“ high-resolution geochemical maps allow us to examine the possible sources, sinks, pathways, mobility and bioavailability for radioactive elements in the environment ”

Mapping radioactivity

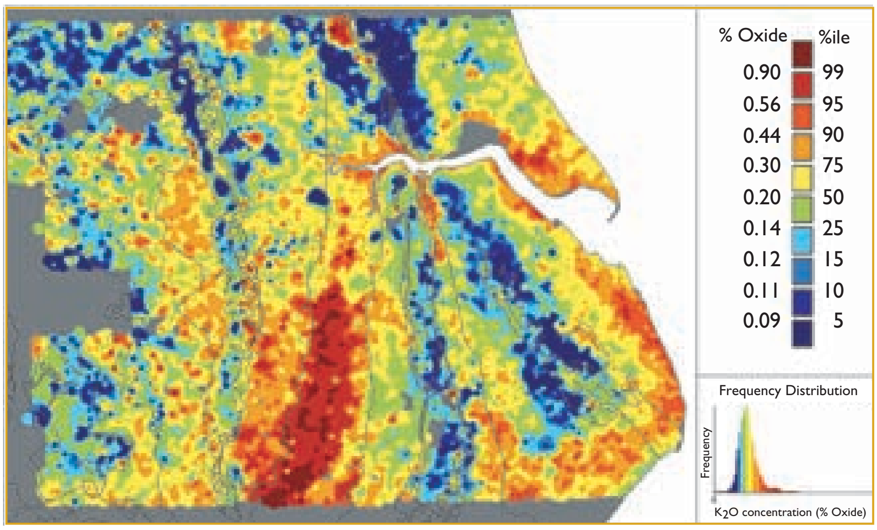
Geochemical baselines for radioactive elements from the G-BASE project

by Neil Breward and Chris Johnson

From a historical perspective the Geochemical Baseline Survey of the Environment (G-BASE) project has its origins in the strategic uranium geochemical reconnaissance work done by the BGS in the late 1960s and sponsored by the UK Atomic Energy Authority (1967–72). Geochemists trained in survey techniques for this uranium work started the multielement regional geochemical mapping of the UK in Sutherland in the summer of 1968.

Since the start of this work, the project has determined uranium (U) on stream sediments and waters collected at a sampling density of one sample per 1.5 square kilometres. G-BASE now has data for 80% of the British mainland. As the programme has evolved, other elements such as thorium (Th) and potassium (K) have been added to the list of determinands and now soils are also routinely collected at a sampling density of one sample per two square kilometres. G-BASE can provide background information for the radioactive elements and this can be used to distinguish between naturally occurring and anthropogenic sources. The store of G-BASE samples continues to be used in isotopic provenancing studies.

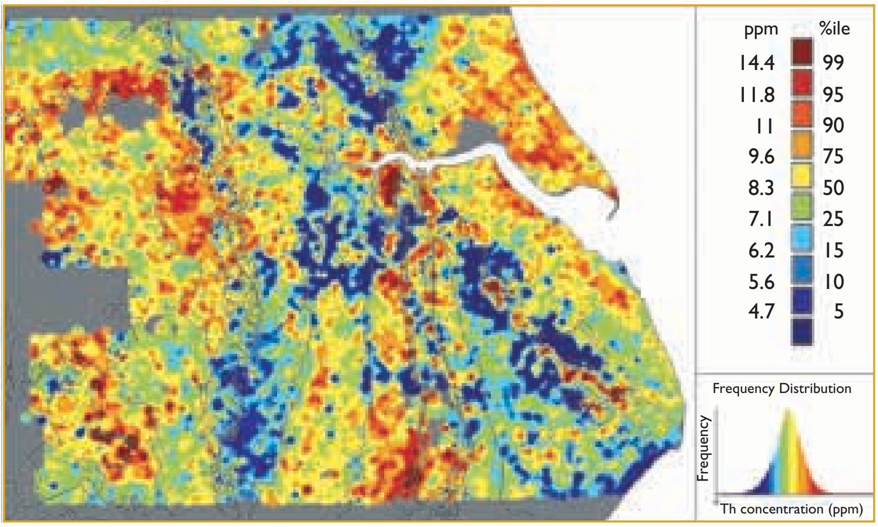
Several naturally occurring chemical elements are radioactive. These include the heavy metals uranium and thorium, the radioactive noble gas radon, very rare elements such as radium and polonium, and unstable but long-lived isotopes of much more abundant elements such as potassium (of which potassium-40 forms about 0.01% of the total mass) and the relatively short-lived carbon-14 (^{14}C) which is formed by cosmic ray interactions with atmospheric nitrogen. Trace amounts of radioactive elements and isotopes of undoubted anthropogenic origin include tritium, caesium, iodine and transuranic elements from nuclear weapon tests and events such as the Chernobyl fire, but these are at levels outside the capability of routine G-BASE determination.



Potassium concentration in profile soils in the Humber–Trent region.

In the G-BASE regional geochemical survey programme, we now routinely determine the concentration of uranium, thorium and potassium in stream sediments, soils and stream waters. This enables us to create high-resolution geochemical maps for the different earth-surface materials and therefore allows us to examine the possible sources, sinks, pathways, mobility and bioavailability for these elements in the environment.

Where the distribution of these elements is geologically determined it is a



Thorium concentration in profile soils in the Humber–Trent region.

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relatively simple matter to determine a ‘geochemical baseline’ value for an element, which would be its natural concentration in the absence of human interference. Significant deviations from this baseline (anomalies) then imply either unexpected variation in the geological background, which may be valuable information for geologists, or anthropogenic modification or contamination, which is important for environmental protection, local authorities and planners.

With elements such as uranium, analysis of the relative abundance of the isotopes can also be used as a ‘fingerprinting’ technique to determine the origin of an anomaly. Thus deviation from the normal $^{235}U/^{238}U$ ratio implies some processing in the nuclear fuel cycle, for example. Isotopic analysis is not done routinely in G-BASE but has been used to examine uranium anomalies for example in the northern Pennines and the Craven Basin which proved to be natural; and near Preston and Ellesmere Port in north-west England, which showed significant anthropogenic modification.

The images shown here are for uranium, thorium and potassium for soils in the Humber–Trent region, which is the next volume in our Regional Geochemical Atlas series. The three elements show very distinct distribution patterns as would be expected from their different geochemical natures, with uranium showing concentrations mainly in the organic-rich shales of the Namurian sediments, thorium being mainly associated with the resistate mineral fraction in the sandstones of the Namurian and the Mesozoic sedimentary ironstones, while high potassium levels are present over the Mercia Mudstone Group.

These images can be usefully compared with the airborne radiometric survey carried out as part of the BGS’s Hi-RES project *(see page 8)* which, although based on gamma-ray spectrometry of daughter elements within the uranium and thorium decay series rather than direct measurement of uranium and thorium, give good correlation with the G-BASE data as well as excellent spatial correlation with the potassium data.

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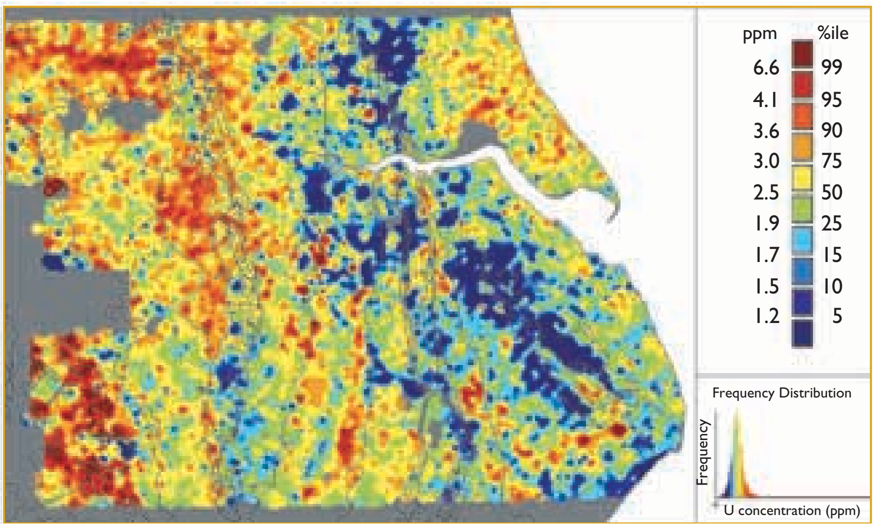

Uranium concentration in profile soils in the Humber–Trent region.