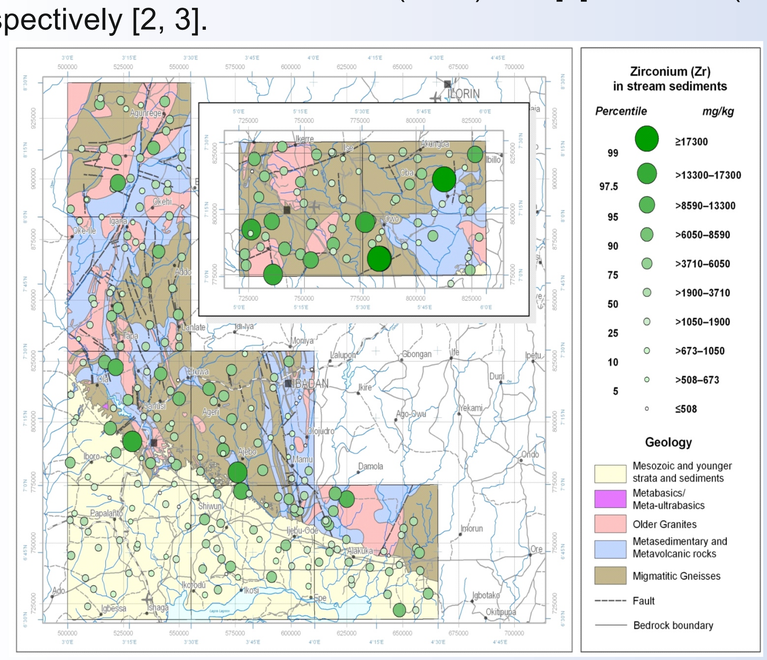
British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

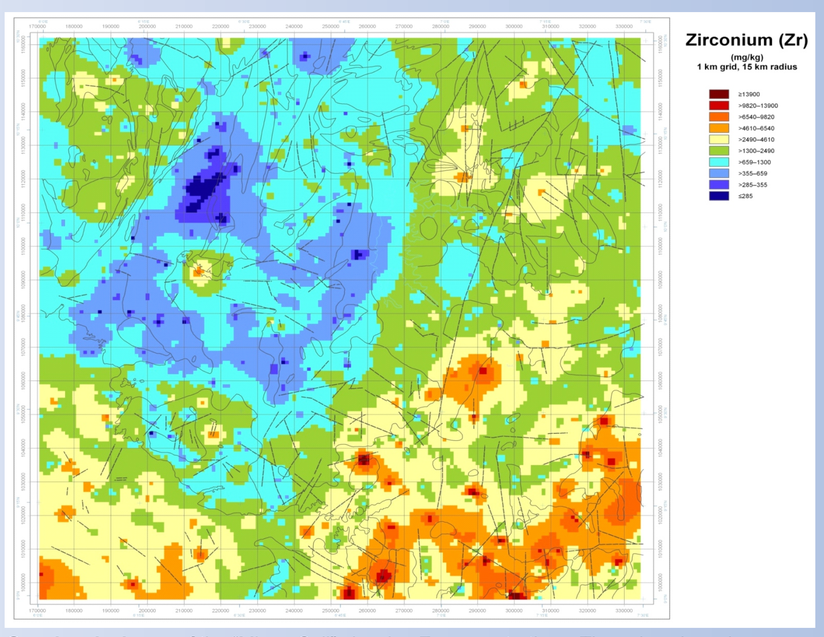
# Investigating the high Zr values in the fine fraction of stream sediments in Nigeria

Roger M. Key, Chris C. Johnson, Matthew S. A. Horstwood, Daniel J. Lapworth, Kate V. Knights, Simon J. Kemp, Michael Adekanmi, Tunde Arisekola, Paul Everett

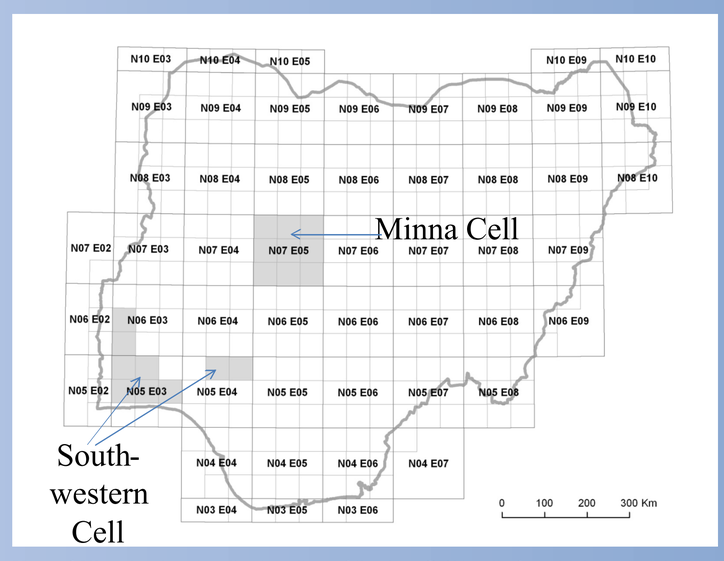
Regional geochemical surveys in Nigeria have consistently found very high concentrations of Zr in the fine (<150µm) fraction of stream sediments irrespective of underlying bedrock in upstream catchment areas. For example, mean/maximum Zr values of about 0.2%/2.3% and 0.3%/2.6% were determined in about 1600 analysed stream sediments collected from two 160X160 km2 Global Reference Network (GRN) cells[1] in central (the 'Minna Cell') and SW (the 'South-western Cell') Nigeria respectively [2, 3].




**Geochemical map** of the "Southwestern Cell" showing Zr concentrations in stream sediments superimposed on a map of bedrock geology. Coloured circles are used to represent sample locations and Zr concentration.




**Geochemical map** of the "Minna Cell" showing Zr concentrations. The values have been interpolated between sample locations to help show how the typical Zr concentration varies across the GRN cell. A higher sampling density of 1 sample per 25 km2 was employed for this cell.



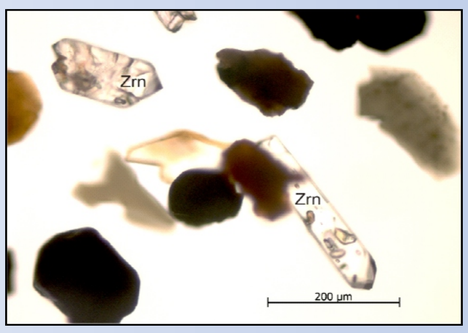

**Map of Nigeria** showing the location of the two GRN cells for which regional geochemical surveys have been completed.

X-ray diffraction (XRD) studies on a sub-set of the analysed stream sediments showed that Zr is predominantly found in detrital zircons grains. The main proximal source rocks for the analysed stream sediments are the widespread Pan-African, late Neoproterozoic 'Older Granites' of Nigeria, their Palaeoproterozoic-Neoproterozoic migmatitic gneiss country rocks and a local cover of Cretaceous siliciclastic sedimentary strata. However, these rocks are not enriched in zircon so the zircon enrichment in the stream sediment must be due to surficial processes.

**Table 1. Published Zr values (in mg/kg) in analysed rocks from SW Nigeria**

| Migmatitic gneisses | Older Granites | Metasedimentary and metavolcanic rocks |
|---|---|---|
| **296** and **666** (King & de Swardt, 1949) [4]; **1177** (Tijani et al., 2006) | 296 and 148 (King & de Swardt, 1949) [4]; **222-962** (Swardt & Vine, 1953) [5]. Jones & Hockey, 1964) [6] ; **68.3** (Tijani et al., 2006) [7] | **284.1** (Tijani et al., 2006) [7] |

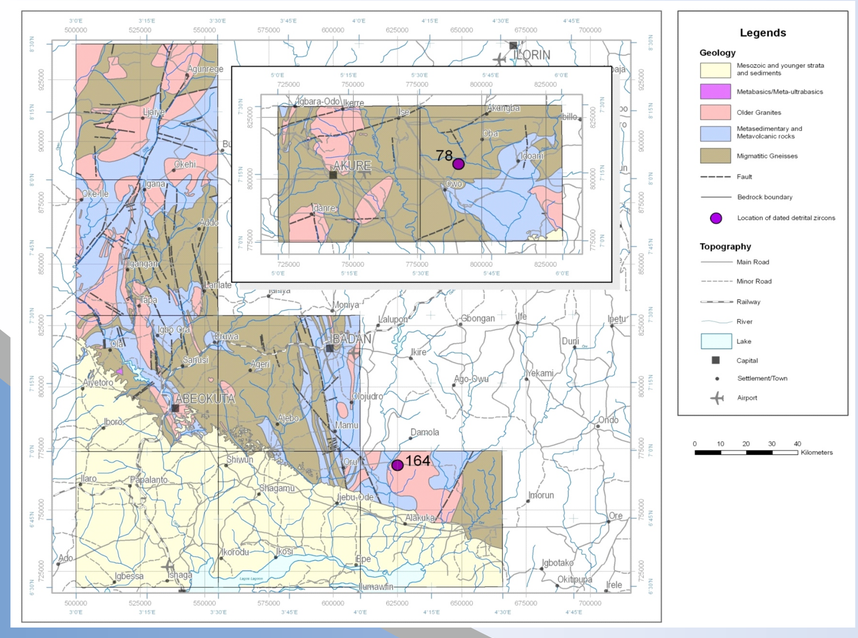
XRF analyses of the three dated Older Granites from the Minna Cell gave **163, 217** and **242** mg/kg Zr for R-1303, 143-PP3 and 165-PP4



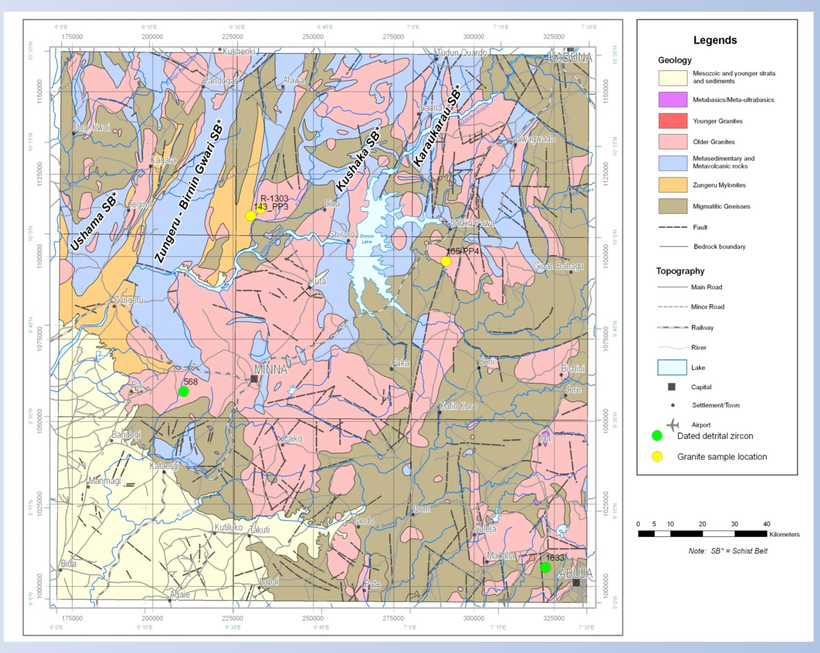

Microscope **photograph** showing heavy minerals from a stream sediment sample. Detrital zircons (labelled) have euhedral shapes, and have not been significantly rounded during transport.

A combination of tropical/chemical weathering and physical weathering involving a combination of wind winnowing during the dry season and flash flooding during the rainy season has effectively broken down bedrock silicate minerals and removed much of the resultant clay phases. The weathering has formed quartz-rich stream sediments enriched in resistant 'heavy' minerals, including zircon. U-Pb LA-MC-ICP-MS dating with cathodoluminescence (CL) imaging on detrital zircons from four stream sediment samples (and on zircons extracted from underlying Pan-African 'Older Granites') confirms a local bedrock source for the stream sediment zircons.

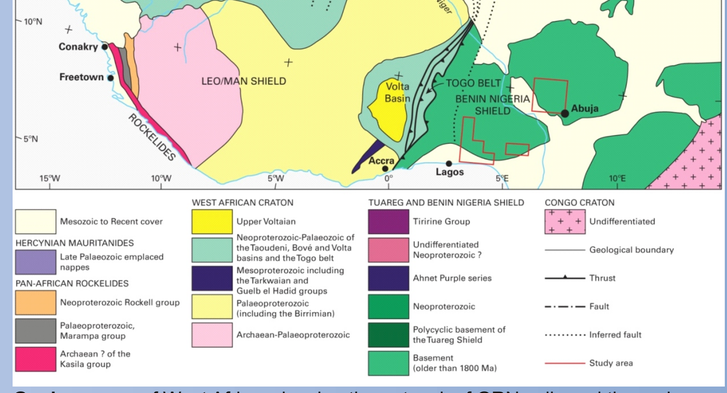
None of the examined zircon grains show significant signs of rounding which might be expected from transported distal material. Detrital zircon grains collected from two stream sediment samples with Older Granite-dominated catchment geology give 630-640 Ma age populations identical to the determined ages of the underlying granites. Detrital zircons from two stream sediment samples collected from migmatitic gneiss terrains yielded a range of Proterozoic ages (580- 640 Ma, 1200 Ma, >2150 Ma, 2200 Ma) to match published absolute ages from the migmatitic gneisses of Nigeria.




**Geological map** of the "Southwestern Cell" showing the sample numbers and locations of the stream sediment samples from which zircons were extracted and dated.



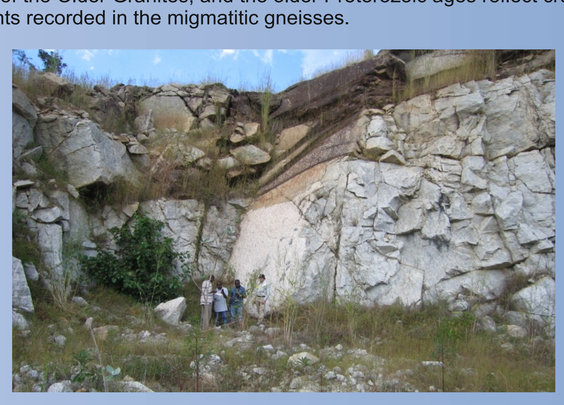

**Geological map** of the "Minna Cell" showing the sample numbers and locations of the stream sediment samples from which zircons were extracted and dated.

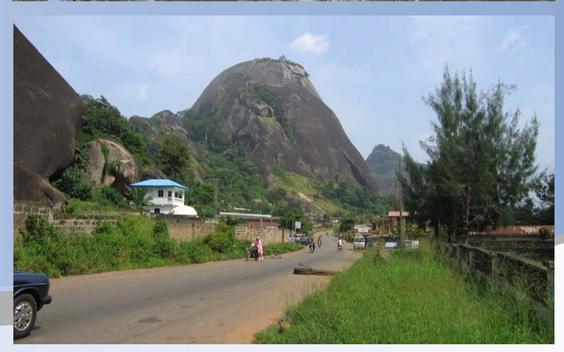



**Geology map** of West Africa, showing the network of GRN cells and the main geological units. The locations of the "Minna Cell" and the "Southwestern Cell" are marked in red.

| Older Granite-dominated catchment geology | Migmatitic gneiss-dominated catchment geology |
|---|---|
| Sample 568 (Minna Cell): **630-640 Ma** dominant with minor concordant ages of **600, 780, 880 Ma** dates. Sample 164 (South-western Cell): **630 Ma** dominant with minor **590, 800, 1130, 1320, 2160 Ma** dates. | Sample 1633 (Minna Cell): **595 Ma** dominant with other concordant ages of **640, 1200, >2150** Ma. Sample 78 (South-western Cell): **c.2.2 Ga** dominant with other concordant ages of **580-630 Ma, 2.0 Ga** and **2350 Ma**. |

**Table 2.** A summary of absolute ages determined from detrital zircons from four stream sediment samples from the Minna and South-western Cells. The 580-595 Ma ages reflect zircon growth during the main Pan-African metamorphic event. The 630-640 Ma dates the emplacement age of the Older Granites, and the older Proterozoic ages reflect crustal events recorded in the migmatitic gneisses.





**Photographs** showing exposure of the Older Granites

The 'anomalous' high values of Zr, as well as other elements concentrated in resistant 'heavy' minerals in Nigeria's streams is predominantly due to in-stream winnowing processes and may not reflect anomalous concentrations of these elements in the bedrock of catchment areas of the collected stream sediment samples. This conclusion has important implications for using stream sediment chemistry as an exploration tool for primary metal deposits associated with heavy minerals. However, Zr appears to be a good pathfinder element for placer deposits of heavy minerals.

## Contact:

**Roger M. Key**
**Murchison House**
**West Mains Road, Edinburgh Eh9 3LA**
**Tel: 0131 650 0250. Email: rmk@bgs.ac.uk**

References
[1] Darnley, AG, Bjorklund, A, Bolviken, B, Gustavsson, N, Koval, PV, Plant, JA, Steenfelt, A, Tauchid, M, and Xuejing, X (1995): A global geochemical database for environmental and resource management. Earth Sciences (19), Paris: UNESCO publishing: pp122.
[2] Knights, KV, Lapworth, DJ, Key, RM, Johnson, CC & Pitfield, PEJ 2010. The regional geochemistry of the Minna Cell, Nigeria: a summary report. Nigerian Geochemical Mapping Technical Assistance Project. British Geological Survey Commissioned Report (CR/10/054): pp150.
[3] Lapworth, DJ, Knights, KV, Key, RM, and Johnson, CC 2010. The regional geochemistry of the South-western Master Cell, Nigeria: a summary report. Nigerian Geochemical Mapping Technical Assistance Project. British Geological Survey Commissioned Report (CR/10/053): pp115
[4] King, BC and de Swardt, AMJ, 1949. The Geology of the Osi Area, Ilorin province. Geological Survey of Nigeria. Bull No. 20.
[5] De Swardt, AMJ, 1953. The geology of the country around Ilesha, Nigeria, Bull. Geol. Surv. Niger. 23 (1953), p. 54.
[6] Jones, .HA and Hockey, RD, 1964. The geology of part of southwestern Nigeria, Bull. Geol. Surv. Niger. 31 (1964), p. 87.
[7] Tijani, MN, 2006. Lithogenic concentrations of trace metals in soils and saprolites over crystalline basement rocks: A case study from SW Nigeria. Journal of African earth sciences vol:46 issue 5 pg:427 -438