Cryptogeology

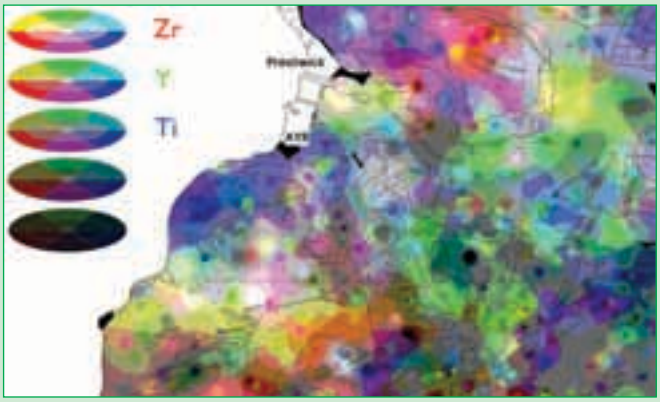
Regional geochemistry as an aid to geological mapping

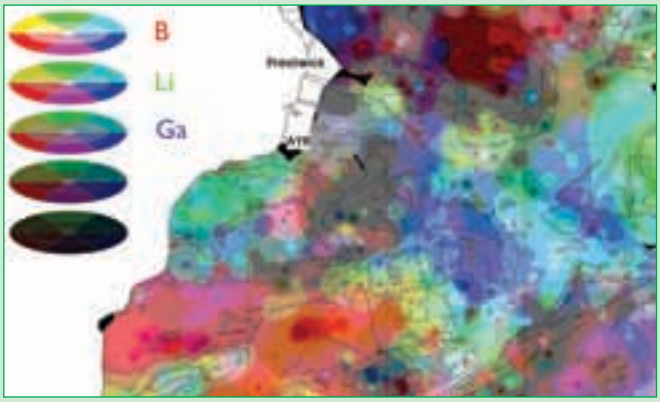
by Neil Breward, Maxine Akhurst and Phil Stone

The Geochemical Baseline Survey of the Environment (G-BASE) project is the BGS's strategic primary geochemical survey of the UK landmass, and has been collecting and analysing geochemical samples, and creating and interpreting geochemical maps, since its inception in 1969. Usually, the observed features and anomalies in geochemical maps are interpreted with respect to the known geology, mineralisation and other factors such as land use and man-made contamination.

More recently, the value of high-quality regional geochemical maps in mapping and interpreting the geology has been appreciated. This is especially useful where the field geologist is faced with, for example, a large area of apparently monotonous rock types and poor exposure but the geochemistry shows clear variations which can be attributed to changes in the bedrock. Examination of the regional geochemistry will also provide information on the association and type of any mineralisation found during the survey.

Examples of the use of geochemistry in two multidisciplinary projects — the Midland Valley Integrated Survey, and the South Scotland and Northern England





Swanshaw Sandstone Formation

The top of the Swanshaw Sandstone Formation, underlying a volcanic formation, has high feldspar elements suggesting a cryptic heralding of the extrusive volcanism. A high chromium content is typical of the middle part of the formation, indicating an ultramafic source. Serpentinised basic clasts have previously been noted and the Ballantrae ophiolite suggested as a source. A heavy mineral suite is also characteristic of the middle part of the formation and is revealed by relatively high concentrations of the elements zirconium (principally in the mineral zircon), yttrium (garnet) and titanium (rutile, ilmenite, and sphene) *(*see Zr–Y–Ti map, *above left)*. The geochemistry is considered to reflect a heavy mineral suite, resistant to chemical weathering ('resistates'), and this suggests a recycled sediment source. This interpretation is supported by the absence of nickel and magnesium, which should occur in association with high chromium if the sediment source had been eroded directly from the Ballantrae ophiolite.

Igneous intrusions with widely ranging composition occur within the base of the Swanshaw Sandstone Formation. High values of copper, zinc and lead content are found and are considered to reflect an igneous derivation. However, the high values of boron in rocks at this horizon may be attributed to detrital tourmalines or clay minerals. The boron–lithium– gallium map *(above right),* shows high values for all three elements, but with higher values of gallium in the northern (younger) part; higher values of boron are typical of the southern (older) part of the formation. It is likely that these distributions reflect a variation in the weathered feldspar component of the Swanshaw sandstones.

Integrated Surveys — are described in this article. For each project, geochemical maps were provided at the regional 1:250 000 scale, and also at the 1:50 000 scale where individual map sheets were being examined.

Midland Valley of Scotland

Within the Ayr–Mauchline sheet, geochemical maps created at the 1:50 000 scale have been used to examine the spatial variation within the Devonian Swanshaw Sandstone Formation *(see box bottom left for a detailed description),* and also to examine the Permian sandstones and volcanic rocks of the Mauchline Basin.

Mauchline Basin

In the Mauchline Basin, which is occupied by Permian sandstones and associated volcanic rocks, a gold anomaly had been found in panned stream sediment concentrates. The mineral reconnaissance work had suggested fracture-fill mineralisation or brine-driven redox front reaction as the source, but the low arsenic and antimony and high tin values in the G-BASE results imply a reworked 'placer' type accumulation, rather than a primary mineralisation source, for the gold. The sandstones show distinct contrasts in zirconium content between the north and south of the basin; this is associated with a reciprocal distribution in titanium concentration which appears to reflect a compositional variation in the sandstones.

Southern Uplands of Scotland

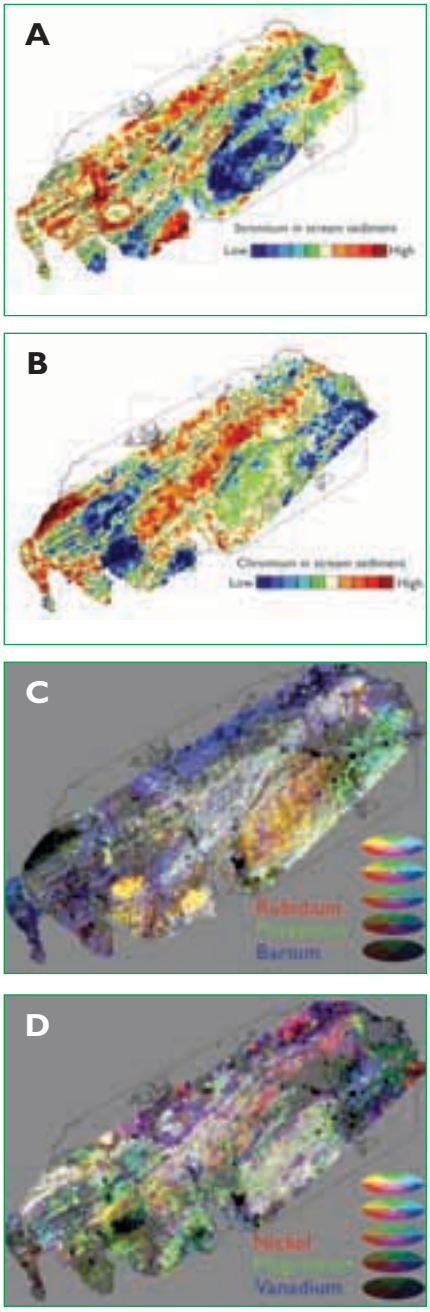
The Southern Uplands Terrane is an accretionary complex comprising a series of 'tracts' trending north-east–south-west. Each tract is bounded by thrust faults and contains a mudstone–sandstone rock sequence dominated by 'greywackes'. The composition of these greywackes varies with their stratigraphical position, reflecting variations in the source (provenance) of the sediment during deposition. Such variations in composition are known from petrographical and analytical work, but are not visible macroscopically. However, stream sediment geochemistry maps reveal a remarkable level of detailed variation that allows stratigraphical subdivision to be made and interpretation of the sediment source to be refined.

The regional geochemical maps for many elements, irrespective of their overall abundance, show a marked strike-parallel, north-east–south-west linearity. The steepest gradients coincide 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 differences in the character of the provenance from which those rocks were derived. The regional geochemical data thus provide a means of tracking the variation in greywacke provenance through time and can be interpreted in terms of the tectonic events involved in closure of the Iapetus Ocean.

The transition metals chromium, nickel, magnesium and vanadium are of particular value, as are variations in the concentrations of the feldspar-related elements strontium, rubidium, potassium and barium. Elements in the latter group define three greywacke populations. The combination of low rubidium, potassium and barium with high strontium concentrations *(a and c, right)* over the Ordovician greywacke sequence north of the Orlock Bridge Fault suggests a plagioclase feldspar provenance dominated by rocks of a dioritic or granodioritic composition. The converse relationships south of the Moffat Valley Fault indicate a potassium feldspar provenance, largely within moderately evolved continental crust. There is an overlap in these trends across the older part of the Silurian sequence, between the two faults, which suggests the interaction of different provenance areas rather than the geochemical evolution of a single source. The older part of the Silurian sequence is also notable for exceptionally high levels of chromium *(b, right),* and to a lesser extent nickel, magnesium, and vanadium *(d, right)*. This may indicate an influx of ophiolitic detritus from the developing Scandian Orogen further to the north-east.

More detailed descriptions of this work were given at the ISEG Conference in Edinburgh and in a scientific paper[1]. ▮

[1]Stone, P, Breward, N and Merriman, R. 2003, Mineralogical controls on metal distribution in stream sediment derived from the Caledonides of the Scottish Southern Uplands and English Lake District *Mineralogical Magazine* **67** 325–38.



BGS © NERC

Geochemical maps of the Southern Uplands of Scotland. Stranraer is in the south-west and Berwick-upon-Tweed in the north-east of the maps. Maps show concentrations of (a) strontium, (b) chromium, (c) rubidium–potassium–barium, (d) nickel–magnesium–vanadium in stream sediments.

For further information, contact:

Dr Neil Breward
Tel: +44(0)115 936 3479
e-mail: nbr@bgs.ac.uk