Regional Geochemical Mapping in Nigeria:

results from the collaborative project between the Nigerian Geological Survey Agency and the British Geological Survey

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BACKGROUND

The Federal Republic of Nigeria is Africa's most populous nation and the economy has been overly dependent on revenue from the great oil reserves. In order to diversify its economy with the development of the solid minerals sector, the government has received support from the World Bank International Development Association to implement the Sustainable Management of the Mineral Resources Project. Part of this project has been to initiate a national geochemical mapping programme through the Nigerian Geological Survey Agency (NGSA). This has been achieved by the Nigerian Geochemical Mapping Technical Assistance Project (NGMTAP) (2008 – 2011) led by the British Geological Survey (BGS) and including several geochemists from the Finnish Geological Survey (GTK). The principal objective of the BGS project was to train and equip Nigerian geoscientists with skills for regional geochemical mapping and this was achieved by the sampling of two pilot areas in Nigeria in 2009.

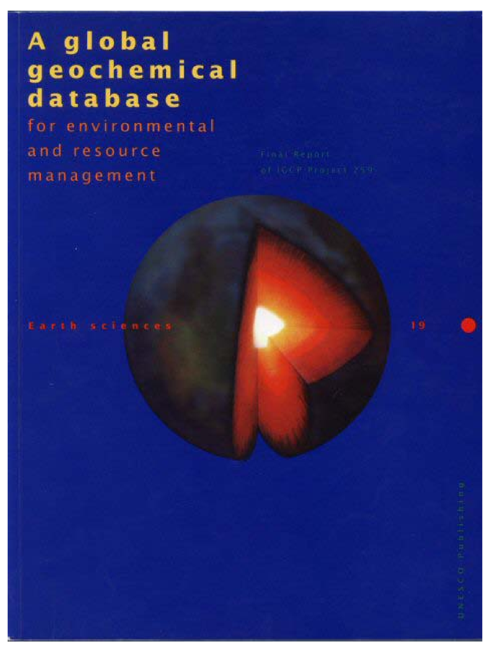

Figure 1:*(left) The IGCP Project 259 was the inspiration for the Nigerian national geochemical mapping programme* (Darnley, AG *et al*. 1995. A global geochemical database for environmental and resource management. UNESCO publishing 19).

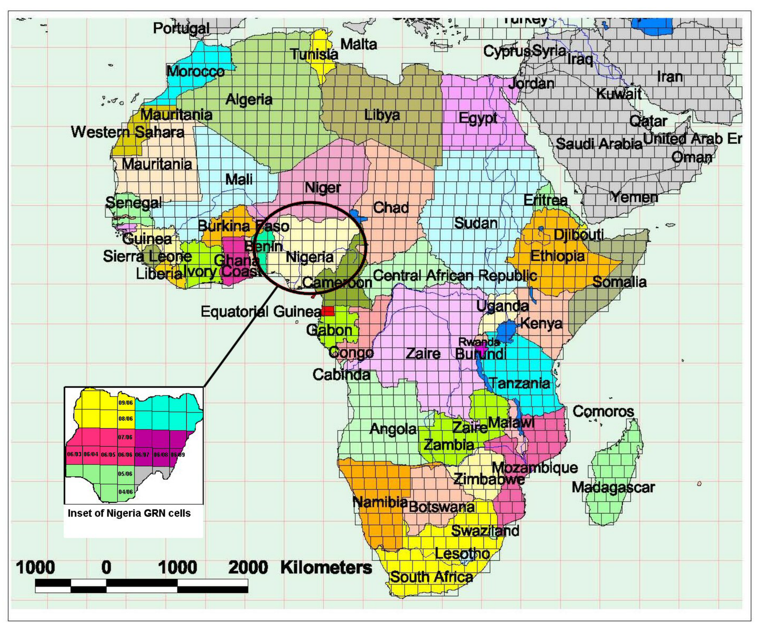

Figure 2:*(right) Forty four of the GRN cells are wholly are partly within Nigeria.*

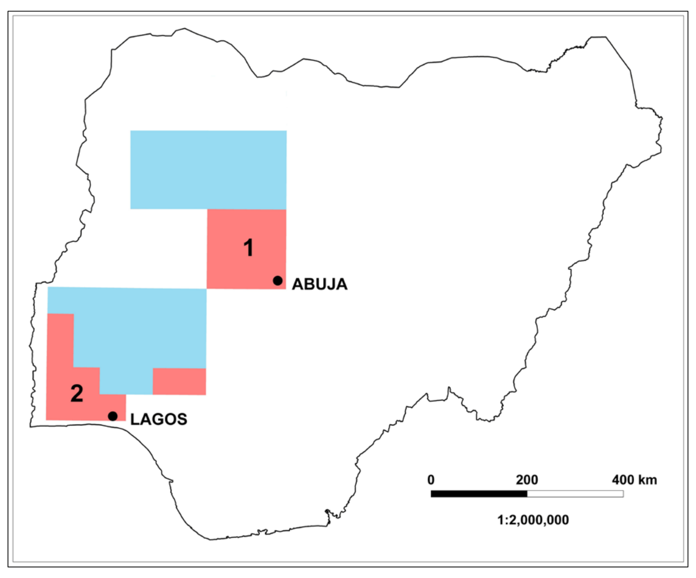

Figure 3: *The BGS-led geochemical mapping was carried out in two pilot areas (shown in red – 1. Minna Cell and 2. SW Cell). By the end of 2010 NGSA had sampled additional areas (shown in blue) and to date have sampled the equivalent of nearly eight Nigerian GRN cells. The pilot areas were sampled over a period of four months at the end of 2009. The Nigerian climate is tropical to semi-tropical in the south, passing through savannah grassland northwards, and becoming semi-arid in the north.*

STRATEGY

The inspiration for the Nigerian national geochemical mapping was the IGCP Project 259 "A global geochemical database for environmental and resources management" (Figure 1). Project 259 introduced a geochemical reference network (GRN) of cells covering the world's entire land surface, including Africa (Figure 2). Each cell is *c*.160 km x 160 km bounded by lines of longitude 1½° apart. There are forty four GRN cells wholly or partly contained within Nigeria and two of these cells – northwest of Abuja ("Minna Cell") and northwest of Lagos ("SW Cell") – formed the basis for the BGS pilot study areas (Figure 3). Although geochemical mapping was carried out for both environmental and exploration purposes, as mineral exploration is a key driver for the economic diversification, much of the strategy was developed to identify metalliferous mineralisation. Therefore sampling focused on drainage sediments (<150 µm) collected at a higher density than prescribed by IGCP Project 259. The main sampling phase was preceded by orientation studies in order to determine the optimum fraction size and methodologies to use.

METHODS

Sample collection: **Sediment was collected from the active drainage channel of 1st or 2nd order streams. The sediment was wet sieved through a 2 mm nylon screen and then a 150 µm nylon sieve and stored in Kraft™ paper bags to assist sample drying. Sampling density varied according to perceived mineral potential of the cell: from 1 sample per 20 km² in the Minna Cell to 1 sample per 90 km² in the SW Cell. A panned concentrate was also collected from the <2mm - >150 µm fraction.**

Sample preparation/analysis: **The initial sample preparation was done at the National Geoscience Research Laboratory (NGRL) in Kaduna, Nigeria. After air-drying samples were split to give an archive and analytical sample. Chemical analyses were done at the BGS laboratories (UK) on samples that had been pulverised in agate ball mills. Determination of 57 elements was done by ICP-MS after a sodium peroxide fusion followed by HF/HCl extraction. Gold, Pd and Pt were determined using fire assay. Primary and secondary reference materials in addition to field duplicates and laboratory replicates were used to give quality control information.**

Data analysis/mapping: **A MS Access relational database was created for all the field and analytical data. Statistical analysis, interpretation and plots were done using open source R code. The principal output was a series of 1:500 000 scale classified symbol maps for each element plotted on a simplified geological basemap (Figure 4). The geochemical mapping and results for each cell were reported as BGS commissioned reports. All project maps and reports are available on application from the NGSA office in Abuja, Nigeria.**

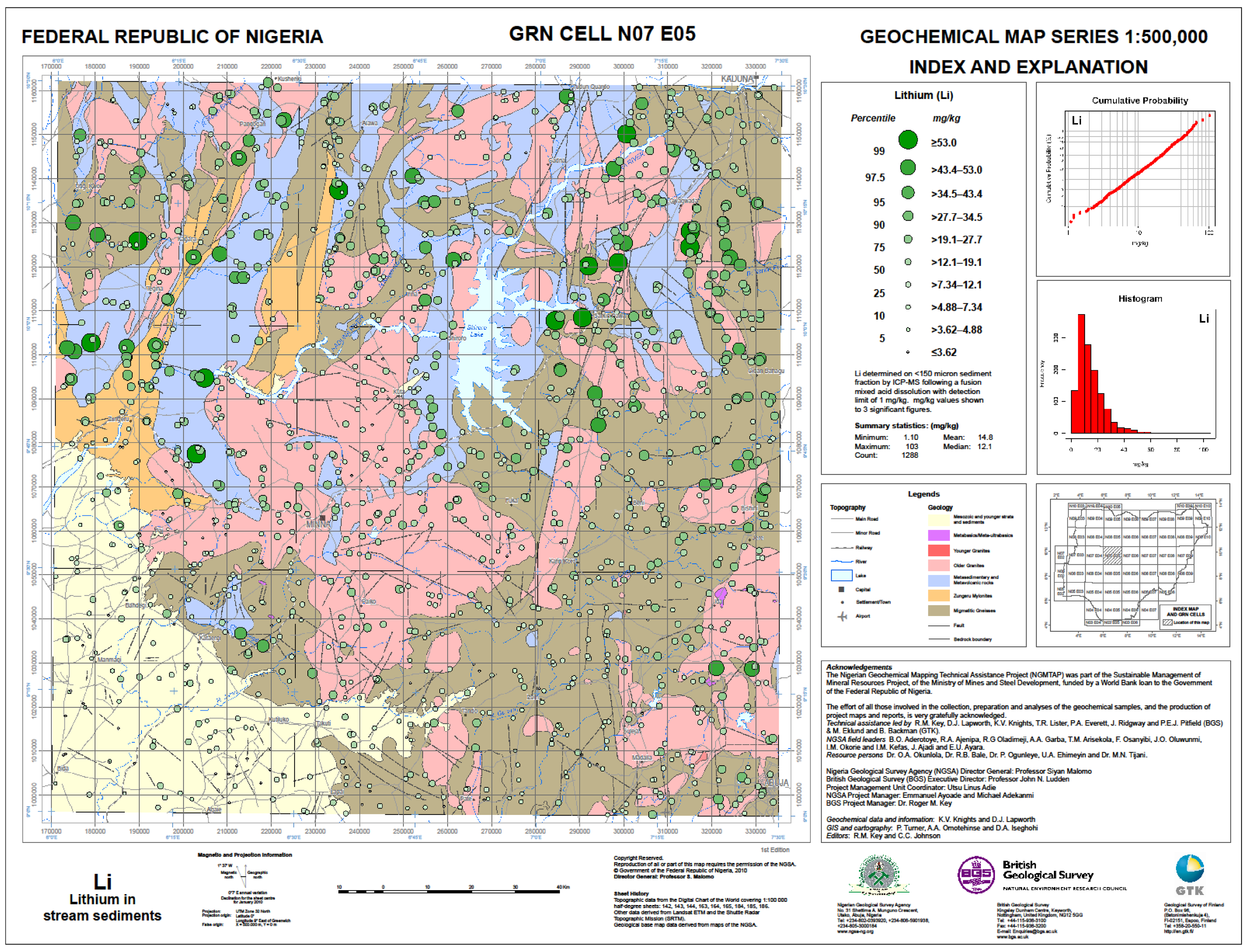

Figure 4: An example of a classified symbol regional geochemical map plotted on a simplified geological base. ESRI ArcGIS v9.2 was used to generate these maps. The statistical analyses and plots, such as the probability plot and histogram shown in the map legend, were done using open source R code.

RESULTS

The results of this work are reported in Lapworth *et al*. (2012) and can be summarised:

- **multivariate statistical techniques (*e.g.* robust principal factor analysis) explored the results to understand the underlying processes controlling spatial geochemical variability. Major geochemical variations are shown to be controlled by source geology and provenance, as well as climatic/ topographic processes such as winnowing of drainage sediments during dry periods. More subtle variations are a result of land use and contamination from anthropogenic activity;**
- **because of this close relationship with the geology for many elements, the geochemical maps can be used to improve the geological mapping;**
- **the work has identified placer deposit targets of potential economic importance including Au, rare earth elements, Ta, Nb, U and Pt;**
- **the geochemical mapping provides important new background/baseline geochemical values for common geological terrains in Nigeria which can be extended into other parts of West Africa; and**
- **very high levels of Zr were recorded in the fine stream sediment which has implications for the sample preparation and analysis. The source of the zircons has been the subject of further investigations (see below left).**

ZIRCONIUM AND THE ZIRCONS

High zirconium (Zr) concentrations (mean > 0.2%) are found in the stream sediments (<150 µm fraction) of the two study areas. Unlike many other elements, there was no clear correlation with the underlying geology and an aeolian origin for the observed fine zircons was suggested. The presence of zircons in the sediment has consequences for the sample preparation (longer pulverisation time required) and analysis (high Zr contents cause spectral interference during X-ray fluorescence spectrometry and also with Ag during ICP-MS determinations). The heavy mineral zircons are associated with other trace elements (*e.g.* rare earths) and so their accumulation can cause anomalously high levels of other elements.

The origin of the zircons was further investigated by mineralogical examination and age-determinations (Key *et al*., 2012). U–Pb LA-ICP-MS dating with cathodoluminescence imaging on detrital zircons, both from stream sediment samples and underlying Pan-African 'Older Granites', supports a local bedrock source for the stream sediment zircons, even though these source rocks are not particularly enriched in Zr. A proximal rather than aoelian source is also indicated by the fact that no rounded grains comparable to the wind-transported zircons found in aeolian sediments were seen (Figure 5). The enrichment of Zr in the sediments is believed to be a result of a combination of tropical and physical weathering in which the wind may have an effect of winnowing dry sediment during the dry season. Therefore, the high contents of Zr, as well as other elements concentrated in resistant 'heavy' minerals in Nigeria's streams, may not reflect proximal bedrock concentrations of these elements. This conclusion has important implications for using stream sediment chemistry as a mineral exploration tool in Nigeria and similar environments.

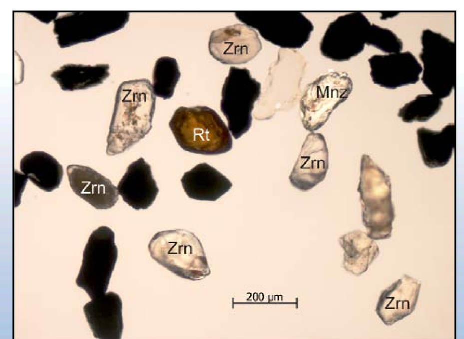

Figure 5: Anhedral and equant zircons (Zrn), monazite (Mnz), and rutile (Rt) in a stream sediment from the SW Cell.

OUTCOMES

- **The Nigerian Geological Survey Agency now has the equipment and the skills to complete a national geochemical mapping programme producing high quality and reliable data for exploration and other sectors. The project gave practical experience to more than 100 Nigerian geoscientists who actively participated in the project; and**
- **the regional geochemical data, along with other World Bank funded initiatives such as comprehensive airborne geophysics coverage, means Nigeria is well-placed to attract inward investment to its minerals sector to unlock its undoubted minerals potential.**

MAIN PUBLICATIONS

Key, R.M., Johnson, C.C, Horstwood, M.S.A., Lapworth, D.J., Knights, K.V., Kemp, S.J., Watts, M.J., Gillespie, M., Adekanmi,M.A. and Arisekola, T.M. 2012. Investigating high zircon concentrations in the fine fraction of the stream sediments draining the Pan-African Dahomeyan Terrane in Nigeria. Applied Geochemistry, 27(8). 1525-1539.

Knights, K.V., Lapworth, D.J., Key, R.M., Johnson, C.C. and Pitfield, P.E.J. 2010. The Regional Geochemistry of the Minna Master Cell, Nigeria: a summary report. Nigerian Geochemical Mapping Technical Assistance Project. British Geological Survey Commissioned Report CR/10/054. 120pp.

Lapworth, D.J., Knights, K.V., Key, R.M. and Johnson, C.C. 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. 115pp.

Lapworth, D.J., Knights, K.V., Key, R.M., Johnson, C.C, Ayoade, E., Adekanmi,M.A., Arisekola, T.M., Okunlola, O.A., Backman, B., Eklund, M., Everett, P.A., Lister, T.R., Ridgway, J., Watts, M.J., Kemp, S.J. and Pitfield, P.E.J. 2012. Geochemical mapping using stream sediments in west-central Nigeria: Implications for environmental studies and mineral exploration in West Africa. Applied Geochemistry, 27(6), 1035-1052.

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