Advances in analysis

PIMMS

Isotopic innovations in earth system science

by Randall Parrish, *Keyworth*

Plasma ionisation multicollector mass spectrometry, or PIMMS for short, is a relatively recent British innovation which is revolutionising the application of isotopic measurements to the earth system. Isotopic ratios of elements recognisable to nearly every one (i.e. calcium, iron, copper, zinc and lead) in addition to many others (uranium, thorium, neodymium, samarium, strontium, lutetium, hafnium, and thallium) can now be more efficiently and in many cases more precisely measured than ever before, and this is opening up new avenues of research with broad applications to both traditional geological projects and the expanding field of environmental investigation.

The instruments comprise an inductively-coupled plasma source (technology established in standard ICP-MS instruments), coupled with a large magnet and energy analyser, and a multiple ion detection system similar to that in traditional thermal ionisation mass spectrometers (TIMS). The marriage of the two types of mass spectrometry components was first achieved in the early 1990s in the laboratories of the British Company VG Elemental, based near Manchester. Subsequently, several other British mass spectrometry companies have developed these instruments, currently dominating the world market. The BGS has, incidentally, been involved in ICP technology since its beginnings, but that is another story!

The NERC Isotope Geoscience Laboratories of the BGS have recently taken delivery of two new instruments of this type in a collaborative venture between three sister organisations of NERC — the Scientific Services and Facilities, the BGS and the British Antarctic Survey. The instruments are supplemented by a state-of-the art laser system which allows solids and liquids to be sampled at the scale of 10–100 microns, and analysed for both chemical and isotopic composition.

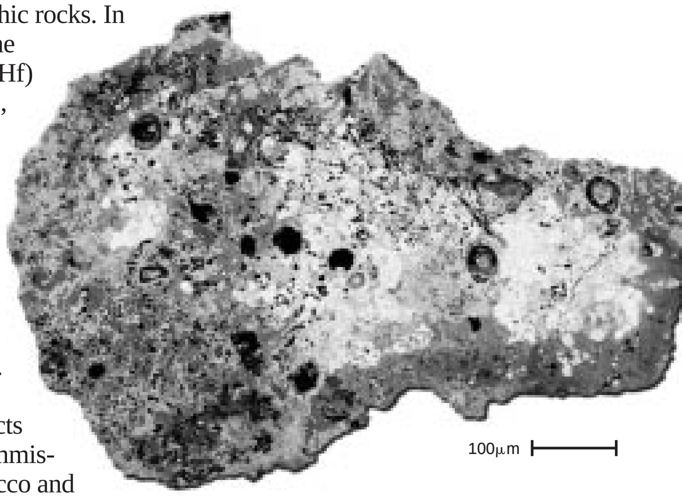
Using these instruments, there are many exciting avenues of research to pursue in the next several years; one of the most promising for 'traditional' geological sciences is the ability to provide *in situ* uranium-thorium-lead (U-Th-Pb) dating within very small regions of crystals of minerals such as, zircon, monazite, or xenotime which are widespread in crustal rocks. The provenance of sedimentary rocks in depositional basins is being rapidly surveyed, using the dating of single detrital grains, as is the more cost-effective dating of certain types of igneous or metamorphic rocks. In zircon or monazite, the isotopes of hafnium (Hf) and neodymium (Nd), respectively, can be measured in addition to the U-Th-Pb isotopes, in order to provide insight into the crustal pre-history of the magmas from which these crystals formed. This technique has been applied to projects in Scotland, BGS commissioned work in Morocco and Canada, EU-funded projects in central Europe, the Himalaya and elsewhere. Perfecting the method has taken about nine months during the past year, and the results rival, and surpass in some cases, the precision of the much better known Australian ANU SHRIMP

Geoff Nowell, BGS © NERC

A formerly active diamondiferous kimberlite mine in the Kimberley district of South Africa, with buildings for scale. Kimberlites sample a wide variety of mantle materials and their isotopic analysis provides important clues about mantle evolution.

ion microprobe. This development will ensure that the laboratories at Keyworth remain an international centre of excellence in geochronology for some time.

Exciting new research is being done with the PIMMS instruments into the



Jonathan Pearce, BGS © NERC

A backscattered scanning electron microscopy image of a probable slag particle from contaminated soil in Wolverhampton. Lead and antimony-rich metal and silicate particles are light grey. Lead isotope measurements can be made on small regions of this particle using LA-PIMMS.

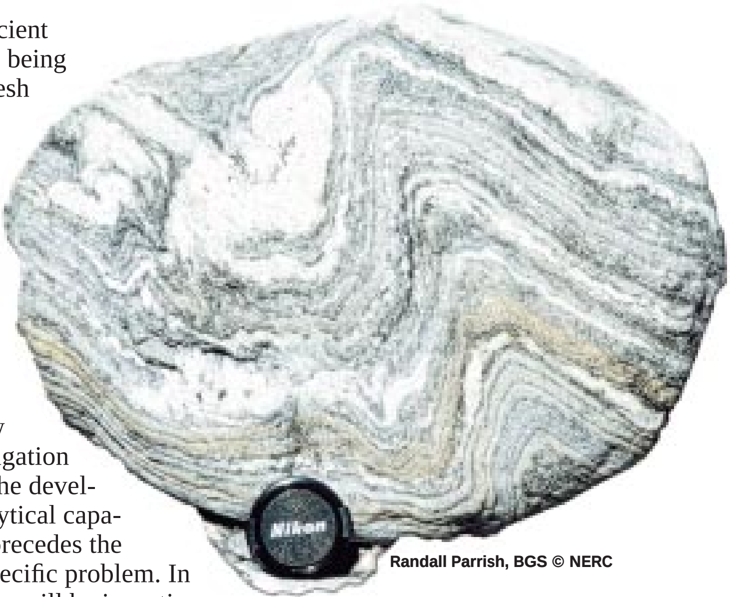
Advances in analysis

bioavailability of potentially toxic elements and species, particularly heavy metals (lead, copper, etc) in contaminated soils in urban brownfield sites. The research funded by the NERC URGENT programme, is investigating how metals are released and mobilised in soils, and in what mineralogical form the metals occur (i.e. lead-rich paint, metal alloys/slags, secondary metal-rich minerals). Scanning electron microscopy (SEM) is employed to identify micron-sized lead-rich particles and then, by using PIMMS , the isotopes of lead can be measured and compared with the lead isotope ratios obtained from conventional geochemical tests involving sequential dissolution and extraction of metals from soils. These latter procedures partly simulate human digestion and/or incorporation into growing plants and vegetables, and are the current benchmark procedures for determining metal mobility, in relation to international health standards. Ultimately, we are trying to relate the soluble metals to specific types of particles to improve our understanding of the mobilisation process, and to recognise the occurrence of any metal species which could pose a significant health risk. The PIMMS technology is pivotal in this research effort.

The element lutetium (Lu) is concentrated in the Earth's mantle, and one of its isotopes (^{176}Lu) is radioactive and decays into hafnium (^{176}Hf). In contrast to lutetium, hafnium migrates into pockets of melt and gradually accumulates preferentially in the Earth's crust. The mantle and crust therefore evolve quite differently and provide time-integrated clues to the dynamics of the Earth's geochemical system. This Lu-Hf system is now being applied to the earth system much more vigorously than ever before because of the ability of PIMMS to ionise this element and make very precise isotopic measurements. In collaboration with scientists from Durham, Leicester, University of London, and others, NIGL has used this system to understand whether plumes such as that beneath Iceland have evolved from sources distinct from those that have produced mid-ocean ridge basalts.It is hoped that those investigations will shed light on the origin of giant outpouring of lavas during plume magmatism. The geochemical characterisitics of the mantle beneath ancient continents are also being studied to bring fresh ideas to the debate on the origin of diamondiferous kimberlites and lamproites, and to develop new techniques relevant to the diamond exploration industry.

As with many new frontiers of investigation in geochemistry, the development of an analytical capability sometimes precedes the application to a specific problem. In the coming year we will be investigating the natural isotopic variability of iron, zinc, copper, cadmium and calcium, and applying these techniques to environmental projects. Shortly thereafter we will tackle problems which address, among other topics, metal smelter pollution, archaeology, and acid mine waste remediation.

It is an exciting time to be in environmental and earth system isotopic research!



Randall Parrish, BGS © NERC

A banded gneissic rock from the Greater Himalayan Series of the Nepal Himalaya. Originally a clastic sedimentary rock, dating using LA-PIMMS shows that metamorphism took place 18–22 million years ago.

For further information contact:
Prof. R Parrish, Head of the Isotope Geoscience Discipline, British Geological Survey, Keyworth, r.parrish@nigl.nerc.ac.uk.

Paul Tod, BGS © NERC

One of the two BGS PIMMS instruments Inset: *a detailed view of the glowing argon plasma ionisation source.*