Baseline Geochemical Mapping in the UK - the G-BASE Programme.

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National geochemical mapping in the UK is undertaken by the BGS as part of the Geochemical Baseline Survey of the Environment (G-BASE) Programme. The programme began in the early 1970's in the North of Scotland and will provide a comprehensive high resolution baseline geochemical database for the whole country by the year 2012. The ongoing development and inclusion of state-of-the-art analytical and computing techniques and rigorous quality control over the past 25 years have been fundamental in creating consistent geochemical maps which reflect geological, geomorphological and landuse parameters.

Fieldwork over an area of approximately 5000 km^2 is carried out between the months of June and September each year. The programme primarily involves the systematic sampling of stream sediments, heavy mineral concentrates, stream waters and more recently, soils. Stream sediment (< 150 µm) and heavy mineral concentrates (< 2000 µm) are collected from first and second order streams at an average sampling density of 1 per 1 - 1.5 km^2. In recent years, the incorporation of soil sampling (based on a density of 1 sample per 2 km^2) in areas with poorly developed drainage networks, has improved the environmental applications of the data. Fully-automated XRF techniques allow rapid, precise determination of 35 elements of economic and environmental importance in stream sediment and soils.

Stream waters have also been collected from the same sites as the other drainage samples, at an average density of 1 per 3 km^2. Initially these were analysed only for pH, conductivity, alkalinity, F and U content. Beginning in Wales, however, the hydrogeochemistry programme has been significantly enhanced to meet a wider range of environmental and economic criteria. In collaboration with the BGS Hydrogeology Group, a hydrogeochemical mapping programme based on the collection of filtered (< 0.45 µm) water samples at a density of 1 sample per 1.75 km^2 was initiated. The development and advancements in ICP-AES and, particularly, ICP-MS analytical techniques allow the rapid determination of 25 elements to parts per billion levels in surface water samples.

Rigorous quality control procedures including the analysis of international standards ensure national consistency of the data despite past changes in analytical techniques and the long term time-scale of the project. The data therefore provide baseline information on the natural abundances of elements in the surface environment of the UK against which anomalous values caused by such factors as industrial mining, agricultural and urban contamination can be compared. Development of a user-friendly database and GIS allows easy integration and comparison of data from a variety of sources including remotely sensed information, geology, and geophysics, and form a multi-disciplinary data interpretation package.

Regional stream sediment data have proved to be valuable in several areas of environmental importance. In agriculture, for example, an EU-funded project in collaboration with the Rowett Veterinary Research Institute and Aberdeen University Medical Faculty demonstrated the close links between Mo toxicity/ Cu deficiency in cattle and high levels of Mo in stream sediments or areas of high pH were Mo is more available. Incidents of Se deficiency in cattle and Co deficiency in sheep have also been shown to be related to regions where the values of these essential elements in stream sediments are low. The application of G-BASE data to human epidemiological studies is an important area for future collaboration with medical scientists.

The BGS has recently completed a major review of Natural Contamination in the UK on behalf of the Department of the Environment providing risk assessment maps of Potentially Harmful Elements (PHEs) (Appleton, 1995). These are based on a combination of G-BASE and Imperial College, London datasets for As, Cd, Cu, Pb and Zn in stream sediments. A statistical procedure involving the interpretation of probability graphs was used to distinguish natural background populations from anomalous concentrations related to contamination from mineralisation and mining. Despite differences in sampling methodology and analytical techniques between the two surveys, it has been possible to use percentile-percentile plots and differential degrees of averaging data to normalise the BGS and Imperial College datasets into apparently 'seamless' maps for the whole country. The maps show areas which are characterised by above national average background concentrations of one or more of the selected PHEs and are designed to provide an indication to planners, environmental health officers, developers and landowners where further site investigations or ground surveys may be required in land-use planning.

Total element concentration maps of surface water sampling in Wales demonstrate that regional hydrogeochemistry is an effective mapping tool. Annual variations in weather conditions and stream flow have less effect on the stream water data than the overall hydrogeochemical contrast. Regional variations show direct relationships with stream sediment geochemical patterns and changes in lithology, geomorphology and land-use. The data also have wide-ranging environmental management applications. Areas of mineralisation and metal mining, for example, are distinguished by low pH in stream waters and anomalous concentrations of cations (Al, Cd, Co, Fe, Mn, Pb, SO_4 and Zn). Areas under intensive agriculture are clearly delimited by high concentrations of NO_3.

Interpretation of the water data is greatly enhanced by recent developments involving thermodynamic modelling packages which analyse the data in terms of major cation and anion concentrations. Maps of sulphate ion dominance expressed as a percentage of the total anion concentration show that despite low total SO_4 concentration, dissolved sulphate contributes significantly to the solute chemistry of upland areas in Wales and particularly to the South Wales Coalfield area. Piper diagrams have been used for many years to interpret chemical analysis of groundwaters and essentially comprise two triangular diagrams summarising the predominance of major cations and anions. Combining Piper diagrams and three component mapping techniques, it is possible to determine the relative importance of dissolved ionic species and distinguish the chemical signatures of different water sources. Upland areas in Wales are dominated by relatively high Na and Cl and low total dissolved solids (TDS) consistent with waters derived largely from atmospheric input. This is in contrast to Ca and Mg dominated waters in lowland areas of south-west and south-east Wales which contain a significant groundwater signature. The use of these techniques provides valuable information on the buffering capacity of waters, and they represent a potentially powerful tool in determining Critical Load Exceedence and water quality. However, the use of ionic dominance diagrams alone cannot be used to predict the equilibrium processes likely to control the co-precipitation and mobility of PHEs. To achieve this, the hydrogeochemical data are superimposed on a saturation diagram for pure calcite ($CaCO_3$). The resultant maps demonstrate that some upland areas in Wales are significantly under-saturated with respect to calcite and have low pH levels and relatively high dissolved O_2. This is indicative of poor buffering capacity and any land-use changes causing increased acidification of the environment are likely to result in increased availability of Al and other PHEs.

In recent years, the G-BASE programme in collaboration with Imperial College London, has developed urban geochemical sampling methods based on the collection of soils at a density of 1 per 0.25 km^2 together with samples of stream water, stream sediment and road dust. These methods complement the regional geochemical programme. Multi-disciplinary urban investigations involving geochemistry, hydrogeology, geology and land-use studies have identified areas with enhanced concentrations of PHEs in soils and surface drainage systems, some of which are related to historic industrial activity, while others are due to modern road traffic. The surveys also include geochemical investigations of platinum group elements (extensively used as exhaust catalysts in motor vehicles) in soils and road dust. The results of these studies enable future urban development to take account of the present distribution of PHEs and the processes by which they enter the environment.

In summary, the G-BASE programme combines comprehensive integrated sampling strategies and the application of state-of-the-art analytical techniques, quality control procedures and computing methods to provide regional, urban and hydrogeochemical maps constituting a high precision, high resolution, multi-media, multi-purpose UK database for the 21st century.

Appleton, J D. 1995. Potentially harmful elements from natural sources and mining areas: characteristics, extent and relevance to planning and development in Great Britain. British Geological Survey Technical Report WP/95/3.