMICAL MAPPING SINCE 1968

In 1968 the Institute of Geological Sciences (IGS) (now BGS) began a regional geochemical sampling programme in the northern Highlands of Scotland. Prior to this, geochemical studies were mainly involved with uranium reconnaissance work, a programme supported by the UK Atomic Energy Authority (1967–1972). Funded by the Department for Trade and Industry (DTI), the project in the early 1970s was known as the Regional Geochemical Reconnaissance Programme and was closely associated with the work of the DTI Mineral Reconnaissance Programme. The earliest samples are from the Sutherland area and were collected in the summer of 1968 as part of the uranium reconnaissance work. The first systematic sampling for regional geochemistry started in Orkney and Shetland in the summer of 1970. The work has progressed southwards from northern Scotland ever since. The first geochemical data from the regional survey of northern Scotland was placed on open file in 1972 for the Caithness ¼ inch geological map sheet area. Work on the Orkney and Shetland geochemical atlases commenced in 1974 and the Shetland atlas was the first to be published in 1978.

Following a reorganisation of IGS in 1977, the Regional Geochemical Reconnaissance Programme became a major project within the Metalliferous Minerals and Applied Geochemistry Unit. Between 1975 and 1990 the work was funded by the UK Department for Trade and Industry. After 1990 funding for the work came from the Department of Education and Science and subsequently, the Office of Science and Technology. The project was renamed the Geochemical Survey Programme (GSP) in 1988 and again in 1994 to the Geochemical Baseline Survey of the Environment Project (G-BASE).

A unique systematic survey

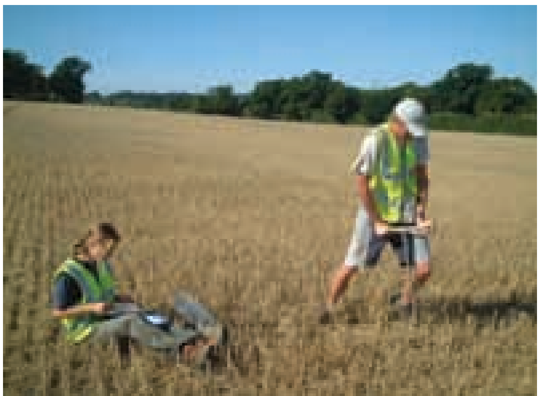
The initial impetus behind the G-BASE project was mineral exploration, firstly uranium then strategic minerals. However, this unique systematic survey has evolved to produce fundamental data about the UK surface environment. The high resolution sampling allows the recognition of significant trends and patterns in the UK geochemical landscape both at regional and localised scales. It is the only survey to be systematically collating information on soil chemistry for the urban environment. Collecting drainage sediments, soils and surface waters gives us a comprehensive insight into the geochemical landscape and provides a sample archive and database available as a resource to the UK's scientific community.

During the lifetime of this long project, analytical, statistical and data processing techniques have evolved substantially. Initially stream sediments were analysed for 16 elements using optical emission spectroscopy, atomic absorption spectrophotometry and delayed neutron activation (U). A direct-reading emission spectrometer was used to determine some 25 elements for the Hebrides and subsequent atlas areas. The current analytical method is XRFS, which commenced on the Welsh stream sediments and determines nearly 50 elements, 36 of which are routinely reported. Major changes in the analytical methodology have meant a need to standardise results produced by different analytical methods over a long period of time. The strict analytical controls and use of standard, duplicate and replicate samples initiated at the start of the work has enabled a high quality, seamless geochemical database to be created and maintained.

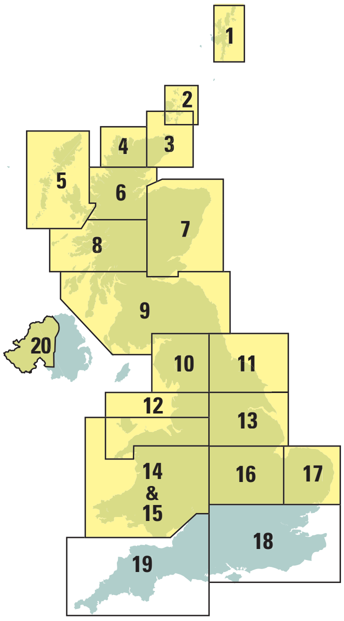
Improved analytical techniques for water analyses by ICP Spectrometry have enabled the project to complete a greater range of determinands on the water samples which were originally just collected for pH, conductivity, HCO_3^-, F and U analyses. The collection of soil samples has also been included as a consequence of moving into lowland areas dominated by intensive agriculture and more mature drainage systems and the growing need for environmental data. In particular, the demand for geochemical baseline data in urban areas has prompted higher resolution sampling using soils in major urban centres.

Alkalinity of waters is determined at field base.

Samplers work in pairs.



Samples are checked-in at the end of the day.



1. Shetland	11. NE England
2. Orkney	12. NW England and N Wales
3. South Orkney and Caithness	13. Humber-Trent
4. Sutherland	14. Wales & W Midlands (soil and sediment)
5. Hebrides	15. Wales & W Midlands (surface water)
6. Great Glen	16. East Midlands
7. East Grampian	17. East Anglia
8. Argyll	18. SE England
9. Southern Scotland	19. SW England
10. Lake District	20. Northern Ireland

An index map of atlas sheet areas showing areas sampled. Shaded areas have been sampled (area 17 due for completion in 2004). Areas 1–15 have been reported as geochemical atlases (Area 13 Humber–Trent due for publication in 2004). Areas 18 and 19 remain to be sampled though part of the Tamar drainage catchment was sampled and reported in 2003. Surveying in Northern Ireland has been done as commissioned work, a complete geochemical survey of this region is due to start in 2004 as part of the RESI project (Resource & Environmental Survey of Ireland). Twenty one urban areas have been sampled: Cardiff, Corby, Coventry, Derby, Doncaster, Glasgow, Kingston-upon-Hull, Leicester, Lincoln, Manchester, Mansfield, Northampton, Nottingham, Peterborough, Scunthorpe, Sheffield, Swansea, Stock-on-Trent, Telford, Wolverhampton and York.

Elements currently determined for soils and stream sediments (by XRFS):

Ag, Al, As, Ba, Bi, Br, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Ge, Hf, I, K, La, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Rb, Sb, Sc, Se, Si, Sm, Sn, Sr, Ta, Te, Th, Ti, Tl, U, V W, Y, Zn and Zr.

Loss-on-ignition and pH are also routinely measured on soils. Soils have only been routinely analysed for Areas 13, 16 and 17 and parts of 11, 12 and 14.

Elements currently determined for surface waters (ICP-MS and ICP-AES):

Al, As, B, Ba, Be, Bi, Ca, Cd, Cl, Co, Cr, Cs, Cu, F, Fe, Ho, K, La, Li, Mg, Mn, Mo, N, Na, Ni, P, Pb, Rb, Sb, Sc, Se, Si, Sn, Sr, Th, Ti, Tl, U, V W, Y, Zn and Zr.

Conductivity, pH, bicarbonate and non purgeable organic carbon (NPOC) are also routinely measured. The survey initially collected stream waters for conductivity, pH, bicarbonate, uranium and fluoride analyses.

G-BASE continues to be one of the BGS's principal science-budget funded projects. Its objectives fit well within the aims of the BGS and the mission of the NERC. Few BGS projects have produced such a wealth of external peer reviewed publications, and as a result BGS regional geochemical mapping is held in high esteem around the world. Geochemists who have worked on this project have established international reputations in the field of geochemistry and have become key figures in the development of global geochemical projects and working groups. Many geological organisations around the world have adapted the G-BASE methodology for their own national geochemical surveys.

COLLECTING SAMPLES

The G-BASE sampling campaign involves the collection of stream sediment, surface water and soil samples. The samples are collected by earth/environmental science undergraduates, during the summer vacation. Where possible, access to sampling sites uses public footpaths; farmers, land owners and other interested local organisations are made aware of the activities. The student samplers work in pairs and average twelve soil/sediment sites each day. A team of samplers consists of four sampling pairs and a team leader and assistant. Teams usually stay in self-catering rented houses during the summer months, preferably accommodation with adequate sample and equipment storage space. Team leaders plan each day's sampling in advance by marking on 1:50 000 OS topographic maps the expected sites for soil and drainage sediment samples. Samplers plan their daily route and can cover as much as twenty square kilometres. They are dropped off in the morning at their preferred starting point and collected at the end of the afternoon, along with their rucksack full of samples, at designated pick-up points. Samplers work six days a week on a job that requires a high level of physical fitness and good map reading skills. During the evening, samples are collated and checked and hung up on lines to dry. Water samples are measured for pH on the evening of collection, with alkalinity and conductivity being determined early the next day. In addition to these field analyses, the team leader's busy day and evening involves inputting field card information into a field database, plotting locations on a stable base map and contacting local farmers regarding the next day's sampling activities. Every one or two weeks samples are sent to the BGS laboratories in Keyworth for preparation and chemical analysis. Sampling of atlas sheet areas (see figure on the previous page) can take four or five years to complete. More targeted drainage catchment surveys, such as the Tamar survey done in 2002, take approximately one year from sampling to reporting the results.

A job that requires a high level of fitness

Samplers work six days a week on a job that needs a high level of physical fitness and good map reading skills, sampling up to 20 km^2 in a day. In addition to planning the next day's sampling and carrying out field analyses on the water samples, the team leader's busy day and evening also involves inputting field card information into a field database, plotting locations on a stable base map and contacting local landowners regarding the next days sampling activities.

Geochemical sampling is a cost-effective and rapid method of geoscience data gathering. The basic sampling equipment is shown in the photograph below. Although the basic kit has changed little since work commenced at the end of the 1960s, new technology has led to improvements in the methodology such as the routine use of GPS for recording sample locations. Future initiatives will make more use of direct digital data gathering in the field.

Stream sediments and heavy mineral concentrates

Stream sediments are collected at a density of 1 per 1½ to 2 km apart and are ideally taken from small streams with an active drainage channel. Sites are chosen to minimise any contamination, for example, by sampling upstream of bridges, tracks and dwellings.

Stream sediment collection involves removing the oxidised layer from the stream bed and collecting the sediment using a trenching tool. This is then wet sieved at site through a coarse sieve (2 mm) and then a fine sieve (150 µm). The less than 150 µm fraction is left to settle in a fibreglass pan and is decanted into a sample collection bag. The excess sediment from the less than 2mm fraction is then panned to collect the heavy mineral concentrate.

The G-BASE sampling equipment.

Wet sieving the fine stream sediment.

Panning the stream sediment.

Collecting sediment from the stream bed.

Filtered water is collected with a syringe.

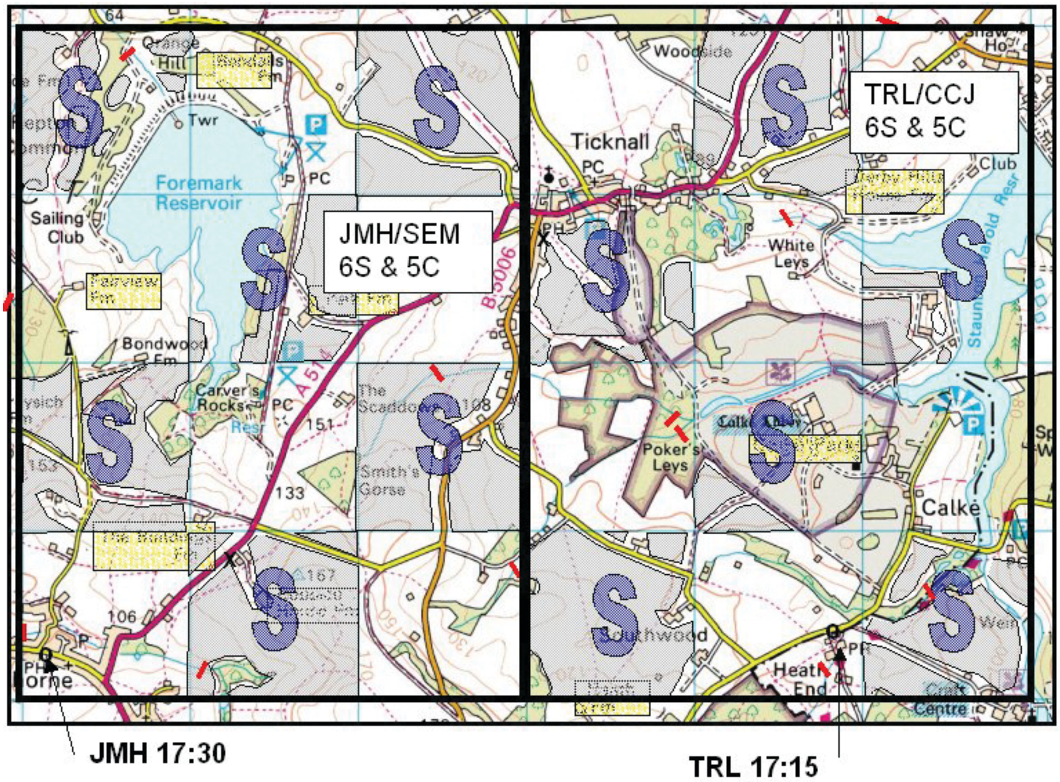
Soil sampling with 1 metre auger.

Stream waters

Water samples are taken before the stream bed has been disturbed and four separate water samples are collected. Two filtered waters are collected (for major and trace elements) and two unfiltered waters (for conductivity, alkalinity and pH). Waters are filtered at site using 0.45 µm cellulose filters. The conductivity, alkalinity and pH are determined at the field base shortly after sample collection.

Soils

Soil samples are collected at a density of one site every two km^2, although in urban areas this density is increased to four sites every one km^2. Samples are collected using a hand held Dutch soil auger and are taken from the surface (0–15 cm) and from a depth of 35–50 cm. Each sample is made of a composite of material from auger flights taken from five holes distributed at the corners and centre of a 20 m x 20 m square. The surface soils are routinely analysed and the deeper samples archived for future reference or use.



This is an idealised figure combining the planning map and the field map. Drainage sample locations (red line), soil sample areas ('S' in kilometre square, sample to be taken within shaded area) and farms (highlighted in yellow) are marked on the planning map. The day before sampling the team leader will mark out field maps allocating suitably sized areas to a sampling pair indicating the number of soils and sediments to be collected. The sampling pair will indicate on the map where they wish to be dropped off in the morning and picked up (with a time) in the evening.

USING BASELINE GEOCHEMISTRY

Looking after the environment

The distribution of chemical elements in the surface environment is subject to change. This may be in the course of normal geological processes where the time scale is measured in thousands or millions of years, or it may be very sudden brought about by catastrophic natural event such as volcanic eruptions, marine transgressions or flooding.

Baseline geochemical data is like a modern day Domesday inventory

The Domesday Book is the ancient record of the survey of most of the lands of England, made by order of William the Conqueror in 1086. The G-BASE project is a survey of the Great Britain that is a geochemical inventory of the current day surface environment.

The activities of man have also caused relatively rapid changes to the natural chemical environment by activities such as mining or intensive agriculture. Baseline geochemical data for the surface environment, including sediments, soils and stream waters, helps us to model the migration of elements and provides a reference point against which we can monitor change.

It is estimated by the Environment Agency that some 300 000 hectares of land in the UK are affected by contamination resulting from industrial activity. Local authorities are required by legislation introduced in 2000 to identify and deal with such contamination. Part IIa of the Environmental Protection Act (1990) provides a framework for the regulation of contaminated land and has been introduced progressively throughout Great Britain since April 2000.

G-BASE baseline geochemistry, particularly that for urban areas, can be used in the context of the Contaminated Land Exposure Assessment (CLEA) model, an ongoing programme of work supported by DEFRA, the Environment Agency and Scottish Environmental Protection Agency. Soil guideline values (SGV) produced by the model are given on the right as a function of land use and indicate a level below which a site can be considered safe.

The EU Water Framework Directive came into force in December 2000, a framework for the integrated protection of the water environment. G-BASE provides information about surface water geochemistry that can be used in support of this directive.

Pollutant	Residential with plant uptake#	Residential without plant uptake*	Allotments+	Commercial/ Industrial•
AS	20	20	20	500
Cd	1 (pH6) 2 (pH 7) 8 (pH 8)	30	1 (pH6) 2 (pH 7) 8 (pH 8)	1400
Cr	130	200	130	5000
Hg	8	15	8	480
Ni	50	75	50	5000
Pb	450	450	450	750
Se	35	260	35	8000

(all concentrations in mg/kg dry weight soil)

House with a garden and therefore the possibility of ingestion of home-grown vegetables.

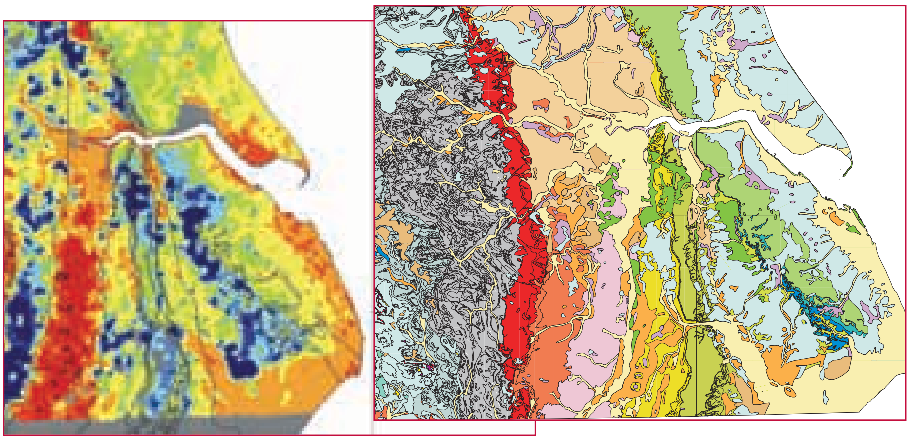
* House or apartment with no private garden area.

+ Open space, often made available by the local authority, for people to grow fruit and vegatables for their own consumption.

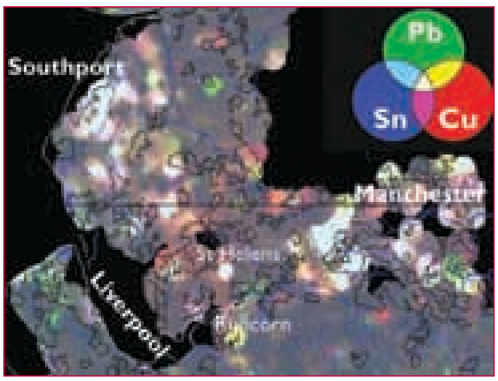
• Assumes that work takes place in a single-storey building, factory or warehouse where employees spend most time indoors involved in office-based or light physical work. Does not apply to sites with 100% hard cover, such as car parks.

Table of soil guideline values for the CLEA model.

In the Humber-Trent region there is a clear correlation of elements in soils (e.g. Mg0 map left) with the solid and drift geology (map right).

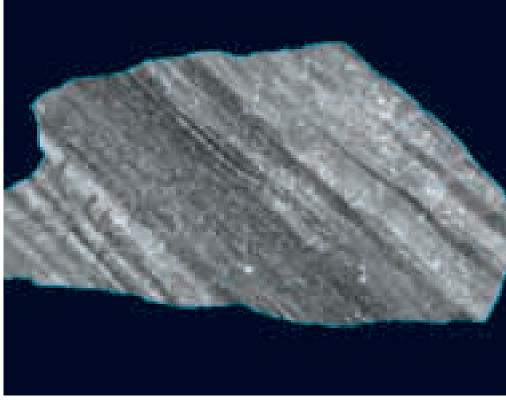


Three component plots such as that illustrated below identify areas of heavy metal contamination. G-BASE data have been used to identify undocumented industrial waste landfill sites.



Mineral Reconnaissance Programme drilling at Kelman Hill, north-east Scotland.

Panning drainage sediment, Sumatra, Indonesia.



Banded baryte from the Foss Mine, Aberfeldy.

Elementary detectives

G-BASE samples have been used to help determine where materials may have originated as the geochemical data can be used as a geochemical fingerprint. For example, this has been done to help archaeologists determine the origins of some Scottish redware pottery using some 45 trace and minor elements. Isotopic studies in particular have utilised G-BASE samples to distinguish between natural and anthropogenic sources of Pb and U. It is possible to distinguish between lead anomalies in the environment derived from ore deposits and the lead derived from petrol engines. High levels of natural uranium can be distinguished from that associated with the nuclear industry.

Dissolved sulphate can cause damage to concrete structures due to reaction with the calcium aluminate phases in Portland cement. This is recognised as a major engineering problem throughout the UK and such damage has been recognised on the M5 motorway in the Worcestershire Basin. The use of combined sulphur and strontium isotopes in G-BASE water samples can be used to identify sources of certain solutes and distinguish between natural and anthropogenic sources (e.g. fertilisers).

Sherlock Holmes in 'The Hound of the Baskervilles' used the red colour of soil to identify the movements of a suspect. G-BASE has both a vast store of soil samples and soil geochemical data. With other techniques such as mineralogical analysis, geochemical fingerprinting may have an increasingly important role in forensic geoscience. This is currently being studied as a 'development of capabilities' project within BGS.

Mineral exploration

In the BGS the application of geochemistry to locate mineral deposits in the UK has been done principally through the now discontinued Mineral Reconnaissance Programme (MRP) in which regional geochemical data generated by the G-BASE project were used to identify targets for further follow-up work. Geochemistry, combined with geophysics, detailed geological mapping and drilling has successfully identified new mineral deposits in many areas of Great Britain. Notable successes, which have attracted significant commercial investment, include discoveries of gold in Devon and the Ochil Hills, barite near Aberfeldy, and base metals and platinum in Shetland.

The G-BASE project produces regional overviews of the geochemistry in the form of its geochemical atlas series, and geochemical anomalies that may be of interest for more detailed exploration are high-lighted. In the past, follow-up investigations of anomalies were carried out as part of the MRP but this is now left to private companies and consultants who use the BGS data under licence.

Solving geological problems

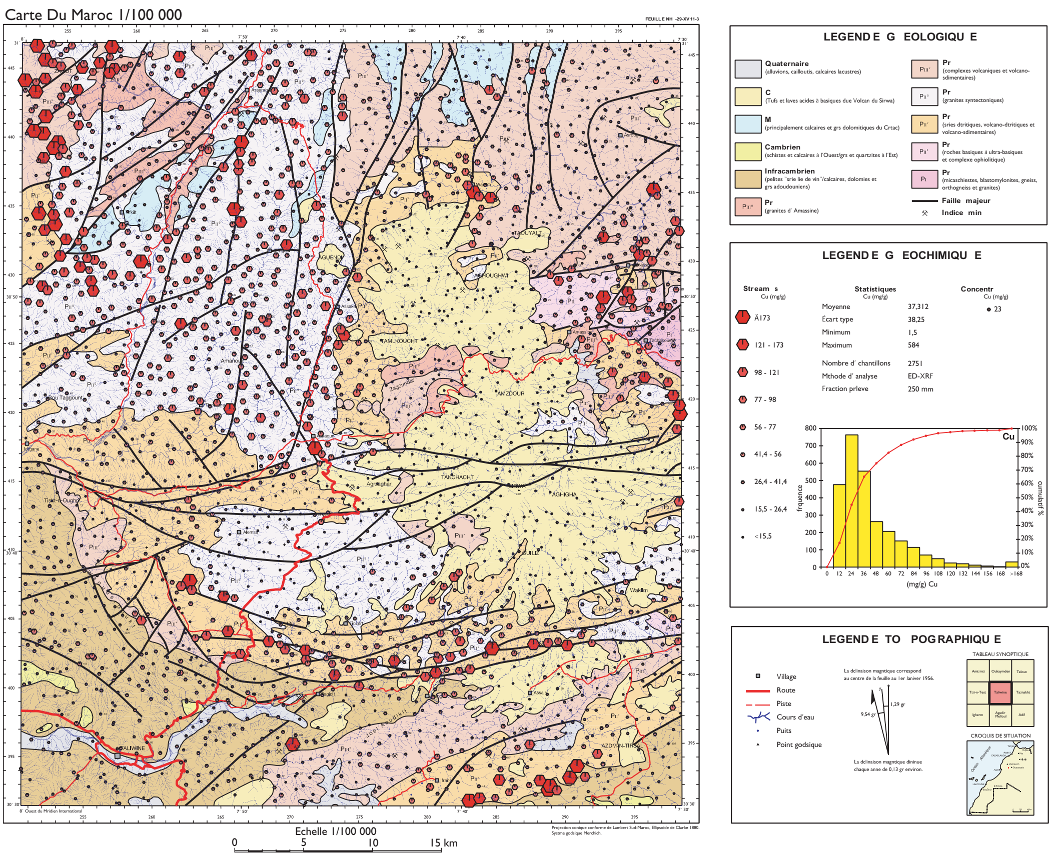
Geochemical maps are usually interpreted with respect to the known geology, mineralisation and other factors such as land use and man-made contamination to explain an element's distribution. However, our high-quality regional geochemical maps can be used to help in the mapping and interpretation of the geology. This is especially useful where the field geologist is faced with, for example, a large area of fairly monotonous lithology and poor exposure, but the geochemistry shows clear variations which can be attributed to changes in the bedrock. Examination of the regional geochemistry will provide information on the association, and type, of any mineralisation found during the survey. In the Southern Uplands of Scotland, for example, the regional geochemical maps for many elements, irrespective of their overall abundance, produce a marked strike-parallel, NE-SW linearity. The steepest gradients are coincident with tract-bounding faults, but different elements show different distribution patterns. This reflects the compositional contrasts between greywackes in adjacent tracts, which in turn indicates character differences in the provenance areas from which those rocks were derived. The regional geochemical data thus provides a means of tracking the variation in greywacke provenance through time, and interpreting that variation in terms of tectonic events involved in closure of the Iapetus Ocean.

USING BASELINE GEOCHEMISTRY

Mapping the world

BGS geochemists, led by Professor Jane Plant, have made significant contributions to international regional geochemical mapping. They have participated in initiatives such as the 'Global Geochemical Database for Environmental and Resource Management' International Union of Geological Sciences (IGCP) Project 259 and the 'Global Geochemical Baselines' IGCP Project 360. These initiatives have brought a degree of standardisation to worldwide geochemical mapping with recommendations for the methods to use. BGS geochemists are also active members of the Geochemistry Working Group of FOREGS (Forum of European Geological Surveys) that was established to publish a geochemical map of Europe from standardised national geochemical mapping data sets and a low density sampling exercise.

G-BASE geochemical mapping methods have been adapted for use by many national surveys around the world ranging from the tropical rain forests of Sumatra to the arid mountainous region of the Anti-Atlas Mountains in Morocco. BGS international geochemistry work is detailed on web pages (see http://www.bgs.ac.uk/int/geochem/). Much of the earlier international geochemical mapping was funded by the UK Overseas Development Administration (ODA), the predecessor to the current UK Department for International Development (DFID). These projects were designed to increase the institutional capabilities of the host national geological surveys and were aimed principally at mineral exploration. The work in Sumatra, Indonesia, for example, involved the collection of some 22 000 drainage samples at a sampling density of one sample every 10–15 square kilometres. This work was part of an integrated geological-geochemical-geophysical mapping programme that continued for more than 20 years. Not only did this work result in a significant strengthening of the mineral exploration sector in Sumatra but the geochemical data could be used to resolve geological problems in areas where access to the tropical jungles were very limited. The more recent international geochemical projects such as Ecuador, Morocco and Mauritania have been work commissioned by the host governments, all containing a large training component in the field of geochemical mapping. G-BASE has a long established record of applying its methods around the world and the team of geochemists now have international skills and experience in many different terrains.



Geochemical map of the Taliwine area, Morocco (used with permission of the Director, Direction de la Géologie, Morocco).

Mike Ramsey, Professor of Environmental Science

'My first experience of geochemical sampling was gained with G-BASE, during my summer vacations as an undergraduate. Not only did I find the work enjoyable and rewarding, but it inspired me to follow a career in environmental geochemistry. My subsequent research has confirmed what I learnt then, that sampling is one of the most important steps in any geochemical investigation'.

Norman Moles, Senior Lecturer in Applied Geology

'Aside from the unforgettable scenery, camaraderie, midge bites and physical exhaustion, the experience helped to shape my career. 'Expertise' in stream sediment sampling secured a job with a mineral exploration consultancy, where I trained others in the BGS sampling techniques. Subsequently, as a university lecturer, I have taught courses on geochemical exploration and published research on alluvial gold and on contaminated sediments'.

Helping the universities

The G-BASE field sampling relies on student labour to collect samples. In this way the BGS assists the universities in training environmental/earth scientists by giving valuable practical experience in geochemical sampling techniques. It is estimated that since the work started at the end of the 1960s approaching 1000 students have benefited from working for the G-BASE team. Many of these samplers have gone on to pursue careers in geochemistry and have benefited enormously from the inclusion on their CV of G-BASE work experience.

The G-BASE project also readily supplies samples, data and supervision for post-graduate students who have been a useful resource in interpreting the geochemical data. Recent examples include: Joe Kelly *Influence of geology and anthropogenic activity on the geochemistry of urban soils* PhD Imperial College London; Russell Staines *The influence of geology on small scale spatial changes in stream water chemistry* PhD Aberdeen; Jessica Lenham *Mapping and validating trace element availability in UK soils* PhD Nottingham: and Dusita Kolaka *Application of GIS for Integrated Catchment Management: The River Cree Catchment,* MSc. Edinburgh.

Geochemistry and health

The application of regional geochemistry to problems in medical geology was pioneered in the 1960s by Professor John Webb (Imperial College) in the UK. This work demonstrated numerous relationships between geochemistry and animal and plant health such as: incidences of cobalt deficiency in sheep; selenium toxicity and molybdenum-induced copper deficiency in cattle; arsenic and lead toxicity in animals; copper and manganese deficiency in seedling spruce; and manganese deficiency in cereals.

Historically we depended on the local environment for our food and water supply. Local environmental deficiencies in essential trace elements such as iodine and selenium can result in endemic diseases caused by insufficient quantities of such elements in the daily diet. Lack of iodine, for example, causes a host of medical conditions grouped together as iodine deficiency disorders ranging from the manifestly obvious goitres (swollen necks) to mental retardation and cretinism. Thankfully a diet of food from a diversity of areas and non-localised water supplies have made such endemic diseases a thing of the past in the UK, but they still persist in many of the developing countries of the world. However, such trace element deficiencies also afflict livestock and measures have to be taken to supplement their diet of predominantly home-grown fodder. Geochemical maps of the UK can help us to predict where such deficiencies occur and such areas can be targeted with trace element supplements.

Some elements that are essential can also be toxic. Selenium and molybdenum are examples of elements which show a relatively narrow concentration range between toxicity and deficiency. The potentially harmful inorganic elements are considered to be part of the PBT chemicals, that is, persistent, bioaccumulative and toxic pollutants. These are long-lasting and highly toxic substances that can build up in the food chain to levels that are harmful to ecosystem health.

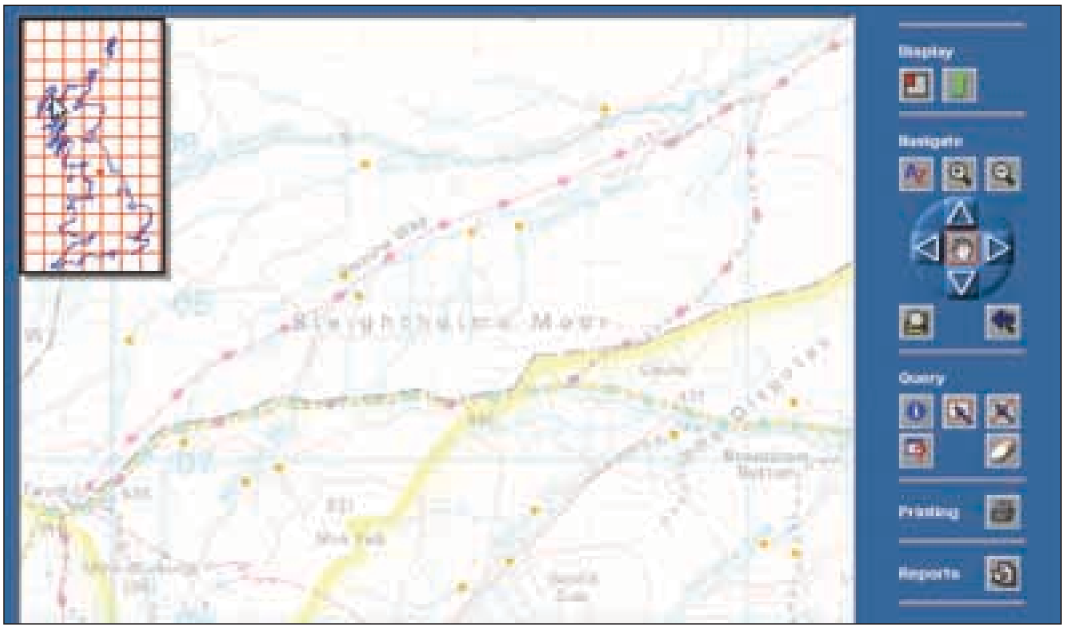
The urban environment

The urban environment by its very nature is an area subject to the most pollution and contamination and the place where most people live. Baseline geochemical data for risk assessment and health purposes is of fundamental importance in such an environment. The BGS is the only organisation in the UK systematically sampling and analysing urban soils. Urban areas sampled are listed on page 5. The urban soil data can be placed in the context of the surrounding rural geochemical data to demonstrate how the history of urban development has modified the geochemical landscape.

AVAILABILITY OF GEOCHEMICAL DATA

BGS Geoscience Data Index (GDI)

G-BASE results along with geochemical data derived from other BGS projects are stored in an Oracle database. The data go through a rigorous quality control procedure before being published and are standardised so as to produce seamless geochemical maps across the sampling campaigns that have continued for more than thirty years. The availability of geochemical data can be determined from the BGS Geodata Index available on the intranet at ww.bgs.ac.uk/geoindex/.



Example screen from the web-based BGS GeoData Index showing the location of stream sediment samples (yellow dots) for an area of northern England. A query of an individual sample shows the sample reference number, its grid coordinates and the elements determined.

Licensing data

The G-BASE data are available free to all BGS and other NERC researchers for non-commercial research. For users from outside NERC the data are available under licence where specific terms apply according to the use.

How to access G-BASE data

Customers wishing to use G-BASE digital data can do so under a licence issued by BGS. This licence usually lasts for a 1–5 year period and is costed on the basis of the number of site records requested. Gridded images, GIS layers, or point maps can also be provided by special arrangement. Information about data and data sales should be addresses to enquiries@bgs.ac.uk.

Data are published in a series of geochemical atlases which display the data as gridded geochemical images accompanied by in depth interpretation relating distributions to factors such as geology and mining. Information about atlases and how to purchase them can be found on the project's website (www.bgs.ac.uk/gbase).

Collaborative projects

G-BASE has systematically sampled the British mainland essentially working from north to south. Opportunities arise to carry out the regional surveying work in more targeted areas when this can be co-funded by external collaborators. Recent examples of this are the Tamar catchment survey, co-funded by the Environment Agency and the Glasgow urban drainage survey, co-funded by Glasgow City Council.

Some G-BASE-related publications

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Economic Minerals and Geochemical Baseline Programme

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